ELECTRICITY DEMAND ELASTICITY IN MAURITIUS: AN ARDL BOUNDS TEST APPROACH TO COINTEGRATION

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Overview

Understanding what factors can potentially impact aggregate electricity consumption in Mauritius remains an important question still unanswered today. This paper empirically investigates the short-run dynamics and long-run relationships between electricity consumption and other economic variables in Mauritius over 1978-2019. The autoregressive distributed lag (ARDL) bounds test approach to cointegration provides evidence of a long-run equilibrium relationship among electricity consumption, real GDP per capita, real electricity price and real exports of goods and services per capita. Electricity consumption is inelastic to price and income in the short- and long-run. However, the significant positive impact of GDP and exports likely outweighs the negative impact of electricity price on consumption over the period considered. Policy measures other than tariff shocks to effectively drive electricity consumption downwards should be considered in Mauritius. Implementing electricity conservation policies and demand-side management actions appears timely and necessary to drive and maintain sustainable consumption levels in the future.

Methods

This study uses annual time series secondary data of aggregate electricity consumption per capita, real GDP per capita, real electricity price and real exports of goods and services per capita covering 1978-2019. Descriptive statistics are presented in the following Table 1.

Table 1 Descriptive statistics in natural logarithm

Variables	Notation	Mean	Std. Dev.	Min	Max	Data sources
Electricity consumption per capita	tecpc	6.8668	0.7550	5.6333	7.7061	Statistics Mauritius
Real GDP per capita	gdppc	8.5361	0.4783	7.7512	9.3010	World Development Indicators, The World Bank
Real electricity price	ep	1.2777	0.2814	0.5136	1.6988	Statistics Mauritius
Real exports of goods and services per capita	exppc	7.83397	0.51481	6.862	8.41338	World Development Indicator, The World Bank

Source: compiled by the author.

To investigate the relationship between electricity consumption and other economic variables, we apply the following ad-hoc function:

$$tecpc_t = \alpha_0 + \beta gdppc_t + \gamma ep_t + \lambda exppc_t + \varepsilon_t \quad (1)$$

Where tecpc is the log of aggregate electricity consumption measured in kWh per capita; gdppc is the log of real gross domestic product per capita in 2010 US $; ep is the log of real average electricity price in 2010 US $, and exppc is the log of real merchandise exports of goods and services per capita in 2010 US $; α_0 is a constant, and ε is the error term.

An ARDL model is estimated to capture the effects of real GDP, real electricity price, and real exports on electricity consumption. The log-linear ARDL model based on Eq. (1) is specified as follows:

$$tecpc_t = \alpha_0 + \sum_{i=1}^{p} \varphi_i tecpc_{t-i} + \sum_{j=0}^{q1} \beta_j gdppc_{t-j} + \sum_{j=0}^{q2} \gamma_j ep_{t-j} + \sum_{j=0}^{q3} \lambda_j exppc_{t-j} + \varepsilon_t \quad (2)$$

Where p and q are the optimal lags of tecpc and the regressors, respectively. β_0, γ_0, and λ_0 represent the estimated parameters that translate the instantaneous effect of the respective explanatory variables on tecpc.

To detect the presence of a long-run equilibrium relationship among the series, we apply the ARDL bounds test approach to cointegration of Pesaran *et al.* (2001) and use Narayan (2005) critical values suitable for small samples. We reparametrize Eq. (2) into an error correction model which enables the analysis of both short- and long-run dynamics:

$$\Delta tecpc_t = \alpha_0 + \sum_{i=1}^{p-1} \varphi_i \Delta tecpc_{t-i} + \sum_{j=1}^{q1-1} \beta_j \Delta gdppc_{t-j} + \sum_{j=1}^{q2-1} \gamma_j \Delta ep_{t-j} + \sum_{j=1}^{q3-1} \lambda_j \Delta exppc_{t-j} + \delta_1 tecpc_{t-1} + \delta_2 gdppc_{t-1} + \delta_3 ep_{t-1} + \delta_4 exppc_{t-1} + \varepsilon_t \quad (3)$$

The bounds test procedure is based on the F-statistic for cointegration analysis (Pesaran et al., 2001). Based on Eq. (3), we test the null hypothesis of no cointegration, i.e. $H_0 : \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$ against the alternative hypothesis $H_1 : \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0$. Pesaran et al. (2001) provide two sets of critical values acting as lower and upper bounds that cover all possible classifications of the regressors into purely I (0), purely I (1) or mutually cointegrated variables. If the F-statistic is lower than the lower bound, the null hypothesis cannot be rejected. If the F-statistic is greater than the upper bound, the null hypothesis is rejected. If the F-statistic lies in the interval, the test is said to be inconclusive. The rejection of the null hypothesis of no cointegration confirms the existence of a long-term relationship in the model. Eq. (3) can be rewritten to derive the lagged error correction term (ECT_{t-1}):

$$\Delta tecpc_t = \alpha_0 + \sum_{i=1}^{q-1} \varphi_i \Delta tecpc_{t-i} + \sum_{j=1}^{p1-1} \beta_j \Delta gdppc_{t-j} + \sum_{j=1}^{p2-1} \gamma_j \Delta ep_{t-j} + \sum_{j=1}^{p3-1} \lambda_j \Delta exppc_{t-j} + \psi_{tecpc} ECT_{t-1} + \varepsilon_t \quad (4)$$

Where ECT_{t-1} represents the deviation of $\Delta tecpc_t$ from its long-run equilibrium. ψ represents the adjustment parameter that restores equilibrium following a disturbance in the long-run equilibrium relationship. For $\Delta tecpc_t$ to error-correct, ψ should be negative and statistically significant (Wang *et al.*, 2011). ϵ_t is assumed to be a serially uncorrelated error term. Eq. (4) is a partial model that requires the weak exogeneity assumption of regressors to hold for optimal inference and dynamic analysis (Engle *et al.*, 1983), where "the hypothesis of weak exogeneity for the long-run parameters is formulated as a parametric restriction on the adjustment coefficients" (Johansen, 1992, p.9).

Results

The ARDL bounds test approach to cointegration is preferable when the sample size is small. The optimal lag length for the ARDL model is based on the Schwarz Information Criterion. The latter suggests estimating the ARDL (1,0,0,0) model. It is tested against serial correlation, heteroscedasticity, functional form misspecification, normality and parameter stability.

Table 2 reports the results of the bounds test approach to cointegration. Since we have a sample size of 42 observations, exact critical values are computed and correspond to Narayan (2005). The results indicate the existence of a unique cointegrating equation when electricity consumption is the dependent variable. The estimated F-statistic of 12.038 is above the upper critical bound at 1% significance level, thus rejecting the null hypothesis of no cointegration. We thus consider real GDP per capita (gdppc), real electricity price (ep), and real exports of goods and services (exppc) as the long-run forcing variables of electricity consumption in Mauritius over 1978-2019.

Table 2 ARDL bounds test results

Function	ARDL model	F-stat	CV at 5%		CV at 1%	
			I (0)	I (1)	I (0)	I (1)
$F_{tecpc}(tecpc \mid gdppc, ep, exppc)$	(1,0,0,0)	12.038***	3.5385	4.8204	5.0448	6.6253
$F_{gdppc}(gdppc \mid tecpc, ep, exppc)$	(3,1,0,0)	3.145	3.5974	4.8532	5.0547	6.6570
$F_{ep}(ep \mid tecpc, gdppc, exppc)$	(1,0,1,0)	2.3874	3.5385	4.8204	5.0448	6.6253
$F_{exppc}(exppc \mid teppc, gdppc, ep)$	(1,0,1,0)	1.3554	3.5385	4.8204	5.0448	6.6253

*** denotes statistical significance at 1% level; lag length for model selection based on SIC. Source: the author.

In this respect, a fundamental interest is to know whether permanent changes in the long-run forcing variables affect electricity consumption's long-run path. The existence of a dynamically stable relationship (cointegration), in this case, implies that electricity consumption can drift away from its long-run path in the short-run but will eventually be pulled back to its long-run trajectory through the error-correction mechanism. The corresponding results for the short- and long-run estimates for Eq. (4) are provided in Table 3.

Table 3 Short- and long-run analysis

ARDL Long Run Form and Bounds Test
Dependent Variable: Δtecpc
Selected Model: ARDL (1, 0, 0, 0)
Case 3: Unrestricted Constant and No Trend
Sample: 1978 2019
Included observations: 41

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
c	-1.151637	0.358753	-3.210115	0.0028
ECT (-1)	-0.210640	0.045512	-4.628238	0.0000

gdppc	0.072662	0.088737	0.818852	0.4183
ep	-0.138045	0.051682	-2.671043	0.0113
exppc	0.280250	0.060655	4.620365	0.0000

Levels Equation
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
gdppc	0.344958	0.272261	1.267013	0.2133
ep	-0.655357	0.209440	-3.129098	0.0035
exppc	1.330465	0.234199	5.680910	0.0000

ECT = tecpc - (0.3450*gdppc - 0.6554*ep + 1.3305*exppc)

Source: the author.

In the short-run, electricity consumption is inelastic to changes in GDP, price, and exports of goods and services. Short-run income elasticity was positive but not significant. Short-run price elasticity is negative and statistically significant, which coherent with economic theory. An increase in electricity price does not significantly change the demand for the commodity in the short-run. A 1% increase in electricity price leads to a decrease of 0.138% in electricity consumption, indicating a relatively slow adjustment of electricity consumption to price increases in the short-run. Exports of goods and services have a positive and statistically significant impact on electricity consumption which rises by 0.28% following an increase of 1% in exports.

The error correction term's (ECT) coefficient is negative and significant (-0.211) at the 1% significance level. The short-run deviations of electricity consumption from its long-run equilibrium are corrected by 21% in the previous year. The relatively low value of the ECT coefficient can be explained by high transaction costs or a longer time required for adjustments.

Electricity consumption becomes more elastic to its price in the long run than in the short-run. A 1% change in electricity prices leads to a decrease of 0.655% in electricity consumption. Overall, increases in electricity prices will likely drive electricity conservation behaviours from end-users. However, given the inelastic nature of the electricity price effect, little can be achieved in discouraging electricity consumption via upward electricity price adjustments. The latter is heavily subsidized and is not cost-reflective to the local network operator.

A 1% change in GDP will likely lead to an increase of 0.345% in electricity consumption in the long-run. Narayan and Smyth (2005) found a similar positive income elasticity of 0.323 for Australia over 1969-2000. However, the coefficient for GDP in this study was not statistically significant. Electricity consumption in other studies was either elastic (Amusa *et al.*, 2009; Adom *et al.*, 2012) or inelastic (De Vita *et al.*, 2006; Zaman *et al.*, 2012) to changes in income in the short-run following a 1% change in real GDP, depending on the country under investigation and the underlying economic structure.

Exports of goods and services are positively related to electricity consumption in the long-run, with a potential 1.33% increase in electricity consumption following a 1% increase in exports. Overall, the signs of estimated parameters are in line with theoretical expectations. The significant positive impact of GDP and exports likely outweighs the negative impact of electricity price on consumption over the period considered. Policy measures other than tariff shocks to effectively drive electricity consumption downwards should be considered in Mauritius.

The model diagnostic tests are provided in Table 4. The cumulative sum (CUSUM) and the cumulative sum of squares plots in Figure 1 confirm the regression relationships' constancy and parameters' stability over time.

Table 4 Tests for model validation

Diagnostic tests	
Specification (Ramsey RESET test)	3.193 [0.054]
Unit root test (ADF test)	-4.450 $[7.6e-05]^{***}$
Serial correlation (Breusch-Godfrey LM test)	0.008 [0.929]
Heteroscedasticity (Breusch-Pagan)	4.739 [0.315]
Normality (Shapiro Wilk test)	0.816 $[1.203e-05]^{***}$
Stability (Recursive CUSUM test)	0.732 [0.208]

*** denotes rejection of the null hypothesis at a 1% significance level (source: the author)

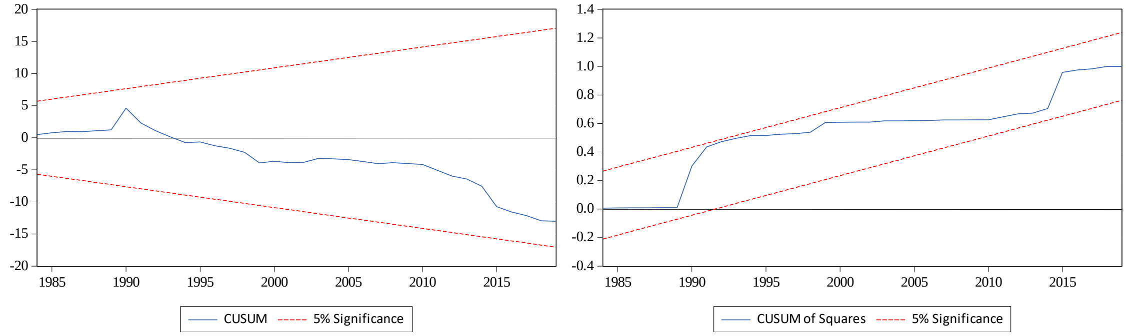

Figure 1 Stability plots for the estimated model (source: the author)

Conclusions

The lack of understanding of the nature and magnitude of the relationship between electricity consumption and other economic variables in Mauritius motivated this study. The ARDL bounds test approach to cointegration with an error correction model (ECM) representation is employed over 1978-2019. There is a stable cointegrating relationship between electricity consumption, real GDP per capita, real electricity price and real exports of goods and services per capita.

Electricity price is the only factor that drives electricity demand downwards. However, the positive effect of GDP per capita and exports that outweighs the negative impact of electricity prices on electricity consumption can explain the continuous increase in electricity consumption. Electricity consumption is price and income inelastic both in the short- and long-run. In the short-run, demand is inelastic due to consumers' inability to quickly react to price changes and adjust their respective consumption pattern. With virtually no other substitutes on the island, electricity is difficult to store or replace, even in the long-run, explaining the relatively inelastic nature of electricity demand to its price.

Mauritius is slowly transitioning to a low carbon economy. Based on the findings in this study, we conclude that electricity conservation policies and demand-side management actions appear timely and necessary to lessen the domestic power sector's pressure without adversely affecting economic growth and the export industry in the long run. Mauritius expects a cumulative energy efficiency target of 10% by 2025 compared to 2008 levels, to reach around 1700 KWh/cap in 2025 if applied to the power sector. Electricity price increases alone are unlikely to achieve this target over a relatively short period considering that the island was still behind its cumulative milestone target of 6% for 2020. This gives momentum for implementing other pricing strategies, including carbon taxes, to accelerate the development and deployment of more efficient technologies for the power sector.

Further research is required to disentangle the complex relationship between electricity consumption and economic growth. The econometric analysis of electricity consumption is essential for analysts, the Government and utility companies in Mauritius, as the findings may provide answers to the likely future electricity consumption pathways. The empirical evidence of a dynamically stable cointegrating relationship presented in this study will be used to forecast electricity consumption in the long-run and enhance energy transition scenarios for Mauritius in future prospective works.

References

Adom, P. K., Bekoe, W., & Akoena, S. K. K. (2012). Modelling aggregate domestic electricity demand in Ghana: An autoregressive distributed lag bounds cointegration approach. Energy Policy, 42, 530-537.

Amusa, H., Amusa, K., & Mabugu, R. (2009). Aggregate demand for electricity in South Africa: An analysis using the bounds testing approach to cointegration. Energy Policy, 37(10), 4167-4175.

De Vita, G., Endresen, K., & Hunt, L. C. (2006). An empirical analysis of energy demand in Namibia. Energy Policy, 34(18), 3447-3463.

Engle, R. F., Hendry, D. F., & Richard, J. F. (1983). Exogeneity. Econometrica: Journal of the Econometric Society, 277-304.

Johansen, S. (1992). Testing weak exogeneity and the order of cointegration in UK money demand data. Journal of Policy Modelling, 14(3), 313-334.

Narayan, P. K. (2005). The saving and investment nexus for China: evidence from cointegration tests. Applied Economics, 37(17), 1979-1990.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of applied econometrics, 16(3), 289-326.

Wang, Y., Wang, Y., Zhou, J., Zhu, X., & Lu, G. (2011). Energy consumption and economic growth in China: a multivariate causality test. Energy Policy, 39(7), 4399-4406.

Zaman, K., Khan, M. M., Ahmad, M., & Rustam, R. (2012). Determinants of electricity consumption function in Pakistan: Old wine in a new bottle. Energy Policy, 50, 623-634.