The causality and determinants of energy and electricity demand in South Africa

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The current energy crisis has many people asking questions related to the factors that influence electricity demand and prices. A study by Dr Roula Inglesi-Lotz of the Department of Economics in the Faculty of Economic and Management Sciences and Prof Anastassios Pouris of the Institute for Technological Innovation focused on existing energy research to investigate the causal relationship between energy consumption and growth or the determinants of energy demand in South Africa from 2007, and to outline recent forecasts for electricity demand. Their findings have the potential to inform the relevant stakeholders to make appropriate interventions to improve operations in the energy sector.

The South African energy crisis of 2007/08 had such negative consequences – not only on the sector itself, but also on the economy – that research in the field has increased substantially, as indicated in Figure 1. This research has been increasing over the last three decades, with the curve becoming steeper from 2007 onwards.

As a result of the crisis, Eskom applied for further electricity price increases in the future. This has sparked debates on whether it is indeed necessary and how increases will affect the energy sector and the economy. The discussions among policy-makers, researchers, industrialists and various stakeholders in the country revolve, firstly, around the relationship between energy demand and economic growth (which one affects which), and secondly, the determinants of energy demand. Both topics are of particular importance for the forecasting of energy demand through the policy decisions made.

Appreciating the importance of these issues, the researchers reviewed, summarised and critically assessed the studies from 2007. The results of this review aimed to identify gaps in existing research on the causality and determinants of energy and electricity.

This research is significant because it is the first primarily econometric study on energy in South African literature. Previous investigations were conducted purely from an engineering perspective.

The causality of energy and electricity demand

The question of whether a relationship exists between energy (electricity) demand and economic growth has attracted massive attention in international literature. The existence of this relationship is of great importance, especially for energy policy-makers. In a global environment where energy conservation is a target for many governments, but where growth, development and sustainability are also high on the political and economic agenda, energy conservation policies should not become obstacles to a country's growth. Apart from the existence of the relationship, the direction of the

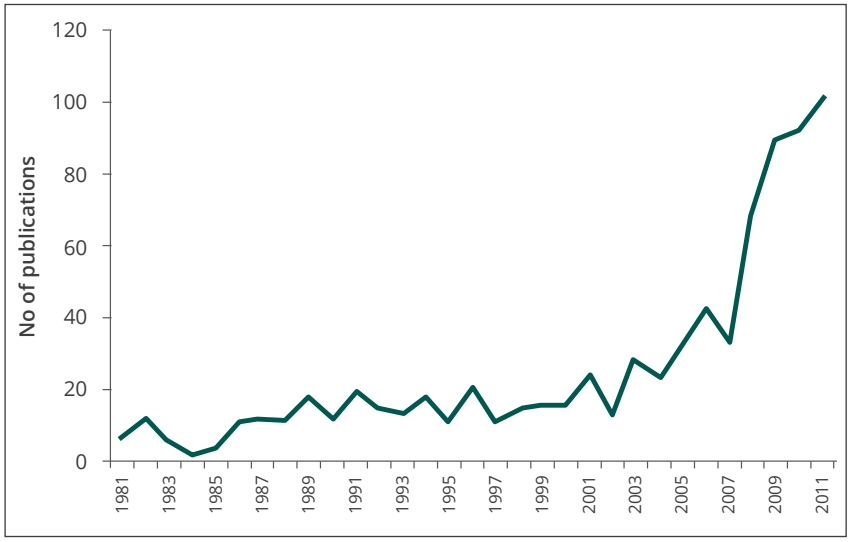

Figure 1: The number of publications in the field of energy and fuels in South Africa from 1981 to 2011 (Source: ISI, 2010).

causality also has significant policy implications. Four possible scenarios of the causal direction have been identified in research by Prof John Asafu-Asjaye (2000), James E Payne (2010a and 2010b) and Dr Jay J Squalli (2007):

- **Growth hypothesis:** According to this hypothesis, there is a unidirectional causality from energy consumption to economic growth. The implementation of policies aimed at the reduction of energy demand/consumption will affect the economic growth of the country.

- **Conservation hypothesis:** This hypothesis assumes that energy consumption is dependent on economic growth. If this hypothesis holds, energy conservation policies, such as phasing out energy subsidies, will have no effect on economic growth (Mehrara, 2007; Kahsai et al., 2012). On the contrary, it is confirmed that the higher the economic growth of a country, the more energy is used.

- **Neutrality hypothesis:** According to this hypothesis, there is no causality between the two variables. Energy conservation policies will have no effect on economic growth, and improving economic growth will not influence energy consumption.

- **Feedback hypothesis:** This hypothesis assumes that the causality between the two variables runs in both directions (they are complementary) (Kahsai et al., 2012). Decreases in energy consumption will affect economic growth, which will subsequently affect energy demand.

The studies have, however, failed to reach a consensus on the direction of the causality. Payne (2010b) surveyed studies that examined the direction of the causality between energy consumption and income, and found that in the individual country studies surveyed, 29.2% of the results supported the neutrality hypothesis, 28.2% the feedback hypothesis, 23.1% the growth hypothesis and 19.5% the conservation hypothesis (Kahsai et al., 2012). Another survey of the studies by Payne (2010a), which investigated the causal relationship between electricity consumption and economic growth, showed approximately the same results: 31.5% supported the neutrality hypothesis, 27.87% the conservation hypothesis, 22.95% the growth hypothesis and 18.03% the feedback hypothesis (Kahsai et al., 2012).

Studies have failed to reach a consensus on the direction of the causality.

Since 2007, nine studies have dealt with the South African case. They have examined the relationship between the country's energy or electricity consumption and economic growth, either individually in a time-series context or in a panel data framework together with other countries, usually from the African continent. Based on the discussion of the findings in the international literature, the fact that the studies' conclusions vary for the South African case is not surprising. For example, Al-Mulali and Sab (2012) and Eggoh et al. (2011) confirm that energy consumption causes economic growth, while Esso (2010) concluded exactly the opposite. Interestingly, Kahsai et al. (2012) found that there is no relationship in the short run (neutrality hypothesis), but a bidirectional causality exists in the long run (feedback hypothesis).

The majority of these studies employed a traditional Granger causality test by estimating vector autoregressive (VAR) models. Interestingly, various studies that use the Granger test differ in the technique they use to identify cointegration: for example, Esso (2010) uses the Gregory and Hansen testing approach, Odhiambo (2010) uses the autoregressive distributed lag (ARDL) bounds testing procedure, while Kahsai et al. (2012) use the cointegration test established by Pedroni in 1999. To improve on the Granger causality test, some studies have used a modified version of this test proposed by Toda and Yamamoto (1995). The advantage of this test is that it avoids potential bias linked with unit root and cointegration tests.

Although a bivariate analysis of the relationship between energy consumption and economic growth is not unusual in the international literature, the majority of the studies concerning South Africa operate within a multivariate framework. Wolde-Rufael (2009) argues that the relationship should be examined from a complete production function view where energy is an input to economic growth, together with capital and labour. Continuing with this argument, he agrees with Lutkepohl (1982) that the exclusion of relevant variables might affect the accuracy of the causality tests. Except for the rest of the factors of production employed as additional variables, such as employment, and labour and capital employment, other studies used prices, financial development or pollutant emissions.

The drawback of the multivariate analysis is the inability to properly compare different studies' conclusions. The variation of the results with regard to the direction of the causality can be attributed to factors such as different econometric techniques, variable selection, the time period examined and specific testing procedures. Balcilar et al. (2010) also argue that the reason behind the variability is partially due to the relatively small data span of the sample periods covered, especially for studies that include the 1980s, and, secondly, due to the structural or regime changes. When omitted, these structural breaks can lead to misspecifications and false results (Eggoh et al., 2011).

→ *Rainbow over Eskom electricity pylons. (Photograph: Chris Kirchhoff, MediaClubSouthAfrica.com.)*

Determinants of energy and electricity demand

In accordance with basic economic theory, the international literature assumes the demand for goods or services is usually dependent on factors such as their own price, the income of the consumers, the price of substitute goods and other exogenous variables related to the nature of the goods. The majority of international studies include the income of the consumers (or economic growth) and the price of energy (electricity) as main explanatory variables. Other studies include the prices of possible substitutes, such as natural gas, heating oil and others.

As studies such as those of Esso (2010), Kahsai et al. (2012) and Odhiambo (2010) have found that economic growth causes energy (electricity) consumption in South Africa, it is considered one of the main determinants. The majority of the studies that examined the determinants of energy or electricity demand in South Africa has included income or economic growth among the significant factors.

Another key determinant is the price of electricity. The first attempt to estimate the influence of electricity prices on electricity consumption was made by Pouris (1987). Since then, different econometric approaches have been used to assess the impact of price.

Ziramba (2008) examined the residential electricity demand and found that, for the period 1978 to 2005, the price of electricity was insignificant in the long run. Amusa et al. (2009) also found that electricity prices had an insignificant effect on aggregate electricity demand for the period 1960 to 2007. On the contrary, Inglesi (2010) found that price was a significant explanatory variable for electricity consumption between 1980 and 2005. The conflicting results are explained by Inglesi-Lotz (2011). She found that price elasticity was becoming lower through the years in absolute terms, and price was thus becoming an insignificant factor, while the real prices of electricity were generally declining. The insignificance indicated by Amusa et al. (2009) can be linked to the almost zero elasticity values; with a focus on short-run dynamics, price was found to be insignificant. Indeed, Inglesi (2010) also concluded that, in the short run, price was not a determinant of electricity consumption. Inglesi and Pouris (2010) used the same approach to forecast electricity consumption and to critically assess Eskom's estimations.

The majority of the studies on the determinants of energy and electricity demand employed time-series econometric analysis. Cointegration techniques were most commonly used, but two studies attempted to identify the factors affecting changes in energy and electricity consumption by using decomposition methods (Inglesi-Lotz and Pouris, 2011; Inglesi-Lotz and Blignaut, 2011). The overall results showed that changes in the structure of the economy and changes in the efficiency with which the country uses energy (electricity) play an important role in the trend of energy usage.

These studies also investigated the behaviour of different sectors of the economy. Inglesi-Lotz and Blignaut (2011) looked at electricity consumption factors for five sectors of the economy. Their results showed that only for the industrial sector, both output and price were significant variables, while for the industrial and commercial sectors, only economic output was a positive factor. For the agricultural, transport and mining sectors, electricity consumption was neither affected by price nor by production between 1993 and 2006.

For residential demand in particular, variables representing micro-behaviour, such as household size or number of appliances, have also been used in the literature, along with variance in weather conditions. For the South African case, Louw et al. (2008) examined the determinants of electricity demand for newly electrified low-income African households. Their results showed that income, wood fuel usage, iron ownership and credit obtained were the main determinants of electricity consumption in the two examined areas, Antioch and Garagapola. For the specific case of Gauteng, Senatla (2011) looked at the energy demand projections and income dynamics of the residential sector. The assumed drivers included the number of households, population, electrification growth rate and the households' mobility among various income categories.

Electricity demand forecasts

Not many studies have dealt with the direct forecasting of electricity demand after estimating its driving forces. Forecasting can be considered an art in the sense that its correctness and accuracy are highly dependent on the choice of variables and the assumptions made for the future.

As part of the Integrated Resource Plan 2010 (IRP2010) formulation process, the System Operations and Planning Division (SO) (2010) and the Council for Scientific and Industrial Research (CSIR) (2010) forecast electricity demand using primarily statistical modelling and expansion of historical trends, while Inglesi (2010), and Inglesi and Pouris (2010) make use of econometric forecasting methods. The main difference between their results may not stem from the employed methodology, though, but rather from the choice of variables to predict the future electricity demand values.

SO (2010) and CSIR (2010) do not use price as a driving force for electricity consumption. SO (2010) suggests that the price sensitivity of consumers should rather be incorporated into the gross domestic product (GDP) growth values than be included as a separate factor. The CSIR (2010) model omits the price impact on electricity demand for two reasons. Firstly, it believes that it is impossible to model price elasticity successfully at the national level and there is a need for sectoral price elasticities. Secondly, due to the fact that such high electricity price increases have not occurred in the past, there is no precedent set for further analysis.

→ *Electricity pylons in Beaufort West in the Western Cape. (Photograph: Chris Kirchhoff, MediaClubSouthAfrica.com.)*

On the other hand, Inglesi (2010), and Inglesi and Pouris (2010) employ econometric methods to estimate the price elasticity, and, based on specific assumptions, show that the inclusion of prices (and their high increases lately) can even overturn the path of electricity consumption from upwards to downwards. It is important to mention that the 1986 review identified that all forecasts for 2000 predicted a demand of 300 000 GWh. No study took the effects of prices, technology-based efficiencies and similar factors into consideration. The actual demand for electricity during 2000 was approximately half of the projected demand.

It should be noted that the recent efforts were made before the effects of the global economic crisis of 2009 were visible. All the studies assumed high economic growth rates and production; a fact that was not confirmed in the recent economic data. As a result, recurring forecasting exercises using the latest available data are needed in the country. As stated by the CSIR (2010), the existence of numerous forecasting studies is beneficial for the country and their aim should not be to replace one another, but rather to provide additional support to each other's methods and results.

Conclusion

Dr Inglesi-Lotz and Prof Pouris found that studies examining the causality direction between energy (electricity) consumption and economic growth failed to reach a consensus. The main differences were the time periods examined, the econometric approaches and the variables included in the estimations. On the other hand, the studies on the factors affecting energy (electricity) demand agreed that economic growth, income and output are considered significant factors. There were a few differences in the results regarding the role of prices, but these can be attributed to the different econometric methods used, as indicated by Inglesi-Lotz (2011). Reaching a consensus on the nature of these relationships is imperative for the proposal and implementation of appropriate policies to conserve energy and promote economic growth.

Along with the diversity of methodological approaches, another potential reason for the results is the availability or lack of data specific to the country. One would expect studies on South Africa to use detailed and exact data from local sources. This is the case for a number of studies, where data is derived from the energy balances of the Department of Energy.

Earlier studies used data from Eskom's annual reports and the electricity supply statistics of the National Energy Regulator of South Africa (Nersa), because the energy balances of the Department of Energy were not up to date.

This fact indicates that because of the increasing econometric modelling of South Africa's energy issues, local stakeholders should focus more on the collection, reporting and publication of reliable and usable energy information. A sectoral analysis of the energy sector is imperative due to the sectoral policies that are needed in South Africa.

The review of the forecasting studies showed a lack of such activity for the South African case, lately. Individual studies that employ different methodologies and assumptions offer policy-makers a range of possible forecasting values that will assist in the appropriate interventions. Critically reviewing the success or failure of past forecasts could also assist in developing more accurate forecasts.

→ *Prof Anastassios Pouris (left) and Dr Roula Inglesi-Lotz.*

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