

ESTIMATING THE PRICE ELASTICITY OF DEMAND FOR ELECTRICITY BY SECTOR IN SOUTH AFRICA

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Abstract

This paper examines the South African economic sector's electricity consumption in response to fluctuations in electricity prices and economic output for the period 1993 to 2006. The results of the panel data analysis show that the industrial sector was the only one with statistically significant price elasticity over the study period. Further, economic output was a positive contributing factor to the industrial and commercial sectors (having high and significant coefficients). This is in contrast with the other three sectors, agriculture, transport and mining, whose electricity consumption was affected neither by price nor by their production.

This anomaly is the result of both the relatively low and declining (in real terms) electricity prices over the study period, and the fact that the proportion of electricity cost to total cost is relatively small for the majority of sectors. There was therefore no major incentive to reduce electricity consumption and/or to be efficient. While these results explain, at least in part, the historical increases in electricity consumption, they may not hold for the period since 2008 (for which adequate data is not yet available), given the sharp increases in electricity prices recently experienced by the country.

Key words: sectoral electricity consumption; price elasticity; energy economics; South Africa

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1 Introduction

Electricity is a low-valued yet necessary good within any economy and is one of the pillars of economic growth (Blignaut, 2009). The generation, supply and distribution of electricity, and access to it, have the potential to unlock economic development. South Africa, with almost 50 million residents, has about 39 000MW of installed electricity capacity. In comparison, Nigeria has an installed capacity of 4 000MW serving 150 million. This comparison indicates a key reason why South Africa could develop in the way it has, while Nigeria, despite its natural resources, climate and arable land, has not.

During the years 2007/08, South Africa experienced periods when there was a severe lack of electricity supply, which led to continual blackouts and load-shedding as a result of the problematic situation in the generation and reticulation of electricity. Eskom, the state-owned electricity supplier for the country, has often argued that the solution

would be the expansion of the current network of power plants.

Recently (from 2008 onwards), Eskom embarked on a price restructuring process that implied sharp increases in the price of electricity across all sectors. These increases were admittedly from a low base, but they have been given a high profile in the media and among various decision-makers and large users of electricity. Given these recent developments, there is no adequate dataset to capture both the price and the electricity usage data to reflect any possible behavioural change. The question is, however, whether price played a role in determining historical electricity consumption.

This paper seeks to answer this question by examining the price elasticity of various economic sectors in South Africa for the period before the price reform. This was done by employing panel data analysis for the period 1993-2006. The results will in all likelihood indicate whether the sectors' behavioural responses have played an important role in the current mismatch

between the demand for and supply of electricity.

The remainder of this paper is structured as follows: the next section presents a brief review of literature dealing with electricity demand and its determinants. The subsequent section describes the situation of the electricity market in South Africa. Next, the research method and data used are presented, while the empirical results are discussed after that. Finally, the conclusions and policy implications of the findings are discussed.

2

Literature review

Energy studies have attracted international attention during the last decades owing to their relatedness to global environmental problems and the relationship between energy and various countries' growth and development trajectories. More specifically, the investigation of the demand-response sensitivity in the electricity sector on both the aggregate and industrial levels has drawn increasing interest as far as analysing the trend of electricity consumption on an aggregate and industrial level goes.

A number of studies for both developed and developing countries have focused their investigations on the demand for energy or, more specifically, for electricity (Amarawickrama & Hunt, 2008; Atakhanova & Howie, 2007; Hondroyiannis, 2004; Dergiades & Tsoulfidis, 2008; Diabi, 1998; Alfaris, 2002; Narayan et al., 2007). The demand for any good or service is typically affected by its own price, the income of the buyers, the price of the substitutes and other variables based on the type of the good. Although the methodologies followed in these studies differ, the majority concentrated on income (or production/output) and electricity price as the main variables to explain electricity demand.

De Vita et al. (2006) estimated the long-run elasticities of the energy demand for three types of energy, that is, electricity petrol and diesel, in Namibia for the period 1980-2002. They estimated the aggregate energy consumption as a function of Gross Domestic Product (GDP) and the price of energy. Depending on

the type of energy in question, they also test for the importance of other variables, such as air temperature, the HIV/AIDS incidence rate and the price of some alternative forms of energy. Their results showed that energy demand is affected positively by the changes in GDP and negatively by the changes in the energy price and air temperature.

Special attention has also been paid to developing economies. Ghaderi et al. (2006), for instance, investigated the electricity demand function of the industrial sector in Iran. A similar sectoral analysis of Russian industries was conducted by Egorova and Volchkova (2004), who found that the electricity prices were a factor of energy consumption, although other factors, such as the output of the industries, proved more significant. Studies were also carried out for developed countries by, for example, Lundberg (2009), who derived a demand function of Swedish industrial electricity use as well as the changes in demand trends over time. By dividing the sample into two periods (1960-1992 and 1993-2002), he showed in his findings that output was a more significant factor in the first period, while price became more significant in the second. A possible explanation for this change was the more efficient use of energy in the latter period.

In Romania, electricity consumption is also considered significantly important for the development of the country (Bianco et al., 2010). In their study, Bianco et al. (2010) modelled non-residential electricity consumption as a function of GDP, non-residential electricity price and the non-residential electricity consumption of the previous period. First, they estimated the GDP and price elasticities for the non-residential electricity consumption for the period 1975-2008, identifying them as the main determinants of the consumption's evolution. They then proceeded with a forecasting exercise. Their findings show that price elasticities varied between -0.075 in the short-run to -0.274 in the long-run, while the income elasticities were between 0.136 in the short-run and 0.496 in the long-run.

In a panel data framework, Narayan *et al.* (2007) examined the residential electricity demand and its determinants for the G7

countries. The electricity consumption is determined as a function of its price and real income per capita. They proposed two models that differ only in the treatment of the prices. The one model includes real electricity prices while the other includes electricity prices relative to gas prices. The main result reported is that residential demand for electricity is income inelastic but price elastic in the long-run.

Regarding the industrial electricity consumption, Dilaver and Hunt (2010) examined the relationship between industrial electricity consumption, industrial value added and electricity prices relating to the Turkish industrial sector for the period 1960-2008. They concluded that output and real electricity prices are the significant factors for the determination of electricity consumption (price elasticity = -0.16 and income elasticity = 0.15).

Locally, Blignaut and de Wet (2001) examined the industrial electricity consumption with regard to the price by estimating the price elasticities for the various sectors between 1976 and 1996. They found weak relationships between electricity price and consumption, some of which were positive. Ziramba (2008) analysed residential electricity demand, showing that price did not have a significant impact on the residential sector for the period 1978-2005. Instead, income was an important determinant of electricity demand. However, these results were challenged by Inglesi (2010), who showed that, for 1980-2005, price was a significant factor in total electricity demand, but at an aggregate or economy-wide level. Given the conflicting evidence, this paper attempts to expand the work done by Blignaut and de Wet (2001) and Inglesi (2010) and to examine the price sensitivity of the electricity consumption for a group of economic sectors separately.

3 Background

3.1 Electricity sector

The South African electricity sector has been characterised over the years by unique traits, while it has passed through different phases in which various key players had dissimilar responsibilities. Here, the main phases as well as the key players and their roles in each are analysed. The following sections discuss the evolution of South African electricity consumption and prices.

According to Marquard (2006), the South African electricity system experienced three main phases. Phase one, the late 19th century to the 1900s, was characterised by the existence of small electricity systems set up by local authorities in cities and relatively larger electricity systems that were self-producers (mainly mines). Phase two, the late 1900s up to the early 1920s, started with the development of a generation monopoly in the Witwatersrand for the provision of electricity to the gold-mining industry. The third phase, from the early 1920s until today, started with the establishment of the state utility, Eskom, and saw the transition towards an integrated national system with Eskom as the generator, transmitter and main distributor of electricity (Marquard, 2006).

The domestic electricity supply and regional trade statistics are provided in Table 1. Electricity generation increased slightly (approx. 4%) during the study period. However, the current maximum generation capacity has a ceiling, as can be noted from the year 2000/2006, which saw no capacity expansion. This makes it unfeasible for the policy-makers to increase the supply substantially in the short-run.

Table 1
Selected electricity supply statistics in South Africa: 1992 to 2006

	GWh			GW	
	Indigenous production	Imports	Exports	Domestic supply	Net maximum capacity
1992	167,816	334	1,814	166,336	36.846
1993	174,581	100	2,589	172,092	37.636
1994	182,452	54	2,679	179,827	35.926
1995	187,825	149	3,000	184,974	35.951

1996	200,266	29	5,579	194,716	36.563
1997	210,052	5	6,617	203,440	37.175
1998	205,374	2,375	4,532	203,217	37.848
1999	203,012	6,673	4,266	205,419	38.517
2000	210,363	4,719	4,007	211,075	39.186
2001	197,908	9,200	6,996	200,112	39.810
2002	206,105	9,496	7,242	208,359	39.810
2003	221,642	8,194	10,263	219,573	39.810
2004	234,045	9,818	13,254	230,609	38.436
2005	230,024	11,079	13,422	227,681	38.644
2006	240,964	10,624	13,589	237,999	39.271

Source: DME (2010b)

The country's economic growth and industrialisation, as well as the electrification programme, resulted in high levels of demand for electricity. This, in combination with the limited supply, led to countrywide power outages that had significant negative effects on the economy as a whole. As the national electricity supplier, Eskom was responsible for managing the situation, focusing on demand-side management (DSM) and the energy efficiency programme in the short term, as well as planning to maintain and expand the current infrastructure in the long term. The current installed capacity per existing power plant is presented in Table A1 in the Appendix, showing that the maximum electricity generated cannot be exceeded in the short term.

For the next five years (until 2013), Eskom plans to be building new power plants in order to cover the difference between demand and supply of electricity (DME, 2010b), focusing more on the long-term increase of the supply. The new build programme includes four new power plants (Kusile, 4,800MW; Medupi, 4,800 MW; Ingula, 1,332 MW; Sere wind-farm, 100MW) that will boost the electricity supply to the country. A new project has also been launched in Botswana, a coal-fired power plant with a capacity of up to 4,800 MW. Moreover, it is also necessary to upgrade the older plants, hence the electricity entity's

intermediate plans, known as the Simunye projects. However, this rise in electricity supply will be in effect only by 2013 or later, so the maximum supply in the short term will remain constant.

3.2 Electricity consumption

In stark contrast to the electricity supply figures, electricity consumption has increased substantially over the past decade: 11.96% between 1995 and 2000, and 34.58% between 2000 and 2006. The growth in demand in this latter period is particularly important, given that it coincides with a period of no supply expansion, as noted above.

A sectoral analysis (Table 2) shows that the industrial sector has always been the largest consumer of electricity. The industrial sub-sectors that have shown the strongest growth over the years are 'chemical and petrochemical' and 'non-metallic minerals'. The 'construction' sector, although not a big consumer in its own right, has almost doubled its electricity consumption over the period, an indication of the growth in the sector during the 2000s. In addition, the 'non-ferrous metals' sector also doubled its contribution to the country's electricity consumption within the studied period. The residential sector's electricity consumption has also increased, while keeping its share in total consumption fairly constant at about 17%.

Table 2
Sectoral electricity consumption in South Africa: 1995, 2000 and 2006

	1995		2000		2006	
	MWh	%	MWh	%	MWh	%
Total consumption	143 172 628	100	160 299 858	100	215 739 110	100
Industry sector	80 657 330	56.336	99 702 977	62.198	116 630 874	54.061
Iron and steel	16 250 811	11.351	20 913 350	13.046	21 342 320	9.893
Chemical and petrochemical	3 602 879	2.516	2 640 440	1.647	10 081 220	4.673
Non-ferrous metals	6 956 009	4.858	15 037 710	9.381	18 640 440	8.64
Non-metallic minerals	1 190 263	0.831	1 153 690	0.72	2 605 740	1.208
Transport equipment	8 590	0.006	69 250	0.043	91 490	0.042
Machinery	104 087	0.073	53 170	0.033	41 680	0.019
Mining and quarrying	33 176 049	23.172	29 038 108	18.115	31 503 470	14.603
Food and tobacco	454 207	0.317	639 090	0.399	760 670	0.353
Paper pulp and print	975 054	0.681	1 493 630	0.932	1 755 710	0.814
Wood and wood products	534 173	0.373	412 370	0.257	296 890	0.138
Construction	13 805	0.01	34 010	0.021	53 980	0.025
Textile and leather	475 421	0.332	376 340	0.235	518 950	0.241
Non-specified (industry)	16 915 982	11.815	27 841 819	17.369	28 938 314	13.414
Transport sector	4 297 357	3.002	5 411 009	3.376	3 479 710	1.613
Other sectors	58 217 941	40.663	55 185 872	34.427	95 628 526	44.326
Agriculture	5 301 173	3.703	3 954 372	2.467	5 841 498	2.708
Commerce and public services	17 306 899	12.088	17 164 007	10.707	28 832 795	13.365
Residential	24 369 099	17.021	28 680 001	17.891	39 670 915	18.388
Non-specified (other)	11 240 770	7.851	5 387 492	3.361	21 283 318	9.87

Source: DME (various issues)

Moreover, the residential sector was the single largest individual consumer of electricity in 2006. The electricity consumption of 'commerce and public services' increased in 2006. In comparison with other sectors, the 'commerce and public services share remained in the range of 10-13%.

From the above statistics it is evident that the country has undergone major economic structural changes, depicted by the changes in the electricity consumption profile. One plausible reason is the economic and social changes that the country has undergone since 1994.

3.3 Electricity prices

Literature abounds with information describing South Africa's electricity prices (Doppegieter et al., 1999; Van Heerden et al., 2008). It has been noted that South Africa has had low and declining real prices of electricity for a prolonged period of time. These can be seen in Table A2 in the Appendix, which presents the

average real electricity prices in selected sectors for the period 1993-2008 and their year-on-year percentage changes. For a more detailed picture of electricity consumption, its prices and the economic output per sector, Figure 1 presents a summary of graphs for the 'industrial', 'mining', 'transport', 'agriculture' and 'commercial' sectors for the period 1993-2006. From this it is obvious that not all the sectors behaved in the same way during the study period as far as their electricity consumption was concerned. From the industrial sector's graphs, it can be observed that electricity consumption showed a positive relatedness with the sector's economic output, while this was negative for the electricity real prices, which were decreasing throughout the study period.

Next, the mining sector's electricity consumption appears unaffected by both its output and the electricity prices. The consumption experienced a sharp decline at the end of the 1990s, picking up during the 2000s. The

mining sector's output increased substantially at the beginning of the 2000s, following the internationalisation of the economy and the end of the sanctions. On the other hand, the real electricity prices for mining steadily decreased until 2002.

The transport sector presents a similar example, with electricity consumption that fluctuated over the years, with an average increasing trend but severe decline in the last years of the sample. Its economic output has been increasing continually over the studied period, while its electricity prices started increasing again only after a period of critical decline from 1993 to 2002.

The electricity consumption of the agricultural sector presents high increases (during 1993-94 and 2001-2003). A structural change is seen during 1999-2000, with consumption decreasing by 31%. On the contrary, its output showed a steady increase over the years, while the electricity prices followed the economy's price overall trend, decreasing until 2002-2003 and slowly rising after that.

Finally, the commercial sector's electricity usage showed an upward trend over the whole period, with the exception of 1997. The picture for its real economic output was exactly the same; however, its price fluctuated, with a decreasing overall trend for half the years of the studied period and it has been more or less stable since 2001.

Considering this analysis, and according to economic theory, there are two ways of dealing with electricity consumption: a) from the supply side, as an input to the output of a sector, or b) from the consumers' side, as a result of output and prices. Figure 1 shows that output and electricity consumption have similar trends, so we ran Ordinary-least squares (OLS) regressions to establish the role of electricity consumption as an input to each sector's output (see Table A3 in the Appendix). From these simple regressions, we can conclude that electricity consumption is not a significant factor in explaining the output trends of the sectors in the specific period 1993-2006. Based on these results, and on the conventional approach discussed in the international literature to looking at the electricity demand, we proceed by examining the electricity demand from the consumers'

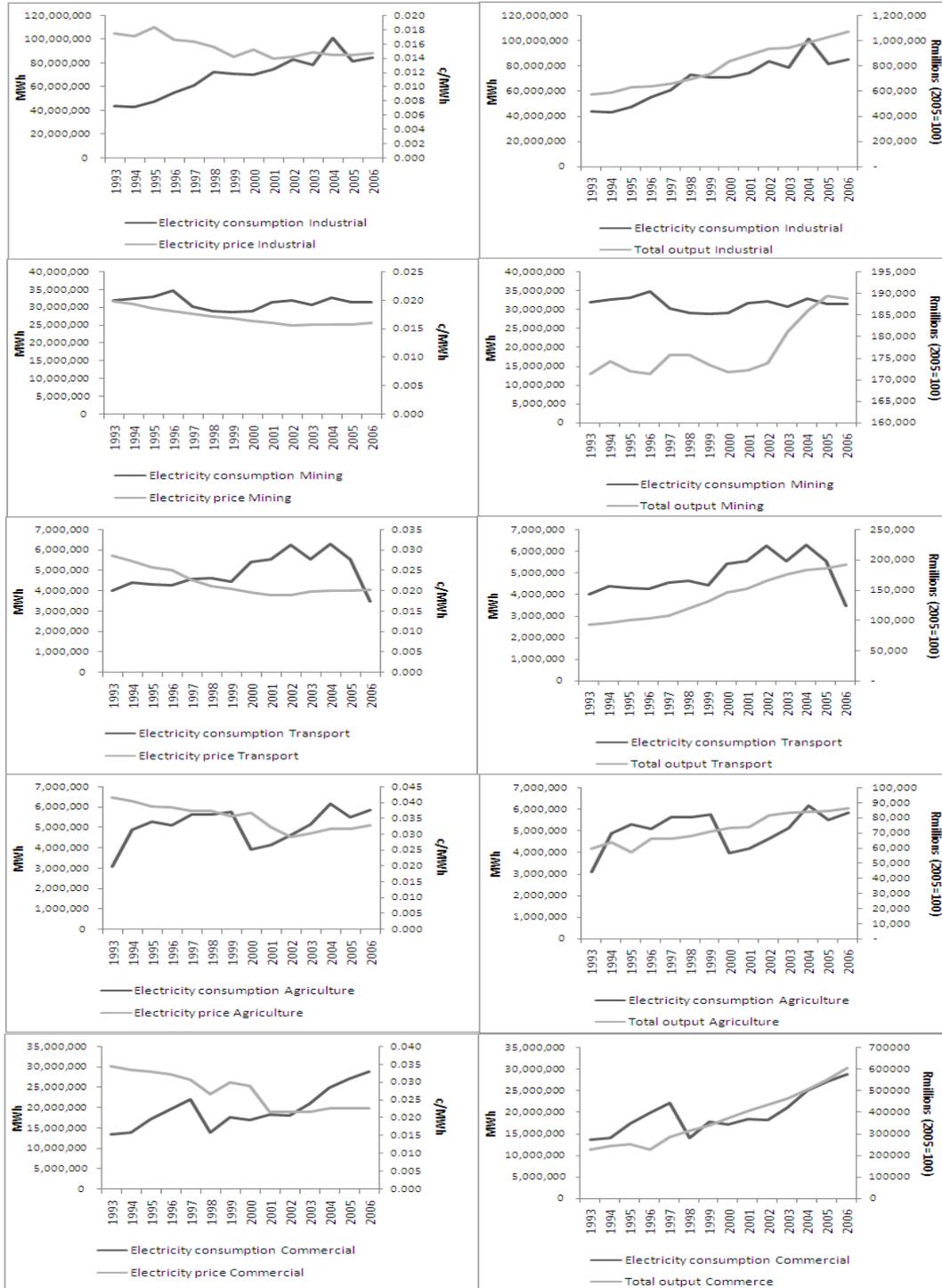
point of view, using a single equation approach in which the quantity of electricity demanded is a function of electricity prices and the output produced in each sector.

4 Data

Local sources of data were used in applying panel data analysis. Sectoral electricity consumption is derived from the *Energy Balances* of the Department of Minerals and Energy (DME various issues) and is measured in MWh. For the purpose of the *Energy Balances*, the economy consists of five sectors (the industrial sector, the commercial, agricultural, residential and transport sectors) disaggregated in 22 industries. The data are collected by the Trade and Industry division in Stats SA in collaboration with the Department of Energy, using a questionnaire via post or fax. The main source of information is Eskom, followed by municipal power stations and other industries (sugar, paper, petroleum and mining). The process of supplying the data is under an agreement for confidentiality. The DME does not conduct any independent surveys, nor does it perform regular data audits. The DME relies on the data providers and the reports released by Eskom and the National Energy Regulator (NERSA). In an effort to verify the data, the DME has a quality control process in place involving a manual data check comparing the current data with datasets from previous years, querying when inconsistencies are observed. Following this, the data is subject to review by various committees and key energy specialists. After the initial peer-review process, the data is released to a number of international organisations, such as the International Energy Agency, the South African Development Community (SADC), academic institutions, government departments and other stakeholders (StatsSA, 2009). Following the approval of the data by these institutions, the data is released to the public. While it can be assumed that the data is not perfect, it is currently the best available and it should be noted that the data did undergo considerable scrutiny.

Figure 1

Electricity consumption, prices and economic output for the Industrial, Mining, Transport, Agriculture and Commercial sectors for the period 1993 to 2006



Source: DME (various issues); DME (2010a) and Quantec

The series on the sectoral electricity prices can be obtained from the *Energy Price Report*, 2009 (DME, 2010), which is not always released annually on account of certain limitations. In this publication, tariffs for various types of energy in South Africa are presented, inter alia, with electricity. The tables for the electricity charges are derived from Eskom's Statistical Yearbooks and Annual reports. More specifically, the electricity prices are presented as sectoral averages and they represent Eskom's revenue per kWh (selling price of electricity, VAT excluded) by customer category: Bulk, Domestic and Street Lighting, Commercial, Industrial, Mining, Rural/Farming, Traction and International. The data are applicable only to Eskom charges to the categories and exclude sales by local authorities. The prices are presented in nominal terms and were converted to real prices by using the annual Consumer Price Index (CPI), with 2005 as the base year, from Statistics South Africa (Statsa).

Finally, the data series on real total output was obtained from the *Quarterly Bulletin* of the South African Reserve Bank (SARB various issues) and *Industry trends database* from Quantec. The output is measured in Rand millions, transformed in real prices for 2005 by using the Consumer Price Index (CPI) from Statistics South Africa (Statsa)

$$y_{it} = \beta_0 + \beta_1 X_{1,it} + \beta_2 X_{2,it} + \varepsilon_{it}, \text{ for } i=1 \dots N \text{ and } t=1 \dots T \quad (1)$$

Where y_{it} is the dependent variable observed for individual i at time t , $X_{1,it}$ and $X_{2,it}$ are the time-variant regressors; β_0 is the constant; β_1 and β_2 are the slope coefficients and ε_{it} is the error term. However, "pooling" has some specific characteristics, such as the increase of the degrees of freedom, hence the potential low standard errors on the coefficients as a

$$y_{it} = \beta_0 + \beta_1 X_{1,it} + \beta_2 X_{2,it} + \alpha_i + u_{it}, \text{ for } i=1 \dots N \text{ and } t=1 \dots T \quad (2)$$

Where α_i is the unobserved individual effect and u_{it} is the error term.

There are two methods of dealing with the unobserved individual effect: the fixed effect model and the random effects model. The first one assumes that α_i is not independent of $X_{1,it}$ and $X_{2,it}$ while the latter assumes

5 Research methodology

5.1 Panel data analysis

A frequently-asked question in energy economics is whether there is a connection between energy consumption and total income. By employing panel data methods, Sadorsky (2009) focused on renewable energy and supported the hypothesis that increases in real per capita income have a significant impact on per capita renewable energy consumption. This result is confirmed by Apergis and Payne (2010), who examined the existence of interaction between renewable energy consumption and economic growth in a panel data context. Six countries in Central America were studied for the period 1980 to 2006. Their results show that, in the long run, a 1% rise in per capita income increases the renewable energy consumption by 3.5%. In addition, the price elasticity of renewable energy consumption was approximately -0.7.

The pooled effects model is considered to be limited for a number of applications, as it does not take into account any cross-section heterogeneity among the sectors. The pooled effects model presents a joint estimation of coefficients, as follows:

result. Also, except for the same slope coefficients, it assumes a common intercept. The next step would be to relax the assumption of a common intercept for the regression. Formally, and to be able to distinguish between different effects, (1) can be rewritten as:

that α_i is independent of $X_{1,it}$ and $X_{2,it}$ or $E(\alpha_i | X_{1,it}, X_{2,it}) = 0$.

Taking the analysis further, the final aim is to estimate a set of equations that will allow different coefficient vectors. The Seemingly Unrelated Regression (SUR) model provides the researcher with that possibility. Analysts in

economics and more particularly in energy have been using SUR models since the 1980s. Recently, Lee and Lee (2009) used a dataset of 109 countries for the period 1971- 2003 to investigate the stationarity properties of CO₂ emissions and GDP per capita within an SUR context. This methodology was preferred because it can account for the presence of

cross-country correlations. The results of Lee and Lee's analysis stress an important aspect of panel data analysis: different orders of integration between countries for some variables can lead to misleading conclusions. Equation (2) should be amended (by representing a different coefficient for each *i*) in order to represent an SUR, as follows:

$$y_{it} = \beta_{0,i} + \beta_{1,i}X_{1,it} + \beta_{2,i}X_{2,it} + \varepsilon_{it}, \text{ for } i=1 \dots N \text{ and } t=1 \dots T \quad (3)$$

5.2 Theoretical model

For an investigation of the effects of prices and industrial output on electricity consumption in different economic sectors, a balanced panel data of five production sectors for the period 1993-2006 was developed. The electricity consumption is thus assumed to be a function of changes in electricity prices and output. It should be noted here that the prices are exogenously determined by the national supplier of electricity, Eskom, so they are not determined by the interaction of supply and demand but by policy decisions. Consequently, and combined with the fact that electricity supply in the country has a specified ceiling (see Section 3.1), the electricity supply is not

considered to be a factor affecting electricity demand.

First, a pooled panel test was employed to investigate the overall relationship between electricity prices and output as related to electricity consumption. Then, to capture sector-specific effects, fixed effects analysis was used to account for cross-section dynamics. Finally, to determine how the various sectors respond to electricity price changes in terms of their own production output, and to describe inter-sectoral dynamics, an SUR model is estimated. Following the international literature review (see Section 2), the equation used is of the following functional form:

$$\text{LnCons} = \alpha_{0,i} + \alpha_{1,i} \text{LnPrice}_{it} + \alpha_{2,i} \text{LnOutput}_{it} \quad (4)$$

where *cons* is the electricity consumption, *price* is the price of electricity and *output* is the total output of the sector *i* at time *t*. The letters Ln in front of the variable notate that all the variables are in their natural logs. Linearising the variables will also be useful in estimating elasticities that are defined as ratios of percentage changes.

presented in Table 4 in the Appendix.

The results of the pooled and fixed effects are presented in Table 3. The pooled effects model is considered to be limited for a number of applications, as it does not take into account any cross-section heterogeneity among the sectors. The fixed effects model, on the other hand, does allow for cross-section heterogeneity and assumes a different intercept for each sector. The results show that both electricity price and output for the industries are significant factors in electricity demand in its entirety. Output has a positive impact, while an increase in price leads to a decrease in the use of electricity. However, when the effects of the different sectors (fixed effects model) are taken into account, the coefficient of electricity prices becomes insignificant, while output becomes less significant.

6

Empirical results

The univariate characteristics of the variables were tested according to the unit root test proposed by Levin, Lin and Chu (2002). The null hypothesis of the test is that each individual time series contains a unit root, as opposed to the alternative that each time series is stationary. The results of the test are

Table 3
Pooled and fixed effects result*

Lncons	Pooled effects	Fixed effects
Lnoutput	0.803 0.000	0.603 0.011
Lnprice	-0.950 0.000	0.259 0.389
Constant	3.087 0.000	
Constant of industrial sector		7.060 0.000
Constant of transport sector		6.000 0.000
Constant of commercial sector		6.453 0.000
Constant of agricultural sector		6.183 0.000
Constant of mining sector		7.113 0.000
Adjusted R ²	0.757	0.970

Note: Numbers in bold show the p-values.

The results of the fixed effects analysis show that cross-section heterogeneity might be the cause of the insignificance of the electricity prices, because in the fixed effects model we allow for sectoral differences, and the price became insignificant. Next, an SUR model is

estimated to capture the importance of electricity prices in each of the sectors separately, knowing that the sample is characterised by heterogeneity in their behaviour towards electricity use (see Table 4).

Table 4
SUR model results

Lncons	Industrial	Transport	Commercial	Agriculture	Mining
Lnprice	-0.869 0.004	-1.220 0.229	0.677 0.145	0.152 0.865	0.204 0.506
Lnoutput	0.712 0.004	-0.242 0.694	0.767 0.029	0.032 0.955	0.030 0.954
Constant	3.059 0.132	8.749 0.001	6.081 0.005	10.076 0.000	11.430 0.004
Adjusted R-squared=0.967					
Total number of observations: 65					
Corrected for serial correlation and heteroskedasticity					

Note: Numbers in bold show the p-values.

The coefficients of the variable *Lnprice* are considered to be the price elasticities of electricity demand for each of the sectors. The results are in accordance with expectations following a careful study of Figure 1. The industrial sector has inelastic electricity

demand (elasticity = -0.869) for the period 1993-2006. The price does not play a significant role in the demand for electricity for the rest of the sectors (their coefficients are all highly insignificant). In contrast, sectoral output is found to be a significant factor that

influences electricity consumption for only the industrial and commercial sectors. However, the output of the other three sectors does not significantly affect the electricity consumption. Some of the plausible reasons for this behaviour are discussed below.

7

Discussion: policy implications

The results of the analysis above suggest that the relation between electricity consumption and electricity prices differ from sector to sector. The price elasticity in the industrial sector is highly significant and negative. In contrast, the rest of the sectors present insignificant price elasticities. Before we turn to discussing the results of the main focus of this study, it is equally important to talk about the findings relating to whether or not the output affected the electricity consumption of the various economic sectors. Economic output was a positive contributing factor to only two out of five of the sectors studied: industrial and commercial; regarding the other three sectors, the output did not play a statistically significant role in their electricity usage.

First, the agricultural sector in South Africa is relatively labour-intensive, and still uses traditional methods of production. Hence, the output should not be expected to relate to the electricity consumption by the sector. Regarding the transport sector, one of its main electricity users during the early part of the study period was freight rail. This sector all but collapsed during the study period when freight transport was shifted to road and long-haul. This implies that the electricity consumption for the sector declined significantly, but the output/production did not. This suggests that the South African transport sector experienced a switch from electricity to other forms of energy, such as oil/petroleum. Finally, during the period under investigation, the mining sector engaged in a process of co-generation whereby the mines started generating their own electricity or creating smaller power units. Consequently, their electricity demand from the national supplier has declined.

The level of the electricity prices is historically very low, which has also caused

a lack of behavioural response to price changes, as Blignaut and De Wet (2001) point out. Moreover, the real prices in a number of sectors declined significantly until 2002, when the price reform began to take effect. There was a long period during which consumption increased more rapidly than prices, owing to other factors, such as product demand or technological change. This is not uncommon. Miketa (2001) found similar results when studying various countries, and attributed this lack of behavioural response to the fact that energy prices were not constructed to be industry-specific.

The low level and declining trend of electricity prices in South Africa have also contributed to the cost of electricity as a significantly low percentage of the total cost. Blignaut and De Wet (2001) have shown that, for a number of years, from 1976 to 1996, the ratio of electricity to total costs was less than 10% for the majority of the South African economic sectors. Table A6 in the Appendix confirms this for the year 2005. The low proportion of electricity costs, showing the low relative importance of the specific product to the consumers' budget, makes one expect low (or even insignificant) price elasticities.

The price policies followed in the country, in addition to the results of the above analysis on electricity, resulted in an enhancement of electricity consumption as reflected by a lack of price sensitivity in all but the industrial sector. Moreover, the stronger the demand for electricity, given the electricity supply mix, which is heavily dominated by coal, the stronger the demand for power.

8

Conclusion

To address the mismatch between electricity supply and demand, such as the one South Africa is currently experiencing, one must understand, *inter alia*, the underlying behavioural responses due to changes in price. The sector-specific approach employed here highlights each sector's reaction to price changes before the recently-proposed increases.

Using panel data, this study examined the price effect on electricity consumption by

sector and the respective price elasticities were estimated. The findings of the analysis point to ambiguous results and even 'abnormal' behaviour towards price changes in all but the industrial sector, which is the only one in which consumption declined with price increases and vice versa.

According to this analysis, the lack of behavioural responses to price changes contributed to the insecure and uncertain environment in which the current policy-makers find themselves. More disconcerting, however, is that the lack of sensitivity to price changes has also acted as a strong stimulus for

the growth in CO₂-emissions. If South Africa wishes to curb the emissions of CO₂ from electricity generation it will do well to induce change that would enhance a behavioural response to price changes. This would include both efficiency improvements and technological changes.

In the future, a structural change is expected due to the high increases in the electricity tariffs. The past insensitivity to price changes might disappear, with different sectors turning to more efficient technologies and other, more affordable, forms of energy.

Endnote

* Both specifications' results are after correction for the serial correlation and heteroskedasticity present. White-heteroskedasticity-consistent standard errors and covariances were used to correct for heteroskedasticity, as well as the Prais-Winstone transformation to correct for serial correlation, as proposed by Baltagi (2008). In addition, the Hausman test concluded that there is no misspecification in the model. For the results of all the tests, see Appendix Table A5.

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Appendix

Table A1
Generation power plants (Eskom)

Power plant	Type	Location	Capacity (GW)
Acacia	Gas	Western Cape	0.171
Ankerlig	Gas	Western Cape	1.338
Arnot	Coal	Mpumalanga	2.352
Camden	Coal	Mpumalanga	1.520
Drakensberg	Pumped storage	Kwazulu-Natal	1.000
Duvha	Coal	Mpumalanga	3.600
Gariep	Hydro	Free State	0.360
Gourikwa	Gas	Western Cape	0.746
Grootvlei	Coal	Mpumalanga	1.200
Hendrina	Coal	Mpumalanga	1.965
Kendal	Coal	Mpumalanga	4.116
Klipheuwel	Wind	Western Cape	0.003
Koeberg	Nuclear	Western Cape	1.930
Komati	Coal	Mpumalanga	0.940
Kriel	Coal	Mpumalanga	3.000
Lethabo	Coal	Free State	3.708
Majuba	Coal	Mpumalanga	4.110
Matimba	Coal	Northern Cape	3.990
Matla	Coal	Mpumalanga	3.600
Palmiet	Pumped storage	Western Cape	0.400
Port Rex	Gas	Eastern Cape	0.171
Tutuka	Coal	Mpumalanga	3.654
Vanderkloof	Hydro	Northern Cape	0.240

Source: Eskom (2010)

Table A2
Average real prices (2005=100) and annual percentage growth

	Real Prices (2005=100)						
	Industry	Mining	Transport	Agriculture	Commerce	Residential	Average
1993	17.49	19.94	28.69	41.55	34.47	26.55	28.12
1994	17.09	19.40	27.45	40.54	33.44	32.15	28.35
1995	18.37	18.75	25.87	38.83	32.94	32.05	27.80
1996	16.63	18.14	25.20	38.50	32.08	32.02	27.09
1997	16.33	17.67	22.79	37.36	30.65	32.32	26.19
1998	15.63	17.33	21.13	37.48	26.74	32.26	25.09
1999	14.25	17.01	20.49	35.86	30.04	34.21	25.31
2000	15.28	16.52	19.65	36.97	28.98	35.46	25.48
2001	13.99	16.16	18.99	32.50	21.72	37.40	23.46
2002	14.29	15.69	19.03	29.37	21.65	37.09	22.85
2003	14.85	15.80	19.90	30.55	21.62	38.35	23.51
2004/05	14.44	15.88	20.02	31.87	22.61	40.00	24.14
2006/07	14.75	16.19	20.25	32.86	22.69	40.08	24.47
2007/08	16.52	17.19	22.28	34.32	23.75	42.59	26.11
Average	15.71	17.26	22.27	35.61	27.38	35.18	25.57

Change in real prices (year-on-year %)							
	Industry	Mining	Transport	Agriculture	Commerce	Residential	Average
1994	-2.25%	-2.72%	-4.31%	-2.44%	-2.99%	21.08%	1.06%
1995	7.45%	-3.30%	-5.76%	-4.20%	-1.50%	-0.31%	-1.27%
1996	-9.48%	-3.28%	-2.59%	-0.86%	-2.59%	-0.11%	-3.15%
1997	-1.76%	-2.61%	-9.58%	-2.96%	-4.46%	0.94%	-3.40%
1998	-4.30%	-1.89%	-7.25%	0.30%	-12.77%	-0.19%	-4.35%
1999	-8.86%	-1.85%	-3.04%	-4.31%	12.37%	6.07%	0.06%
2000	7.28%	-2.86%	-4.12%	3.09%	-3.54%	3.63%	0.58%
2001	-8.46%	-2.22%	-3.35%	-12.09%	-25.03%	5.48%	-7.61%
2002	2.15%	-2.90%	0.21%	-9.62%	-0.35%	-0.82%	-1.89%
2003	3.89%	0.71%	4.58%	4.03%	-0.13%	3.40%	2.75%
2004/05	-2.74%	0.48%	0.60%	4.30%	4.60%	4.29%	1.92%
2006/07	2.15%	1.98%	1.15%	3.12%	0.33%	0.20%	1.49%
2007/08	11.97%	6.21%	10.02%	4.45%	4.68%	6.26%	7.27%
Average	-0.23%	-1.10%	-1.80%	-1.32%	-2.42%	3.84%	-0.50%

Source: DME 2010

Table A3

OLS regressions for each of the five studied sectors:
 $\ln_output_t = a \ln_capital_t + b \ln_labour_t + d \ln_electricity_consumption_t + constant$

Dependent variable: Ln_output _t					
	Industry	Mining	Transport	Commerce	Agriculture
Ln_capital _t	1.811 0.079	1.153 0.001	4.020 0.000	4.042 0.004	-4.107 0.065
Ln_labour _t	-2.209 0.023	0.103 0.126	-0.403 0.091	0.462 0.022	-0.195 0.593
Ln_electricity_consumption _t	0.162 0.522	-0.181 0.239	0.197 0.018	-0.115 0.399	0.106 0.327
C	19.013 0.222	-0.300 0.924	-37.842 0.000	-43.640 0.002	59.980 0.008
Adjusted R ²	0.890	0.655	0.989	0.963	0.795
F-statistic	35.964 0.000	9.229 0.003	390.038 0.000	114.108 0.000	17.829 0.000

Table A4

Unit root test of Levin, Lin and Chu (2002)

Variable	Possible deterministic structure	Statistic	p-value	Level of significance	Conclusion
Lncons	None	0.95	0.83	-	-
	Intercept	2.272	0.01	**	stationary
	Intercept and trend	0.16	0.56	-	-
Lnprice	None	1.19	0.88	-	-
	Intercept	-4.448	0.00	***	stationary
	Intercept and trend	1.74	0.96	-	-
Lnoutput	None	5.96	1.00	-	-
	Intercept	0.15	0.56	-	-
	Intercept and trend	-2.062	0.02	**	stationary

Note: *, **, *** denote 1%, 5% and 10% level of significance respectively

Table A5
Statistical tests results

Test	Null hypothesis	Statistical value	Level of significance	conclusion
Hausman test	H0: No misspecification	2.125	-	Cannot reject the null: No misspecification
Serial correlation (pooled)	H0: No serial correlation	17.558	**	Reject the null: Serial correlation
Serial correlation (fixed)	H0: No serial correlation	2.899	***	Reject the null: Serial correlation
Serial correlation (Durbin-Watson)	H0: No serial correlation	1.084	-	Reject the null: Serial correlation
Serial correlation (Durbin-Watson) after correction	Ho: No serial correlation	1.716	-	Cannot reject the null: No serial correlation
Heteroskedasticity	H0: No heteroskedasticity	28.784	***	Reject the null: Heteroskedasticity

Table A6
Electricity cost as a percentage of total cost in South African sub-sectors: 2005^{1*}

Sector	Ratio	Sector	Ratio
Plastics in primary forms	14.048%	Services relating to printing	0.335%
Soap, detergents, polishing, perfumes	5.833%	Chrome	0.330%
Other mining and quarrying	3.701%	Steam generators	0.323%
Finishing of textiles	3.366%	Machinery for textile, apparel, leather	0.322%
Glass and glass products	2.806%	Machinery for mining, quarrying, construction	0.321%
Platinum	2.296%	Other chemical n.e.c	0.310%
Structural non-refractory products	2.110%	Parts, accessories for motor vehicles	0.297%
Refractory ceramic products	2.007%	Other rubber tyres	0.279%
Non-structural, non refractory ceramicware	1.995%	Building, repairing of boats and ships	0.247%
Other metal ore	1.667%	Fish	0.246%
Forestry	1.427%	Veneer sheets, plywood, laminboard	0.232%
Agriculture	1.373%	Other special purpose machinery	0.216%
Basic iron and steel	1.219%	Structural metal products	0.214%
Household appliances n.e.c	1.166%	Agriculture, forestry machinery	0.207%
Casting of metals	1.064%	Machine tools	0.182%
Tanks, reservoirs, containers of metal	1.063%	Industrial process control equipment	0.175%
Fishing	1.026%	Other food	0.171%
Coal	0.988%	Wooden containers	0.164%
Railway, tramway locomotives, rolling stock	0.964%	Accumulators, primary cells, batteries	0.152%
Basic chemicals	0.926%	Fruit, Vegetables	0.143%
Other transport	0.923%	Cement, lime, plaster	0.128%
Builders' carpentry and joinery	0.908%	Bakery	0.126%
Carpets, rugs and mats	0.804%	Plastic	0.124%
Lifting and handling equipment	0.800%	Furniture	0.117%
Treatment and coating of metals	0.704%	Knitting, crocheted fabrics	0.115%
Copper	0.655%	Other special purpose machinery	0.111%
Aircraft	0.598%	Recycling of metal, non- metal waste and scrap n.e.c.	0.104%
Service activities	0.547%	Tanning, dressing of leather	0.099%
Bodies of motor vehicles, trailers	0.515%	Rubber tyres, tubes, rethreading	0.083%
Corrugated paper, containers of paper	0.510%	Other manufacturing n.e.c.	0.082%
Basic precious and non-ferrous metal	0.507%	Newspaper, journals and periodicals	0.081%
Iron ore	0.497%	Pump, compressor, taps and valves	0.080%

¹ The table excludes all the sub-sectors whose ratio of electricity to total costs was lower than 0.05%

Pulp, paper, paperboard	0.496%	Cordage, rope, twine, netting	0.075%
Other textiles	0.486%	Motor vehicles	0.067%
Gold	0.467%	Paints, varnishes, printing ink, mastics	0.066%
Spinning, weaving of textiles	0.451%	Cocoa, chocolate	0.064%
Machinery for food, beverage, tobacco	0.448%	Manganese	0.064%
Other fabricated metal products n.e.c.	0.441%	Engines and turbines	0.063%
Grain mill	0.436%	Wearing apparel	0.062%
Cutlery, hand tools, general hardware	0.434%	Television, radio transmitters, apparatus	0.060%
Forging, pressing, stamping of metal	0.425%	Insulated wire cable	0.049%
Other articles of paper	0.381%	Electricity distribution, control apparatus	0.049%

Source: Authors' calculations with data from Statssa (2010)