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DYNAMICS OF ELECTRICITY DEMAND IN LESOTHO: A KALMAN FILTER APPROACH

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Abstract:

This study provides an empirical analysis of the time-varying price and income elasticities of electricity demand in Lesotho for the period 1995-2012 using the Kalman filter approach. The results reveal that economic growth has been one of the main drivers of electricity consumption in Lesotho while electricity prices are found to play a less significant role since they are monopoly-driven and relatively low when compared to international standards. These findings imply that increases in electricity prices in Lesotho might not have a significant impact on consumption in the short-run. However, if the real electricity prices become too high over time, consumers might change their behavior and sensitivity to price and hence, energy policymakers will need to reconsider their impact in the long-run. Furthermore, several exogenous shocks seem to have affected the sensitivity of electricity demand during the period prior to regulation, which made individuals, businesses and agencies to be more sensitive to electricity costs. On the other hand, the period after regulation has been characterized by more stable and declining sensitivity of electricity demand. Therefore, factors such as regulation and changes in the country's economic activities appear to have affected both price and income elasticities of electricity demand in Lesotho.

Key words: *electricity demand, price elasticity, income elasticity, Kalman filter, Lesotho*

1. Introduction

The mismatch between demand and supply of electricity has been a major concern among stakeholders and energy policymakers in Lesotho. This becomes apparent during the public hearings when the Lesotho Electricity Company (LEC), a sole national supplier of electricity, has to apply to the regulator (Lesotho Electricity

and Water Authority – LEWA) for a hike in tariffs in order to meet its current and future investment needs. Usually, there is no consensus in those public hearings over whether LEC should be allowed to adjust electricity tariffs in line with its proposed structure and the consequences of such a decision.

One side of the debate is that the tariff hikes are necessary for LEC to be able to procure power and to maintain and expand its existing distribution, transmission and supply network within the country. On the other hand, others argue that a continuous rise in electricity tariffs will have a negative impact on the economy, especially if the increment is considered to be relatively high. In order to contribute to this ongoing debate, the paper analyses the sensitivity of electricity consumption to fluctuations in prices and income throughout the years. Thus, it aims at estimating the time-varying price and income elasticities of electricity demand in Lesotho for the period 1995-2012 using the Kalman filter approach.

The rest of the study is organized as follows. Section 2 provides an overview of the electricity sector in Lesotho. Section 3 specifies the model while the Kalman filter estimation strategy is presented in Section 4. The results and their analysis are discussed in Section 5 and the last section offers the concluding remarks.

2. Overview of Electricity Sector in Lesotho

In the 1960s and before, the electricity supply in Lesotho was under the direct control of the government. At that time, a small coal-fire generating plant was used to supply electricity to a few residential areas occupied mostly by foreigners and the administrative center in the capital city of Maseru. With the aim of improving the provision of electricity throughout the country, the government established a parastatal now known as LEC in 1969. According to the Electricity Act No.7 of 1969, LEC was empowered to generate, transmit, distribute and supply electricity within the country.

As the demand for electricity increased in Lesotho, an agreement was made with the South African national electricity supplier called Eskom to provide Lesotho with electricity. Over the subsequent years, the country had to import all its electricity supply from Eskom and this continued till the 1998 operation of the 72 MW capacity 'Muela Hydropower Plant (MHP), which is owned by the Lesotho Highlands Development Authority (LHDA). In 2004, LEWA was established to regulate the electricity sector in Lesotho. Then LHDA was licensed to generate power, LEC licensed to transmit, distribute and supply electricity, and the Department of Energy granted a license-exemption to operate Electricity Access Pilot Projects (EAPPs).

The electricity demand in Lesotho has been growing significantly over the last few years. For example, the maximum demand during the 2013 winter was estimated at 140 MW, with figures showing that the MHP supplied 446 GWh of the total 757 GWh of electricity consumption in the country (LEC, 2014). Thus, about 41% of the electricity deficit had to be met not only by more expensive imports from Eskom, but also from Mozambique's EDM (*Electricidade de Moçambique)*. Hence the MHP's effect of

stabilizing electricity prices is diminishing and the long run marginal cost of electricity in Lesotho is largely determined by Eskom and EDM prices.

3. Model Specification

According to Inglesi-Lotz (2011), the demand for electricity can be modelled as a function of price and income as follows:

$$\ln\_elec_t = \alpha_1 \ln\_price_t + \alpha_2 \ln\_income_t + \varepsilon_t \quad (1)$$

where the variables $\ln\_elec_t$, $\ln\_price_t$ and $\ln\_income_t$ represent the natural logs of electricity consumption, electricity price and the economy's national income, respectively, and all at time period t. Furthermore, ε_t is the error term at period t and the α's are parameters to be estimated. The coefficient α_1 then captures the price elasticity of electricity demand and it is expected to be negative (implying that the higher the price, the lower the demand). On the other hand, the income elasticity of electricity demand is represented by the coefficient α_2, which is expected to be positive (meaning that the higher the income, the higher the demand).

If equation (1) is estimated using the traditional econometric models like the Johansen's (1988, 1995) multivariate cointegration analysis or the autoregressive distributed lag bounds testing approach of cointegration developed by Pesaran et al. (2001), it would result in constant (or average) coefficients of price and income elasticities throughout the period under study. This is because these procedures depend on the stationarity nature of the concerned variables and hence assume that the estimated parameters do not vary significantly over the years. However, the price (and income) elasticity is considered to be a time-varying indicator since it can be influenced by factors such as regulation and fluctuations in prices, changes in the country's economic activities and the prevailing conditions within the electricity market (Jamil et al, 2011). Therefore, the sensitivity of demand for electricity to changes in prices as well as income could also be analyzed through a dynamic econometric technique that allows its coefficients to vary stochastically over time (see Inglesi-Lotz, 2011 and Hunt et al., 2003).

4. Kalman Filter Estimation Strategy

The study employs the Kalman (1960, 1963) filter estimation strategy, which is based on state-space models that are applied to linear regressions with stochastically time-varying parameters, to determine the evolution of price and income elasticities of electricity demand in Lesotho. The use of this technique compared to other conventional econometric methods is based on the following advantages. First, this approach is considered an ideal model for estimating regressions with variables whose impact changes over time (Slade, 1989). Second, the Kalman filter is believed to be superior to the least squares models, especially in the presence of parameter instability

(Morisson and Pike, 1977). Third, this procedure can be used with non-stationarity data and it is predictive and adaptive (Inglesi-Lotz, 2011).

In line with Inglesi-Lotz (2011), the formal representation of this dynamic model (assuming its parameters are functions of time) is given by the following observation and state equations, respectively:

$$x_t = \alpha(z_t) + [B(z_t)]'\xi_t + w_t \quad (2)$$

$$\xi_{t+1} = H(z_t)\xi_t + v_{t+1} \quad (3)$$

where α is a constant parameter, B and H are matrices of parameters, x_t is a vector of observations and z_t is a vector of exogenous variables. Furthermore, $\alpha(z_t)$ and $B(z_t)$ are vector and matrix valued functions, respectively, and $H(z_t)$ is a matrix with elements that are functions of x_t. A vector of unobserved variables is then given by ξ_t while w_t and v_t are the disturbance vectors that are assumed to be independent and white noise.

Before estimating equations (2) and (3), which allow for stochastically time-varying parameters, the paper has to determine the possibility of existing parameter instability. This can be achieved through the use of Hansen (1992) test, which applies the *Lc* statistic from the theory of Lagrange Multiplier tests, with the null hypothesis of parameter stability being tested. After confirming that the estimated parameters do change over time, the time-varying coefficients of price and income elasticities from the equation (1) can be expressed as follows:

$$\ln\_elec_t = \alpha_{1t}\ln\_price_t + \alpha_{2t}\ln\_income_t + \varepsilon_t \quad (4)$$

Equation (4) is then specified below as a state-space model following the *Eviews* software notation in order allow for time-varying coefficients:

$$\ln\_elec_t = sv1\ln\_price_t + sv2\ln\_income_t + sv3 \quad (5)$$

$$sv1 = sv1(-1) \quad (6)$$

$$sv2 = sv2(-1) \quad (7)$$

$$sv3 = c(2)sv3(-1) + [\mathrm{var} = \exp(c(1))] \quad (8)$$

where $sv1$ and $sv2$ are the final estimates for price and income elasticities, respectively, $sv3$ is the value of other factors affecting the demand for electricity, and $c(1)$ and $c(2)$ are the constant parameters of estimation. From equations (6) and (7), the evolution of price and income elasticities over time is therefore shown to follow a random walk process.

5. Data and Estimation Results

5.1Data and Descriptive Statistics

The study uses quarterly time-series data for the time period spanning from 1995 to 2012 (The analysis is restricted to this period because of data unavailability on electricity prices prior to 1995). The data on national income proxied by the real GDP (constant prices 2004) is obtained from the Ministry of Finance, while the series on aggregate electricity consumption and average electricity prices (expressed in 2004 real terms) are sourced from the LEC. The descriptive statistics of these series are presented in Table 1 while their trends are provided in Figure 1 and 2.

Table 1. Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Electricity Consumption, *elec* (GWh)	377	131	203	645
Electricity Price, *price* (c/KWh)	25	6	18	40
Real GDP, *income* (Million Maloti)	8450	1796	5938	13585

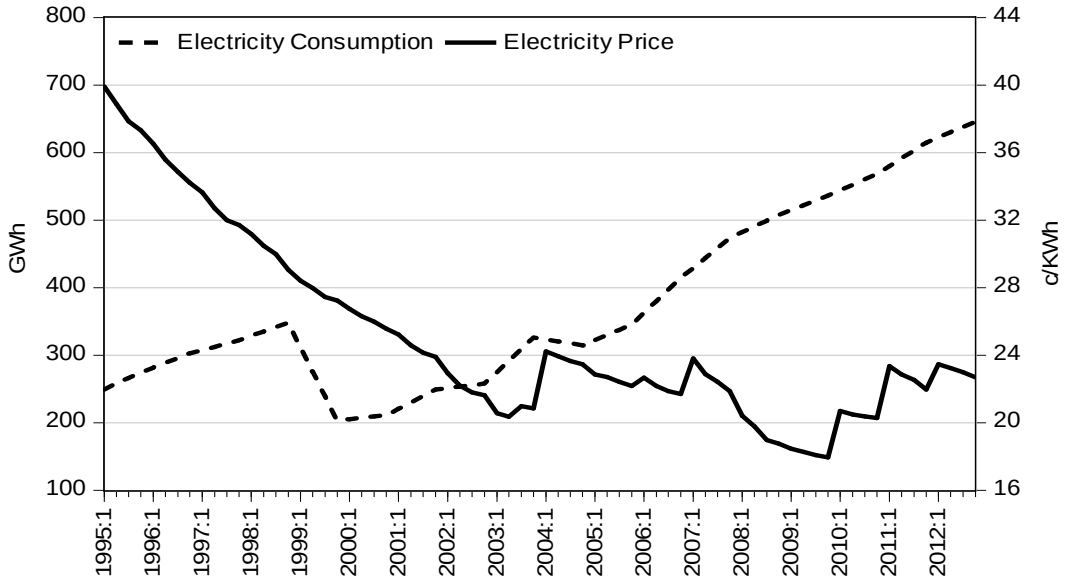

Figure 1. Trends of electricity consumption and real electricity prices, 1995-2012.

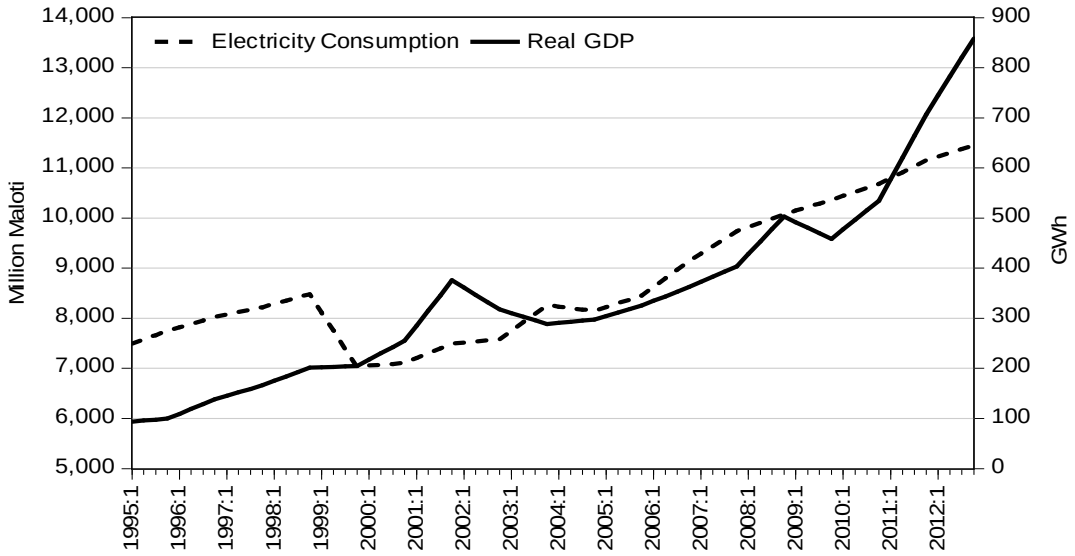

Figure 2. Trends of electricity consumption and real GDP, 1995-2012.

The relationship between electricity consumption and real electricity prices in Figure 1 has generally been negative throughout the period under consideration, with electricity consumption experiencing an upward trend while real electricity prices have declined over that period. On the other hand, Figure 2 shows a positive relationship between electricity consumption and the economy's real GDP since both series have exhibited an upward trend through the period under study.

5.2.Hansen Test Results

The Hansen test is used to ascertain whether the estimated parameters change over time and its results are reported in Table 2. On the basis of the *p*-value, the *Lc* statistic is found to be significant at the 5% level and thus the null hypothesis that the parameters are stable is rejected. Given this finding, the Kalman filter model can be applied to analyse the dynamics of electricity demand in Lesotho.

Table 2. Hansen Test Results

Series	ln_*elec* ln_*price* ln_*income*
Null hypothesis	Parameters are stable
Lc statistic	1.064
p-value	0.011
Inference	Parameters are not stable (Null rejected at the 5% level)

5.3.Kalman Filter Estimation Results

Table 3 displays the results from the Kalman filter estimation technique, with the final (average) estimates for price and income elasticities being significant and having the values of -0.113 (-0.155) and 1.009 (1.797), respectively. These show that, on average, increases (decreases) in real electricity prices have resulted in less than proportionate fall (rise) in electricity consumption, implying that the demand for electricity in Lesotho is price inelastic. This could be expected given the monopolistic nature of the country's electricity sector as well as the relatively low electricity prices when compared to international standards. Thus, increases in electricity prices in Lesotho might not have a significant impact on consumption in the short-run. However, if the real electricity prices become too high over time, consumers might change their behavior and sensitivity to price and hence, energy policymakers will need to reconsider their impact in the long-run.

Table 3. Kalman Filter Estimation Results

Space Model		
Sample	1995:1 - 2012:4	
Included observations	72	
Number of iterations to convergence	9	
Variables	Estimated coefficients	*p*-values
c(1)	-7.333	0.000
c(2)	0.770	0.000
	Final state	*p*-values
*sv*1 (price coefficient)	-0.113	0.082
*sv*2 (income coefficient)	1.009	0.001
*sv*3 (intercept)	-0.014	0.601

Notes: Average values for *sv*1, *sv*2 and *sv*3 over the studied time period are -0.155, 1.797 and -0.008, respectively.

On the other hand, these findings reveal that the electricity demand in Lesotho is income elastic. This is because the effect of a rise in the country's national income has generally produced a more than proportionate increase in electricity consumption. Therefore, economic growth seems to have been one of the main drivers of electricity consumption in Lesotho. Nevertheless, this study focuses on the evolution of price and income elasticities of electricity demand over time as shown in Figure 3.

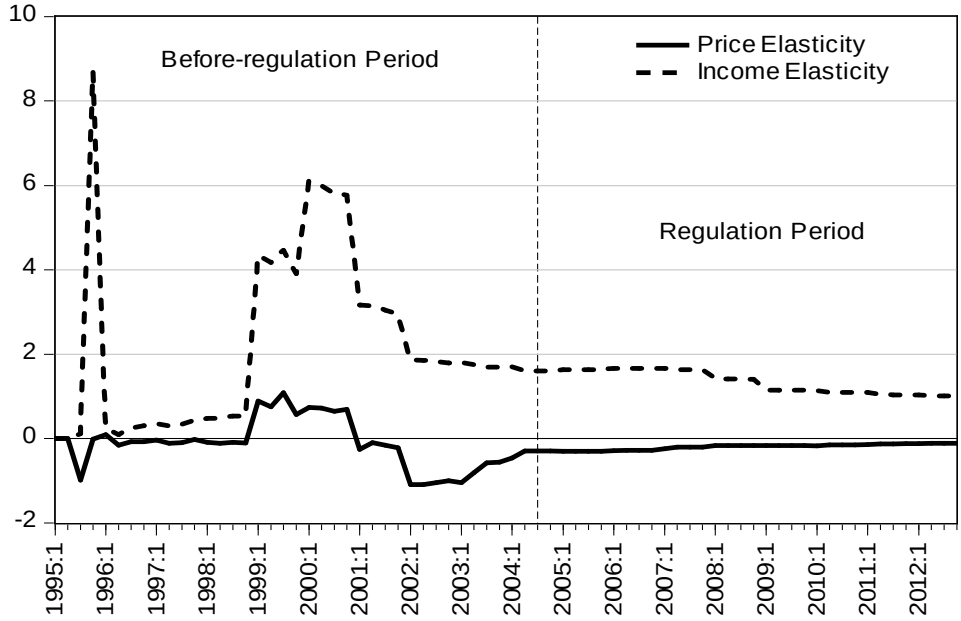

Figure 3. Trends of price and income elasticities, 1995-2012.

The sample period in Figure 3 is divided into two sub-periods: before-regulation period (prior to 2004:3) and regulation period (after 2004:3), in order to observe the effect of the introduction of regulation in the electricity sector in Lesotho. The results show that much instability in price and income elasticities is observed during the period before regulation while the regulation period is characterized by more stable and declining sensitivity of electricity demand. During this latter period, the estimates of price and income elasticities are even found to be within the empirical ranges of -2-0 for price and 0-2 for income (see Inglesi-Lotz, 2011 as well as Nakajima and Hamori, 2010).

However, several exogenous shocks seems to have affected the sensitivity of electricity demand during the period prior to regulation. The first instance where price and income elasticities fell outside the empirical ranges is noted during the period between 1995:2-1996:2. This period corresponds to the political instability that started with the military coup slightly before 1995, then followed by some industrial unrests in 1995. These incidents had a negative impact on economic growth, which made individuals, businesses and agencies to be more sensitive to electricity costs, but their impact seems to have been short-lived.

The second instance that appears to be sustained over time is observed during the period 1998:3-2002:1. This reflects the effects of the 1998 political turmoil, which resulted in an unprecedented level of violence, looting and destruction of property. The negative impact of such political instability on economic growth was further exacerbated by the completion of the LHDA infrastructure programme – the Lesotho Highlands Water Project (LWHP), which occurred between 1998 and 2002. Therefore, factors such as regulation and changes in the country's economic activities

seem to have affected both price and income elasticities of electricity demand in Lesotho.

6. Conclusion

This study provides an empirical analysis of the time-varying price and income elasticities of electricity demand in Lesotho for the period 1995-2012 using the Kalman filter approach. The results show that economic growth has been one of the main drivers of electricity consumption in Lesotho while electricity prices are found to play a less significant role since they are monopoly-driven and relatively low when compared to international standards. This implies that increases in electricity prices in Lesotho might not have a significant impact on consumption in the short-run. However, if the real electricity prices become too high over time, consumers might change their behavior and sensitivity to price and hence, energy policymakers will need to reconsider their impact in the long-run.

Furthermore, the findings reveal that several exogenous shocks, including the 1995 military coup and industrial unrests, the 1998 political turmoil, and the completion of the LHDA infrastructure programme, seem to have affected the sensitivity of electricity demand during the period prior to regulation. Although the impact of such incidents has appeared to be short-lived, they have had a negative impact on economic growth, which made individuals, businesses and agencies to be more sensitive to electricity costs. On the other hand, the period following the introduction of regulation in Lesotho has been characterized by more stable and declining sensitivity of electricity demand to changes in both prices and income. Therefore, factors such as changes in the country's economic activities as well as regulation seem to have affected both price and income elasticities of electricity demand in Lesotho.

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