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International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2022, 12(6), 283-292.

Effects of Energy Pricing on the Mining Sector Performance in South Africa: An Econometric Approach

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Received: 15 August 2022 **Accepted:** 28 October 2022 **DOI:** https://doi.org/10.32479/ijeep.13678

ABSTRACT

Mining plays a very substantial role in the economy of South Africa. This sector remains to be amongst the greatest consumers of energy in the country, especially electricity. It is against these background that the main objective of this study is to determine the effects of energy pricing on the mining sector performance in South Africa from 1990 to 2019. Johansen and ADRL procedures were used to determine the effects of energy pricing on the mining sector performance in South Africa. The results of the Error correction model (ECM) under Johansen cointegration technique are negative as expected but they are not statistically significant. The study error term is -0.122975, which meant that cointegration relationship is established. The results show that capital stock and labour play an important role in balancing mining productivity, while energy prices, Gross Domestic Product and import prices, on the other hand, play a lesser role in balancing mining productivity. The results of the Error correction model (ECM) under ARDL designate the short-run coefficient for D (LNCT) and D (GDP2) are statistically significant at 1% level and the coefficient of error correction term ecm (-1) valued at -1.037410 is negative and highly significant signifying that in the short-run changes in Capital stock and Gross Domestic Product are associated with mining production. The long-run relationship is illustrated by a negative sign on the coefficient of the ECT. Policy implication of a long-run optimistic relationship between electricity pricing and Mining Sector productivity is that mines should invest on producing their own energy, in that way they will be responsible for reducing their costs and that could results in mines increasing their productive capacity in the long-term.

Keywords: Energy Pricing, Mining Sector Performance, Autoregressive Distributed Lag, South Africa
JEL Classifications: D04, C32, Q47, Q42, Q01

1. INTRODUCTION

South Africa is classified as a developing country and one of the most industrialized countries in Africa. The importance of energy towards the production phases cannot be ignored, as it plays a very essential part in the supply chain because it serves as an input in the production stages of businesses also as a final good for end-users. South Africa's energy production and distribution competencies are extremely complex. "Minerals commodities continued to be the foundation of the South African economy throughout the 1990s and into the 21st century" (Ziramba, 2009). The world today is facing many energy challenges such as power outages experienced internationally and in South Africa. The energy demand is constantly increasing. This sentiment is echoed by Oshikoya and Hussain (2001) indicate that the issue of unstable and high cost disruption of power supply leads to inefficiency in output and affects long-term growth and efficiency, as is the case in most African countries.

The energy sector is a critical vehicle in ensuring that the growth trajectory targeted is achievable and it is critical to the betterment of the lives of poor South Africans. Electricity infrastructure consists of generation, transmission and distribution. In terms of generation, Eskom (state-owned utility) is the major electricity Generation Sector in South Africa (Kohler, 2013). As stated by Creamer, Naidoo and Tyrer (2006), Eskom produces roughly 90% of the power consumed in South Africa from 26 power stations (the Eskom generation mix). Municipalities and redistributors, as well as a private generator, produce the remaining 10%. Eskom is ranked the eleventh largest power utility globally, in terms of generating ability. It is also rated number nine in terms of sales, and boast the world's largest cooling power station. It also owns and operates numerous power stations (coal, gas hydro and pumped storage and nuclear) (DoE, 2018).

2. LITERATURE REVIEW

2.1. Empirical Studies of Developed Economies

Rybak and Rybak (2016) researched Poland's coal mining on possible strategies for hard coal mining because of Production Function analysis. They used productivity, the substitution of production factors and marginal productivity as their selected indicators. They compared the 2006 analysis done by Przybyla and Rybak (2008) with their 2010 results, and the comparison revealed that within 4 years, aggregate production (AE) decreased by 50%, marginal productivity (AE and PR) declined three times and the absence of economies of scale still occurred.

Lundberg (2009) developed the market feature for Swedish industrial energy usage as well as shifts in demand patterns over time by splitting the study into two phases (1960-1992 and 1993-2002). In his results, he found that production was a more substantial factor in the first sample, while the price in the second sample became more trivial. The more effective use of electricity in the second phase was a conceivable reason for this variation.

Kamin΄ski (2008) conducted a study on the impact of liberalisation of the electricity market on the hard coal mining sector in Poland. As a reference model, MON (integrated and centralized monopoly power sector structure) and LIB (fully liberalized electricity market) were used. Kamin΄ski (2008) discovered that the LIB power plant, which is independent of political control, no longer wanted to import coal from domestic sources because it was costly and that saved them money relative to the MON power plants. Results have shown that the demand for hard coal for electricity generation in the MON scenario is much higher, particularly after 2008; the discrepancies between scenarios are between 1, 5 and 3 Mt per year until 2020. The overall demand gap for the entire studied span is 31 Mt.

Katta et al. (2020) developed a study of the disaggregated energy use and greenhouse gas (GHG) emission footprint for Canada's iron, gold, and potash mining sectors. The study found that bottom-up energy demand trees were developed for iron, gold, and potash mining. The energy intensities for each end-user were calculated and used in a bottom-up energy-environmental model to determine the associated GHG emissions of the end-use process using Sankey diagrams. The results revealed that the total energy and GHG emission intensities for iron, gold, and potash mining were 0.7, 149.8, 1.8 GJ/Mg and 33, 4922, 158 kg CO2eq/Mg, respectively. In iron mining, firing had the highest GHG emission share of 66%, in gold mining, ore transport had the highest GHG emission share of 22%, and 34% of potash mining GHG emissions came from product drying and steam generation.

Dagoumas et al. (2020) examined the relationship between energy prices and growth in Europe from 1990 to 2018 using the Engle Granger method to estimate annual data and using the VECM. The study found a causality between the crude oil price and the industrial electricity price to the electricity price for private households. The results also indicate that an increase in electricity prices would not negatively affect European growth rates.

Kirikkaleli et al. (2021) Toda Yamamoto used causality and wavelet coherence tests to analyze the causal relationship between nuclear energy use and growth in the UK from 1998 to 2017. The study concluded that changes in growth will lead to changes in nuclear energy consumption in the UK over the long term. In the short term, between 2002 and 2006, there was a positive correlation between nuclear energy use and growth.

2.2. Empirical Studies of Developing Economies

Agheli-Kohneshahri (2006) projected Iran's production function. He used panel data of the mining industry in several provinces of Iran throughout 1996-2002. To estimate the studies, he used logarithmic Cobb-Douglas, Transcendental and Translog production functions. This was built on the estimates piloted by the Pooled Least Square (PLS) as well as Generalized Least Square (GLS). He discovered that the mines in Iran are more labour intensive and that the return to scale has marginally been bigger than 1. This meant that cumulative returns to scale in Iran's mining exist.

Ghaderi et al. (2006) investigated the role of the energy demand market in Iran. While Egorova and Volchkova (2004) discovered that electricity prices were a factor in energy consumption, while other variables, such as industrial production, proved to be more important, carried out similar sectoral study of Russian industries.

Hosking and Keseke (2012) carried out an analysis on the cost of the discharge of electricity to mines in Zimbabwe using a Straightforward Assessment Method. One clear finding of the report is that the weak state of power supply in Zimbabwe has cost the mining industry tremendously.

Lin and Zhu (2021) conducted a study on the energy efficiency of the mining sector in China. The two-way fixed effects model and the threshold panel model were used to calculate the marginal effect of industrial agglomeration on the total factor energy efficiency (TFEE) of the mining sector. Furthermore, the threshold panel model is used to calculate the influence of industrial agglomeration in regions with different levels of economic development on the energy efficiency of mining. The results show that increasing industrial agglomeration improves the energy efficiency of the mining sector.

2.3. Empirical Studies focused on South Africa

Little to no research have been done on the effects of electricity prices on the production of the mining industry in South Africa and only a handful have been done on power use and industrial development or economic development. Studies in South Africa include, but are not limited to, Szcygielski, Ensil and du Toit

(2018), Inglesi-Lotz and Pouris (2012), Kohler (2013) and Inglesi-Lotz and Blignaut (2011).

Szcygielski, Ensil and du Toit (2018) investigated a study on investment in gold mining stocks and its linkage to the gold price, where they looked at its benefits to investors in a developing economy. They applied a regression analysis tool to investigate the relationship between gold mining proceeds, the gold mining price and the exchange of rand-dollar using a multifactor model inspired by the arbitrage pricing theory. They discovered that there is a resilient, yet changing relationship between gold price, gold mining proceeds and the rand-dollar exchange. Part of their recommendation was that more research into individual gold betas within the ten mining companies must be conducted to achieve more results.

The investigation by Inglesi-Lotz and Pouris (2012) highlights the crucial need to increase energy production in the South African industry in the light of the high percentage of overall electricity usage in the sector. According to Fawkes (2005), energy production developments are opening up to South African firms to raise revenues, improve environmental enforcement, to some degree alleviate competition from competitive suppliers and help resolve capital expenditure constraints. Industrial producers in the country should, as such, support the enhancement of electricity production.

Inglesi-Lots and Blignaut (2011) examined the South African economic sector's electricity consumption in response to fluctuations in electricity prices and economic output for the period 1993-2006. The study adopted a panel data analysis, and results found that the industrial sector was the only sector over that study period with statistically significant price elasticity. In addition, economic production contributed favorably to the commercial and industrial sectors (with strong and significant coefficients). This was in disparity with the other three industries, mining, agriculture and transport, whose electricity use was not influenced either by output or by their expense.

Kohler (2013) has published a report on the differential prices of electricity and energy production in South Africa, with a specific focus on energy-intensive manufacturing and mines. The author claims that by applying a differential pricing strategy, the authorities will target energy-intensive industries by charging certain higher tariffs (as implemented in China after 2004) in order to improve output efficiency and lower overall demand for electricity. A differential tariff system will increase the cost of energy inefficiency and promote the re-optimization of manufacturing processes so that more material inputs and less energy inputs will be required in energy-intensive industries.

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Gonese et al. (2019) examined the impact of electricity prices on production at a sectoral level in South Africa from 1994 to 2015 using the generalized least squares method. The results show that electricity prices have a negative impact on production.

Takentsi et al. (2022) investigated the causal relationship between energy prices and economic performance in South Africa using the Auto-Regressive Distributed Lag (ARDL) Bounds test technique for the period 1994 to 2019. The study established a long-term relationship between the variables. The results showed that electricity prices have a significant negative impact on economic growth in the short and long term, while crude oil prices have a significant positive correlation with economic growth in the long and short term.

3. METHODOLOGY

To investigate the correlation between energy pricing and mining sector performance in South Africa, the study adopted Johanson cointegration technique and Autoregressive Distributed-Lag (ADRL) methods for analysis purpose. Selected variables used in this study are energy (electricity) pricing, labour (mining employment), capital stock, Gross Domestic Product (mining sector contribution), import prices, mining sector output (performance). The research used both formal and informal methods for stationarity analysis. Informal methods provide graphical presentation, while formal methods include all statistical analyses. Lastly, the Granger-Causality technique has been used to assess the causality of the variables.

3.1. Model Specification

To estimate a long-run relationship between energy pricing and mining sector performance in South Africa. The study adopts and modify a model used by Kohler (2013) on differential electricity pricing and energy efficiency in South Africa. Gonese et al. (2019) focused on electricity price impacts on aggregate GDP rather than on mining productivity and Kohler (2013) chose electricity consumption and electricity pricing as variables.

The literature on the relationship between electricity and output has largely focused on the direction of the causality between electricity consumption on industrial sectors rather than the electricity prices on Mining productivity. The model used in this study augments a Cobb-Douglas production function using the following variables: (Electricity price, mining employment (represented by labour), Capital Stock representing the machinery used by mines in the productions process, mining as a contribution to GDP at constant prices, import prices represents the prices of imported inputs in mining production and mining sector performance as the dependent variables).

The implementation of electricity pricing relates with the research by Kohler (2013) and Gonese, Hompashe and Sithole (2019) which also looked at the causality between electricity prices and sectoral outputs in South Africa. Capital stock and import prices are used in the model in such a way as to prevent relevant variables which, according to Gujarati and Porter (2009), may contribute to a bias in the outcome. According to Gonese, Hompashe and Sibanda (2019), there exists a relationship between electricity (energy) prices and production. The empirical model can be defined as follows:

$$M_p = f(CT^+, LAB^+, EP^-, GDP^+, IMP^{-/+}) \quad (1)$$

where MP = Mining sector performance
CT = Capital stock
LAB = Labour
EP = Electricity prices
GDP = Gross Domestic Prices
IMP = Imported Prices

Therefore, equation 4.1 can be represented in the logarithm form in equation 4.2:

$$M_p = \beta_0 + \beta_1 CT + \beta_2 LAB + \beta_3 EP + \beta_4 GDP + \beta_5 IMP + \varepsilon_t \quad (2)$$

where β = Slope coefficients
ε_t = Error term

The expected relationship between Capital stock and Mining performance is positive. This notion to use capital stock to explain mining performance is based on the assumption that as more capital stock increased these may translate into more output of performance (Cobb and Douglas, 1928). Labour was also considered to be in this model, therefore its expected relationship with mining performance is positive. The theory posed that an increase in labour will increase output in mining performance. There is an expected negative relationship between electricity pricing and mining performance. This relationship is viewed in a sense that electricity as an input in mining activity. Therefore, as input prices goes up this might translate in a sabotage in mining output. This is consistent with Adebola (2011); Bildirici et al. (2013); Masuduzzaman (2013); Ciarreta and Zarranga (2010) and Kohler (2013), who substantiate that an increases in electricity price have an unfavorable effect on productivity.

The gross domestic product of a country is one of the main indicators used to measure performance of a country, therefore its expected relationship with mining performance is positive. According to Fedderke and Pirouz (2002), mining sector in particular the gold sector, remains the most essential foreign exchange earner for South African economy. Various studies Atinay and Karagol, 2005; Blignaut et al., 2015; Goosh 2002; and Polemis and Dagoumas, 2013 submit that energy costs have an insignificant effect on the gross domestic product of South Africa.

From the import prices the relationship is expected to be either positive or negative, as the rand appreciate against foreign currencies it will be cheaper to buy input such as machinery and if the rand depreciate against foreign currency it will be expensive to buy machinery. A positive and significant impact of imports is consistent with Rahardja and Varela (2015) who mentioned that sectors import for various reasons such as quality, variety and value. The accessibility of imported inputs has contributed to improved product quality in the Indonesian Manufacturing sector. This entails that production can be improved through imports of cheaper quality machinery and advance technology.

3.2. Data Collection

Abbreviation	Description	Unit of measure	Source
MP	Mining Performance	Millions rands	STATS. SA, DME
EP	Electricity Pricing	Cents per kilowatt hour (c/kWh)	Eskom
CT	Capital Stock	Millions of 2011 U.S dollars	Penn World Table
LAB	Labour (Mining)	Thousands people	STATS. SA.
GDP	Gross Domestic Product	Millions of rands	Trading Economics
IMP	Import Prices	Points	Trading Economics

3.3. Unit Root

There are many ways of checking for unit root. These include the Durbin-Watson (DW) test, the Dickey-Fuller (DF) test (1979), the Augmented-Dickey Fuller (ADF) test (1979), the Phillip Perron (PP) test (1988) and the Kwiatkowski et al. (1992), among others. Nkoro and Uko (2016) define non-stationary time series as a stochastic practice with unit-roots or structural disturbances. Conversely, unit-roots is a primary source of non-stationarity. The presence of unit roots implies that a time series under reflection is not stationary, although the absence of it allows a time series to be stationary.

This depicts that the root unit is one of the sources of non-stationarity. Trend Stationary (deterministic) Process (TSP) or Difference Stationary Process (DSP) can be a non-stationary stochastic system. A time series is said to be a steady-state pattern if the trend is completely linear and not variable where, if not constant, it is considered an integrated or stochastic difference trend. In the case of a deterministic trend, the divergence from the original value (non-stationary mean bodies) is fairly arbitrary and perishes rapidly. They may not influence or contribute to the long-term progress of the time series.

3.4. Co-integration Test

Granger (1981) and Engle and Granger (1987) initially developed the idea of co-integration. It is an econometric procedure that explores the correction of non-stationary variables. If two or more series are non-stationary, but the linear structure of them is stationary, then the series is co-integrated. According to Nkoro and Uko (2016), the cointegration test shows how time series, which can be individually non-stationary and drift far away from balance, can be coupled in such a way that the function of the balance powers certifies that they do not drift too far apart. Cointegration testing is a key step in the establishment if the model shows meaningful long-term relationships in an empirical way. Brooks (2008) stated that cointegration contracts with relationships between a set of variables where each has a root unit.

Mostly, if two variables which are I (1) are regression and correlation, the combination will be I (1) as well. There are several methods to co-integration testing, including Autoregressive Distributed-Lag (ADRL), Engle-Granger, Engle Yoo and Johansen, among others. When a cointegrating vector exists, the method of cointegration of Johansen and Juselius (1990) cannot be implemented. It is therefore imperative to discover Pesaran and Shin (1995) and Pesaran et al. (1996) proposed an ADRL cointegration approach for a long-term relationship, regardless of whether the variables are I(0), I(1) or a combination of both. The research will therefore use the ADRL to provide practical and effective predictions, as well as the Johansen (1998) approach to the cointegration test.

3.5. Granger-causality

The last step of the analysis is to observe the causality relationship amongst the variables. In economics, causality is well-defined as the ability of one variable to forecast the other. The study is focused particularly on two time series variables, which concentrated on analyzing the bilateral causality. The ECM specification is employed to test the causality as it guarantees the consistency of the variables. The null hypothesis to be confirmed here is that there is no existence between two variables of Granger causality. The Granger Causality Test is as follows:

$$X_i = \sum\nolimits_{i=1}^{n} \alpha_{x,i} X_{t-1} + \sum\nolimits_{i=1}^{n} \beta_{x,i} Y_{t-1} + \mu_{x,t} \quad (3)$$

$$Y_i = \sum\nolimits_{i=1}^{n} \alpha_{y,i} Y_{t-1} + \sum\nolimits_{i=1}^{n} \beta_{y,i} Y_{t-1} + \mu_{y,t} \quad (4)$$

where Xt is the first variable log and time t and Yt is the log of the second variable at time t. μx, *t and* μy, t are the white noise error terms at time t. αx, *I* is the past value parameter of value X, which explains to us how much past value of X describes the current value of X and $\beta x,i$ is the past parameter of value Y, which explain to us how much past value of Y describes the current value of X. Related explanations are used to $\alpha y,i$ and $\beta y,i$.

4. FINDINGS OF THE STUDY

4.1. Unit Root Tests

The Unit root test for stationarity presented in Table 1 shows that variable are *I (1),* which suggests that the series are non-stationary and they only become stationary after being differenced once except for LNEP which became stationary in level under ADF. Both LnCT and LnEP are not stationary at first difference under ADF and PP. They only became stationary at levels under KPSS. Variables are *I (1)* under KPSS, which suggests that the study rejects the null hypothesis. The null hypothesis of unit root is rejected when the test statistic is more negative than the critical value.

4.2. Co-integration

Before testing for cointegration, lag selection test must be chosen. The results demonstrated in Table 2 evidently indicate that VAR (1) is the most applicable. The LR test, SIC and HQ all selected one lag while FPE and AIC selected two lags. With VAR order having been recognised, Johansen's (1988) test for cointegration can be applied. For this study 1 lag is chosen because 2 lags gave inconclusive results.

The trace test in Table 3.1 specifies that there are three cointegrating vectors, whereas Table 3.2 specifies that there is one cointegrating vector. Banerjee et al. (1993) specified that in a situation of there is different value of two tests, the results attained from Maximal Eigenvalue for stochastic matrix will be chosen.

Akanbi (2014) mentioned that if we are faced in a conflicting cointegration set-up, the maximum eigenvalue test is accepted when estimating the error correction model as it has a sharper marginal hypothesis that pins down the number of cointegrating vectors. This study decided to choose one cointegrating equation since it makes economic sense. This provides an allowance to evaluate a long-term relationship and Error Correction Model (ECM). The long term equilibrium vector is estimated at Z=LNMP + 1.49 LNCT – 0.278 LNEP – 0.135LNIMP – 0.152 LNGDP2 + 0.447 LNLAB. The coefficient of LNCT, LNEP, LNIM, LNGDP2 and LNLAB are significant at 0.17, 0.03, 0.02, 0.02 and 0.06 respectively.

Table 1: Unit root tests

Variables	Model	ADF		PP		KPSS	
		Levels	Difference	Levels	Difference	Levels	Difference
LnMp	Intercept	−2.018	−5.815*	−2.107	−5.815*	0.273[abc]	0.064
	Trend and Intercept	−2.380	−5.733*	−2.405	−5.731*	0.090[abc]	0.052
LnCT	Intercept	−2.035	−1.072	0.861	−1.276	0.686[a]	0.278
	Trend and Intercept	−2.574	−0.082	−2.221	0.225	0.167[c]	0.157
Ln Ep	Intercept	−1.050	−1.560	0.311	−1.712	0.545[a]	0.288
	Trend and Intercept	−2.736*	−2.365	−1.283	−1.904	0.171[c]	0.098
Ln Gdp	Intercept	−3.455**	−5.162**	−8.473**	−5.162**	0.351[ab]	0.281
	Trend and Intercept	−2.963*	−5.589**	−5.821**	−5.614**	0.165[c]	0.127
Ln Imp	Intercept	−1.034	−4.313*	−1.034	−4.313**	0.661	0.118
	Trend and Intercept	−1.810	−4.304*	−1.680	−4.308***	0.094[ab]	0.099
LnLab	Intercept	−6.150***	−4.306*	−2.403	−4.300***	0.300[c]	0.246
	Trend and Intercept	−3.293**	−4.392*	−2.003	−4.400***	0.135[abc]	0.107

*, **, and *** designates the MacKinnon critical values for ADF and PP at 1%, 5% and 10% levels are−3.679, −2.967 and−2.622 respectively. [a,b]and [c]denotes rejection of null hypothesis of stationarity in KPSS at 1%, 5% and 10% levels at 0.739 ,0.463 and 0.347 respectively. Ln represents logarithms of variables

Table 2: Selection order criteria

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	127.1513	N/A	7.03e-12	−8.653663	−8.368191	−8.566391
1	338.7610	317.4146*	2.68e-17	−21.19722	−19.19891*	−20.58631*
2	381.5092	45.80161	2.46e-17*	−21.67923*	−17.96809	−20.54469

Sample: 1990-2019 LR: Sequential modified LR test statistic (each at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SIC: Schwarz information criterion, HQ: Hannan-Quinn information criterion
Source: own calculations *Indicates lag orders selected by criterion

Table 3.1: Unrestricted cointegration rank test (trace)

Hypothesized No. of CE (s)	Eigen value	Trace Statistic	0.05 Critical Value	Probability**
None *	0.779571	42.34109	40.07757	0.0273
At most 1	0.647251	29.17599	33.87687	0.1644
At most 2	0.576870	24.08215	27.58434	0.1319
At most 3	0.403664	14.47462	21.13162	0.3274
At most 4	0.316085	10.63782	14.26460	0.1733
At most 5	0.069743	2.024245	3.841466	0.1548

Source: own calculations Trace test indicates three (3) cointegrating eng (s) at the 0.05 level,* denotes rejection of hypothesis at the 0.05 level, **Mackinnon-Haug-Michelis (1999) P-values

Table 3.2: Unrestricted cointegrated rank test (maximum eigenvalue)

Hypothesized No. of CE (s)	Eigen value	Max-Eigen Statistic	Critical Value	Probability**
None*	0.779571	42.34109	40.07757	0.0273
At most 1	0.647251	29.17599	33.87687	0.1644
At most 2	0.576870	24.08215	27.58434	0.1319
At most 3	0.403664	14.47462	21.13162	0.3274
At most 4	0.316085	10.63782	14.26460	0.1733
At most 5	0.069743	2.024245	3.841466	0.1548

Source: own calculations Trace test indicates one (1) cointegrating eng (s) at the 0.05 level, *denotes rejection of hypothesis at the 0.05 level, **Mackinnon-Haug-Michelis (1999) P-values

There was a consistent relationship between LMNP, LNCT, LNEP, LNIMP, LNGDP2 and LNLAB between 1990 and 2019. It can be inferred that there is a long-term relationship between variables, but that they could drift apart in the short run. The analysis will use residues from the long-term relationship to examine the short-term correction. The coefficients with negative figures suggest a stable long-term relationship between the dependent variable and its explanatory variables. Cointegration equation one reflects a favorable but not significant relationship between mining efficiency, capital stock and labour, whereas energy prices, Gross Domestic Product and import prices show a negative relationship. The results show that capital stock and labour play an important role in balancing mining productivity, while energy prices, Gross Domestic Product and import prices, on the other hand, play a lesser role in balancing mining productivity.

The significant error correction term between zero and negative two specifies a constant long term equilibrium. In this study the error term is −0.122975, which entails that cointegration relationship is established. The speed of adjustment is 12.3%. This is the speed at which mining productivity returns to equilibrium after a shock in independent variables like electricity pricing. It shows that 12.3% of the gap between mining sector productivity and its equilibrium value is eliminated in the short-run. VECM was piloted at one lag length order with one cointegrating vector at trend 3, Intercept NO tend CE in VAR. Table 4 below gives a summary of Error Correction Model. The Error Correction Model (ECM) of the Johansen test is negative as expected but it is not statistically significant; however, the study holds on the information that the long-run information variables are statistically significant and consistent to economic theory.

The first stage of ARDL modelling identifies the relationship between mining productivity (LNMP) which is a dependent variable and electricity pricing (LNEP) and other explanatory variables. The research examines the existence of long-run cointegration relationship by computing the F statistic. Specified by few observations available for estimation, the maximum lag order for the numerous variables in the model is set at (m=3) and the period of estimation is from 1990 to 2019 presented in Table 3. The F statistic for testing the joint null hypothesis that there is no long run relationship between the variables as defined above is explained in as follows using the bound test. The computed F statistic is F=52.23110 as illustrated in Table 5. The appropriate critical value for this test as computed by Persan, Shin and Smith (2001) at the 99% level is specified by 4.68 upper bound *I (1)*. Since the F statistic surpasses the upper bound of the critical value bound, the test rejects the null hypothesis of no long-run relationship between variables. This test propose that there is a long-run relationship between LNMP, LNCT, LNEP, LNGDP2, LNIMP and LNLAB. Henriksson, Söderholm and Wǻrell (2014) specified that long-run electricity demand in the mining industry is delicate to changes in electricity prices. According to Kummel (1982), the substantial relationship between energy (electricity) prices and sectoral production is constant with the Capital-Labour- Energy and Creativity (KLEC).

Since the null hypothesis of no long-run cointegration relationship amongst variables has been rejected, the study estimates the ARDL model using univariate ARDL cointegration test selection with the maximum lag m=3. The ARDL model specifications nominated based on Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion are the same. The ARDL estimates for these models are presented in Table 6 below.

Table 7 presents the estimated coefficients of the long run relationship are significant for LNCT, LNGDP2 and LNIMP and are not significant for LNEP and LNLAB. The estimated coefficients are positive for LNCT, LNGDP2 and LNIMP and negative for LNEP and LNLAB. This specifies that Capital Stock, Gross Domestic Product and Import Prices have an optimistic statistically significant influence on Mining Productivity/Output rate at 5% level, whereas a change in Electricity price and labour have an insignificant influence on Mining productivity/Output at 5% level. Various studies (Blignaut et al., 2015; Gosh, 2002; Inglesi-Lotz, 2014; Polemis and Dagoumas, 2013) support the

Table 4: Vector error correlation model (johansen technique)

Long-run correlation							
Cointegrating equation	**LNMP(-1)**	**LNCT(-1)**	**LNEP(-1)**	**LNGDP(-1)**	**LNIMP(-1)**	**LNLAB(-1)**
Coint. Eq. 1	1.000000	−1.492399	0.278221	0.015273	0.135544	0.447622
C	21.00824	(0.17966)	(0.03403)	(0.01899)	(0.02606)	(0.06357)
		(−8.30670)	(8.17491)	(0.80412)	(5.20143)	(−7.04127)
Short-run correlation						
Error correction	**D (LNMP)**	**D (LNCT)**	**D (LNEP)**	**D (LNGDP)**	**D (LNIMP)**	**D (LNLAB)**
Coint. Eq. 1	−0.122975	0.151000	−0.83199	2.021939	0.601098	0.362331
	(0.28759)	(0.04138)	(0.36583)	(1.55618)	(1.46779)	(0.56639)
	(−0.42760)	(3.64953)	(−2.27431)	(1.29930)	(0.40953)	(0.63972)

Source: Own calculations

Table 5: ARDL Co-integration test

Test Statistic	**Value**	**K**
F Statistic	52.23110	5
Critical values		
Significant	***I (0)* Bound**	***I (1)* Bound**
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Source: Own calculations

notion that electricity prices have an insignificant effect on the Gross Domestic Product in South Africa.

Tips (2014) stated that electricity price rises have had a wavering impact on the mining value chains in South Africa. The estimation point for the two ARDL models are equivalent and the estimated standard errors attained for the model designated by the SBC and AIC are the same.

The long-run model matching the ARDL for the natural log of Mining Productivity/Output can be written as follows:

$$CointEg = LNMP_t - (1.2589^* LNCT_t - 0.2092^* LNEP_t$$
$$+1.0464^* LNGDP2_t - 0.1324^* LNIMP_t + 0.2851^* LNLAB_t - 27.8581$$

4.3. Error Correction Model (ECM) Estimates for ARDL

According to Arize (2016), Error Correction Coefficient must be between −1<P<0 and should be significantly negative. With the series within the unit interval, it records the speed of adjustment such that when the dependent variable outstrips the long-run relationship with the IV's, they bend downwards at the rate within the range. Hence, it offers an indirect test of cointegration. Bhattacharya (2016) mentioned that if there is a negative Error Correction Coefficient and is significant than a long run relationship between dependent and independent variables, the long-run coefficients resulting from the cointegrating equation will indicate the long-run impact and the coefficient of the first differenced variables will display the short-run impact.

Table 8 explains the results of the estimated ECM model which corresponds with the long-run estimates of Akaike Information Criterion. The estimated Error Correction Model (ECM) has two sections. The first section covers the estimated coefficients of short-run dynamics and the second section covers the estimates of the Error Correction Term (ECT) that measures the promptness of adjustment, where short-run dynamics join the long-run equilibrium path in the model.

Short-run coefficients estimates display the dynamic changes of all variables. The Short-run coefficient D (LNCT) and D (GDP2) are statistically significant at 1%. The coefficient error correction term ECM (-1) appraised at −1.037410 is greatly significant, indicating that mining sector productivity and Capital Stock and Gross Domestic Product are cointegrated. The estimated coefficient of the error correct term is over adjusting as specified with the value of −1.037 and it is statistically significant. According to Jamil and Ahmed (2010), the error correction model works in a manner that error in the previous analyses the correction toward long-run equilibrium. Adebola (2011) indicated that the long-run relationship is illustrated by a negative sign on the coefficient of the ECT.

To evaluate if the adopted model in this study is reasonably appropriate for the data. Diagnostic tests were done and they include Serial Correlation, Ramsey's RESET test (Linearity tests), Normality test and Heteroscedasticity. It is vital to conduct diagnostic tests when analysing because they reveal whether there is a problem in the evaluation of a model or not. If the problem is identified, it means that the model is not effective and this can also suggest that we have biased results. For this study, results were presented in a way that we can say they have economic significance and reasonable. As specified in Table 9 residuals are not serially correlated as indicated by LM-stat probability with 45.51%. Output from the Ramsey's RESET test shows that null hypothesis cannot be rejected since the P-value is 0.1341 which is more than 0.1. The Jarque-Bera test statistic is 8.955 and the probability is 0.011. Therefore, we reject the null since residuals are not normally distributed. It has also been detected that the model is free from existence of heteroscedasticity threats as shown by probability of 82.07%.

Figure 1 indicates the residual's pattern or performance with reverence to its stability. If the curved line which symbolises the residuals were to fall outside the two extreme lines signifying the critical regions, the residuals would have been viewed unstable. The stability of the model is supported from the results of the stability testing using CUSUM test. Meanwhile the residual plot did not fall outside the 5% significant borders, which means the estimates are considered to be stable over the period. Figure 2 shows the CUSUMSQ. The figure illustrates that electricity pricing

Table 6: Autoregressive distributed lag estimates (ARDL) model

Regressor	Coefficient	Standard Error	T-statistic (Prob.)
Dependent variable is LNMP			
LNMP(-1)	−0.179329	0.147610	−1.214887 (0.311)
LNMP(-2)	−0.171872	0.93861	−1.831125 (0.164)
LNMP(-3)	0.085458	0.077658	1.100438 (0.351)
LNCT	1.912626	0.676331	2.827944 (0.066)
LNCT(-1)	−0.970914	0.749160	−1.296003 (0.286)
LNCT(-2)	−2.330395	2.781330	−0.837871 (0.436)
LNCT(-3)	2.694684	2.645147	1.018728 (0.383)
LNEP	−0.049188	0.057035	−0.862413 (0.452)
LNEP(-1)	−0.047249	0.054323	−0.869780 (0.448)
LNEP(-2)	−0.153554	0.106963	−1.435577 (0.246)
LNEP(-3)	0.032979	0.056113	0.587717 (0.598)
LNGDP2	1.081601	0.101894	10.61493 (0.002)
LNGDP2(-1)	0.006321	0.021994	0.287403 (0.792)
LNGDP2(-2)	0.027878	0.017185	1.622205 (0.203)
LNGDP2(-3)	−0.030228	0.017678	−1.709932 (0.186)
LNIMP	0.011602	0.023687	0.489819 (0.658)
LNIMP(-1)	−0.019267	0.029582	−0.651297 (0.561)
LNIMP(-2)	−0.032650	0.021688	−1.505419 (0.229)
LNIMP(-3)	−0.097087	0.035089	−2.766852 (0.070)
LNLAB	−0.083702	0.079274	−1.055848 (0.368)
LNLAB(-1)	0.023919	0.052673	0.454107 (0.680)
LNLAB(-2)	0.169096	0.081976	2.062739 (0.131)
LNLAB(-3)	0.186423	0.119623	1.558424 (0.217)
C	−28.90024	8.740591	−3.306440 (0.045)
R-Squared	0.998726	Adjust. R-Squared	0.988957
S.E. of regression	0.004242	F-Statistic	102.2391 (0.001)
Mean of dependent variable	4.6186	S.D. of Dependent Variable	0.040372
Residual sum of squares	5.40E-05	Equation Log-Likelihood	138.8415
Akaike information criterion	−8.506776	Schwarz Bayesian Criterion	−7.354921
DW-statistic	2.9668	Hannan-Quinn Criterion	−8.164269

Source: Own calculations

Table 7: Estimated long-run coefficients using the ARDL approach for model

Regressor	Coefficient	Standard Error	T-ratio (Prob.)
Dependent variable is LNMP			
LNCT	1.258907	0.413867	3.041813 (0.056)
LNEP	0.209187	0.078609	−2.661104 (0.076)
LNGDP2	1.046425	0.227782	4.593987 (0.019)
LNIMP	−0.132446	0.034354	−3.855328 (0.031)
LNLAB	0.285072	0.118039	2.415071 (0.094)
C	−27.858076	7.094437	−3.926750 (0.029)

Source: Own calculations

Table 8: Error correction representation for ARDL model

Regressor	Coefficient	Standard error	t-statistic (prob.)
ARDL dependent variable in LNMP			
D (LNCT)	1.912626	0.676331	2.827944 (0.066)
D (LNEP)	−0.049188	0.057035	−0.862413 (0.452)
D (GDP2)	1.081601	0.101894	10.614932 (0.002)
D (LNIMP)	0.011602	0.021688	−1.622205 (0.203)
D (LNLAB)	−0.083702	0.079274	−1.055848 (0.368)
ECM(-1)	−1.037410	0.174003	−5.962037 (0.009)

Source: Own calculations

is a good measure of mining performance since residuals move somehow in the bent at 5% at the level of significance.

4.4. Granger Causality

Table 10 presents the granger causality results. Therefore, it should be noted that only results of the main variables of interest are presented in this chapter and the remaining other results are in the appendix (G). The presence of a long-run relationship amongst variables indicate that causality may exists. The study used pairwise (bilateral) approach which indicates the causal relationship between electricity pricing and mining performance (output) with f statistic of 2.36021 and probability of 0.1169, due to the insignificance of the probability, conclusion can be that electricity pricing does not granger cause mining performance.

Table 9: Short-run diagnostics

Test	Null Hypothesis	t-statistic	Probability
Langrange multiplier (LM)	No Serial Correlation	21.408	0.455
Linearity (Ramsey's)	Cannot reject null hypothesis	5.993	0.341
Jarque-Bera (JB)	There is normal distribution	8.955	0.011
Breusch-Pagan (CH-sq)	No conditional heteroscedasticity	0.562	0.820

(A) Lagrange multiplier test of residual serial correlation. (B) Ramsey's RESET test using the square of the fitted values. (C) Based on the skewness and kurtosis of residuals. (D) Based on the regression of squared residuals on squared fitted values.
Source: Own calculation

Furthermore, the results indicate that mining performance with F statistics of 2.46586 and the probability of 0.1071 is significant at 10% probability does not granger cause electricity pricing. This implies that there is no bidirectional relationship between mining performance and electricity prices for the observed period. Berk

Figure 1: CUSUM

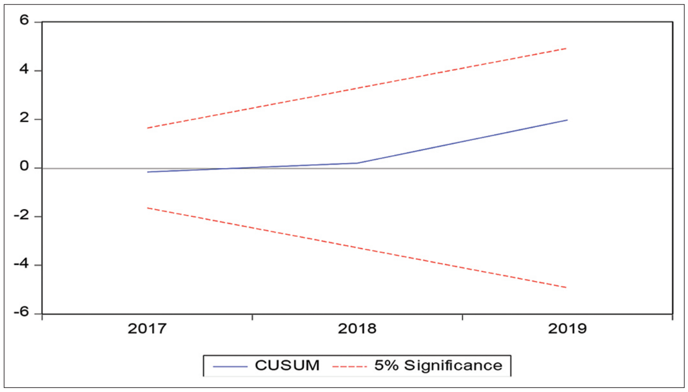

Figure 2 : CUSUM of squares

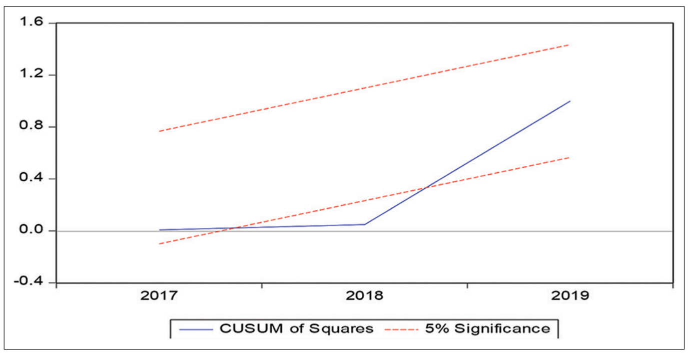

Table 10: Granger causality test

Null hypothesis	Obs.	F-statistics	Prob.
LNEP does not Granger cause LNMP	28	2.36021	0.1169
LNMP does not Granger cause LNEP		2.46586	0.1071***

*,**, and *** show significant at 1%, 5% and 10% respectively. Source: Own calculation

and Ÿetkiner (2013) used facts on the U.S energy prices and economic relationship for the period of 1951-2010 which revealed that the growth rate of energy prices may negatively influence growth rates of both GDP and energy demand. Narayan and Smyth (2005a) observed the relationship between electricity consumption, employment and real income for Australia using multivariate Granger causality for the period 1966-1999. They found a unidirectional relationship between GDP to electricity consumption and from GDP to employment. Wolde-Rufael (2009) found unidirectional causality between energy consumption and economic growth, while Ziramba (2009) discovered a bio-directional causality between the energy consumption and industrial output.

5. CONCLUSION

Mining remains a critical Industry with an enormous influence on the economy. South Africa instantly needs to advance the regulatory environment in the mining industry. High consumption costs led to retrenchments because of high tariffs hikes in electricity pricing. The experience of the South African electricity supply sector over the past 30 years has proven that electricity prices do not reflect accurate economic expenses of delivering power, which led to gross misallocation of resources and poor decision-making. After the 2008 power crisis, it has been proven that there is a direct relationship between electricity prices and mining sector productivity. The reality is that the South African mining sector has been experiencing serious challenges. Electricity prices increases resulted in a decrease in productivity, especially in the gold industry, power outages and a decline in GDP contribution. The sector is looking at mechanisation to address these problems. The study discovered that there was a cointegrating relationship between mining sector productivity, electricity pricing, capital stock, gross domestic product, import prices and labour. The results revealed that approximately −1.037 of the disequilibrium is corrected for mining sector output.

South Africa's Mining Sector has been subjected to a deterioration in its output (especially gold mining) due to extreme increase in electricity tariffs since the 2008 economic crisis. To reduce electricity price hikes, South African Government should invest on renewable energy technologies. This is in line with National Development Plan (NDP) and South African climatic change (NPC, 2011) with the objective to support the scale-up of low carbon local technology market. The observed results on this study found that there is a long-run optimistic relationship between electricity pricing and Mining Sector productivity. The study also agrees with Mineral Council South Africa that mines should invest on producing their own energy, in that way they will be responsible for reducing their costs and that could results in mines increasing their productive capacity in the long-term. Policy makers should also adopt Kohler (2013) proposal that authorities should target electricity intensive industries by employing a differential pricing policy. This will not only improve the mining sector output but it will also create further employment opportunities in the country.

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