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Electricity consumption, economic growth, urbanisation and trade nexus: empirical evidence from Iceland

Faisal Faisal[a,c], Turgut Tursoy[a], Nil Gunsel Resatoglu[a] and Niyazi Berk[b]

[a]Faculty of Economics and Administrative Sciences, Department of Banking and Finance, Near East University, Nicosia, Cyprus; [b]Faculty of Economics and Administrative Sciences, Bahcesehir University, Besiktas-Istanbul, Turkey; [c]Institute of Business Studies and Leadership, Abdul Wali Khan University, Mardan, Pakistan

ABSTRACT

This study empirically investigates the relationship between economic growth, electricity consumption, trade and urbanisation in Iceland, covering the period 1965–2013. The A.R.D.L. bounds testing approach to co-integration is applied to investigate the existence of the long-run relationship. The causality was investigated among the variables using Granger causality under the V.E.C.M. framework. The A.R.D.L. bounds testing approach to co-integration confirms a long-run relationship between electricity consumption and its regressors. The empirical estimation indicates the existence of a positive and statistically significant impact of economic growth, trade and urbanisation on electricity consumption for Iceland, not only in the long-run, but also in the short-run. Furthermore, electricity consumption converges to its long-run position by 45.63% speed of adjustment using the channels of urbanisation, trade and economic growth. The results of Granger causality imply the presence of a feedback causal relationship between urbanisation and electricity consumption in the long-run, thus validating the feedback hypothesis. However, economic growth is causing trade, thus validating the growth-led trade hypothesis in the short-run. Additionally, no causal relationship was found between electricity usage and economic growth, which confirms the neutrality hypothesis. Implementing the energy conservation policy will have no damaging effect on economic growth for Iceland.

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1. Introduction

Electricity is one of the most important sectors and plays a major role in the economic development of many countries. It is a multifaceted sector that supports the development of a wide range of products and services, playing an active role in improving living standards, increasing the productivity and efficiency, as well as encouraging investors and entrepreneurial activities. The electricity sector has a close relationship with real G.D.P. (gross domestic product) per capita and, on the basis of the above-mentioned facts, both

CONTACT Faisal Faisal faisal.faisal@neu.edu.tr

the real per capita G.D.P. and electricity consumption are highly correlated, which has been extensively documented by Ferguson, Wilkinson, and Hill (2000) in a study covering approximately 100 countries. Iceland has a significant manufacturing sector, making the consumption of electricity in that country one of the highest compared with the rest of the world. The source of electricity production in Iceland is predominantly from hydroelectric and geothermal energy.

The most important aspect of this issue is the investigation and gathering of sufficient knowledge on the causality direction between G.D.P. and electricity consumption (E.C.), with a view to devising appropriate policies for future energy and energy conservation measures. The central theme of the debate revolves around whether electricity consumption promotes or retards economic growth. The utilisation of modern energy in the production process, along with capital and labour, is considered as a pre-requisite for social, economic and technological progress (see Dunkerley, 1982; Ebohon, 1996; Templet, 1999). The researchers, who are in support of the above-mentioned hypothesis, confirmed that, without energy, economic growth and technological progress will be unachievable. The importance of modern energy, particularly electricity, cannot be ignored, as it has been a significant factor in the improvement of people's living standards, as well as the scientific and technological developments of even developed countries (Rosenberg, 1998). In developing countries, in particular, the use of electricity has significantly improved the health and education standards of the population (International Energy Agency, 2002). In the modern era, the utilisation of electricity cannot be ignored in terms of the development of the economy and infrastructure. Furthermore, the literature on energy suggests a reliable and effective infrastructure is one of the most important criteria for sustained growth and diversification. In the recent literature, it has been demonstrated that the improvement of infrastructure has resulted in an increase in urbanisation, witnessed by the rapid increase in the development of urban areas. Over the past four decades, the urban population in Iceland has been abruptly rising. Since 1965, the urbanisation in Iceland has risen from 82.7% to 93.94% by the year 2014, with an average annual growth rate of 0.229%. Liu and Xie (2013) argued in their study that a rapid increase in population in urban areas has a favourable and positive impact on economic growth. However, on the other hand, the increase in the urban population is increasing energy consumption, thus creating an energy crisis (Al-Mulali, 2012).

Various studies have elucidated the relationship between electricity consumption, economic growth and urbanisation. However, to the authors' knowledge, no study in the literature exists that has analysed the electricity demand function for Iceland, together with urbanisation and trade. Thus far, Khraief, Shahbaz, Mallick, and Loganathan (2016) estimated the electricity demand function using urbanisation and trade in their study on Algeria. The relationship between E.C. and G.D.P., together with trade and urbanisation, will be analysed in the present. Therefore, this study tries to cover the gap in the literature.

The present study contributes to the literature in four different ways. First, up-to-date data from the World Bank (2017) has been acquired based on the data availability. Second, the bounds test for co-integration is employed to examine the presence of co-integration, in order to estimate the long-run relationship in the electricity demand function for Iceland. Third, the long-run and short-run elasticities are investigated under the Autoregressive Distributed Lag (A.R.D.L.) framework, using trade and urbanisation together in an electricity demand function. Fourth, the causal relationship among the estimated variables is investigated using the Vector error correction model (V.E.C.M.) Granger causality test. Suitable recommendations, based on empirical results, will be crafted that will aid the Government of Iceland in adopting efficient energy policies.

The remainder of the article will be structured as follows. A literature review is explained in Section 2. The econometric methodology is highlighted in Section 3. Section 4 focuses on the empirical findings of the study. Section 5 concludes the study in the light of these findings.

2. Literature review

There are many studies available in the literature that have been conducted in recent decades on the topic of G.D.P. and E.C. from both empirical and theoretical perspectives. The studies were conducted with the aim of ascertaining the causality direction of energy consumption and economic growth. Three specific views have been inferred from the empirical studies conducted. One view is that, as the economy expands, the increase in energy consumption rises due to demand. The following view confers that the economy expands because of the upsurge in energy usage. However, the third view is that both economic growth and energy consumption affect each other simultaneously, i.e. there is a bi-directional causality. In these studies, not only was the causal relationship examined, but also the long-term relationship was determined between energy consumption and economic growth. This is evident from the studies conducted by Ewing, Sari, and Soytas (2007), Ozturk (2010) and Lee (2006), who established four different hypotheses. The growth hypothesis (unidirectional) states that the E.C. plays an important role in improving economic conditions and the direction of causality runs from energy consumption to economic growth; this indicates that economic growth will cease if there is a severe energy crisis; hence, energy conservation measures may not be a feasible option. However, in the conservation hypothesis, it is the economic growth that causes the increased consumption of energy, supported by a causality that moves from G.D.P. to E.C. This suggests that, even if there is an energy crisis, the economic growth will not stop, thus implying that an energy conservation measure is a feasible option. The feedback hypothesis, implying that the growth causes the energy or the energy causes the growth, is supported by the mutual relationship between E.C. and G.D.P., reinforced by its bi-directional causality. In the neutrality hypothesis, neither the energy consumption nor the G.D.P. effects each other. Recent studies on the above-mentioned issue include papers by Acaravci and Ozturk (2010) and Ozturk and Acaravci (2011). The G.D.P. and E.C. per capita variables were studied to investigate the causal relationship between 15 selected transition countries by Acaravci and Ozturk (2010) using Pedroni Panel co-integration for the period 1990–2006. The authors' estimations confirmed the absence of any relationship between E.C. and G.D.P. In a similar study by Ozturk and Acaravci (2011), the A.R.D.L. bounds testing approach was used to examine the relationship between G.D.P. and E.C. from 1990–2006 for 11 M.E.N.A. (Middle East and North Africa) countries. The authors reported the absence of any long-run relationship between E.C. and G.D.P. in Syria, Morocco and Iraq. The estimations further showed a unidirectional causality in the short-run from G.D.P. to E.C. for Israel. However, a unidirectional causality was found in Saudi Arabia, Oman and Egypt in both the long-run and short-run, as well as from electricity consumption to G.D.P. The authors concluded that the results indicate confirmation of a weak long-run causal relationship between EC and GDP. Table 1 shows a summary of the literature review on electricity and energy consumption.

However, in the current scenario, the studies pertaining to E.C. and G.D.P. have been extended by using urbanisation. The empirical results from many different studies conducted in different countries are varied. Many studies identified that G.D.P., urbanisation and E.C. are correlated. Parshall et al. (2010) reported a positive relationship among E.C. and urbanisation for the case of the U.S.A. Likewise, similar findings were reported by Salim and Shafiei (2014), who investigated this relationship for O.E.C.D. (Organisation for Economic Co-operation and Development) countries. Lenzen et al. (2006) conducted a study using panel data for different countries, which included Denmark, Japan, Australia and Brazil, by analysing the influence of urbanisation on E.C. The findings of the study indicated that the influence of urbanisation on G.D.P. differs, even during the same time period. A similar study was conducted by Liddle (2013) and found a strong association between urbanisation and G.D.P. However, the study further suggested that urbanisation is the driver of economic growth, and its impact varies across regions (countries), depending on their level of income and development. In their recent study, Liddle and Messinis (2015) further identified that the association between urbanisation and G.D.P. shows an increased correlation in high-income and low-income countries. In another study, Liddle and Lung (2014) utilised panel data and the causality direction moves from E.C. to urbanisation. Kasman and Duman (2015) conducted a study for European Union member countries using panel data. Their findings suggested evidence of a one-way causality from urbanisation to G.D.P. and G.D.P. to E.C. However, the study conducted by Poumanyvong and Kaneko (2010) identified

Table 1. Literature review.

Reference	Country	Sample	Methodology	Causality direction	Hypothesis
Soytas and Sari (2003)	Italy, Japan, South Korea	1950–1992	Vector error correction model, Granger Causality test	G.D.P. — E.C.	Neutrality hypothesis
Akinlo (2008)	Ghana, Gambia and Senegal	1980–2003	Fully modified Ordinary Least Square (O.L.S.)	G.D.P. ↔ E.C.	Feedback hypothesis
Twerefou, Akoena, Agyire-Tettey, and Mawutor (2007)	Ghana	1975–2006	Vector Error Correction (V.E.C.) model, Granger causality	G.D.P. → E.C.	Conservation hypothesis
Fatai, Oxley, and Scrimgeour (2004)	Philippines	1960–1999	Toda and Yamamoto	G.D.P. ↔ E.C.	Feedback hypothesis
Stern (2000)	U.S.A.	1948–1994	Co-integration, Granger causality	E.C. → G.D.P.	Growth hypothesis
Halicioglu (2007)	Turkey	1968–2005	A.R.D.L., Granger causality	G.D.P. → E.C.	Conservation hypothesis
Odhiambo (2009a)	Tanzania	1971–2006	A.R.D.L. Bounds test	E.C. → G.D.P.	Growth hypothesis
Odhiambo (2009b)	South Africa	1971–2006	A.R.D.L. Bounds test	G.D.P. → E.C.	Conservation hypothesis
Shiu and Lam (2004)	China	1971–2000	Co-integration and V.E.C.M.	G.D.P. → E.C.	Conservation hypothesis
Narayan and Smyth (2005)	Australia	1966–1999	Multivariate Granger causality	G.D.P. → E.C.	Conservation hypothesis
Faisal, Türsoy, and Reşatoğlu (2016)	Russia	1990–2011	Toda and Yamamoto	E.K. ↔ G.D.P.	Feedback hypothesis
Faisal, Türsoy, and Reşatoğlu (2017)	Pakistan	1971–2013	A.R.D.L., V.E.C.M.	G.D.P. → E.C.	Conservation hypothesis

Notes: ↔ Bidirectional between EC and GDP, E.C. → G.D.P means unidirectional from EC to GDP, G.D.P. — E.C. absence of any relationship between EC and GDP.
Source: Literature Review.

that urbanisation causes a decrease in energy consumption in the low-income group, while the reverse causality occurs for middle- and high-income groups. Likewise, Shahbaz and Lean (2012) confirmed a long-run causal relationship between urbanisation and energy consumption for Tunisia. The same results were confirmed by Shahbaz, Sbia, Hamdi, and Ozturk (2014) for the United Arab Emirates (U.A.E.). The above-mentioned studies predominantly explained the connection between E.C., urbanisation and G.D.P. However, there are also some studies in the literature that have further extended this model by including foreign direct investment and trade. For example, the study conducted by Acaravci, Erdogan, and Akal (2015) investigated the production function using the A.R.D.L. bounds test to investigate the relationship between E.C. and G.D.P. in the presence of foreign direct investment and trade. Their study findings indicated that electricity consumption and F.D.I. (Foreign direct investment) affect G.D.P. positively, while trade affects G.D.P. negatively. The results of the Granger causality test in their studies suggested that electricity consumption Granger causes economic growth.

Marques et al. (2016a), in their study on Greece, analysed the relationship between electricity consumption and industrial production for the period between 2004 and 2014 using monthly data. Their findings suggested that the electricity generated from fossil sources plays a major role in promoting industrialisation and, hence, causes economic growth.

Ozatac, Gokmenoglu, and Taspinar (2017) investigated the environmental Kuznets curve hypothesis for Turkey using financial development, urbanisation, trade and energy consumption for the period 1960–2013. The existence of an inverted shaped relationship was confirmed. It was further noted that E.C., trade and urbanisation positively affects the CO_2 emissions. However, the impact of financial development was insignificant. The causal relationship suggests the existence of uni-directional causality from trade openness to CO_2 emission implies the validity of the scale effect for Turkey.

Marques et al. (2016b), in another study, applied the A.R.D.L. bounds test to analyse the relationship between the electricity generation mix and economic growth for France. The findings of the study confirmed a long-run relationship among the estimated variables. Furthermore, electricity that is generated from nuclear energy has a positive impact on economic growth, with less CO_2 emissions.

In a similar respect, there are many studies in the literature that have interlinked electricity consumption demand with urbanisation and economic growth, which are considered as important determinants for various other economies. To the extent of the author's knowledge, no study has been conducted for Iceland that specifies electricity demand as a function of urbanisation, economic growth and trade for Iceland and explores an empirical relationship that is supported by well-developed methods that are reliable. There is a deficit in the literature linking and analysing a relationship among these variables, which provides the motivation to estimate an electricity consumption demand model that is suitable for Iceland in order to determine an effective energy policy.

3. Methodology of the study

3.1. Data

The multivariate framework includes the electric power in kWh per capita and real G.D.P. per capita (in constant 2010 US$); urbanisation is measured by total urban population and trade openness as a percentage of G.D.P. The data series is from the period 1965–2013 and was collected from the World Bank (2017) database. The data has been collected for a period of 49 years, which is sufficient to apply the A.R.D.L. technique on the time series.

3.2. Model specification and econometric methodology

3.2.1. Model

This study investigates the relationship between electricity consumption and economic growth by incorporating trade and urbanisation in the electricity demand function. In their study, Lin and Liu (2016) argued that increases in electricity consumption have been predominantly caused by the population increases in urban areas, the establishment of new industries, commercial usage, new construction and the household sector. The sudden growth in urbanisation and trade openness has attracted the attention of researchers to ICT development, industrial activities, trade, improvements to the infrastructure in urban areas and financial development. Bento and Moutinho (2016) argued that these indicators not only encourage domestic economic activities at a local level, but also cause an upsurge in the volume of exports and imports. On the basis of the above-mentioned discussion, an empirical model was identified by Khraief et al. (2016), which includes trade and urbanisation, and can be written as:

$$EK_t = \beta_0 + \beta_1 GDP_t + \beta_2 TR_t + \beta_3 URB_t + \varepsilon_t \tag{1}$$

where EK_t represents electric power consumption (kWh per capita), GDP_t represents real G.D.P. per capita (constant 2010 US$), TR_t is the sum of real exports and imports as percentage of G.D.P., URB_t represents the urban population and ε_t is the error term that should be white noise. All the variables highlighted in equation (1) are transformed in the natural logarithms to reduce the existence of potential heteroscedasticity. All the series have been converted to per capita by dividing it using population series. The proposed econometric model can be written in log form[1] as:

$$\ln EK_t = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln TR_t + \beta_3 \ln URB_t + \varepsilon_t \tag{2}$$

where β_0 is the constant term and β_i (where $i = 1, 2, 3$) are the long-run elasticities with respect to G.D.P., trade and urbanisation. Equation (2) is examined to check for a possible long-run relationship among $\ln EK_t$ (the natural log of electricity per capita Kwt per capita), $\ln GDP_t$ (natural log of real GDP per capita) and $\ln TR_t$(*the* natural log of trade per capita) and is the sum of imports and exports as a percentage of G.D.P./total population, $\ln URB_t$ and the natural log of urbanisation, which is equal to urban population/total population. The expected sign for β_1, β_2 and β_3 must be positive, as discussed in the literature section.

3.2.2. Estimation methodology

3.2.2.1. Unit root. The stationarity of the data can be analysed by using the unit root test. The unit root tests allow researchers to determine the appropriateness of the model for application in the study. Furthermore, it can be challenging to select the most appropriate unit root test. This study adopts the Augmented Dickey Fuller test (1981), and the Philips-Perron (P.P.) test (1988), as recommended by Enders (1995), to examine the existence of the unit roots in the selected variables. Additionally, this study also uses the Kwiatkowski-Philips-Schmidt-Shin (K.P.S.S.) unit root test, which confirms the integration of the series.

3.2.2.2. Bounds test of co-integration. After identifying the order of integration of series, this study further applies the Pesaran, Shin, and Smith (2001) A.R.D.L. bounds test to investigate the existence of co-integration. The bounds test is more flexible in its application to the mixed order of series, as compared to the other conventional co-integration tests that require a unique order of integration. Pesaran et al. (2001) argued that the A.R.D.L. model performs well in small samples, thus making it superior to the Johansen and Juselius (1990) approach. The dependent and independent variables can be identified in the A.R.D.L. model. The A.R.D.L. model is used to examine the long-run relationship by selecting the optimal lag length. The Wald test of joint significance or *F*-test is used to analyse the existence of a long-run relationship using the variables identified in equation (3).

$$\begin{aligned}\Delta \ln EK_t = \beta_0 &+ \sum_{i=0}^{p} \beta_i \Delta \ln EK_{t-i} + \sum_{k=0}^{q} \beta_k \Delta lnGDP_{t-k} \\ &+ \sum_{l=0}^{r} \beta_l \Delta lnTR_{t-l} + \sum_{m=0}^{s} \beta_m \Delta lnURB_{t-m} \\ &+ \lambda_{EK} \ln EK_{t-1} + \lambda_{GDP} \ln GDP_{t-1} + \lambda_{TRA} \ln TR_{t-1} + \lambda_{URB} \ln URB_{t-1} + \upsilon_t,\end{aligned} \tag{3}$$

where the error term is represented by υt and Δ indicates short. When the coefficients of the short-run are more than one, then the Wald test is used. In the Wald test of significance, the coefficients of all short-run differenced variables are equal to zero. The *F*-statistics value is used to compare with the $I(0)$ and $I(1)$ critical values that have been obtained from Pesaran et al. (2001). These values have been classified in the upper and lower bounds value based on 90, 95 and 99% significance level. If the value of the estimated *F*-statistics is higher than the upper critical bounds value, that implies the rejection of null hypothesis H_0: $\delta_{lnEK} = \delta_{lnGDP} = \delta_{lnTR} = \delta_{lnURB} = 0$ against the alternative hypothesis H_1: $\delta_{lnEK} \neq \delta_{lnGDP} \neq \delta_{lnTR} \neq \delta_{lnURB} \neq 0$, showing evidence of a long-run relationship. However, the results regarding the evidence of co-integration are inconclusive, provided that the estimated *F*-statistics lies in the middle of the upper and lower bounds critical values. The decision regarding the null hypothesis of no co-integration is not rejected if the *F*-statistics value lies beneath the $I(0)$ bounds critical. This implies the absence of a long-run relationship.

After the identification of co-integration, the elasticity of the long-run coefficients and short-run coefficients can be estimated under the A.R.D.L. framework using equations (4) and (5).

$$\ln EK_t = \alpha_1 + \sum_{i=1}^{p} \varphi 1_i \ln EK_{t-i} + \sum_{k=1}^{q} \omega 1_k \ln GDP_{t-k} + \sum_{l=1}^{r} \partial 1_l \ln TR_{t-l} + \sum_{m=1}^{s} \emptyset 1_m \ln URB_{t-m} + \mu_t \tag{4}$$

$$\ln \Delta EK_t = \gamma_0 + \sum_{i=1}^{p} \gamma 1_i \Delta lnEK_{t-i} + \sum_{k=1}^{q} \gamma 1_k \Delta lnGDP_{t-k} + \sum_{l=1}^{r} \gamma 1_l \Delta lnTR_{t-l} + \sum_{m=1}^{s} \gamma 1_m \Delta lnURB_{t-m} + \psi ECT_{t-1} + \mu_t \tag{5}$$

where ECT_{t-1} represents the error correction term, which must be negative and the value of its coefficient must lies between 0 and 1. From equations (4) and (5), both the short-run and long-run elasticity can be estimated, respectively. The negative sign of error correction implies the system stability to revert back to its normal position after a short-run shock.

3.3. Model stability and diagnostic tests

The evidence of a long-run relationship among the estimated variables using equation (2) does not necessarily imply the stability of the estimated coefficients over the sample period (Bahmani-Oskooee & Chomsisengphet, 2002). In order to investigate the reliability and validity of the A.R.D.L. model, several diagnostic tests are applied, along with the stability tests. In this connection, the diagnostic tests are used to identify the presence of heteroscedasticity, the residual serial correlation and the correlogram of residuals to ensure that they are white noise. Brown, Durbin, and Evans (1975) proposed a test of cumulative sum (C.U.S.U.M.) that is applied to investigate the stability of the long-run coefficients for the selected sample period.

Once the long-run relationship among the estimated variables has been confirmed using equation (2), this study further employs the Granger causality test to investigate the direction of causality among the estimated variables. If an existence of a long-run relationship among the estimated variables is confirmed using equation (2), then the error correction model can be developed using equation (6):

$$\begin{bmatrix} \Delta lnEK \\ \Delta lnGDP \\ \Delta \ln URB \\ \Delta \ln TR \end{bmatrix} = \begin{bmatrix} \alpha 1 \\ \alpha 2 \\ \alpha 3 \\ \alpha 4 \end{bmatrix} + \begin{bmatrix} S11,1 & S12,1 & S13,1 & S14,1 \\ S21,1 & S22,1 & S23,1 & S24,1 \\ S31,1 & S32,1 & S33,1 & S34,1 \\ S41,1 & S42,1 & S43,1 & S44,1 \end{bmatrix} \times \begin{bmatrix} \Delta \ln EKt - 1 \\ \Delta \ln GDPt - 1 \\ \Delta \ln URBt - 1 \\ \Delta \ln TRt - 1 \end{bmatrix}$$

$$+ \dots + \begin{bmatrix} S11,m & S12,m & S13,m & S14,m \\ S21,m & S22,m & S23,m & S24,m \\ S31,m & S32,m & S33,m & S34,m \\ S41,m & S42,m & S43,m & S44,m \end{bmatrix} \times \begin{bmatrix} \Delta \ln EKt - m \\ \Delta \ln GDPt - m \\ \Delta \ln URBt - m \\ \Delta \ln TRt - m \end{bmatrix} \quad (6)$$

$$+ \begin{bmatrix} \varphi 1 \\ \varphi 2 \\ \varphi 3 \\ \varphi 4 \end{bmatrix} \times (ECT_{t-1}) + \begin{bmatrix} \eta 1t \\ \eta 2t \\ \eta 3t \\ \eta 4t \end{bmatrix}$$

where Δ represents the first difference operator, while ECT_{t-1} denotes the lagged error correction term. This value of the lagged error correction term must be between 0–1, with a negative sign that represents that after the short-run shock the variables in the model are stable enough to converge back to the equilibrium position. The evidence of co-integration among the variables identified in equation (2) necessarily implies the presence of a causal relationship, among the estimated variables, which is either unidirectional or bidirectional (Engle & Granger, 1987; Johansen & Juselius, 1990). The error correction term of the V.E.C.M. model identifies the evidence of a long-run relationship. Furthermore, the *F*-statistics (Wald test), along with the corresponding *p*-values, are used to compute the short-run or weak Granger causality. Furthermore, Asafu-Adjaye (2000) proposed a joint test of both the short-run and long-run by suggesting that, following a short-run shock, the variables in the system re-organise themselves to re-establish a long-run relationship among the estimated variables. Lee and Chang (2008) identified it as a strong Granger causality test that can be performed by testing the relevant coefficients of the first difference series, along with the relevant coefficients of the lagged error correction term.

4. Empirical discussion

4.1. Stationarity tests results

The A.R.D.L. model can be applied to any series that have a mixed order of integration. However, the A.R.D.L. bounds critical values become invalid if any of the variables in the series is $I(2)$. For this reason, the Augmented Dickey Fuller (A.D.F.) test proposed by Dickey and Fuller (1979), Türsoy (2017), the Philips-Perron (P.P.) test by Philips and Perron (1988) and the K.P.S.S. from Kwiatkowski, Phillips, Schmidt, and Shin (1992) are applied to analyse the integration order of the series. All the mentioned unit root tests are performed first by using intercept and then both the intercept and trend with level and first difference. The results of the unit root tests have been shown in Tables 2–4, respectively.

Tables 2–4 show a summary of the A.D.F., P.P. and K.P.S.S. unit roots, respectively. It was found that electricity consumption, economic growth and trade are non-stationary at the level, as they become stationary when we use the first difference for these variables. However, urbanisation is stationary at the level, which is confirmed by all the unit root tests. As the variables have a mixed order of co-integration, the traditional co-integration tests, including the Johansen and Juselius (1990), are not applicable and, therefore, cannot be employed. All the regressors of the current study have been found to be $I(1)$, except urbanisation, which is $I(0)$. However, the electricity consumption (EK_t) is the dependent variable and is integrated of order $I(1)$ and no variable in the series is integrated of order 2. This further fulfils the conditions necessary for the A.R.D.L. approach to be used.

Therefore, it is possible to proceed with the bounds test or F-test to investigate the presence of a long-run relationship among economic growth, urbanisation, trade and electricity consumption, as proposed by Pesaran et al. (2001), using equation (3). The bounds test results for co-integration is shown in Table 5.

The optimum lag length, which was selected on the basis of the Akaike Information Criterion (A.I.C.) criterion, is demonstrated in the second row. The A.R.D.L. computed F-statistics is analysed to verify the existence of co-integration. The critical values from Pesaran et al. (2001) have been shown in Table 5 to determine the existence of co-integration. The computed F-statistics (8.91) exceeds the upper bounds critical values. This highlights the rejection of the null hypothesis of no co-integration. Additionally, it further implies that the estimated variables in the model are in a long-run association in the Icelandic economy. The result further confirms that electricity usage, trade openness, G.D.P. and urbanisation move together in the long-run. The long-run elasticity and short-run elasticity are computed using equations (4) and (5) under the A.R.D.L. framework. Long-run and short-run results are revealed in Table 6.

Table 2. A.D.F. unit root test.

	A.D.F.Level		A.D.F.1st difference		
Iceland (1965–2013)	C.O.	C.O. & T.R.	C.O.	C.O. & T.R.	Decision
$LnEK_t$	−1.8565 (1)	−3.0805 (1)	−4.7622*** (0)	−4.8481*** (0)	$I(1)$
$LnGDP_t$	−1.0269 (1)	−2.2065 (1)	−4.5138*** (0)	−4.4877*** (0)	$I(1)$
$LnTR_t$	−1.7927 (0)	−1.1630 (0)	−5.6247*** (0)	−5.6356*** (0)	$I(1)$
$LnURB_t$	−81.9530*** (0)	−18.7763*** (0)	−3.4668** (0)	−2.2693 (4)	$I(0)$

Note: The A.D.F. tests have been utilised using the intercept and both the trend and intercept first with level and then with the first difference. The figures in the parentheses represent the lag that was selected using the Schwarz information criteria (SIC). ** and *** represent significance at 5 and 10%, respectively. C.O. and C.O. & T.R. represent intercept and intercept and trend and A.D.F. stands for Augmented Dickey Fuller Unit Root test.
Source: Author's own computation.

Table 3. P.P. unit root test.

Iceland (1965–2013)	P.P. Level		P.P. 1st difference		Decision
	C.O.	C.O. & T.R.	C.O.	C.O. & T.R.	
$LnEK_t$	−1.5144 (1)	−2.1953 (1)	−4.7947*** (1)	−4.8481*** (0)	*I*(1)
$LnGDP_t$	−1.4552 (2)	−1.7041 (1)	−4.5567*** (3)	−4.4107*** (4)	*I*(1)
$LnTR_t$	−1.7927 (0)	−1.1630 (0)	−5.6247*** (0)	−5.6356*** (0)	*I*(1)
$LnURB_t$	−56.8794*** (3)	−13.0768*** (3)	−3.6618*** (1)	−1.3084 (5)	*I*(0)

Note: The P.P. tests have been utilised using the intercept and both the trend and intercept first with level and then with the first difference with Newey-West using Bartlett Kernel. The figures in the parentheses represent the lag that was selected using the Schwarz information criteria (SIC). *** represents significance at 10%. C.O. and C.O. & T.R. represent intercept and intercept and trend and P.P. stands for Philips Perron unit root test.
Source: Author's own computation.

Table 4. K.P.S.S. unit root test.

Iceland (1965–2013)	K.P.S.S. Level		K.P.S.S. 1st difference		Decision
	C.O.	C.O. & T.R.	C.O.	C.O. & T.R.	
$LnEK_t$	0.8716*** (5)	0.4864*** (0)	0.2351 (0)	0.1100 (1)	*I*(1)
$LnGDP_t$	0.8692*** (5)	0.3312*** (1)	0.1710 (1)	0.0158 (1)	*I*(1)
$LnTR_t$	0.9388*** (2)	0.2836*** (2)	0.2081 (2)	0.0508 (2)	*I*(1)
$LnURB_t$	1.6618** (2)	0.4249*** (2)	1.6238*** (2)	0.3749*** (2)	*I*(0)

Note: The K.P.S.S. tests have been applied first using the intercept and both the trend and intercept with level and then with the first difference with the Spectral estimation method selected is Bartlett Kernel, while the Newey–West method is used to select the bandwidth. The figures in the parentheses represent the corresponding *p*-values. ** and *** represent significance at 5% and 10%, respectively. C.O. and C.O. & T.R. represent intercept and intercept and trend and K.P.S.S. represents the Kwiatkowski–Philips–Schmidt–Shin unit root test.
Source: Author's own computation.

Table 5. Co-integration results.

Model	F_{LEK}(LnEK/LnGDP, LnTR, LnURB)			
O.P.L. length (A.I.C.)	(4,0,0,0)			
F-Stat. (Bound Test)	8.9126*			
C.V.	1%	2.5%	5%	10%
L.B.C.V.	4.29	3.69	3.23	2.72
U.B.C.V.	5.61	4.89	4.35	3.77

Note: *represents the significance level at 1%. The optimal lag is selected using the A.I.C. information criteria. Pesaran et al. (2001) critical values have been used to compare with the *F*-statistics value. O.P.L., C.V., L.B.C.V. and U.B.C.V. are optimal lag length, critical values, lower bounds critical values and upper bounds critical values, respectively.
The above A.R.D.L. model is computed using case III (with unrestricted intercept and no trend).
Source: Author's own computation.

Table 6 shows both the long-run and short-run coefficients, whereas electricity consumption is taken as the dependent variable. The long-run elasticity of economic growth with respect to electricity consumption is elastic, positive and statistically significant. This indicates a positive and significant impact of economic growth on electricity consumption. This also implies that a 1% rise in economic growth leads electricity usage by 1.41% by keeping other factors constant. These empirical findings are in concordance with the studies by Zhao and Wang (2015) for China, Khraief et al. (2016), Narayan and Smyth (2009), Odhiambo (2009b) and Solarin and Shahbaz (2013). This suggests that more economic growth has been achieved with more electricity consumption over time. The elasticity of trade with respect to economic growth is positive and statistically significant as well. It was found that a 1% increase in trade will cause the electricity consumption to increase by

Table 6. Long-run and short-run results under A.R.D.L. framework.

Dependent Variable: Ln EK_t			
Variable	Coefficient	S.E.	*t*-Stat.
Long-run results			
Ln GDP	1.4120	0.3865	3.6524*
Ln TR	1.1373	0.2487	4.5733*
Ln URB	9.0231	3.8375	2.3512*
R^2	0.987	*F*-statistics	430.7932*
Adj. R^2	0.985	D.W.	2.21
Short-run results			
ΔLn EK (−1)	0.2986	0.1130	2.6410*
ΔLn EK (−2)	−0.0195	0.1214	−0.1611
ΔLn EK (−3)	0.2821	0.1152	2.4478*
ΔLn GDP	0.6443	0.2228	2.8916*
ΔLn TR	0.5190	0.1226	4.2321*
ΔLn URB	4.1177	1.9035	2.1631*
Constant	2.4906	0.3942	6.3167*
ECM_{t-1}	−0.4563	0.0735	−6.2081*
R^2	0.558	S.E of regre.	0.0708
Adj. R^2	0.514	Sum Sq. reside	0.2010
F-Stat.	12.6603*	D.W.	2.21

Note: *represents significance level at 1%.
Source: Author's own computation.

1.13% if all other factors are constant. This further implies that trade (imports and exports) causes an upsurge in electricity demand. This rise in demand for electricity is large because of the import of 'big ticket' items like washing machines and refrigerators. To the best of the authors' knowledge, few studies have analysed the trade activities and electricity consumption relationship utilising time series data (Keho, 2016; Lin & Liu, 2016; Lin, Omoju, & Okonkwo, 2016; Rafindadi & Ozturk, 2015). These outcomes, based on this empirical study, are in concordance with previous studies, such as those by Keho (2016), Rafindadi and Ozturk (2015) and Bento and Moutinho (2016); indicating the positive and causal impact of trade openness (imports and exports) on electricity consumption.

The elasticity of urbanisation with respect to electricity consumption (E.K.) is elastic, positive and statistically significant at 1%. This indicates that a 1% increase in urbanisation would lead to the demand for electricity increasing by 9.02%. The results of this study are in line with the previous studies of Gam and Rejeb (2012), Solarin and Shahbaz (2013), Liddle and Lung (2014), Zhao and Wang (2015), Acaravci and Ozturk (2010) and Rafindadi and Ozturk (2015). The positive impact in the case of Iceland is not surprising, as the population of Iceland has been gradually increasing, with 97% of the population currently living in urban areas, which has consequently increased the consumption of electricity.

The results of the short-run model are also shown in Table 6. In the short-run, the signs for the estimated variables are the same as in the long-run. This implies that economic growth, trade and urbanisation have a statistically significant and positive impact on economic growth, not only in the long-run, but also in the short run. The error correction term is −0.4563 with the expected sign and it is statistically significant, even at 1%. This demonstrates the speed of adjustment of the electricity demand function from the short-run towards its long-run equilibrium path. The short-run variations are adjusted by 45.63% within the first year. This convergence from the short-run to the long-run would take approximately 2 years and 2 months. The ability of the system to converge back to its equilibrium position implies the system has stability.

The diagnostic tests for these estimations have been conducted not only for the long-run, but also for the short-run. The results of the diagnostics tests have been demonstrated for both the long-run and short-run in Tables 7 and 8, respectively. The diagnostic tests indicate that the estimations have no problems of serial correlation and the residuals are homoscedastic. The residuals of the Q-statistics were checked at all lags and the absence of serial correlation was found, which verifies the assumption of the classical linear regression model. Furthermore, the stability of both the short-run and long-run model was tested by using the C.U.S.U.M. and cumulative sum of squares (C.U.S.U.M.sq), as suggested by Brown et al. (1975). The plots of both the C.U.S.U.M. and C.U.S.U.M.sq lie between the two-bonded lines at 5% significant level as displayed in Figure 1. This confirms the stability of the long-run and short-run coefficients for the selected period in the present study.

The diagnostic test further strengthens the reliability of the findings and estimations.

4.2. Granger causality results

The current study investigated the causal relationship among urbanisation, trade, electricity consumption and economic growth within the V.E.C.M. framework. The V.E.C.M. is applied to the co-integrated series. The causality results have been shown in Table 9.

The short-run results of the present study imply the existence of a unidirectional causality from urbanisation to electricity consumption. This implies that increasing population in the urban areas would cause an upsurge in aggregate demand for electricity consumption. The import of big ticket consumer items further requires more electricity consumption, thus affecting Iceland's electricity demand. Also, urbanisation and economic growth are causing trade, thus validating the growth-led trade hypothesis in the short-run for Iceland, which is in concordance with the findings reported by Shahbaz (2012) for Pakistan. This suggests that both urbanisation and economic growth stimulate trade. This further highlights the importance of the trade variable in the econometric model. Moreover, no short-run or long-run causalities from either direction have been found between economic growth and electricity consumption, thus validating the neutrality hypothesis. However, as can be observed, the coefficient of ECT_{t-1} (−0.2981 and −0.0138) are negative and statistically

Table 7. Diagnostic tests (long-run).

Diagnostic test	χ^2sc	$\chi^2 w$	χ^2AR
Iceland	3.8073 (0.1490)	37.0159 (0.1185)	0.2149 (0.6430)

Note: χ^2serco, χ^2*whi* and χ^2ARh for serial correlation, White test for heteroscedasticity, Arch tests for heteroscedasticity. The figures in the parentheses show the corresponding *p*-values.
Source: Author's own computation.

Table 8. Diagnostic tests (short-run).

Diagnostic test	χ^2sc	$\chi^2 w$	χ^2AR
Iceland	2.4649 (0.2916)	41.5427 (0.1462)	0.0709 (0.7899)

Note: χ^2serco, χ^2*whi* and χ^2ARh are the Lagrange multiplier value for serial correlation, White test for heteroscedasticity and Arch tests for heteroscedasticity. The figures in the parentheses show the corresponding *p*-values.
Source: Author's own computation.

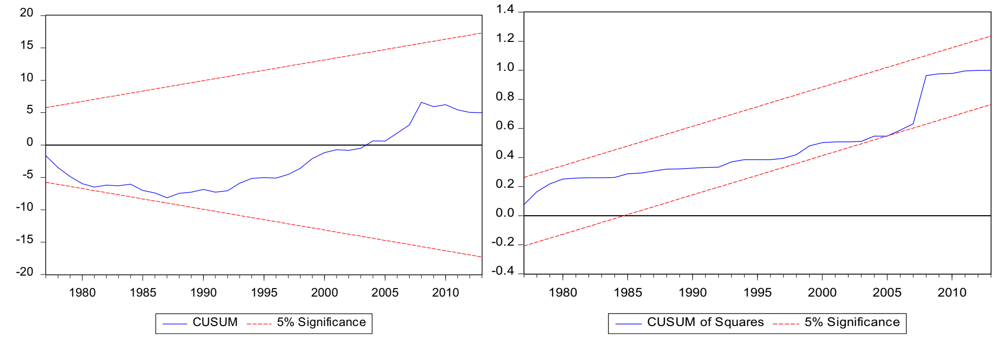

Figure 1. Plots of stability tests using C.U.S.U.M. The blue line lies between the two red lines at 5% significance level, implying the stability of both long-run and short-run coefficients. Source: Author's own computation.

Table 9. Results of Granger causality tests.

Dependent variable	*F*-statistics (probability) long-run	Joint (short- and long-run) *F*-statistics (probability)							
	Δ ln EK_{t-1}	Δ ln GDP_{t-1}	Δ ln TR_{t-1}	Δ ln URB_{t-1}	ECT_{t-1} [*t*-stat]	Δ ln EK .ECT_{t-1}	Δ ln GDP. ECT_{t-1}	Δ lnTR .ECT_{t-1}	Δ ln URB .ECT_{t-1}
Δ ln EK	—	0.9611 (0.3921)	0.9798 (0.3852)	4.6705* (0.0157)	−0.2981* [−3.1396]	—	3.5623* (0.0235)	4.4026* (0.0097)	5.0813* (0.0049)
Δ ln GDP	1.0242 (0.3693)	—	0.8128 (0.4516)	1.4271 (0.2532)	−0.1524 [−1.3528]	1.1478 (0.3430)	—	1.1209 (0.3534)	1.5534 (0.2175)
Δ ln TR	0.8679 (0.4284)	4.6470* (0.0160)	—	3.2135** (0.0520)	0.1269*** [1.7393]	1.2119 (0.3193)	3.1840* (0.0353)	—	2.1626 (0.1094)
Δ ln URB	1.1443 (0.3297)	0.2215 (0.8023	1.5130 (0.2339)	—	−0.0138* [-2.3828]	3.5695* (0.0233)	2.0165 (0.1289)	3.5247* (0.0245)	—

Note: *, ** and *** show the significance level at 1, 5 and 10%, respectively. The figures in the parentheses represent the corresponding *p*-values. and the *T*-statistics are shown in the square brackets. The lag length was chosen based on A.I.C., Final Prediction error (F.P.E.), Hannan-Quinn information criterion (H.Q.) and Sequential modified LR test statistic (L.R.) lag criteria.
Source: Author's own computation.

significant at 10% in the electricity usage equation and urbanisation equation. These outcomes from this study are in concordance with the results reported by Sbia, Shahbaz, and Ozturk (2017) for the U.A.E. This further infers the evidence of a long-run bi-directional causality between electricity usage and urbanisation in Iceland, which validates the feedback hypothesis. This indicates that the increasing rate of the urban population in Iceland may contribute to enhance trade and output, given the skilled labour as a factor of production. This would lead to further development of the Icelandic economy due to improvements in its infrastructure, including to transport, the electricity network and better housing to maximise the efficiency of the economy by satisfying the urban population.

5. Conclusion

This article investigated the nexus between electricity consumption and economic growth, including trade and urbanisation for Iceland, by using time series data from 1965–2013. The

A.R.D.L. bounds testing approach was employed to investigate the long-run relationship between the estimated variables. Strong evidence of co-integration was found among trade, electricity consumption, economic growth and urbanisation for Iceland. The economic growth, trade and urbanisation have a positive impact on electricity consumption, not only in the long-run, but also in the short-run. Furthermore, urbanisation appears to be the driver of electricity consumption.

Moreover, the results of the Granger causality confirm the existence of a short-run unidirectional causality from urbanisation to electricity consumption. This implies that more inward movement of the urban population would cause an increase in consumption of electricity. Additionally, evidence of a long-run bidirectional causality has been found between electricity consumption and urbanisation in Iceland, which confirms the feedback hypothesis. This infers that the Government of Iceland should continue to invest more in the generation of electricity to sustain the developments in urbanisation by using renewable energy. The evidence of a feedback hypothesis between urbanisation and electricity consumption further confirms that both urbanisation and electricity consumption are important elements for the development of the Icelandic economy. However, no causal relationship between economic growth and electricity consumption for both the long-run and short-run have been found from either direction, which validates the neutrality hypothesis. This infers that any changes in the economic growth of Iceland will not have a substantial effect on electricity usage. These findings are of more importance to the policymakers, as implementing the energy conservation policy in this regard will have no damaging effect on economic growth for Iceland.

The empirical results of this study provide a contribution to the literature and sufficient information to policy-makers to achieve a better understanding of the economic growth, electricity consumption nexus in the context of urbanisation, as well as to formulate energy policies in Iceland. Additionally, the government of Iceland may encourage and invest more funds in research and development to support technological innovation that could increase energy savings. By doing so, the environmental degradation may be simultaneously decreased by increasing the economic development in the Icelandic economy. Moreover, the government may consider the economic stages (situations) while formulating and implementing energy policies.

Note

1. The logarithmic transformation helps to eliminate the variations in the time series data. Without logarithmic transformation, the results may be inappropriate and unreliable (Tursoy and Faisal (2016)).

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