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ORIGINAL ARTICLE

Examining the determinants of electricity consumption in the nine South African provinces: A panel data application

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Abstract

South Africa has been experiencing a series of power cuts since 2008 due to the state-owned electricity distributor's (Eskom) insufficient power generation capacity. The ongoing energy crisis has negatively impacted the growth and development of the South African economy. Therefore, it is imperative to have an insight into what explains electricity demand in an attempt to address issues facing the energy sector and electricity access at the provincial level. The study's main objective is to examine the determinants of electricity demand in the nine South African provinces from 1995 to 2019 to highlight regional intervention and policy implementation potential. The empirical examination was carried out through two-panel estimation techniques, namely Fixed Effects and the Pooled Mean Group, to account for time-invariant unobservable individual aspects that can be associated with the observed explanatory variables and to provide both short- and long-run coefficients thus allowing the intercept, the slope coefficients and the regression for electricity demand to be province-specific in the short-run. The results demonstrate the importance of examining the demand for electricity at the provincial level and providing critical province-specific developments that can potentially influence economic growth.

KEYWORDS

electricity demand, intervention, provincial, South Africa

1 | INTRODUCTION

Recent decades have been characterised by frequent shortfalls in electricity supply in South Africa with severe consequences for the economy and demonstrating that electricity and energy overall is one of the backbones for economic growth, particularly for a developing country. Babatunde and Enehe[1] accentuate that one of the most basic needs for human survival is access to clean, affordable, and convenient energy.

Specifically, in the South African economy, most electricity is consumed by the industrial and mining economic subsectors,[2] while the country boasts one of the largest coal reserves globally and hence, a coal-dominated electricity generation sector.[3] In the country, electricity generation has been monopolised by a state-owned company, Eskom, which produces 90% of the country's supply. The market has been regulated from a price perspective by the National Energy Regulator of

South Africa (NERSA), and investment is promoted in the form of Independent Power Producers (IPPs).[3,4]

The country experienced its first serious electricity supply crisis in 2007/2008, resulting in extensive power cuts. Since then, for most of the years, Eskom had to choose load shedding to counter the supply system's inability to cover electricity demand. The consequences of these load shedding *waves* have been severe for the South African economy. Before 2008, the country's electricity tariffs were considered relatively low compared to international tariffs. For some, these tariffs were not cost-reflective and were kept at those levels for societal reasons and to protect the country's poor population. Since the 2008/09 crisis with concerns on the financial viability of the national utility, the pricing structure significantly changed, with increases of even up to 25% annually during the first years after the restructuring (Figure 1).

The government policymakers had shown the importance of electricity provision for the country's economic growth since the 1990s when universal access to electricity was identified as one of the priorities for development and addressing inequalities.[5] The willingness of the South African policymakers to assist struggling low-income households with access to electricity and affordability is demonstrated in the 1998 White Paper on Energy Policy. That White Paper is the first to focus on universal access and Free Basic Electricity (FBE) to South African households. The FBE programme was officially launched in 2003, providing 50kWh per month free electricity to poor households. This amount is estimated to provide sufficient electricity services for essential lighting, water heating and ironing.

By the end of the 2010s, the Department of Energy recorded approximately 90% of South African households had access to the national electricity grid.[6] Nevertheless, economic growth and development did not occur homogeneously in all country's regions, even if infrastructure has reached all urban and rural areas. Such differences in the socioeconomic and developmental conditions of the nine provinces create differences in the behaviour of electricity consumers and their reaction to changes in economic conditions and policies.

Figure 2, illustrating the GDP and electricity demand of the nine South African provinces in 2018, demonstrates a positive relationship between the two variables (correlation, not causality).

The primary purpose of the study is to examine the determinants of electricity demand in the nine South African provinces to compare and contrast the relationship of electricity demand with various factors such as GDP at the provincial level (real income), population size at disaggregated provincial levels, and the average price of electricity. Table 1 presents the electrification statistics of the country, demonstrating that with equal access to electricity, the provinces have shown differences in distributed electricity. One of the possible reasons is the population differences as per Table 1. However, the law of demand directs us to evaluate the impact of the economic wealth of the users (and not only the number of users) and their price sensitivity. To examine these factors, this study employs an annual panel data approach from 1995 to 2019, which comprises Fixed Effects (FE) and the Pooled Mean Group (PMG) estimators. The FE estimator allows us to account for

TABLE 1 Electrification statistics 2018

Province	Projected households (April to March 2018)	Total households connected (April to March 2018)	Houses without electricity	Houses electrified	Access per province	Electricity generated and available for distribution	Electricity generated and available for distribution (% of total)
Eastern Cape	1,863,009	66,243	323,411	1,539,598	82.64%	8930	3.94%
Free State	909,007	4586	123,589	785,418	86.40%	11,674	5.15%
Gauteng	4,315,876	11,876	776,997	3,538,879	82.00%	60,839	26.81%
Kwazulu Natal	2,803,735	70,765	485,472	2,318,263	82.68%	41,307	18.21%
Mpumalanga	1,187,426	33,496	88,320	1,099,106	92.56%	32,849	14.48%
Northern Cape	332,775	3400	44,196	288,579	86.72%	6257	2.76%
Limpopo	1,565,699	58,666	22,723	1,542,976	98.55%	20,617	9.09%
North West	1,172,550	16,271	158,795	1,013,755	86.46%	22,119	9.75%
Western Cape	1,804,068	10,527	185,394	1,618,674	89.72%	22,304	9.83%
Total	15,954,146	275,830	2,208,898	13,745,248	86.15%	226,896	100.00%

Source: StatsSA and INEP (http://www.energy.gov.za/files/INEP/inep_overview.html).

time-invariant unobserved individual aspects of the observed explanatory variables. The PMG estimator allows short-run coefficients and intercepts to differ across groups while restricting long-run relationships to be the same.

Electricity demand modelling is a significant aid for strategy development and energy policymaking.[7] This paper chooses to model the provincial electricity demand to focus on policymakers, strategy developers, and any intervention to increase electricity demand and access. Bohlmann and Inglesi-Lotz[8] mentioned in their study that the majority of South African literature has considered aggregate,[9,10] household electricity demand[2,11] and sectoral[12–14] electricity demand. This study contributes to the electricity demand literature discussing differences of regions within a country to derive valuable conclusions from advising local and national development strategies. The study is done at the provincial level to lay a foundation and pave the way to achieve inclusive and sustained growth at the micro and eventually at the macro level.

The rest of the paper is organised as follows: the second section is the review of existing literature, Section 3 explains the theoretical framework, econometric model, data description, and the proposed techniques adopted to achieve the objective of the study, and Section 4 provides empirical results while Section 5 provides conclusions and recommendations.

2 | LITERATURE REVIEW

The first emphasis on the importance of electricity is its role in everyday livelihoods. While it has been identified as one of the important sources for human survival, it is also a core enabler of development.[1] As a country gradually progresses, its reliance on modern energy increases, showing a positive correlation between economic growth and electricity demand.[1]

Understanding this important relationship is built on and well explained by the theory of the energy ladder hypothesis.[15] According to this hypothesis, ease of use, quality, and prices of energy sources tend to increase as one goes up the ladder. Electricity stands at the top, followed by transition fuels such as oil and gas, and primitive fuel such as firewood and coal at the bottom. The country's gain of economic status influences the desire to move towards the very top of the ladder. Households' preference is accessing cleaner energy that is good for their health and the environment for basic and traditional usage such as lighting, warmth, and cooking. Recent studies such as Jones and Lomas[16] focused on the importance of electricity for the new and efficient usage of domestic electric appliances.

Leach[17] also highlights that increasing income promotes the movement from primitive fuels to advanced electricity, as illustrated by the ladder. Electricity is also an essential feature for promoting some critical Sustainable Development Goals (SDGs) such as (1) no poverty, (2) zero hunger, (3) good health and wellbeing, (4) quality education, (7) affordable and clean energy, (8) decent work and economic growth, (9) industry innovation and infrastructure and (11) sustainable cities and communities.

In fundamental economics, demand for any good or service is dependent on its price, prices of substitute goods, the income of the buyer, and many other variables. Having explained electricity importance, understanding the determinants of electricity demand, particularly income and price, is essential for projecting current and future demand.[18] Such knowledge is also important for more informed energy policy decision making, and it will also support the successful execution of new and existing policies aimed at increasing electricity access.

Most researchers have investigated income and prices as significant determinants of electricity demand and found demand less responsive to price changes in the long- and short-run.[19] In a similar study, Holtedahl and Joutz[20] also found that electricity demand differs with changes in income and the price responsiveness is relatively low for Taiwan. While Athukorala and Wilson[21] analysed determinants of households' electricity demand for Sri Lanka in both the short and long run using time series analysis and found that demand for electricity increases with households' disposable income. Ziramba[11] also analysed the demand for electricity in the residential sector in South Africa from 1978 to 2005. He found that income is more significant in explaining electricity demand than all other factors. In most general cases, a response to a specific price will be affected by the share of additional income that a consumer is willing to spend on electricity. This analysis of the correlation between electricity demand, income, and price of electricity reflects usage in the more affluent and poorer countries. Several households are still at the bottom of the energy ladder in African countries.

Over the past years, South Africa has gradually moved from dependence on traditional energy to advanced energy. The higher levels of economic growth in 1990 have brought about an overall rise in electricity demand. This was also due to the emerging commitment of the government to higher electrification.[22] Due to the 2008 recurring electricity disruptions, Eskom has suggested that the situation could be improved by constructing new power stations and a vast improvement in the existing power plants and, therefore, applied to the

National Energy Regulator for electricity price increments a source of funding to the above-suggested solution. On the other hand, policymakers argue that this will only result in a price increase, significantly negatively impacting the economy in the long run.[23]

The debate on price and income elasticity became more engaging, and research on other factors that determine electricity demand also became crucial for understanding targets to increase electricity access. Over the years, price elasticity took on a coefficient close to zero, and Inglesi-Lotz[23] highlights that prices have a more negligible effect on the consumption trends since they are not an estimate of market factors but rather a monopolist decision.

However, demand in different regions is still divergent due to the varying availability of efficient energy processes, the output produced in other provinces, and the nature and growth in each province. Inglesi-Lotz[23] highlights that the demand and supply of electricity mismatch have been of great concern to policymakers. Further, Ye et al.[22] explained that a few energy-sufficient plans had been implemented to curb the high overall electricity demand. While all the suggested efforts have not been entirely practical, there is a great possibility for improvement in these strategies, which would be achieved through more understanding of the end-users of electricity.

The consumption pattern in South African provinces is deemed to be structured similarly. The most developed regions or provinces rely heavily on electricity; their composition is reflected by their social, economic, behavioural patterns and dwelling physical factors related to energy.[24,25]

The examination of the determinants of electricity consumption receives attention in the literature as the findings are dynamic, changing and of high importance for policymakers that explore all positive avenues to promote energy savings. In a panel of 26 high-income countries and 29 middle-income countries for the period 1978–2013, Liddle and Huntington[26] found that 'Relative to high-income country responses, long-run elasticities for middle-income nations are larger for income (0.8 compared to 0.6), larger for cooling (0.3 vs. insignificant), and smaller for prices (−0.08 relative to −0.2). As middle-income economies are likely to grow more rapidly than high-income/OECD economies, the trends related to income and cooling responses are likely to place greater pressure on a warming world unless the power sector can be decarbonised globally'. Mikayilov et al.,[27] confirmed that income, price and population are the main determinants of electricity demand in Saudi Arabia. They stress and demonstrate with their results that differences in regional characteristics can intensify or tone down the impact of each of the main drivers of electricity consumption.

The differences in the conditions of consumers are also stressed in the study of Bohlmann and Inglesi-Lotz[8] that examined what determines the electricity consumption behaviour of South African households. The study shows that income per capita and electricity prices are the main contributors to electricity demand, positively and negatively, respectively.

Even in centralised and regulated electricity markets such as the South African one, the policymakers need to consider the differences between consumers and how they will react to any changes to anticipate the impact proactively. So far, the differential treatment in policy-making is directly related to the municipal distributors and secondly to the type of sector the consumer belongs to (industrial, mining, etc.). This study argues that even electricity consumers in the same industry might behave differently depending on their geographic location. As such, the analysis classifies consumption based on its provincial location.

3 | METHODOLOGY AND DATA

This section unpacks the empirical strategy used in this study. It first explains the theoretical framework, the econometric methodology, justification and prior expectations of the variables before empirical results, data description, and lastly, an overview of possible estimation techniques and various tests.

3.1 | Theoretical framework

The econometric model specified is informed by Blignaut et al.,[12] adapted for the specific research purpose to estimate provincial electricity demand. The model specification and theoretical framework (and hence, variables chosen) are based on the law of demand. The law of demand is one of the fundamental principles of economics. Demand is derived from the law of diminishing marginal utility, the fact that consumers use economic goods to satisfy their most urgent needs first.

A straightforward representation of factors influencing the demand for electricity (q) is focused on provincial-level demand attributes associated with electricity usage (Z) and electricity prices (P).[9] As the panel approach is followed in the study, the subscript ($i = 1 \ldots N$) shows an individual province under analysis and subscript ($t = 1 \ldots N$) shows the corresponding period. As such, the underlying equation is stated as:

$$q_{it} = (Z_{it}; P_{it}). \quad (1)$$

As stated from the demand function above, the study's model is expressed as:

$$y_{it} = \alpha + \beta \times X_{it} + \mu_{it}. \quad (2)$$

where y_{it} is the annual provincial electricity demand, α is the constant, β denotes the coefficients to be estimated, and μ is the error term. X is a vector consisting of all explanatory variables that affect electricity demand: GDP (gross domestic output per province) is an indicator for levels of real income per province, POP is the size of the population per province, CPI is an indicator for the average price of electricity (all in their natural logarithmic form as in Equation 3).

The model to estimate provincial electricity demand is thus:

$$\begin{aligned} \text{LELECDD}_{it} = \alpha + \beta_1 \text{LGDP}_{it} + \beta_2 \text{LPOP}_{it} \\ + \beta_3 \text{LCPI}_{it} + \mu_{it}, \end{aligned} \quad (3)$$

where $\beta 1$ is expected to be positive, representing the contributing effect of economic growth to the growth in electricity demanded (especially in specific developmental stages and in some provinces during the first years of connection to the electricity grid); $\beta 2$ is also expected to be positive as population increases will eventually mean more people with access to electricity and hence higher electricity demand; while $\beta 3$ is expected to be negative representing the price elasticity of demand.

3.2 | Econometric methods

The study examines the determinants of electricity consumption in the long run for a panel of nine South African provinces ($N = 9$) with annual data from 1995 to 2019. This paper uses two common panel unit root tests proposed by Levin et al.[28] and Im et al.,[29] designed for cross-sectionally independent panels to test and generalise the model to acknowledge the heterogeneity of individual deterministic effects.

The nature of the data series and its stationarity made it appropriate to employ FE and Pool Mean Group (PMG) estimation techniques employed at Sulaiman and Abdul-Rahim.[30] An advantage of the PMG technique is that it performs well under small sample data and when variables are integrated in different orders. Furthermore, the method can provide both short- and long-run coefficients, restricting long-run coefficients to be the same across provinces and allowing the intercept, the short-run slope coefficients, and the regression to be province-specific. A PMG estimation is appropriate for this analysis, appreciating the intuitive differences among the cross-sections (provinces) that may have a different level of serial correlation. Enforcing the same level on all cross-sections might cause the results to be biased.

3.3 | Data description

The study uses annual panel data spanning 1995 to 2018, sourced primarily through StatsSA. Several studies in the past had concluded that electricity prices had been an insignificant factor to electricity demand before the price restructuring of 2008/09 (that also coincided with the first significant load shedding wave that also altered the consumers' behaviour) to the point that their estimations made use of dummies to account for this fact.[8,12,13] In this study's unbalanced data set, the proxy used for electricity prices could only be sourced in a disaggregated format per province from 2008 onwards. Hence, we will interpret the specific indicator as such. Table 2 below presents a complete description of the data and variables.

Table 3 presents the descriptive statistics of the variables used and the correlation coefficients in the last four columns. The correlation coefficients show the overall strong positive correlation between electricity demand and GDP and population (as per Figure 1 too).

TABLE 2 Data description

Variable name	Unit of measure	Variable description
ELEC_DD	Gigawatt-hours (GWh)	According to the province, electricity generated and distributed by Eskom is an indicator of demand.
GDP	Constant 2010 prices: Actual (R Million)	Gross Domestic Product, at the provincial level. This is an indicator of real income per province.
POP	Number of people	Population, densities and number of households: By population group at a local municipal level.
CPI	Index–(average of monthly values) (2006 = 100)	CPI: South Africa—Electricity and other fuels

TABLE 3 Descriptive analysis output and correlation matrix

Variable	Obs	Mean	Std. dev.	Min	Max	LELECDD	LGDP	LPOP	LCPI
LELECDD	171	9.836	0.740	8.435	11.098	1			
LGDP	225	12.265	0.724	10.706	13.915	0.81*	1		
LPOP	234	15.332	0.676	13.757	16.556	0.69*	0.91*	1	
LCPI	117	4.336	0.362	3.406	4.853	−0.06	0.05*	0.07	1

Note: * denotes statistically significant at 1%, 5% and 10%, respectively.

In contrast, the proxy for electricity price presents a negative coefficient with electricity demand (as per the a priori theoretical expectations but not statistically significant for the pooled sample of the nine provinces).

4 | EMPIRICAL RESULTS

4.1 | Results of unit root testing

This study used two stationarity tests to test the unit root variables, including the LLC and IPS stationarity tests. We assume the model and variables to have a constant trend; thus, we will focus our tests for stationarity at constant. Both tests were consistent across all variables at constant models. From Table 4, it is evident that all the variables except log POP are stationary at levels.

4.2 | FE

Table 5 provides the results for the FE regression employed in a panel data set, which controls for the average differences in the unobservable individual aspects associated with the below observed explanatory variables across provinces.

From Table 5, GDP was not statistically significant for all nine provinces, which does not confirm the a priori expectations. The relationship between GDP and electricity demand is well documented in the literature, noting that the relationship is dynamic and changes over time and is affected by regional characteristics. In a fixed-effects model, there might have been some of the cross-sections (provinces) driving the results, and that is why we have proceeded with a PMG estimation to explore these differences.

However, the population shows a negative effect on electricity demand, contrary to prior expectations of the study. As described in the data section, ELECDD represents the number of units distributed by Eskom according to provinces. It contains the number of electricity units generated, consumed, and purchased in South Africa. Some possible reasons why we observe a negative relation between POP and ELECDD might be due to the proportion of the population receiving Free Basic Electricity (FBE) and not having to purchase electricity from Eskom. In other words, the impact of the number of consumers entering or exiting a province is also related to the wealth of these consumers and a potential threshold associated with the urbanisation levels.

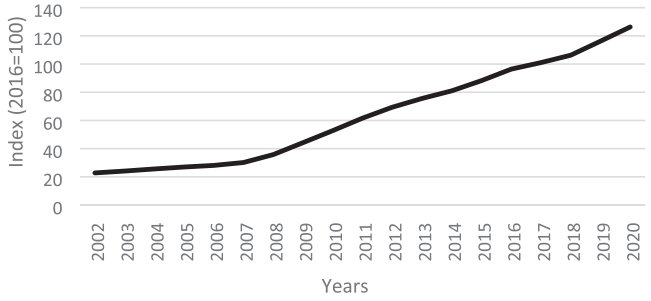

FIGURE 1 CPI electricity and other fuels (2016 = 100). *Source*: StatsSA and Quantec

4.3 | PMG estimation

The PMG technique was utilised to examine drivers of electricity demand at the provincial level. PMG can estimate and restrict similar long-run coefficients across provinces by employing a panel of cross-province and time-series observations. The regression, short-run coefficients, and intercepts are province-specific. The output is provided in Table 6 below.

When analysing the provincial electricity demand, GDP, an indicator for real income in each province, was found to be statistically significant in explaining electricity demand in all provinces. On the downside, however, in Kwazulu-Natal and Free State, a percentage increase in GDP decreases electricity demand by 0.773% and 0.50%, ceteris paribus, contrary to the prior expectations of this study. Such a relationship might not be in accordance with the a priori theoretical expectations. In

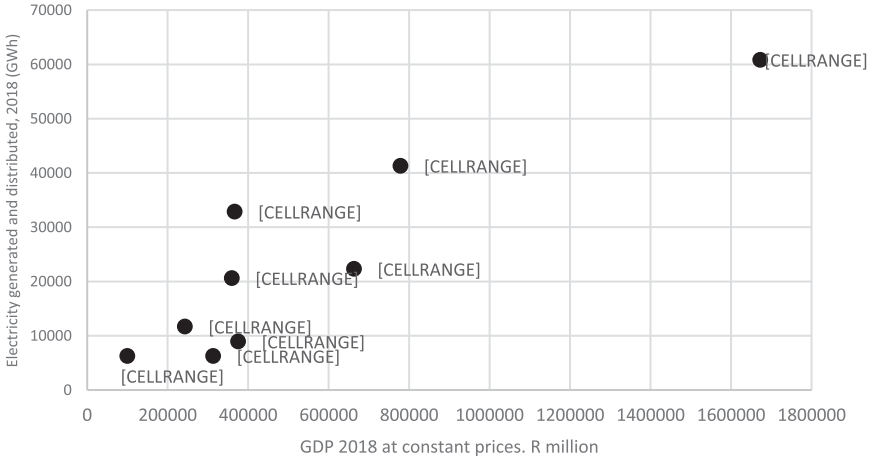

FIGURE 2 Electricity demand and GDP in 2018 per province. *Source*: StatsSA and Quantec

TABLE 4 Unit root test results

Model	LLC	IPS
Variable	LELECDD	
Include time trend	−2.016**	−0.642
Suppress panel-specific means	−1.019	-
Subtract cross-sectional means	3.747	2.981
None	−2.646**	−1.670**
Variable	**LGDP**	
Include time trend	2.53	3.587
Suppress panel-specific means	6.576	-
Subtract cross-sectional means	−2.237**	0.878
None	−3.602*	−1.186
Variable	**LPOP**	
Include time trend	−0.322	−1.008
Suppress panel-specific means	6.571	-
Subtract cross-sectional means	−2.367	3.518
None	−0.164	2.59
Variable	**LCPI**	
Include time trend	−8.230*	−1.385***
Suppress panel-specific means	5.3	-
Subtract cross sectional means	−3.216*	−2.635**
None	−1.25	−6.420*

Note: * denotes statistically significant at 10%, respectively.

TABLE 5 Fixed effects output (dependent: LELECDD)[a]

	Coef.	Std. Err.	*T*	P > t
LGDP	0.115	0.841	0.14	0.892
LPOP	−3.078	0.697	−4.41	0.000*
LCPI	0.371	0.0.145	2.55	0.012*
_cons	54.274	12.893	4.21	0.000*
LGDP	0.115	0.841	0.14	0.892
LPOP	−3.078	0.697	−4.41	0.000*
LCPI	0.371	0.0.145	2.55	0.012
_cons	54.274	12.893	4.21	0.000*

Note: *, ** and *** denote statistically significant at 1%, 5% and 10%, respectively. R^2: Within = 0.1746, Between = 0.05774, and Overall = 0.5322. *F* test that all $u\_i = 0$: $F(8, 96) = 61.76$ Prob > $F = 0.0000$

[a]Hausman test results: Null hypothesis: No Misspecification Chi-sq statistic: 15.1794 P-value: 0.0017, Reject the null when p-value < α →Misspecification with the Random Effects specification.

this case, the two provinces show that economic growth might be related to electricity savings (decrease in electricity consumption), potentially associated with gains from energy efficiency applications or self-generation options.

The population coefficient is shown to be insignificant for most of the provinces, except Gauteng and Mpumalanga. Gauteng is characterised by high levels of urbanisation that intensifies the impact of the population on electricity demand, also appreciating that Gauteng has high levels of access to the national electricity grid. The negative coefficient of the Mpumalanga province might be attributed to two factors: the province also presents an increase in a population similar to Gauteng's because of the infrastructure in the region; however, there is also a presence of choices for energy that are preferred by low-income households (see energy ladder). Therefore, it has been considered that renewable energy is an alternative that can improve or not fulfil the energy needs of these populations and minimise their reliance on fossil fuel, the electricity demanded from Eskom.[31]

The results with regard to electricity prices are classified into two categories: the coefficients of electricity are statistically insignificant for Western Cape,

TABLE 6 PMG output

Exp variable	Overall	WC	EC	NC	FS	KZN	NW	GP	MP	L
LGDP	1.860*	2.523***	1.905**	1.864*	−0.507***	−0.773***	1.765*	1.098**	2.910*	1.993*
	(0.272)	(0.510)	(9.330)	(336)	(0.262)	(0.432)	(0.360)	(0.477)	(0.279)	(0.516)
LPOP	−2.931*	−29.201	19.891	9.091	−5.119	−6.997	5.129	43.561*	−22.304*	−2.211
	(0.207)	(21.739)	(0.313)	(12.120)	(7.669)	(16.474)	(45.520)	(8.209)	(5.212)	(11.387)
LCPI	0.299*	0.526	−0.468	−0.162	−0.563**	−1.098*	−0.002	−0.354***	−0.200	−0.743**
	(0.043)	(0.546)	(0.370)	(0.137)	(0.283)	(0.379)	(0.476)	(0.214)	(0.225)	(0.309)
Constant		−4.779	−11.694***	−14.995*	−5.065***	−8.479***	−2.600	−32.843*	−48.234*	−43.120*
		(6.456)	(6.874)	(4.387)	(2.920)	(4.822)	(9.019)	(5.244)	(5.561)	(10.831)

Abbreviations: EC, Eastern Cape; FS, Free State; GP, Gauteng; KZN, Kwazulu-Natal; L, Limpopo; MP, Mpumalanga; NC, Northern Cape; NW, North West; PMG, Pooled Mean Group; WC, Western Cape.

Note: *t*-statistics are provided in bracket. *, ** and *** denote statistically significant at 1%, 5% and 10%, respectively.

Eastern Cape, Northern Cape, North-West and Mpumalanga, while the rest of the provinces are negative and statistically significant. In other words, prices either negatively impact electricity demand, as expected as per the law of demand and the sharp increases of electricity costs. The highest negative coefficient is observed for the Limpopo province: affordability issues that affect the electricity demand are well represented by a province with a high share of households below the poverty line.

All in all, the results show that theoretical considerations regarding the electricity demand and its determinants are not always and, in all cases, confirmed. Electricity demand response can be more or less elastic depending on the conditions of the economy and users in the specific case. Population and Economic output seem to be the main contributors to provincial demand for electricity, with price being a secondary factor (if at all).

The majority of the South African studies (aggregate, sectoral and residential) report an inelastic price demand while they all agree that income/economic output has a positive influence on electricity consumption.[8,12,22,32] The findings of this study agree with the literature results with regard to the impact of GDP on electricity consumption. In contrast, the rest of our findings are not homogeneous across provinces, confirming the arguments of studies such as Blignaut et al.[12] and Bohlmann and Inglesi-Lotz[8] that a variety of factors (geographical, socioeconomic) diversify the consumers' behaviours with regard to changes in the cost of electricity.

5 | CONCLUSION AND RECOMMENDATIONS

This study examined provincial electricity demand in South Africa as a function of GDP (real income) per province, population size, and electricity prices from 2008 to 2019. The first estimation technique used, the FE technique, revealed that population and electricity costs are the main contributors to explaining electricity demand in South Africa.

With PMG at the provincial level, the main overall finding of the study is that the South African provinces do not have homogeneous responses and determinants of their electricity demand status. Their socioeconomic and geographical characteristics might play a role in how the consumers react to changes in electricity costs (e.g., the Limpopo consumers react more to changes in tariffs), GDP (all provinces are affected by the economic production) and population (number of consumers and their preferences play a role too).

These findings have important policy implications. Energy policymakers should consider these differences

when planning infrastructure development and changes in pricing structures. Such evidence-informed policies also have consequences for the just energy transition of the country. Further investigations may be helpful to ascertain the total electrical energy generated from renewable sources and investigate areas to install renewable energy systems to save Eskom from its dependence on coal for the provision of electricity. This is also a possible intervention and other possible policies for provinces in which population is a driver for increased electricity demand. Policies regarding electricity tariffs should be individualised for such provinces where it has been observed that prices are significant in explaining the decrease in electricity demand, and maybe get away from umbrella tariff structures based only on geographical location of generation and revenue and cost structures of the municipalities.

Socioeconomic and geographical characteristics play an essential role in explaining consumers' responses to price changes, but this study did not delve into these characteristics (future research direction). A delimitation of this study is that the modelling exercise starts with the hypothesis that the provincial cross-sections are not homogenous, focusing only on their economic output and population differences.

Finally, considerations of the source of electricity can play an important role in regionally-specific policymaking: coal-generated electricity and distribution are less flexible and costly as the network needs to connect remote areas with the power plants and sub-stations. In contrast, as electricity generation switches to renewable energies with higher flexibility in location and size, the distribution network will tend to each region's electricity needs more appropriately. Consumers' self-generation options will change the electricity demand. As Akinbami et al.[33] state, the deployment of renewable energy will not be the same in the various provinces due to natural resources available for example: 'the Northern Cape region ranked highest among all the provinces in terms of RE (solar PV, CSP, wind and Biomass) deployment in South Africa closely followed by the Eastern Cape Province then Western Cape'.

Within the concept of energy transition that will alter the current conditions within a country, liberalisation of the electricity markets (such as Chilean) will bring about changes in electricity pricing and consequently to the demand response of users, and as the middle- and low-income countries suffer by high levels of income inequality and poverty, such price restructuring will affect their electricity affordability.

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