Impact of coal prices changes on prices of electricity in South Africa

Gugulethu Nene
Pfano Mashau
Sinakhokonke Mpanza
University of KwaZulu-Natal, South Africa

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Abstract
The main purpose of this research is to analyze the impact of changes in coal prices. Scholars insinuated that the extensive capital requirements of building thermal power stations and coal mines lead to power production costs parachuting beyond the reach of many economic players. These rising costs in coal prices and power production costs, the retail price of electricity has not been adjusted, resulting in many players in this industry incurring losses. This study will use Statistical multiple regression and correlation analysis to test the relationship between two variables, coal price changes being an independent variable and changes in the price of electricity being the dependent variable. The findings show a strong dependence between changes in coal prices and electricity pricing in South Africa. People scrambling to coal mining is a concern since no proper regulations lead to land degradation. Moreover, since NERSA regulates electricity prices, miners are forced to use cheaper methods of extracting coal to keep the costs low.

1. Introduction

The cost of electricity may be determined using economic models with different degrees of confidence. According to Deloitte & Eskom (2009), the most trusted way to judge such predictions is by looking at historical costs and trends. They also suggested that electricity has moved substantially in real and nominal terms. The research by Deloitte (2016), stated that in 1960s prices of coal were characterized by price stability, followed by substantial nominal price increases in the 1970s. Between the 1980s and 1990s, price stability was realized again. The trend changed around 2000, where prices started to increase. Similar long-term movements have been realized in coal, natural gas and crude. The explanation can be that electricity generation is dependent on its input fuel source. Specifically, the same trend has been witnessed between electricity and coal (Mohammadi, 2009).

An increase in the competitiveness in the electricity markets may translate to spot markets that immediately respond to input fuel source market changes (ESKOM, 2016). The reverse is true that electricity price changes cause movement in the source price (Asche et al.2006). The unit cost of electricity largely depends on the power plant cost in which it is produced. The cost is compounded by the generating plant's basic installed cost, and the fuel costs in the case of a fossil-fuel powered plant. The power plants fired with coal accounts for about 40% of the global power generation. This makes it the most important source of electricity today, with renewable sources continuing to grow from a small base (Chamber of Mines of South Africa, 2018).

It should also be noted that coal fired electricity generation is the most polluting one. This raises environmental concerns over global warming, one of the world's greatest problems. The new pragmatism banks on the realization that the use of coal should continue at least for another generation. However, both environmentalists and generators have reached the consensus that carbon capture and storage is the only hope for future coal combustion, a process which is being financed partly through carbon taxes.

The interest of this study is propelled by the need to empirically measure the effect of coal price changes on the prices of electricity in South Africa. The issue of coal price changes is crucial, as coal prices affect the macroeconomic indicators of every country. In early 2008, South Africa experienced the first of a series of highly disruptive outages and load-shedding episodes that came at an enormous cost to the economy. The electricity supply crisis prompted decision makers to respond with greater urgency to the capacity shortage that had been threatening to emerge for some time, and Eskom was given the go-ahead to embark on a massive investment programme. However, in the 20 years since Eskom had last invested in base load capacity, real electricity tariffs had declined to such an extent that it became apparent that Eskom would not be able to finance the newly built programme on the basis of its existing low tariffs and inadequate revenue. In the five years between 2008 and 2013, electricity prices more than doubled in real terms, rising by a cumulative 114%, as the national energy regulator (NERSA) granted Eskom tariff increases to help it raise debt for the new build. However, the sharp increases in real electricity tariffs over this period prompted a public outcry, and NERSA took a decision to limit the increase in real electricity tariff to approximately 2% per year for the 5-year period from 2013 to 2018 (NERSA, 2013).

Due to the magnitude of the problem, which is facing the economy, the researcher is motivated to follow the bandwagon of other researchers who already weigh in to try to come up with solutions to solve and analyze the real causes of the increases in electricity prices. The overall aim of the research of the study is to provide different interested parties with the history of electricity prices and consumption on a wide spectrum. To evaluate the major, South African electricity pricing policy criticism and to surface the challenges faced by Eskom as the provider and regulator of South African electricity pricing.

2. *An overview of electricity in South Africa*

According to the Eskom (2013), it is a 100% state-owned vertically integrated electricity utility enterprise. It supplies approximately 95% of South Africa's electricity from a net maximum generating capacity of 41.9 GW and a transmission and distribution network of 373 280 kilometres (km). The remaining 5% of the electricity supply is made up of a small group of municipal and industrial representatives, predominantly for their own use. In 2012, approximately 42% of Eskom's sales were to (re)distributors in the form of municipalities, which also fund and maintain distribution networks in their respective geographical areas. Municipal customers in turn include industrial, commercial and residential users. From the 1970s, Eskom embarked on a strategy to leverage economies of scale through the construction of power stations, each with a capacity of 3600 MW or larger.

These power stations are built adjacent to the coalfields in order to minimize coal transport many of the adjacent coal mines supply coal to Eskom by conveyor on a long-term cost-plus station is ageing and many of the power stations are nearing retirement age. A period of very low economic growth (and thus power demand) at the end of the 1980's and early 1990s resulted in a delay in the introduction of new electricity supply capacity. This was followed by a more recent, high economic growth in the late 1990's and early 2000's. Over time, the lack of investment in new supply capacity has narrowed the electricity supply reserve margin. Additional coal supplies will be required for power stations running at higher load factors or longer lifetimes beyond what was originally planned. In addition, Eskom has two new large coal-fired power stations under construction (approximately 4800 MW each), due to be commissioned between 2013 and 2019.

In 2003, the South African Cabinet made a policy decision to introduce independent power producers (IPP) into the electricity supply industry, such that future electricity generation capacity would be divided between Eskom (70%) and the IPPs (30%). In 2007, the Cabinet designated Eskom as the single buyer of power from the IPPs in South Africa.

In 2011, the Department of Energy published the current iteration of the Integrated Resource Plan (IRP) for South Africa (IRP2010). This plan specifies the new generation capacity requirement for South Africa for the period 2010 to 2030. The IRP is expected to be updated on a regular basis. The need to accelerate development in Africa is widely recognized and access to clean, reliable energy is vital to that task. Excluding South Africa and Egypt, it is estimated that no more than 20%, in some countries as little as 5% of the population, has direct access to electricity (Eskom, 2016). To deal with the challenge of financing new generation capacity, some countries have sought to increase the level of generating capacity to work towards integrating national power grids and creating cross-border power pools. The Southern African Power Pool (SAPP) is Africa's first formal international power pool. It was created to provide reliable and economical electricity supply to the consumers of each SAPP member, consistent with the reasonable utilization of natural resources and the effect on the environment. The current countries/utilities that are SAPP members include Mozambique (Electricidade de Mozambique, HCB, Motraco), Botswana (Botswana Power cooperation), Malawi (Electricity Supply Commission of Malawi), Angola (Empresa National de Electricidade), South Africa (Eskom); Lesotho (Lesotho Electricity Corporation); Namibia (Nam Power), Democratic Republic of the Congo (Société National d'Électricité), Swaziland (Swaziland Electricity Board), Tanzania (Tanzania Electric Supply Company), Zambia (Zambia Electricity Supply Corporation) and Zimbabwe (Zimbabwe Electricity Supply Authority). SAPP has made it possible for members to delay capital expenditure on new plants due to the existence of interconnections and a power pool in the region. This is an important aspect of developing the economies of Southern Africa. While Eskom (and hence, South Africa) is currently a net exporter of electricity, net international sales (sales less purchases) represented only 2.8% of Eskom's total sales in 2013. The majority of the imports are from Cahora Bassa (HCB) in central Mozambique, with small volumes from Lesotho. Eskom exports firm power to the national utilities of Botswana (BPC), Namibia (NamPower), Swaziland (SEC) and Lesotho (LEC).

2.1. Market design

Historically, the National Electricity Regulator (NER) was the regulatory authority that presided over the electricity supply industry (ESI) in South Africa. NERSA replaced the NER in terms of the National Energy Regulatory Act 40 of 2004. Under the Electricity Regulation Act 4 of 2006, it is required to issue licences to all players involved in the production and supply of electricity and to "regulate prices and tariffs" that are supplied by electricity licensees. For much of the past three decades, electricity prices in South Africa have been low and declining in real terms, where electricity price increases did not keep up with inflation. However, from 2008, the trend in prices took a dramatic turn. This increase in electricity prices is the outcome of a policy to charge cost-reflective tariffs.

The move towards cost-reflective prices in the electricity sector started with Eskom's first price application to Nersa, including the following components:

- primary energy, including costs relating to IPPs.
- operating costs, including integrated demand management programmes.
- depreciation, based on Eskom's recently valued replacement asset base.
- return on assets.

In regulatory terms, a price that fully addresses all of the above components would be "cost reflective." Demonstrating that Eskom is on a sound financial footing is a necessary pre-condition to raising the investment required to fund the building of new electrical supply capacity projects. According to a report by Deloitte (2012), between 2008 and 2011, real electricity prices rose by 78%. However, despite the significant increases, they also claim that electricity prices in South Africa are still low by international standards and do not yet reflect the full economic cost of supplying power Eskom continues to apply for multi-year price determinations (MYPD) from NERSA. After extensive stakeholder engagement, NERSA then makes a decision on what revenue will be permitted per year, for the period requested. As a result of NERSA's previous two multi-year price determinations, electricity revenues have exceeded operating costs. Effectively, a determination is made on the average price increase, which is then translated into a range of tariffs, which are differentiated according to customer class. It is important to note that individual customers may not experience this average price increase; some customers experience higher increases and others experience lower increases (including subsidies, where the government has identified a social imperative). Redistributors also incorporate their own network costs and revenue requirements to decide on their final electricity prices.

2.2. Operating costs

Since Eskom has a monopoly on electricity production in South Africa, the average electricity price is determined by NERSA, through the process outlined above. On the production side, Eskom minimizes costs by dispatching plant according to lowest variable costs, a significant portion of which is attributable to fuel inputs. The low electricity supply reserve margin necessitates that all plants run whenever possible and cost order dispatch is not currently possible. This situation is expected to persist until sufficient new capacity is brought on board. Although currently there is no explicit carbon price in South Africa, carbon constraints were factored into the most recently promulgated national electricity supply plan (IRP2010) and the electricity price also carries an environmental levy of ZAR 3.5c/kWh. More explicit carbon pricing has been proposed in the form of a carbon tax. To date, the information provided concerning the proposed carbon tax according to the National Treasury, (2013) is that:

- a carbon tax which was implemented in January 2015 is adhered to
- the first phase of implementation covers the period 2015 to 2020
- the basic tax-free threshold on emissions remains at 60% during this first phase
- the 60% may be reduced or removed in the second phase.

Certain industries may be allowed to increase this threshold by up to 10% for trade exposure and 10% for process emissions, plus 5% to 10% for offsets (but how these offsets will be assessed is still to be defined); the tax value is set at ZAR 120 per ton of carbon and will increase by 10% annually, during the first phase; Scope 2 (including electricity) emissions will be taxed. Considering the regulatory rules governing tariff increases in the electricity sector, any environmental tax is likely to be passed through to consumers. Another report by the South Africa Department of Environmental Affairs (2011) indicated that the Department of Environmental Affairs was developing a carbon budget for the country per the National Climate Change Response Strategy. This would be expressed as desired emissions reduction outcomes per economic sector. The interface between sectoral carbon budgets and the proposed carbon tax is also being assessed. South African coal-fired power stations are supplied exclusively by the domestic market, either through dedicated, cost-plus mines, or with the middling product from multiproduct mines or through short and medium-term contracts. There is an indirect connection to the world market through the beneficiation choices of multi-product mines, as well as the future investment choices of mining houses. The impact of global coal market prices on short and medium-term domestic contract prices has been partially limited by the constrained infrastructure to export coal from inland reserves. National domestic coal prices are, on average, well below international prices. Given the volatility of coal prices, the relation between domestic and international prices has varied greatly through the years. Since 2008, when export coal prices at the port (Richard's Bay Coal Terminal) were on average almost five times higher than the domestic prices at mine gate, the ratio has been closer to three to one more recently. However, these prices are not directly comparable, given the differences in qualities (yield factors and beneficiation costs) and location (transport, handling costs and terminal charges). South Africa only has 2 409 MW of open cycle gas turbine electricity generation installed capacity, about 5% of the total. Due to the lack of local availability of natural or liquified natural gas, these stations are run on liquid fuels. They are only dispatched during peak periods and extreme emergencies due to high operating (fuel) costs. The cost of coal in 2012 constituted around 27% of Eskom's total operating costs (calculated from Eskom, 2013). The NERSA determination allows Eskom an average nominal coal price increase of approximately 8% per annum, between 2014 and 2018. Meeting the NERSA ruling is of concern to Eskom as the unit cost of coal burnt increased by approximately 14% (adjusted for contractual penalties) between the financial years ending March 2012 and March 2013. Price increases reflect both changes in coal sources and the effect of longer transport distances.

However, there is not necessarily a direct correlation between coal and electricity prices. Electricity prices are regulated, and other cost components vary in addition to primary energy costs. Based on certain assumptions on the value of assets, under the IRP2010, it was projected that the cost of electricity should rise to approximately 78c/kWh (2010 ZAR), in order to reflect the full economic cost of electricity supply from the existing fleet (Republic of South Africa, Government, 2011). This compares with an average electricity selling price of around ZAR 45c/kWh in 2010 (Eskom, 2012b). The current price discrepancy reflects a smaller depreciation allowance or a lower allowed rate of return, which NERSA has determined to minimize potential negative effects of electricity tariff increases on the economy and South African society.

How have consumer prices for electricity developed since 2000, differentiated according to important customer groups? In South Africa, different customers pay different prices for electricity. Domestic and street lighting, for example, almost doubles industrial prices. If we compare the evolution of the different consumer groups in the decade starting from 2001, prices in nominal terms have doubled on average, but with different profiles. Domestic and street lighting only increased 45%, partially offsetting higher increases in most of the other groups.

2.3.4 Global Trends of coal and electricity prices

Global electricity markets are in transition. Major drivers across all continents are the ongoing liberalization movement to implement competitiveness and cost efficiency, the extension of renewable energy sources to increase sustainability and the need to guarantee sufficient available generation capacities in all markets to implement and maintain the security of supply. Although short-term challenges and political measures vary across the different electricity markets in the world, these general targets are internationally valid. This is illustrated within five electricity market studies from Europe, the United States, Australia, Japan and South Africa.

The markets use the competitive position of coal-fired power plants and their technical flexibility to compensate for short-term hangs in power demand, i.e., in times of rising electricity consumption, additional coal plants are requested by the market to be ramped up and in times of declining consumption, some coal capacities are temporarily disconnected from the grid. Therefore, coal-fired plants' dispatch behaviour is transferred into wholesale market power prices. In order to incentivize some plants to connect and disconnect from the grid, electricity prices still need to follow their specific generation cost. As a consequence, the price impact of the generation cost of coal-fired plants is significantly higher than their market share. In some European markets, the price impact of coal further increased, although renewables partly substituted the market share. Globally, coal fired power generation covered more than 40% of global electricity demand in 2012. According to the analyzed market impact of coal-fired generation capacities, the influence of coal generation cost on the world electricity prices is even higher than the world market share. Based on the current outlook for the world energy markets, a remaining cost pass-through of more than 50% is likely in the time frame 2013 to 2020. Hence, temporary scarcities in the coal supply chain and adjacent price shocks for coal are to be avoided to keep wholesale electricity prices on a stable level.

3. *Empirical review*

Bachmeir and Griffin (2006) tested for cointegration within and between different crude oil, coal and natural gas markets. Various crude oils from global markets seem to be highly cointegrated and a cointegration relationship in the long run between oil and natural gas is found, but in contrast, a weak cointegration relationship in the U.S. coal market is the case.

In 2009, Mjelde and Bessler studied dynamic price relationships between US peak and off-peak electricity wholesale spot prices from the PJM and Mid-Columbia (Mid-C) for the period 2001-2008. These prices were linked to four major fuel sources: natural gas, crude oil, coal and uranium. They studied eight price series and found all eight to be cointegrated with all series included in the long-run relationships, keeping the price-movements together. However, they found less than n-1 cointegrating vectors, meaning the markets are not fully integrated and there is no common trend. Electricity prices influence natural gas prices in contemporaneous time and natural gas prices influence oil prices. In the long-run, fuel source prices have a leading role on electricity prices. The fuel prices (except uranium) are stable when disequilibrium finds place. Uranium and electricity are the variables that change in order to restore equilibrium.

Mohammadi (2009) researched the long and short-run dynamics between electricity prices and three fossil fuels (coal, natural gas and crude oil) in the U.S, making use of yearly data for 1960 – 2007. He finds only evidence of significant long-run relations between electricity and coal. Crude oil prices have no significant influence on electricity prices and the relationship between natural gas and electricity prices is statistically weak. In the short run, a one-way causal relationship is detected from coal and natural gas prices to electricity prices.

With regards to the passing through of carbon costs, Sijm, Neuhoff and Chen (2006) distinguished between the behaviour of individual generators and the impact on the price system as a whole, by defining the 'add-on' and the 'work-on' rate. The 'add-on' rate is the extent to which individual generators pass on carbon costs into their bidding prices (which is usually 100 percent). The 'work-on' rate is the rate that is effectively passed-on to the power prices on the market (which is often less than 100 percent due to a variety of reasons). "One reason why the work-on rate may be lower than the add-on rate is market demand response" (Sijm, Neuhoff and Chen, 2006). Higher electricity prices may reduce the total demand and prevent an expensive generation unit from operating as the marginal producer. The electricity price will thus be lower, but the variation in price will be lower than the change in marginal costs due to emissions trading. As a result, the add-on rate will remain at 100 percent and the work-on rate will be lower than 100.

According to Neuhoff et al. (2005), the opportunity cost of emitting carbon may be reduced when allocation is updated. They argue that updating implies a cost of not-emitting: high emissions today hold the promise of a higher allocation tomorrow. In case of updating and elastic power demand, power producers will not pass on the full opportunity costs, as this will reduce their output/emissions and, as a consequence, the number of free allocations in the next period. Hence, they will balance these two (opposing) effects until an optimal equilibrium is reached (Sijm et al, 2005). Overall, if updating is applied beyond the first commitment period, it may reduce today's electricity prices and future electricity prices.

To estimate the carbon pass-through rate onto power prices, Sijm et al (2006) relied on empirical and statistical analyses of trends in prices of fuels, carbon and electricity in Germany and the Netherlands, over the period between January-July 2005. Rates of pass-through of carbon costs onto power prices are estimated based on four cases: Germany, for peak and off-peak hours where coal-fired producers mainly set prices; the Netherlands, for peak and off-peak hours, where gas fired plants set peak prices, while coal plants fix off-peak prices. The Ordinary Least Squares (OLS) and Prais-Winston (PW) methods are two statistical regression approaches. Energy Research Centre of The Netherlands developed one simple regression-line approach. The difference between the OLS and PW methods mainly concerns the incidence of so-called autoregression or autocorrelation among the data used. The existence of such autocorrelation could bias the estimated results. While the PW method corrects for this incidence/bias, the OLS does not. The method developed by Energy Research Centre of the Netherlands is based on analysing dark/spark spreads over a certain period, excluding and including carbon costs. When the costs of carbon are included, these are called clean dark/spark spreads. The authors assume that the trend line of these spreads in Germany and the Netherlands should be flat when including the carbon costs, assuming in effect that all remaining variations of these spreads can be attributed to random variables with an expected value of zero. The method consists in solving for the pass-through rates that will satisfy this condition.

Sijm, Neuhoff and Chen (2006) update this analysis with a longer observation period and a more refined statistical approach. They found much higher pass-through rates. The very high rate for Germany may be partially explained by increasing gas prices during 2005. "Given that gas generators (instead of coal generators) set the marginal price in Germany during their competence modelling work, the authors could further differentiate load periods throughout a calendar year. While the marginal technology may remain constant throughout (most of) these load periods, the authors noticed a switch in marginal technology between these periods. Bootstrapping: a method of calculating errors using only the data at hand as a distribution. As explained by the authors, they constructed a subset data by bootstrapping samples from a window of a two-month period, and then ran their regressions based on the combined data from the peak hours, this could contribute to power prices' increase in peak forward contracts. As coal generators benefit from this gas cost-induced increase in power prices, it leads to overestimating the pass-through rate of carbon costs for coal-generated power. The method used, which consists in assuming away other factors behind price variations (averaged at 0), makes the observation period crucial.

In a report from the Energy Information Administration which assesses the impacts of a greenhouse gas emissions regulation on electricity prices in the US through a cap-and-trade scheme, it is expected that if a portion of allowances is provided for free to regulated utilities, regulators are expected to pass these savings on to consumers. Increases in electricity prices equivalent to the opportunity costs of free allowances would not occur. The report concludes that the impact on electricity prices is slightly smaller than in a full auctioning scenario. It also notes that in contrast, 23 in regions where electricity prices are set competitively, the changes relative to the reference case are the same in both partial and full auction cases.

A Finnish study (Honkatukia et al, 2006) empirically assessed the developments of the European Union Emission Trading Scheme in the first 16 months. Based on econometric calculations from the collected data, the estimated results indicate that on average, approximately 75 to 95 percent of the price changes in the European Union Emission Trading Scheme are passed on to the Finnish Nord Pool day-ahead prices. The authors analyzed the development of daily and hourly Nord Pool prices in the Finnish market area of Nord Pool and tested their correlation regarding several factors: various scarcity capacity indicators, input cost indicators such as the prices of coal, natural gas and carbon allowance prices and demand shaping indicators (e.g., weather, working day or weekend, etc.). They ran three econometric models on Finnish electricity prices from February or May 2005 to May 2006.

The authors also simulated to what extent the passing on of allowance prices varies when the state of the power system varies (and hence the power prices). The presented indications for the extent to which the prices of the European Union Emission Trading Scheme are passed on to electricity prices reflect a situation of the past over historical data from May 2005 to May 2006. The results share a rise in European Union Allowances Prices (EUAP) passed on to the Electricity Spot Price (ESP) for different single-day European Union Allowances (EUA) price increases for different typical loads, low loads, medium loads and high loads variation in percentage Share of variation in European Union Allowances price passed onto spot price

According to a report by Ilex (2004), in the several European electricity markets studied, it is likely that carbon allowance prices will be passed onto electricity wholesale and retail prices. Key elements influencing the pass-through rate include the Market Structure (MS) of generation, new entry and closure rules, tightness or looseness in National Allocation Plans (NAP-T/L) and the influence of government and regulators. Ilex makes a general assumption for all countries that there will be a full pass-through of carbon allowance prices onto wholesale and retail prices unless there are specific reasons for expecting otherwise. In countries with incomplete pass-through, regulatory or political intervention is the main factor that will curtail price rises. Nevertheless, in its report, Ilex assigns relative confidence levels to its estimates, 1 being low confidence and 3 being high. They mention uncertainty with respect to Germany in particular: full pass-through is by no means guaranteed as a result of a relatively achievable NAP, dominant generators, and uncertainty, as to the level of intervention by the regulator.

Some of the previous literature directly focused on the relationship between absolute energy prices and energy consumption, which can reveal a visible relationship between energy prices and consumption. Many studies support the notion that rising energy prices lead to reduced energy consumption (Fei & Rasiah, 2014). Some of these studies focus primarily on the channels through which energy prices influence energy consumption. However, Steinbuks and Neuhoff (2014) argue that improvements in energy efficiency and reductions in energy input, resulting from rising energy prices are the main reasons for reduced energy consumption. In practice, the own-price elasticity of energy in different industries, the purposes of energy consumption (Zheng & Wei 2014), and the sensitivity of energy prices in different areas all vary (Moshiri, 2015). These studies support the premise of this study that the effects of relative energy prices can be studied from the perspective of inflation costs.

Another study which was examined in China by Xinye and Chen Zhan-Ming (2016) found that China is currently facing significant economic uncertainties brought forward by the instability of coal price. By separating the asymmetric effects of upward and downward coal price changes on the economy, this study re-examines the relationship between coal price and general price level in China. The asymmetric effects are investigated via vector autoregression models, Granger Causality tests, and impulse response function analyses using the monthly time series data from Jun1998 to Sep2014. The results showed that a negative coal price change significantly impacts electricity prices. The prices of electricity responses vary abruptly to coal price shock in the short run.

4. Methodology

This is a desktop study that makes use of secondary data. The researcher extracted quantitative data. Quantitative methods highlight the objective "measurements and the statistical, mathematical, or numerical analysis of data collected through polls, questionnaires, and surveys, or by manipulating pre-existing statistical data using computational techniques. Quantitative research focuses on gathering numerical data and generalizing it across groups of people, mainly explaining a particular phenomenon" (Muijs, Daniel, 2010:47).

The main objective of conducting a quantitative research study is to conclude the relationship between subjects called an independent variable and in this research is the changes in coal prices, another subject called a dependent variable, and in this study is electricity pricing. Quantitative research deals with numbers, logic, and an objective stance. Quantitative research focuses on numeric, fixed data and comprehensive, convergent cognitive rather than conflicting cognitive, this allows the development of several concepts about a research problem in an unprompted, free-flowing manner (Gibson, 2014).

In developing economies like South Africa, to carry out research of this nature is generally problematic because data are not easily accessible. The research made use of data from the period 2000 to 2016.

This study relied on secondary data, extracted from secondary sources; that is, annual audited financial reports and reliable published reports by reputable organizations such as ESKOM, the South African Reserve Bank and Quantec Online Database between the period of 2000 and 2016. In this research, the author used nominal figures. The study also makes use of time series data, which has the advantage of providing information about the economic dynamics of some of the variables. This may prove useful in this case since electricity prices fluctuated over time.

5. *Results from the Autoregressive Distributed Lag (ARDL)*

ARDL tests, also popularly known as Cointegration test, were conducted to determine whether there is a long-run equilibrium relationship among the variables. The ARDL cointegration method stipulates the lag order and determines the trend hypothesis for the vector autoregressive. This complementary route is to validate the results of the VECM (Dritsakis, 2011). The results of the lag order criterion are shown in Table 1 below:

Table 1: Lag Order Specification

Lag	Log	LR	FPE	AIC	SIC	HQIC
0	-23.2304*	32.1078	2.14e-04*	2.1360	5.2369	7.1432
1	-9.8542	19.2354	2.17e-01	2.1589	3.2105	4.2586
2	4.8947	13.2546*	4.02e-05	1.0256*	2.4125*	3.4108*

*Shows the chosen lag order criterion
L.R- sequential modified LR test statistic (each test at 5% level)
FPE-Final prediction error
AIC - Akaike information criterion
HQIC- Hannan-Quinn information criterion
SIC - Schwarz information criterion

The appropriate lag structure is determined using Akaike Information Criterion (AIC) (Wolde-Rufael, 2005). The lag length with the lowest AIC value is always encouraged as it reflects a better model. However, lag length 2 is selected in this regard, as it has the lowest AIC value. Other information criteria which have selected lag 2 are sequential modified LR test statistic at 5 per cent level, Schwarz information criterion and Hannan-Quinn information criterion. After viewing the appropriate lag length criteria, the Cointegration is carried out and the results of the cointegration tests are displayed in Table 2 and Table 3 below:

Table 2: Results of Cointegration Trace Rank Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value at 0.05 LOS	Probability
None*	0.7785	89.2354	56.2145	0.0847*
At most 1	0.7458	78.2145	78.2685	0.0458
At most 2	0.4587	95.2569	81.0214	0.0354

The table above shows that cointegration trace Rank Test has 2 cointegrating equations at the 0, 05 level of significance (LOS). The first equation (none*) shows that the null hypothesis rejected it at 0.05 LOS.

Table 3: Results of Cointegration Maximum Egen Value Rank Test

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	Critical Value at 0.05 LOS	Probability
None*	0.7788	19.0054	16.5145	0.147*
At most 1	0.8890	16.2100	28.2485	0.0258
At most 2	0.9087	23.2119	25.0217	0.0454

Like the trace rank test, the Maximum Eigen Value Rank Test also shows two cointegrating equations at the 0, 05 level of significance (LOS). The first equation (none*) indicates that the null hypothesis rejected it at 0.05 LOS.

Results from the Johansen cointegration in both tables above show that there exist two cointegrating equation at 5% level of significance. The null hypothesis of no cointegrating vectors has failed to be accepted since the results reflects a 5% significance level. Therefore, it can imply that there are two cointegrating equations in this model, and this implies that there are significant long-run associations between these variables, namely coal prices and electricity pricing.

6. *The Vector Error Correction Model (VECM) Empirical Results*

After testing for cointegration, as well as determining an appropriate lag length of the variables, the study also applied a standard VECM econometric modelling technique to the annual data using the following function form:

The VECM estimates the short and long run dynamic relationships in the impact of coal prices on electricity prices, with all exogenous variables lagged once. The results of the above VECM are presented in Table 4.2.

Table 4: VECM Results

Variable	Coefficient	Standard Error	T - Statistic
Constant	1.3078		
Coal	10.0034	0.4567	2.0147
Electricity	5.6780	0.3576	3.2547

The above results from the model suggest that coal prices have a positive long-run relationship with electricity prices, both variables have absolute t-values greater than 2, which means that is statistically significant in explaining this relationship in the long term. Furthermore, the VECM results suggest that a percentage increase in coal prices will also increase electricity prices, with almost the same percentage. VECM has been of much significance in this research, since both the model's short-run and long-run coefficients are simultaneously estimated to show that changes in coal prices positively impact electricity prices. The short-run impacts in the model are illustrated in the table below.

Table 5: VECM Short-run Results.

Variable	Coefficient	Standard Error	T - Statistic
Constant	**1.3078**	**0.00**	**0.00**
Coal	**0.8457**	**0.1625**	**0.0145**
Electricity	**0.9321**	**0.1857**	**0.2841**

The above table 5 shows the short-run speed of autocorrelation adjustment. Both variables' coefficients are positive and statistically significant, meaning there is also a short-run adjustment. This also means that a change of coal prices will result in an instant increase in electricity prices. Moreover, it means in this study, there are both long-run and short-run effects between coal prices and electricity prices.

7. *Diagnostic Tests*

In order to test for the reliability and validity of the model, diagnostic tests were performed. The researcher tested the model using three main checks, which include the langrage multiplier (LM) test for serialized correlation; the white test was used to test the heteroscedasticity and the Jarque-Bera test was used for assessing the normality. The results in Table 4.6 below were observed.

Table 6: Diagnostic Check Results

Test Method	Null hypothesis	T – Statistic	Probability
White (Chi-square)	No conditional heteroscedasticity	89.4587	0.7412
Langrage Multiplier (LM)	Strong serial correlation	60.1478	0.2135
Jarque-Bera (JB)	Normal distribution	**4.1236**	0.4123

The White's test of heteroscedasticity found that the t-statistic was 89.4587, with a corresponding probability of 0.7812. This implies that there is no conditional heterodasticity on the model. The Lagrange Multiplier (LM) test of autocorrelation found that the data used on this research is serial correlated. According to the Jarque-Bera (JB) test, we fail to reject the null hypothesis of normal distribution of residuals.

8. Discussion

The Autoregressive Distributed Lag (ARDC) results show a significant long-run association between coal and electricity prices. This satisfies one of the objectives to determine the relationship between the tested variables. It can then be concluded that the study is statistically significant.

The Vector Error Correction Model suggests that there is a positive long-run relationship between the independent variable coal prices and the dependent variable electricity prices. The same test has established the same relationship in the short run.

The Vector Error Correction Model further shows that a percentage increase in coal prices will have a subsequent increase in electricity price, with almost the same magnitude. This is consistent with the expectations of the study's second objective, which sought to investigate the magnitude and direction of the relationship between coal price change and electricity prices in South Africa.

When electricity prices are determined at enquiries in a regulated country like South Africa, it may be difficult to establish the presence of asymmetry of coal price and domestic electricity prices. It is also assumed that in addition to input and wholesale prices, other factors such as market conditions, also determine retail or household energy prices. Generally, household electricity prices in South Africa are driven by subsidies from the government.

Similar studies that yielded the same results include Mohammadi (2009), who explored the long and short-run underlying forces between electricity prices and three fossil fuels (coal, natural gas and crude oil) in the United States of America, he used yearly data from 1960 to 2007. He also found evidence of significant long-run correlations between electricity and coal.

A Finnish study as discussed by Honkatukia et al, (2006) empirically assessed the changes of coal prices. His study was based on the econometric calculations from the collected data, the projected results indicated that on average, roughly 75 to 95 percent of the price changes in the coal prices are passed on to the Finnish Nord Pool day-ahead prices. The researchers analysed the progress of daily and hourly Nord Pool prices in the Finnish market area of Nord Pool and tested their correlation regarding numerous factors such as various scarcity capacity indicators, input cost indicators such as the prices of coal, natural gas and carbon allowance prices, as well as demand shaping indicators. They ran three econometric simulations on Finnish electricity prices running from between February and May 2005 to May 2006.

The results of their study are also supported by the Economic Principle, which proposes that there should exist a relationship between input and output prices in a static framework. Other studies Bencivenga and Sargenti (2010) who investigated the short and long-run connections between crude oil, natural gas and electricity prices in the United States of America and European commodity markets. The short-run results showed no decisive outcomes. Cointegration tests tested the long-run dynamics. The results showed cointegration relationships between each pair of commodities. Emery and Liu (2002) found a cointegration relationship between future electricity and natural gas prices. Although the two studies are not directly linked to coal and electricity prices, their relevance can be explained by the fact that natural gas and crude oil are inputs for power generation just like coal.

This study thus makes several contributions to the literature. It is one of the few studies done to demonstrate the empirical connection between the effects of coal prices and electricity around the world, let alone in South Africa. Although other studies tried to explain the link between the two variables in question, most were too broad and indirect, and the cases were not of South Africa.

It is important to note that most of the research in this area of study commences by providing a general background of the pricing mechanisms and analyses that affect energy prices on energy efficiency and intensity. On that same note, Martinez and Ines (2011), they used theoretical and empirical approaches to investigate between energy efficiency and energy prices. They found that energy prices are not an important main factor to improve energy efficiency. However, results from many studies shows a positive relationship between energy prices and efficiency, in addition to confirming the positive effects of rising energy prices on industrial energy savings (Chen & Wu, 2011), although a rebound effect cannot be denied. Some studies like the one by Apeaning & Thollander, (2013), scrutinized the variability that characterises the relationship between energy prices and energy efficiency and intensity. More studies on this regard includes the non-linear effects (Kaufman, 2004), asymmetric effects (Hang & Tu, 2007), dynamic effects and even regional differences.

Taking into cognisance the studies pronounced above, it is obvious that higher energy prices have an energy saving effect. However, from a macroeconomic viewpoint, energy prices also have a vivacious impact on other facets of the economy. One of these chief important aspects is the influence of the GDP, which is the focus of many studies. Bashmakov (2007) and Aucott and Hall (2014) observed the proportion of energy costs versus the GDP and found that when energy costs increase to over 10–12 %, the GDP growth declines, and when energy costs are 5–6 %, GDP growth increases. Another issue that this study emphasises is the influence of energy prices on the general price level. Although some studies showed that there is no relationship between energy prices and the general price level (Bohi, 1991), the majority of studies generally confirmed that there is a positive correlation between energy prices and the general price level (Cunado & Perez de Gracia, 2005; Cologni & Manera, 2008; Irz et al., 2013). Some studies measure the conducive influence of energy prices on the general price level (Baffes, 2007; Chen, 2009), whereas other studies indicate that the relationship between energy prices and inflation has varied over different time periods (Hooker, 2002).

9. Conclusion

The findings of the study show that changes of coal prices have an impact on electricity pricing. In addition, it means that when the coals price increases, the price of electricity also increases. This study reveals that there is a strong interdependence between coal and electricity in South Africa. Therefore, any manipulations of the prices of electricity by policy makers or government, which means it needs to be intervened by, subsidize in order, for ESKOM to operate efficiently.

Currently, South Africa is relying mainly on fossil energy, which is coal, to be precise. The rising costs in the mining industry, which lead to the increase of coal prices, will eventually result in the detrimental rise of electricity prices. Based on previous studies, there is no doubt that electricity is the main production function in the economy. This means that an increase in electricity prices will drive the prices of all other factors of production. This research established a very strong positive relationship between coal and electricity prices, the government needs to invest more in other ways of generating electricity, in order to reduce the dependency of using coal as a main source of generating electricity.

Furthermore, policymakers should facilitate a regulatory framework for private-sector participation in the provision of electricity. These options for capitalization should be taken into consideration. However, policymakers should ensure that cost reflectivity is not diminished and market competition thrives in the electricity supply industry.

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