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The Effect of Electricity Prices on Industrial Electricity Consumption in South Africa

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ABSTRACT

Industries face growing pressure to improve productivity and stay globally competitive, making them more vulnerable to fluctuations in electricity prices, as they are energy-intensive. Understanding how electricity price changes affect industrial electricity consumption is crucial for maintaining production efficiency, economic development, and competitiveness. However, limited insights exist in South Africa, especially after the implementation of steep electricity price hikes and the economic impact of Covid-19. The aim of the study was to assess the effect of electricity prices on industrial electricity consumption in South Africa from 1975 to 2023 using the Quantile Autoregressive Distributed Lag (QARDL) model. The results emphasize that high electricity prices negatively affect South African industries, with industrial output similarly having a negative impact on electricity consumption. Conversely, economic growth positively influences industrial electricity consumption. These findings highlight the need for policies that stabilize electricity prices and support industrial electricity consumption while minimizing environmental impacts. The policy implication of rising industrial electricity consumption without reducing output calls for energy efficiency measures, renewable energy adoption, and smart grid development in the industrial sector. Furthermore, policies focusing on stimulating economic growth and demand for goods and services are crucial for boosting industrial production levels.

Keywords: Industrial Electricity Consumption, Economic Growth, Industrial Output, Electricity Prices, Quantile Autoregressive Distributed Lag, South Africa

JEL Classifications: C32, C51, L11, Q41

1. INTRODUCTION

Industries encounter increasing pressure to enhance productivity in order to remain competitive on a global scale, making it more prone to electricity price fluctuations as the sector in energy intensive (Ikome et al., 2022). In South Africa, consumption of industrial electricity is crucial for enhancing production efficiency, fostering economic development, and ensuring sustainable energy practices while upholding industrial competitiveness. With industrial sector being one of the largest consumers of electricity in the country, its consumption is heavily influenced by the mining and manufacturing industries, which are energy-intensive sub-sectors (Sehlapelo and Inglesi-Lotz, 2022). Mining operations in particular, rely on substantial electricity for processes such as extraction and processing (Majola and Langerman, 2023). While in manufacturing, electricity is essential for powering machinery, automation, industrial processes like heating and molding, it supports lighting and communication systems, while driving productivity and efficiency (Kan et al. 2020). The automotive sector, in particular, has become a key player, with many international companies establishing plants in South Africa (Wuttke, 2023). In 2023, the industrial sector accounted for a substantial portion of approximately 47% of total electricity consumption, reflecting the importance of electricity to economic activities (Eskom, 2023).

However, it falls short compared to countries like China and the United States, which have much larger industrial bases (Saber et al., 2021). While South Africa relies heavily on coal for electricity generation, this contrasts with nations like Germany and Brazil, which have made substantial investments in renewable energy and energy efficiency (Jin et al., 2024). As South Africa grapples with high electricity costs and reliability issues, it faces a critical need to diversify its energy sources and improve efficiency to enhance the competitiveness and sustainability of its industrial sector (Mabuza and Maphosa, 2023).

Historically, the global financial crisis of 2008 had a profound effect on South Africa's industrial sector, leading to a marked slowdown in economic activity. Many industries faced reduced demand, and the frequent electricity shortages that began in 2007, characterised by load shedding, severely disrupted productivity (Kan et al., 2020). These energy challenges led to increased operational costs, making South African industries less competitive (Ateba et al., 2019).

The COVID-19 pandemic also contributed severely to the impact of industrial activities, causing widespread disruptions (Biyela and Utete, 2024). However, as restrictions eased in 2021, the sector began to recover, with a renewed focus on resilience and innovation. In 2023, the South African industrial sector continued to grapple with ongoing challenges, including high electricity prices that have been a growing concern for businesses (Mirzania et al., 2023).

Over the past decade, electricity prices have risen sharply due to factors such as an increase in production costs, aging infrastructure, and the need for investment in new energy generation capacity (Ye et al., 2018). Eskom, the state-owned utility, has faced financial difficulties, leading to tariff increases that affected even industrial consumers (Reid et al., 2021). Abbasi et al. (2021) highlighted that high electricity prices erode profit margins, reduce competitiveness, and deter investment in the industrial sector. The rising cost of electricity poses significant challenges for South African industries. High electricity prices can further lead to increased operational costs, making it difficult for industries to compete both locally and globally (Guan et al., 2023).

According to Qeqe et al. (2022), the price of electricity determines the rate of which electricity is consumed. For the industrial sector that might go further in determining the level of productivity and growth of the industry. Figure 1 below provides a depiction on how industrial electricity consumption has been fluctuating throughout the years.

Based on Figure 1, industrial electricity consumption has been fluctuating over the past years whereby between 1985 and 2003 it consumed <60,000 GWh and reached its peak in 2005 by consuming 71,629 GWh. Since consumption by the sector has slightly been decreasing over the long run, whereby in 2019 the industrial sector consumed 48,785 GWh of electricity as compared to a decrease to 45,696 in 2020. By 2021 it consumed 40,973GWh as compared to an increase of 45,220GWh in 2022 this was due to lockdown restrictions from Covid-19 being lifted and production resuming. By 2023 it reduced to 44,635 GWh, the decrease was mainly due to the power cut implemented and high electricity price adjustments by the power utility which affected industrial electricity consumption (Odhiambo, 2023).

According to previous analysis executed by variety of researchers such as Hassen et al. (2022); Bohlmann and Inglesi-Lotz (2021); Gonese et al. (2019); Ye et al. (2018); Kohler (2014); Inglesi-Lotz (2014); and Lim and Yoo (2013) it is certain that electricity prices play an important part on determining the level of electricity consumption in different industries. Developed and developing countries depend on electricity as it is the cornerstone of technological advancements and the catalyst for economic growth. Those studies provided the importance of pricing electricity efficiently so that different sectors may enjoy the convenience it comes with. The studies further provided empirical results articulating that the costly electricity may hinder the consumption of electricity from industrial sector.

Therefore, the aim of the study is to provide insights into the diverse effect of electricity prices on industrial electricity consumption in South Africa with a time frame that accommodate economic shocks such as Covid-19 which significantly reduced industrial activities. Secondly, the study aims to provide robust results analysis by introducing quantile asymmetries in the short-term and long-term adjustments on industrial electricity consumption in different quantiles using the Quantile Autoregressive Distributed Lag (QARDL). To the best of the author's knowledge, this approach is a relatively new addition to the South African literature.

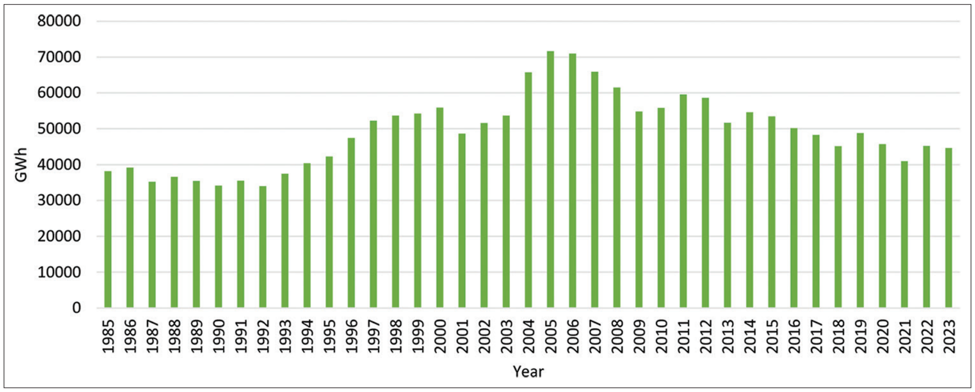
The outline of this study is as follows. Section 2 presents the literature review. Section 3 describes the method implemented. Section 4 discusses the empirical results. Section 5 provides the conclusion and policy implications of this study.

2. LITERATURE REVIEW

The role of electricity prices on industrial electricity consumption is highlighted in both theoretical and empirical literature. Munasinghe and Warford (1982) emphasise that prices reflecting true economic costs are crucial for efficiently linking supply and demand. Previous studies have investigated the impact of electricity prices on industrial electricity consumption across different contexts. Burke and Abayasekara (2018) report a negative correlation between electricity prices and consumption in United State, with firms potentially relocating to areas with lower prices.

Additionally, Liddle and Hasanov (2022) find that subsidies can influence consumption levels, particularly in middle-income countries. In South Africa, Inglesi-Lotz (2014) and Masike (2019) revealed that industrial sectors react negatively to electricity price increases, especially amid fluctuating prices. Deutschmann et al. (2021) argue that aligning electricity prices with supply quality can enhance productivity and promote industrial growth by reducing operating costs in Senegal. Conversely, research by Lim and Yoo (2013), Kohler (2014), and Gonese et al. (2019) indicated that rising electricity prices lead to decreased production output, forcing firms to cut back or even close operations. Goliger and McMillan (2018) suggest that higher electricity costs in South Africa may drive firms to invest in self-generation capacities, affecting national energy policy.

Figure 1: Industrial electricity consumption in South Africa (1985-2023)



The above studies highlight the significant negative relationship between electricity prices and industrial electricity consumption. While on the other hand, multiple studies have explored the relationship between industrial output and industrial electricity consumption. Olufemi (2015) identified a strong positive correlation in Nigeria, where increased production drives higher electricity demand. Husaini and Lean (2015) found a similar link in Malaysia, emphasising the role of government in securing sufficient electricity to support industrial growth. Li and Yuan (2021) observed that industrial growth in China leads to higher electricity use, stressing the importance of energy efficiency for sustainable development. Zou (2022) provided new evidence from China, confirming that industrial output significantly impacts electricity consumption, with crucial implications for energy planning.

Numerous studies have explored the impact of economic growth on industrial electricity consumption, highlighting key trends and areas for further analysis. Chen and Fang (2018) found a positive relationship in China, where industrial growth drives electricity demand. Cui et al. (2021) also observed that economic growth in China leads to higher electricity consumption due to expanding industries, raising concerns about energy security and environmental impacts. Chandio (2019) identified a unidirectional relationship from economic growth to industrial electricity consumption in Pakistan. Tiwari et al. (2021) confirmed a similar relationship in India, particularly in industries that are energy-intensive sectors. Azam et al. (2021) found a bidirectional causal relationship in newly industrialised countries, where economic growth and industrial electricity consumption influence each other.

The literature reveals a significant gap in empirical evidence pertaining this study for South Africa, and given the recent fluctuations in electricity prices and economic shocks, there is a need for a comprehensive study that examines how these changes affect industrial electricity consumption patterns. This study aims to fill this gap by uncovering new insights in underexplored areas with the time frame that capture both electricity price fluctuations and economic shocks, offering valuable insights for policymakers on effective energy pricing strategies to enhance industrial productivity and sustainability. While various studies have explored this relationship in other countries using diverse empirical techniques, no research has employed the Quantile Autoregressive Distributed Lag (QARDL) approach to analyze this link in South African context. Hence the study aims to provide a fresh perspective on the topic and validate previous empirical results across a refined method.

3. METHODOLOGY

To investigate the effect of electricity prices on industrial electricity consumption in South Africa across quantiles the recently developed QARDL model constructed by Cho et al. (2015) is employed. This approach explains the possible asymmetry in the response of one variable to changes in another variable over a range of different quantiles. The QARDL methodology is preferred because conventional OLS and linear ARDL techniques are based on conditional mean, and it does not provide detailed information for different quantiles (Shahbaz et al., 2018).

3.1. Model Specification

The study adopts and modifies the model of Inglesi-Lotz (2014) which used the dataset from 1970 to 2007. The Kalmer Filter technique was employed, using variables such as electricity consumption of industrial sector (LCONS), average electricity price (LP), real economic output of industrial sector (LY) and employment of industrial sector (LN) for the analysis. The basic model of that study is presented as follows:

$$LCONS = \alpha_0+\alpha_1 LP+\alpha_2 LY+a_3 LN+\varepsilon_t \tag{1}$$

In this study, the focus was narrowed to include electricity prices, industrial output, and economic growth to reflect the key drivers of electricity consumption in the industrial sector. Additionally, the time period was extended to incorporate more recent data, allowing the study to account for contemporary economic shifts and energy consumption patterns in South Africa. This modification ensures the model is more relevant to the current industrial context and better captures the dynamics influencing electricity consumption.

$$LIEC_t = \beta_0+\beta_1 LGDP_t+\beta_2 IO_t+\beta_3 LAEP_t+\propto_t \tag{2}$$

Where LIEC, is industrial electricity consumption, GDP represent economic growth, IO is industrial output, LAEP denotes average electricity prices. β_0, is the intercept, β_1, β_2, β_3, are coefficients of explanatory variables and μ_t is the error term.

3.2. Descriptive Statistics

The descriptive statistics provide important information about the variables of the study. It gives a brief summary of the descriptive coefficients by means of a central tendency measures which include the mean, median and mode (Cooksey, 2020). In addition, the measures of variability are considered which include the variance, standard deviation, minimum and maximum variables.

3.3. Multivariate Normality Tests

The study employs a collection of normality tests which intend to find out whether the data is normally distributed. Tests such as Shapiro-Wilk, Henze-Zirkler, Mardia's Skewness, Adjusted Mardia's Skewness, Mardia's Kurtosis and Doornik-Hansen are employed. The null hypotheses of all the tests presented below assumes that the data is significant if it is ≥0.05 significant level.

3.4. Stationarity

Augmented Dickey-Fuller (1979) and Zivot and Andrews (1992) are tests that the study uses to test the unit root. Those tests are crucial for determining if a time series is stationary or non-stationary, a stationary series has a constant mean, variance, and auto-covariance. Testing for stationarity is vital for accurate econometric forecasting to avoid bias from non-stationarity. Zivot-Andrews unit root test is advantageous over ADF test as it incorporates a structural break on the time series. A structural break may be a change in the time series data as a result of changes in large economic shocks, economic policies or even institutional and legislative (Razzaq et al., 2022). Therefore, testing for unit root by allowing structural break may prevent the results from becoming biased towards the unit root by identifying the possible year of when the break occurred (Liu et al., 2023).

3.5. Quantile Autoregressive Distributed Lag (QARDL)

QARDL model is more detailed and advantageous than the linear model by investigating the nonlinear association between all the study variables compared to the traditional method of focusing on the linear association through mean regressed outcomes (Wang et al., 2021). Then based on this, the QARDL model becomes most suitable for the nonlinear and asymmetric relationship of industrial electricity consumption, economic growth, industrial output and electricity price. QARDL shows that short- and long-run parameters depend on quantile. This signifies that the QARDL parameter can be different through quantiles.

At the starting point, the traditional linear ARDL model is presented as:

$$liec_t = \alpha + \sum_i^p \beta_1 liec_{t-i} + \sum_i^q \beta_2 lgdp_{t-i} + \sum_i^m \beta_3 io_{t-i} + \sum_i^n \beta_4 laep_{t-i} + \varepsilon_t \tag{3}$$

Where p, q, m and n are various lag order based on Schwarz Information Criterion then ε_t is the error term. Equation 3 was modified according to Cho et al. (2015) to include quantiles. Therefore, the QARDL forms of Equation 4 is given as:

$$Qliec_t = \alpha(\tau) + \sum_i^p \beta_1(\tau) liec_{t-i} + \sum_i^q \beta_2(\tau) lgdp_{t-i} + \sum_i^m \beta_3(\tau) io_{t-i} + \sum_i^n \beta_4(\tau) laep_{t-i} + \varepsilon_t(\tau) \tag{4}$$

Where $\varepsilon_t(\tau) = liec_t - Qliec_t(\tau/\varepsilon_{t-1})$ and 0> τ <1 indicates quantiles and the values can be written as (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9). However, it is necessary to generalise the QARDL displayed in Equation 4 due to probability of serial correlation. Therefore Equation 4 is restructured as:

$$Q\Delta liec_t = \alpha(\tau) + \rho liec_{t-i} + \varphi_1 lgdp_{t-i} + \varphi_2 io_{t-i} + \varphi_3 laep_{t-i} + \sum_i^p \beta_1(\tau) liec_{t-i} + \sum_i^q \beta_2(\tau) lgdp_{t-i} + \sum_i^m \beta_3(\tau) io_{t-i} + \sum_i^n \beta_4(\tau) laep_{t-i} + \varepsilon_t(\tau) \tag{5}$$

To account for QARDL-ECM Equation 5 is generalised into the following Equation 6:

$$\Delta liec_t = \alpha(\tau) + \rho(\tau)[liec_{t-i} - \varphi_1(\tau) lgdp_{t-i} - \varphi_2(\tau) io_{t-i} - \varphi_3(\tau) laep_{t-i}] + \sum_{i=1}^{p-1} \beta_1(\tau) \Delta liec_{t-i} + \sum_{i=0}^{q-1} \beta_2(\tau) \Delta lgdp_{t-i} + \sum_{i=0}^{m-1} \beta_3(\tau) \Delta io_{t-i} + \sum_{i=0}^{n-1} \beta_4(\tau) \Delta laep_{t-i} + \varepsilon_t(\tau) \tag{6}$$

By employing the delta (Δ) procedure, the short run impact of: Previous industrial electricity consumption on its current consumption has been determined by $\beta_* = \sum_{i=1}^{p-1} \beta_1$ the same goes for economic growth represented by $\sum_{i=0}^{q-1} \beta_2$, industrial output represented by $\beta_* = \sum_{i=0}^{m-1} \beta_3$ and electricity prices represented by $\beta_* = \sum_{i=0}^{n-1} \beta_4$ respectively.

It is then expected that the error correction term to be negative and statistically significant (Razzag et al., 2022; Liu et al., 2023)

The long-run cointegrating parameters of average electricity price and industrial output are calculated as:

$$\beta lgdp_* = -\frac{\beta_{lgdp}}{\rho}, \beta io_* = -\frac{\beta_{io}}{\rho}, \beta laep_* = -\frac{\beta_{laep}}{\rho}$$

3.6. Slope Equality Test

The slope equality test developed by Koenker and Bassett (1982) is a robust test for heteroskedasticity. The slope equality tests are performed to examine if the difference between the values of the slope parameter, estimated at the different quantiles, is statistically significant (Chevapatrakul, 2015). The null hypothesis is described as follows:

$$H_0: \beta(\tau_1) = \beta(\tau_2) = \beta(\tau_3) = \beta(\tau_4) = \ldots\ldots = \beta(\tau_k) \tag{7}$$

Which imposes *(p−1)(k−1)* restrictions on the coefficients. Then the corresponding Wald Statistics is distributed as $x^2_{(p-1)(k-1)}$. Rejecting this hypothesis suggests the parameters exhibit significant differences across quantiles**.**

4. RESULTS

This section presents the description statistics results, normality results, QARDL long run and short run results and graphical quantile representations along with slope equality results for both long and short run.

4.1. Descriptive Statistics Test Results

Descriptive statistics are used to describe the basic features of the data in a model. Table 1 presents the descriptive statistics.

The descriptive statistics results of industrial electricity consumption, economic growth, industrial output and electricity prices is shown in Table 1, the mean of all variables is positive. The relatively stable range of industrial electricity consumption (9.8-11.17) suggests a steady demand for electricity, which highlights the sector's reliance on electricity for production. However, fluctuations in electricity prices (0.22-4.92) could significantly affect industrial costs, potentially impacting competitiveness. Economic growth (24.44-26.85) indicates moderate overall economic expansion, but its sensitivity to factors like energy prices suggests vulnerability. The variation in industrial output (23.35-42.40) reveals that while some industries are performing well, others may face challenges, possibly due to higher energy costs.

4.2. Normality Test Results

The study employed variety of normality tests to determine if the variables meet the assumption of non-normality before proceeding to QARDL, Table 2 provides outcomes of those normality tests.

The results from Table 2 reveals that the data deviate from the normal distribution, justifying the use of the QARDL method against the ARDL method, as the latter only uses the overall averages and thus fails to recognise changes and the asymmetric characteristics of parameters from one quantile to another while the former captures this asymmetric relationship within the sample period.

4.3. Unit Root Results

Before QARDL estimations, it is important to confirm the stationarity properties of all variables. The study employs the Augmented Dickey Fuller and Zivot-Andrews unit root tests. Table 3 below provides information of the variables being tested at levels, while Table 4 provides information of variables at first difference.

According to the ADF and ZA tests for unit root in Table 3 at levels, industrial electricity consumption, electricity prices, industrial output and economic growth are non-stationary at all formulas. With the results presented above the study concludes that the series is non- stationary, a motivation for the study to perform unit root at first difference.

Table 1: Descriptive statistics results

Variables	Mean	Median	Maximum	Minimum	Std.Dev.
LIEC	10.66088	10.71929	11.17926	9.800901	0.321621
LGDP	25.87195	25.75705	26.85057	24.44050	0.717594
IO	30.42012	28.53161	42.40275	23.35065	5.942058
LAEP	2.575095	2.520917	4.918925	0.223144	1.363493

Source: Own calculation

Table 2: Normality tests results

Test	Statistic	Scaled Statistic	Probability
Shapiro-Wilk	0.6831	-	0.0000
Henze-Zirkler	2.0889	1.0000	0.0000
Mardia's Skewness	11.7043	95.5850	0.0000
Adjusted Mardia's Skewness	11.7043	103.9316	0.0000
Mardia's Kurtosis	25.7944	-	0.3647
Doornik-Hansen	23.1387	-	0.0032

Source: Own calculation

Table 4 presents results of the variables after they were first differenced using ADF and ZA unit root tests. Once the series was differenced for both tests all the variables (industrial electricity consumption, electricity prices, industrial output and economic growth) became stationary at I(1) at 5% significance level. Therefore, the null hypothesis of the series has a unit root is rejected in first difference as removal of unit root has been achieved. The ZA test results are preferred over the ADF as the test is regarded as superior among the traditional ADF unit root test due to identification of structural breaks attributed to price restructuring of Eskom, global financial crisis, socio economic turmoil and political uncertainties.

4.4. Quantile ARDL Results

Since the data does not follow the assumption of normal distribution, the study applies the QARDL. To provide a detailed presentation of different quantiles the study adopted 10 quantiles (i.e., 1st quantile to 9th quantile) whereby 1st-3rd quantile represent the lower quantiles, 4th-6th quantile represent the middle quantiles and 7th-9th quantile represent the upper quantiles throughout the analyses.

Table 5 presents the results of QARDL model, in the long run, the effect of economic growth on industrial electricity consumption is positive on all quantiles. Nevertheless, the effect is statistically significant mostly on the lower quantiles indicating that as economies grow, demand for goods and services typically rises, leading to higher production levels in industrial sectors in the long run, the results are in line with Tiwari et al. (2021); Azam et al. (2021) and Hu et al. (2015) results. This increased output requires more electricity, as industries ramp up operations to meet consumer needs. However, the effect fades away on the middle and upper quantiles.

The effect of industrial output is negative on all quantiles. Nevertheless, the effect is mostly statistically significant on the middle and upper quantiles. Highlighting that a decrease in electricity consumption despite higher output typically indicates that industries are becoming more energy-efficient in the long run, this revelation is in line with the work of (Gonese et al., 2019;

Table 3: Unit root results of ADF and ZA tests at levels

Variable	Formula	Levels					Conclusion
		ADF		ZA			
		t-values	5% critical value	t-values	5% critical value	break-point	
LIEC	Intercept	−3.315**	−2.924	3.037	−4.93	1993	Stationary
	Trend and Intercept	−1.588	−3.506	−3.740	−4.42	2006	Non-Stationary
	None	1.605	−1.948	−4.235	−5.08	2004	Non-Stationary
LAEP	Intercept	−0.387	−2.928	−2.950	−4.93	1996	Non-Stationary
	Trend and Intercept	−1.908	−3.511	−2.333	−4.42	2007	Non-Stationary
	None	2.350	−1.948	−2.37	−5.08	1996	Non-Stationary
IO	Intercept	−0.699	−2.924	−3.585	−4.93	1991	Non-Stationary
	Trend and Intercept	−1.489	−3.506	−3.753	−4.42	2006	Non-Stationary
	None	−1.950	−1.948	−3.733	−5.08	2003	Non-Stationary
LGDP	Intercept	−1.692	−2.924	−3.818	−4.93	2015	Non-Stationary
	Trend and Intercept	−3.080	−3.508	−4.425	−4.42	2013	Non-Stationary
	None	2.277	−1.948	−4.374	−5.08	2009	Non-Stationary

***, ** and * indicate significance level at 1%, 5% and 10% respectively. Source: Own calculation

Table 4: Unit root results of ADF and ZA tests at first difference

Variable	Formula	1st Difference					Conclusion
		ADF		ZA			
		t-values	5% critical value	t-values	5% critical value	break-point	
LIEC	Intercept	−5.282**	−2.925	−6.303**	−4.93	1993	Stationary
	Trend and Intercept	−5.897**	−3.509	−5.584**	−4.42	1998	Stationary
	None	−5.162**	−1.948	−6.502**	−5.08	1993	Stationary
LAEP	Intercept	−4.173**	−2.925	−6.464**	−4.93	2008	Stationary
	Trend and Intercept	−4.106**	−3.509	−4.550**	−4.42	1999	Stationary
	None	−2.876**	−1.948	−6.719**	−5.08	2009	Stationary
IO	Intercept	−5.368**	−2.925	−6.677**	−4.93	1991	Stationary
	Trend and Intercept	−5.321**	−3.509	−5.854**	−4.42	2015	Stationary
	None	−5.113**	−1.948	−5.825**	−5.08	2000	Stationary
LGDP	Intercept	−5.211**	−2.925	−6.140**	−4.93	2003	Stationary
	Trend and Intercept	−5.338**	−3.509	−5.078**	−4.42	2010	Stationary
	None	−5.816**	−1.948	−6.372**	−5.08	2003	Stationary

***, ** and * indicate significance level at 1%, 5% and 10% respectively. Source: Own calculation

Table 5: Quantile autoregressive distributed lag (QARDL) for long-run results

Quantiles	Long-Run			
	C	LGDP	IO	LAEP
1	−5.660 (−1.579)	0.641 (4.510)***	−0.003 (−0.196)	−0.144 (−1.635)*
2	−4.854 (−1.282)	0.623 (4.256)***	−0.011 (−0.604)	−0.168 (−1.734)*
3	−0.918 (−0.118)	0.497 (1.874)*	−0.027 (−0.821)	−0.199 (−2.085)**
4	2.289 (0.252)	0.396 (1.268)	−0.043 (−1.288)	−0.226 (−3.019)***
5	6.939 (1.639)	0.240 (1.590)	−0.060 (−4.130)***	0.240 (−4.262)***
6	8.359 (2.650)	0.192 (1.691)*	−0.065 (−5.869)***	−0.246 (−5.061)***
7	9.894 (3.653)	0.143 (1.461)	−0.071 (−7.500)***	−0.256 (−5.750)***
8	10.819 (4.383)	0.110 (1.238)	−0.073 (−8.461)***	−0.249 (−6.410)***
9	9.952 (2.626)	0.129 (1.008)	−0.060 (−3.241)***	−0.245 (−6.418)***

***, **and *indicate significance level at 1%, 5% and 10% respectively. Source: Own calculation

Goliger and McMillan, 2018; Montmasson-Clair and Ryan, 2014; Kohler, 2014). This could be due to the adoption of advanced technologies, improved processes, or better energy management practices that allow companies to produce more while using less energy which is crucial for maintaining competitiveness in a resource-constrained environment. This trend may prompt government and policymakers to support further investments in energy efficiency and renewable energy initiatives. The study results contradicted those of Husaini and Lean (2015), Olufemi (2015), Li and Yuan (2021) as they established that industrial output has a positive effect towards industrial electricity consumption.

The effect of electricity prices in negative on all quantiles. The effect is mostly statistically significant on all quantiles from lower, middle and upper quantiles. Implying that when electricity prices rise, they directly affect operational expenses, which can squeeze profit margins resulting to reduced electricity consumption as a way of managing operating costs in the long run. Industries with thin margins, such as textiles or food processing, are particularly vulnerable, leading some to cut back on production or even consider relocating to countries with lower electricity costs, this negative relationship is supported by earlier studies (Liddle and Hasanov 2022; Abbasi et al., 2021; Masike, 2019). In addition, elevated electricity prices can deter investment in energy-intensive projects. Industries may postpone or scale down expansions, reducing overall production capacity. This can hinder growth in sectors like manufacturing and mining, which are crucial for the economy.

Turning to the short run results in Table 6, error correction term representing the speed of adjustment is negative across all quantiles. It is statistically significant at lower quantiles and upper quantiles then highly significant at the middle quantiles. The coefficient values of economic growth specify that current and past variations of economic growth slightly affect current variations of industrial electricity consumption negatively and significantly on the lower quantile in the short run. The coefficient values of electricity prices specify that current and past variations of electricity prices negatively and significantly affect current variations of industrial electricity consumption on the lower, middle and upper quantiles in the short run.

4.5. Quantile Processes Results

This section covers the quantile process for residential electricity consumption model. The tests that are included are graphical representation of quantile coefficients and the slope equality test.

Figure 2 presents the graphical representation of the quantile effect of economic growth, industrial output and electricity prices on industrial electricity consumption. The quantile effect economic growth is declining from the lower quantiles until the upper quantiles. While quantile effect of industrial output revealed that from the lower quantiles to the middle quantiles the effect decreases, it was only then on the upper quantiles where the effect started to increase. The effect of electricity prices slowly declined from the lower quantiles whereby on the middle quantiles the effect become stable until the upper quantiles.

4.6. Slope Equality Test

The null hypothesis is that there is slope equality across all quantiles and the alternative is that there is no slope equality

Table 6: Quantile autoregressive distributed lag (QARDL) for short-run results

Quantiles	Short-run				
	C	ECT	Δ LGDP	Δ IO	Δ LAEP
1	−0.048 (−0.888)	−0.119 (−0.874)	0.067 (0.353)	−0.027 (−0.866)	(−0.323) (−0.743)
2	0.014 (0.334)	−0.260 (−1.954)	0.064 (0.304)	−0.033 (−1.149)	−0.346 (−0.914)
3	0.056 (1.794)	−0.410 (−3.771)	0.238 (1.956)*	−0.019 (−1.247)	−0.517 (−2.074)**
4	0.051 (1.985)	−0.354 (−3.621)	0.190 (1.593)	−0.024 (−1.525)	−0.461 (−2.107)**
5	0.055 (2.348)	−0.211 (−2.623)	0.060 (0.472)	−0.007 (−0.426)	−0.329 (−1.619)
6	0.055 (2.476)	−0.202 (−2.698)	0.032 (0.276)	−0.007 (−0.435)	−0.324 (−1.673)***
7	0.069 (3.283)	−0.169 (−2.707)	0.007 (0.065)	−0.008 (−0.521)	−0.353 (−2.005)**
8	0.096 (4.369)	−0.138 (−2.436)	−0.046 (−0.488)	−0.005 (−0.400)	−0.346 (−2.145)**
9	0.084 (3.440)	−0.127 (−1.931)	0.076 (0.616)	−0.018 (−1.043)	−0.174 (−0.980)

***, ** and * indicate significance level at 1%, 5% and 10% respectively. Source: Own calculation

Figure 2: Graphical quantile processes results

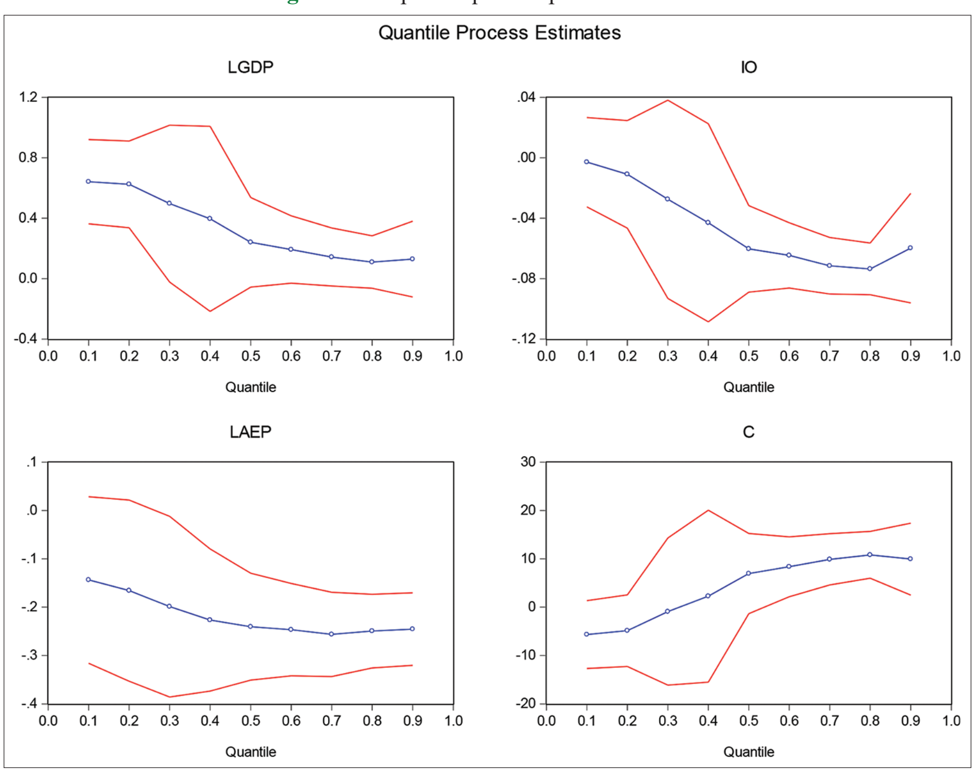


Table 7: Slope equality test

Wald-Test	LGDP	IO	LAEP
Long-run			
Chi-Sq statistics	14.064	20.680	1.615
Probability	0.041	0.008	0.021
Short-run			
Chi-Sq Statistics	4.203	8.093	5.783
Probability	0.838	0.424	0.671

Reject if P<0.05. Source: Own calculation

across quantiles. Therefore, the null hypothesis is rejected if the probability value is <5% level of significance. However, if the probability value is >5% significance then the study fails to reject the null hypothesis.

Table 7 presents results of slope equality test. The results of economic growth reject the null hypothesis of slope equality as the probability of 0.041 is <5% significance value concluding that the slope of economic growth is not equal across quantiles. The results of industrial output also reject the null hypothesis of slope equality as the probability of 0.008 is <5% significance value concluding that the slope of industrial output is not equal across quantiles. The probability value of 0.021 reject the null hypothesis of slope equality across quantiles for electricity prices, concluding that the slope of electricity price is different across all quantiles. In the short run the study cannot reject the null hypothesis of slope equality as probability values of economic growth (0.838), industrial output (0.424) and electricity price are >5% significance level.

5. CONCLUSION

In South Africa, industrial electricity consumption is important, with the industrial sector being one of the largest consumers of electricity in the country. With the rising electricity prices the sector can face decreased profit margins, making it challenging to sustain operations and investing in growth within the industrial sector. Hence the aim of the study was to assess the effect of electricity prices in South Africa covering the period from 1975 to 2023 using QARDL.

The findings revealed mixed results in the long run and short run. It was revealed that economic growth positively and significantly impacts industrial electricity consumption through increased production demands, capacity expansion, and technological advancements. While growth can lead to higher electricity use, it also creates opportunities for efficiency improvements and infrastructure development. Balancing these factors is essential for ensuring sustainable industrial growth and energy management.

The ability to increase output while reducing electricity consumption demonstrates a pathway toward sustainable industrial practices in South Africa. As this is seen by a significant negative relationship across quantiles. Electricity prices on the other hand also revealed a negative and significant impact on industrial electricity consumption. High prices drive industries to seek efficiency improvements, reconsider investment plans, and adapt their operational strategies. Addressing electricity pricing and ensuring a reliable supply are essential for fostering a competitive and sustainable industrial sector.

Increasing industrial electricity consumption is beneficial as it stimulates economic growth, enhances productivity, and supports technological advancements when balanced with sustainability efforts to minimise environmental impacts. This has led to calls for policies that reduces electricity prices and support industrial growth. Implementing targeted incentives, infrastructure investments, and support for energy efficiency and innovation can effectively boost electricity consumption of industries without reducing output. Policies focusing more on growing economies, stimulating demand for goods and services are to be implemented to rise production levels in industrial sector along with its industrial electricity consumption and overall sector's growth.

Future studies may further examine the industrial sector by individually investigating the sub-industries to have a sense on how they behave individually. This reflect the shortcomings of this paper, therefore when reliable data becomes available future studies may go deeper into the industrial sector by considering the above-mentioned shortcomings.

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