On the causality and determinants of energy and electricity demand in South Africa: A review

R. Inglesi-Lotz[a] and A. Pouris[b]

[a]Department of Economics, University of Pretoria, Pretoria, South Africa;
[b]Institute for Technological Innovation, University of Pretoria, Pretoria, South Africa

ABSTRACT

The purpose of this paper is to review, summarize, and critically assess the academic studies that have dealt with either the causal relationship between energy consumption and growth or the determinants of energy demand in South Africa from 2007 and outline recent forecasts for electricity demand. The results of this review aim to identify gaps in the existing research. From a policy point of view, the findings of this effort have the potential to inform the relevant stakeholders to make appropriate interventions to improve the status quo of the energy sector. The results have indicated that studies examining the causality direction between energy (electricity) consumption and economic growth have failed to reach a consensus. The main differences identified were the time periods examined, the econometric approaches, and the variables included in the estimations. Another potential reason for the results is the availability—or lack thereof—of data specific for the country. On the other side, the studies looking at the factor affecting energy (electricity) demand have agreed that economic growth or income or output are considered significant factors. The role of prices was debatable among different studies. This has become more apparent when reviewing the few forecasting efforts in the country that resulted in conflicting results.

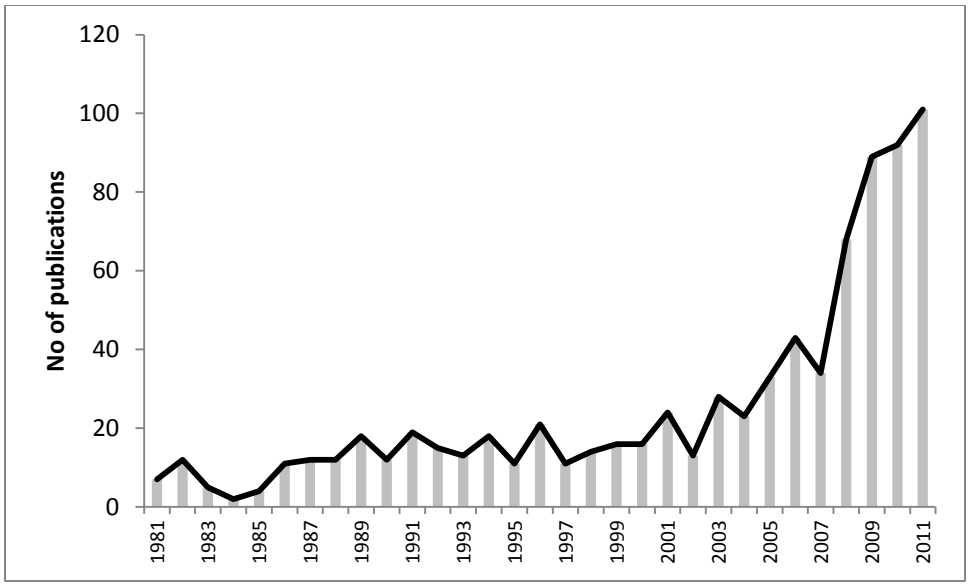
Keywords: Causality, determinants, energy sector, review, South Africa

Introduction

The global concerns on climate change in combination with the increasing worries on energy demand and supply have sparked research on these fields recently. On top of that, energy is considered an essential factor of the production capabilities of the economy and also a source of economic growth, urbanization and industrialization (Esso,2010).

South Africa's research is not an exception to the international trends. Figure 1 presents the number of publications in the field of "Energy and Fuels" in South Africa from 1981 to 2011. It can be seen that over the last three decades the trend is increasing, becoming steeper from 2007 onwards. Pouris (2008) found that the South African energy research publications have shown an increase through the years, but from a small basis.

Figure 1: Number of publications in the field of "Energy and Fuels" in South Africa



Source: ISI (ISI, 2010)

In 2007/08, the South African energy sector has experienced a severe crisis that had resulted in numerous power cuts with negative consequences both for the specific sector but also for the economy in its entirety (2010). The figure shows that especially after the crisis, the research on the field increased substantially. Pouris (2008) argued that the lack of substantial research expertise that would be materialized in research publications may have partially been the cause of the 2007/08 failure of Eskom (the country's national electricity supplier) to prevent the crisis.

After the 2007/08 crisis, Eskom has applied for further electricity price increases in the future and that has sparkled debates on whether this is needed indeed and how they will affect the energy sector and the economy. The discussions in the country among policy makers, researchers, industrialists and various stakeholders revolve around firstly, the relationship between energy demand and economic growth (which one affects which) and secondly, the determinants of the energy demand. Both topics are of particular importance for the forecasting of energy demand through the policy decisions made.

Appreciating this importance, the purpose of this paper is to review, summarise and critically assess the studies from 2007 to date. The reason for choosing 2007 is twofold: firstly, according to 2007 the total number of papers in the "Energy and Fuels" field has experienced a steep increase and secondly, the 2007/08 energy crisis has made the research on the field more crucial than ever before. The results of this review aim to identify gaps in the existing research on the two topics-causality and determinants of energy end electricity. From a policy point of view, the findings of this effort have the potential to give answers to the general debate and inform the relevant stakeholders to make appropriate interventions to improve the status quo of the energy sector.

A further contribution of the paper to the South African literature is that it examines primarily econometric studies on the field of energy. This type of analysis is a relatively new phenomenon for South Africa. In the past, another review paper (1986) investigated the demand for electricity in the country by surveying a number of relevant investigations. It identified that the literature was dominated by engineering studies ignoring economic principles. It should also be mentioned that the sub-fields that dominated the energy research field in South Africa for the

period 1997 to 2007 (Figure 1) were primarily engineering related such as chemical engineering, thermodynamics and mechanical engineering (Pouris, 2008).

This paper is structured as follows. Firstly, the literature that deals with causality issues on electricity and energy in South Africa is reviewed. In the next section, the studies that examined the determinants of energy and electricity demand in South Africa are discussed followed by a summary on the forecasting studies. Finally, concluding remarks are given in the last section.

Causality of energy and electricity demand in South Africa

The question of whether a relationship between energy (electricity) demand and economic growth exists has attracted massive attention in the international literature. The existence of this relationship is of great importance especially for the energy policy makers. In a global environment where energy conservation is a target for many governments but at the same time growth, development and sustainability are also high on the political and economic agenda, energy conservation policies should not become obstacles to the country's growth. Hence, apart from just the existence of the relationship, the direction of the causality has also significant policy implications. Four possible scenarios of the causal direction have been identified in the literature (Asafu-Asjaye, 2000; Payne, 2010a and 2010b; Squalli, 2007):

1) Growth hypothesis

Under this hypothesis, there is a unidirectional causality from energy consumption to economic growth. In this case, the implementation of policies aiming at the reduction of energy demand/ consumption will affect the economic growth of the country.

2) Conservation hypothesis

This hypothesis assumes that energy consumption is dependent to 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.

3) Neutrality hypothesis

Under this hypothesis, there is no causality between the two variables. Energy conservation policies will have no effect on economic growth and improvement of economic growth will not influence the energy consumption in the country.

4) Feedback hypothesis

This hypothesis assumes that the causality between the two variables runs in both directions, or in other words they are complementary (Kahsai et al., 2012). In this case, decreases in energy consumption will affect the economic growth that will subsequently affect energy demand.

However, the various studies have failed to reach a consensus for the direction of the causality. Payne (2010b) did a survey on studies that examined the direction of the causality between energy consumption and income and found the following: "Individual country studies surveyed show 29.2% of the results supporting the neutrality hypothesis, 28.2% the feedback hypothesis, 23.1% the growth hypothesis and 19.5% support the conservation hypothesis" (Kahsai.et al., 2012). A survey by the same author (Payne, 2010a) on the studies that investigated the causal relationship between electricity consumption and economic growth concluded approximately the same results: "…31.5% supporting the neutrality hypothesis; 27.87% the

conservation hypothesis; 22.95% the growth hypothesis; and 18.03% the feedback hypothesis" (Kahsai et al. 2012).

Nine studies have dealt with the issue for the South African case since 2007 that the high increase on "Energy and Fuels" field has started (see Figure 1). These studies have examined the country's energy or electricity consumption-economic growth relationship either individually in a time-series context (for example Odhiambo (2009)) or in a panel data framework among other countries, usually from the African continent (for example Al-mulali and Sab (2012)). Based on the discussion on the international literature's findings, the fact that the studies' conclusions for the South African case vary 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 not relationship in the short-run (neutrality hypothesis) but a bidirectional causality exists in the long-run (feedback hypothesis).

The majority of these studies have employed a traditional Granger causality test by estimating vector autoregressive (VAR) models (Esso, 2010). 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) the ARDL-bounds testing procedure; Kahsai et al. (2012) the Pedroni's (1999) cointegration test.

To improve on the Granger causality test, some studies (Wolde-Rufael, 2006; Wolde-Rufael, 2009) have used a modified version of this test proposed by Toda and Yamamoto (Toda and Yamamoto, 1995). The advantage of this test is that it avoids potential bias linked with unit root and cointegration tests.

Table 1: Studies on causality of energy and electricity demand in South Africa

Author(s)	Time period	Results for SA	Source of SA data	Notes
Al-mulali and Sab (2012)	1980-2008	EC→EG	World Bank and Energy Information Administration (EIA)	The paper examines a panel of Sub-Saharan countries and reports the overall results.
Eggoh et al (2011)	1970-2006	EC→EG (short run)	World Bank	The paper examines a panel of 21 African countries and reports the overall results.
Esso (2010)	1970-2007	EG→ EC (short-run); EG≠EC (long-run)	World Bank and African Development Bank	The paper examines a panel of 7 African countries and reports the results of each country separately.
Kahsai et al. (2012)	1980-2007	EG≠EC (short-run) but EG↔EC (long-run)	Energy Information Administration (EIA)	The paper examines a panel of 40 African countries and reports the results of each country separately.
Menyah and Wolde-Rufael (2010)	1965-2006	EC→ EG	World Bank	The paper examines only the South African case and includes pollutant emissions.
Odhiambo (2009)	1971-2006	ELEC↔EG	International Energy Agency (IEA)	The paper examines only the South African case and includes pollutant emissions.
Odhiambo (2010)	1972-2006	EC→EG	World Bank	The paper examines a panel of 3 African countries and reports the results of each country separately.
Wolde-Rufael (2006)	1971-2001	ELEC≠EG	World Bank	The paper examines a panel of 17 African countries and reports the results of each country separately.
Wolde-Rufael (2007)	1971-2004	EC→EG		The paper examines a panel of 17 African countries and reports the results of each country separately.
Ziramba (2009)	1980-2005	ELEC≠EG	World Bank	The paper examines various forms of energy and focuses on their relationship with industrial production.

Note: EC= energy consumption; EG= economic growth; ELEC= electricity consumption; and →, ↔ and ≠ denote unidirectional, bidirectional and no causality respectively.

Although in the international literature a bivariate analysis of the relationship between energy consumption and economic growth is not unusual, the majority of the studies concerning South Africa are operating within a multivariate framework (only Esso (2010) and Kahsai et al. (2012) have investigated the relationship between only the two variables). 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 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 (for example Odhiambo (2009): employment; Wolde-Rufael (2009): labour and capital), other studies have used prices (Eggoh et al. 2011; Odhiambo, 2010), financial development (Al-mulali and Sab, 2012) or pollutant emissions (Menyah and Wolde-Rufael, 2010).

The drawback of the multivariate analysis is the inability to properly compare their conclusions. For instance, Eggoh et al. (2011) and Menyah and Wolde-Rufael (2010) have looked at the same time period with the first one including prices while the second one included pollutant emissions. Eggoh et al. (2011) concluded that energy consumption causes economic growth while on the other side Menyah and Wolde-Rufael (2010) found no causal relationship between the two in the short-run. The findings might be a result of the inclusion of the extra variables.

The variation of the results with regards to the direction of the causality can be attributed to factors such as the different econometric techniques, variable selection, time period examined and specific testing procedures (Payne, 2010a and 2010b; Paul and Bhattarcharya, 2004; Balcilar et al. 2010). Balcilar et al. (2010) also argues that the reason behind the variability is partially the

sample periods covered, especially for studies that include the 1980s, due to the relatively small data span and secondly because of the structural or regime changes. These structural breaks when omitted can lead to misspecifications and false results (Eggoh et al., 2011).

Determinants of energy and electricity demand in South Africa

In the international literature in accordance to basic economic theory, the demand of a good or a service is usually dependent on factors such as its own price, the income of the consumers, the price of substitute goods and other exogenous variables related to the nature of the good (Inglesi, 2010). The majority of international studies include as main explanatory variables the income of the consumers (or economic growth) and the price of energy (electricity) (for example, Atakhanova and Howie (2007) Nasr et al (2000); Narayan et al. (2007)). Other studies also included prices of possible substitutes such as natural gas, heating oil and others (Anderson and Hsiao, 1982; Wilson, 1971; Narayan and Smyth, 2007).

From the previous section, studies such as Esso (2010), Kahsai et al.(2012) and Odhiambo (2010), have found that economic growth causes energy (electricity) consumption in South Africa, hence it is considered one of the main determinants. Looking at Table 2, the majority of the studies that examined the determinants of energy or electricity demand in South Africa have 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 to its consumption was made by Pouris (1987). Since then different econometric approaches have been used to assess the impact of price (Inglesi, 2010; Ziramba, 2008, Amusa et al., 2009; Inglesi-Lotz and Pouris, 2010; Inglesi-Lotz, 2011).. Ziramba (2008) examined the residential electricity demand and found that for the period 1978 to 2005, price of electricity was insignificant in the long-run. Amusa et al. (2009) also found that electricity prices

Table 2: Studies on the determinants of energy and electricity demand in South Africa

Author(s)	Time period	Determinants of energy/electricity	Sources of SAn data	Notes
Amusa et al. (2009)	1960-2007	Income (price is insignificant)	Eskom and NERSA	The paper focuses on aggregate electricity demand.
Inglesi (2010)	1980-2005	Price and GDP (long-run); Income and population (short-run)	Eskom	The paper focuses on aggregate electricity demand.
Inglesi and Pouris (2010)	1980-2005	Price and GDP (long-run); Income and population (short-run)	Eskom	The paper focuses on aggregate electricity demand.
Inglesi-Lotz and Pouris (2011)	1993-2006	Changes in the structure of the economy followed by changes in the efficiency.	South African Department of Energy (DoE)	The paper focuses on aggregate energy consumption and also analyses the economy at a sectoral level.
Inglesi-Lotz and Blignaut (2011)	1993-2006	Changes in the production of the country followed by structural changes of the economy and last, changes in efficiency.	South African Department of Energy (DoE)	The paper focuses on aggregate electricity efficiency and also analyses the economy at a sectoral level.
Inglesi-Lotz and Blignaut (2011)	1993-2006	Only for the industrial sector, both price and income. For the rest either only income or none of the two.	South African Department of Energy (DoE)	The paper analyses electricity demand for five economic sectors.
Inglesi-Lotz (2011)	1980-2005	Price and GDP.	National Energy Council and South African Department of Energy (DoE)	The paper focuses on aggregate electricity demand.
Louw et al. (2008)	2001 and 2002	Income, woodfuel usage, iron ownership and credit obtained. (price and cross-price elasticities could not be determined due to lack of information)	Study by Energy Research Center (ERC)	The paper focuses on two low income, rural sites in South Africa: Atioch and Garagapola.
Ziramba (2008)	1978-2005	Income (price is insignificant).	International Energy Agency (IEA)	The paper examines the electricity demand by the residential sector.
Ziramba (2009)	1980-2005	Industrial production (employment is insignificant)	Energy Information Agency (EIA)	The paper examines various forms of energy and focuses specifically with their relationship with industrial production.

have 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 during the period 1980-2005. The conflicting results are explained by Inglesi-Lotz (2011): she found that price elasticity was becoming lower through the years in absolute terms and hence, price was becoming an insignificant factor while the real prices of electricity were generally declining. The insignificance concluded by Amusa et al. (2009) can be connected to the 'almost' zero elasticity values; therefore with focus on short-run dynamics price was found insignificant. Indeed, Inglesi (2010) also concludes that in the short-run, price was not a determinant of electricity consumption. Inglesi and Pouris (2010) also used the same approach to forecast electricity consumption and critically assess Eskom's estimations.

The majority of the studies reported in Table 2 employed time-series econometric analysis. The most commonly used were various cointegration techniques (Inglesi, 2010; Ziramba, 2008; Amusa et al. 2009). However, there were two studies identified that tried to unfold 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 as well as changes in the efficiency that the country uses energy (electricity) play an important role in the trend of energy usage. These studies also looked at the behaviour of different sectors of the economy. Inglesi-Lotz and Blignaut (2011) also looked at the electricity consumption's 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 and finally for the agricultural, transport and mining sectors electricity consumption was affected neither by price nor by their production for the period 1993 to 2006.

Specifically for residential demand, variables representing micro-behaviour such as household size, or number of appliances have also been used in the literature (Wilson, 1971; Westley, 1984) along with variance in the weather conditions (Zachariadis and Pashourtidou, 2007; Diabi, 1998; Hondroyiannis, 2004; Donatos and Megos, 1991; Abosedra et al., 2009). For the South African case, except for Ziramba (2008) that looked at the residential demand but in a macro-approach, Louw et al. (2008) examined the determinants of electricity demand for newly electrified low-income African households. Their results showed that income, woodfuel 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 the Gauteng province, Senatla (2011) looked at the energy demand projections and income dynamics of the residential sector. The assumed drivers included number of households, population, electrification growth rate and the households' mobility among various income categories.

Electricity demand forecasts

Not many studies have dealt with direct forecasting of electricity demand after estimating its driving forces. Forecasting can be considered "art" in the sense that its correctness and accuracy is highly depended on the choice of variables and the assumptions made for the future. Table 3 summarises the two academic papers and three reports identified that proceeded in a forecasting exercise.

As part of the IRP 2010 process, SO (2010) and 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 methods to forecast. The main difference behind their results may not, though, stem from the employed methodology but rather the choice

Table 3: Studies on forecasting energy (electricity) demand in South Africa

Author(s)	Forecasted time period	Determinants of energy/electricity	Sources of SAn data	Method	Notes
CSIR (2010)	2010-2035	Population, sector-specific production indices; GDP; Final consumption expenditure of households	South African Department of Energy (DoE); StatsSA	Statistical modelling (sectoral)	Increase in aggregate and sectoral electricity demand by 2035
Inglesi (2010)	2010-2030	Price and GDP (long-run); Income and population (short-run)	Eskom	Econometric modelling (aggregate)	Decrease in aggregate electricity demand by 2030
Inglesi and Pouris (2010)	2010-2025	Price and GDP (long-run); Income and population (short-run)	Eskom	Econometric modelling (aggregate)	Decrease in aggregate electricity demand by 2030
SO (2010)	2010-2035	GDP; access to energy; electricity efficiency; customer-specific parameters; international sales; system losses; temperature and load profiles	Eskom	Statistical modelling – Historical trends (sectoral)	Increase in aggregate and sectoral electricity demand by 2035

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 in the country. SO (2010) suggests that the price sensitivity of consumers should rather be incorporated in the GDP growth values (or through their effect in inflation) than be included as a separate factor. The CSIR (2010) model omits the price impact on electricity demand for two reasons: a) the team believes that it is impossible to model price elasticity successfully at the national level and there is a need for sectoral price elasticities such as Ziramba (2008) [in 2011, Inglesi-Lotz and Blignaut (2011) answered this predicament] and b) due to the fact that such high electricity price increases have not occurred in the past, so there is no precedent set to analyse further. On the other side, 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 the electricity consumption from upwards to downwards. It is important to mention that the 1986 review (Pouris, 1986) identified that all forecasts for the year 2000 predicted a demand of 300.000 GWH +/_10% and no study was taking into consideration the effects of prices, technology based efficiencies and similar. The actual demand for electricity during 2000 was approximately half of the projected one.

It should be also noted that the recent efforts were made before the effects of the global economic crisis of 2009 are visible. All the exercises 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 in CSIR (2010), the existence of numerous forecasting exercises is beneficial for the country and their aim should not be to replace one another but to provide additional support to each other's' methods and results. CSIR (2010) also states that "Another way to improve

forecasts would be to use different forecasting approaches, and then to compare results between the different methods in order to highlight areas of uncertainty or identify potential improvements to the various methodologies. If the different methods seem to provide similar forecasts, then that provides a further measure of trust in the reliability of the forecasts".

Conclusion

The purpose of this paper was to review, summarize and critically assess the knowledge gathered and published with regards to the determinants of energy (electricity) consumption and its relationship with economic growth for South Africa.

The results have indicated that studies examining the causality direction between energy (electricity) consumption and economic growth have failed to reach a consensus. The main differences identified were the time periods examined, the econometric approaches and the variables included in the estimations. On the other side, the studies looking at the factor affecting energy (electricity) demand have agreed that economic growth or income or output are considered significant factors. There were a few differences in the results regarding the role of prices but that, as indicated by Inglesi-Lotz (2011), can be attributed to the different econometric methods.

Along with the diversity of methodological approaches, another potential reason for the results is the availability –or lack thereof– of data specific for the country. The studies that looked at the topic in a panel data environment made use of international databases that ensure homogeneity of data among countries, such as the ones by the World Bank, the International Monetary Fund (IMF), the Energy Information Administration (EIA) and the International

Energy Agency (IEA). Regarding the energy data required, these international institutions usually collect their data from individual countries' statistics stakeholders.

One would expect that studies on South Africa specifically would have used detailed and exact data from local sources. This is the case for a number of studies such as Inglesi-Lotz (2011) and Inglesi-Lotz and Blignaut (2011) whose data were derived from the Energy Balances of the Department of Energy (DoE). Earlier studies such as Inglesi (2010) and Amusa et al.(2009) used data from Eskom's annual reports and NERSA's Electricity supply statistics because the Energy Balances of DoE were not up to date. The rest of the studies such as Ziramba (2008, 2009) and Menyah and Wolde-Rufael (2010) have utilized data from IEA, EIA and the World Bank respectively. This fact gives us an indication that with the increasing econometric modeling at the energy field for South Africa, the local stakeholders should focus harder on the collection, reporting and publication of reliable and usable energy information. More specifically, sectoral analysis of the energy sector is imperative due to the sectoral policies that are in need in South Africa (Inglesi-Lotz and Blignaut, 2011). Sources of sectoral data are limited to only the Energy Balances of DoE. Inglesi-Lotz and Blignaut (2011) explain DoE's method of data collection and quality assurance and indicate that DoE relies on data providers and Eskom and NERSA's reports. They perform only a manual data check comparing current data with past years' only querying where inconsistencies are found. Moreover, they span in a time period only from 1992 providing very few annual observations especially for time-series analysis. For the studies including the prices for energy, the sources of data are more limited especially when looking at the sectoral level. Eskom's Price reports are the only local sources available whose limitation is the level of sectoral disaggregation; for example one price for the manufacturing/industrial sector. CSIR (2010) also notes that "Attention should be paid by

agencies such as NERSA, Department of Energy or StatsSA to produce a reliable, accurate and sustainable source of information".

The review of the forecasting exercises showed a certain lack of such activity for the South African case, lately. Apart from the different methodologies employed, it was discussed that the decisive factor for the different findings is the inclusion (or not) of specific variables such as the price of electricity. However, individual studies employing different methodologies and assumptions will be able to offer the policy makers a range of possible forecasting values of electricity demand that will assist in the appropriate interventions. Reviewing critically the success or failure of past forecasts could also assist in the development of more accurate forecasts.

The conflicting results in all three topics (causality, determinants and forecasting) may also be partially attributed specifically to the choice of the time period. In this case, there is an indication that the existence and direction of the causality between energy (electricity) consumption and economic growth as well as the determinants change over the years. As a result, there is a need for more studies that look at these phenomena in a time-varying manner. First effort was made by Inglesi-Lotz (2011) to look at the evolution of price impact on aggregate electricity consumption over the years and was continued by Inglesi-Lotz (2012) that examined the same phenomenon for the industrial electricity consumption. 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.

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