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Electricity consumption and economic activity in Cyprus using an asymmetric cointegration technique

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Η ηλεκτρική κατανάλωση και η οικονομική δραστηριότητα στην Κύπρο χρησιμοποιώντας τη μέθοδο της ασύμμετρης συνολοκλήρωσης

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ΠΕΡΙΛΗΨΗ

Το άρθρο αυτό επιβεβαιώνει τα όσα ξέρουμε για τη σχέση μεταξύ ενέργειας και οικονομικής ανάπτυξης στην Κύπρο. Στη συνέχεια προχωρά στην εξέταση των επιπτώσεων και των αποκλίσεων που έχουν τα θετικά και αρνητικά shocks από τη μακροχρόνια ισορροπία καθώς και το βαθμό επιμονής του κάθε shock.

Τα ευρήματα δείχνουν ότι η ελαστικότητα της κατανάλωσης ηλεκτρικής ενέργειας προς το εισόδημα υπερβαίνει το 1, ενώ η ηλεκτρική ενέργεια είναι ανελαστική σε σχέση με την οικονομική ανάπτυξη και τις σχετικές τιμές ενέργειας. Η σχέση μεταξύ ενέργειας και εμπορίου είναι στατιστικά μη σημαντική μακροπρόθεσμα. Τα αποτελέσματα αυτά συνάδουν με τα ευρήματα της υπάρχουσας βιβλιογραφίας.

Η κύρια συμβολή αυτής της εργασίας είναι η χρήση της μεθοδολογίας Enders and Siklos (2001) που επιτρέπει στον ερευνητή να διακρίνει τις επιπτώσεις που έχουν τα θετικά από τα αρνητικά shocks σε κατάσταση ισορροπίας. Τα αποτελέσματα δείχνουν ότι οι αρνητικές αποκλίσεις από τη μακροπρόθεσμη ισορροπία εξαλείφονται πιο αργά σε σύγκριση με τις θετικές. Ως εκ τούτου, μια οικονομική ύφεση θα μπορούσε να έχει πιο επίμονη επίδραση στην κατανάλωση ηλεκτρικής ενέργειας, ωστόσο, περισσότερη ανάπτυξη θα οδηγούσε σε ακόμη υψηλότερη κατανάλωση ηλεκτρικής ενέργειας μακροπρόθεσμα. Αυτό υπογραμμίζει την ανάγκη για εξεύρεση πολιτικών, που θα έχουν στόχο την εξοικονόμηση ενέργειας και την προώθηση πράσινων πηγών ενέργειας.

Όπως δείχνουν τα αποτελέσματα, ένα ανανεώσιμο ενεργειακό shock, το οποίο δυνητικά θα μειώσει την κατανάλωση ηλεκτρικής ενέργειας, θα μπορούσε να έχει πιο μόνιμες επιδράσεις και ως εκ τούτου να προωθήσει περαιτέρω μια πιο πράσινη πορεία. Τέτοιες εξελίξεις θα μειώσουν επίσης την ενεργειακή εξάρτηση της Κύπρου από το πετρέλαιο και θα βελτιώσουν τα ζητήματα ενεργειακής ασφάλειας, δεδομένης της υψηλής ανελαστικότητας της ζήτησης στις μεταβολές των τιμών. Η βελτίωση των ζητημάτων ενεργειακής ασφάλειας μέσω της αύξησης πιο πράσινων πηγών ενέργειας, εκτός από την παροχή μιας φιλικής προς το περιβάλλον εναλλακτικής λύσης, θα είχε επίσης θετικές μακροοικονομικές επιπτώσεις, καθώς θα προστατεύει την οικονομία από εξωτερικούς κραδασμούς.

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Electricity consumption and economic activity in Cyprus using an asymmetric cointegration technique

Nektarios A. Michail and Christos S. Savva*

Abstract

This paper examines whether deviations from the equilibrium have a different degree of persistence when shocks are positive or negative. To this end, the paper employs, for the first time in the electricity-growth literature, an asymmetric cointegration (threshold adjustment) technique using data for Cyprus. Results from the asymmetric technique suggest that positive discrepancies from the long-run are eliminated faster compared to negative ones. Furthermore, the elasticity of electricity consumption to income appears to be higher than unity. Electricity consumption is found to be relatively inelastic to financial development and relative energy prices, while trade openness is statistically insignificant in the long-run. The above findings bear important implications, especially for forecasters and system administrators.

Keywords: threshold adjustment, electricity, growth, cointegration

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1. Background

Since the work of Kraft and Kraft (1978), who were the first to empirically examine the causal relationship between electricity consumption and economic growth, many a study has dealt with the aforementioned issue in various countries and regions (see, inter alia, Abosedra et al. 2009; Apergis and Payne, 2010; Tang et al., 2013; Narayan and Prasad, 2008; Sadorsky, 2011).

Thus far, the main focus of the literature has been the flow of causality. In other words, emphasis has been mainly placed on whether causality is unidirectional, i.e. running either from electricity consumption to economic growth (the growth hypothesis) or from economic growth to electricity consumption (the conservation hypothesis). Both hypotheses have important policy implications: if the growth hypothesis holds then energy conservation policies may have a negative impact on output growth; if the conservation hypothesis holds then energy conservation policies may not have an effect on economic growth. Additionally, two other hypotheses are also considered: the first, named the feedback hypothesis supports that causality is bidirectional, i.e. that growth causes electricity consumption and vice versa, while the second, called the neutrality hypothesis, suggests that no causality relationship exists (see Payne, 2009).

To our knowledge, there has been no study to support the neutrality hypothesis. The existing studies have provided support for the existence of the remaining three hypotheses. For example, Aqeel and Butt (2001), Lee and Chang (2007), Narayan and Singh (2007), Abosedra et al. (2009), Ighodaro (2010), Yoo (2005), among others, support the growth hypothesis as they find evidence of uni-directional causality running from electricity consumption to economic growth. On the other hand, the results of Narayan and Smyth (2005), Ciarreta and Zarraga (2010), Shahbaz and Feridun (2012), Ho and Siu (2007) support the view that unilateral causality runs from economic growth to electricity consumption in a variety of countries. Finally, Zachariadis and Pashourtidou (2007), Tang (2008, 2009), Lean and Smyth (2010), Shahbaz and Lean (2012), Tang et al. (2013) Osman et al. (2016) and Farhani and Solarin (2017) find support for the feedback hypothesis, i.e. of bi-directional causality between electricity consumption and economic growth. In general, results are found to be country-specific as recent studies have shown (Keho, 2016; Kahouli, 2017; Rodríguez-Caballero and Ventosa-Santaulària, 2017). The interested reader can refer to Menegaki (2014) for a recent meta-analysis of the literature.

Fitting within this literature, this paper first tests for the presence of a long-run relationship between electricity consumption and economic growth in the Mediterranean island of Cyprus and then proceeds to examine whether equilibrium deviations have a different degree of persistence when shocks are positive or negative. The findings suggest that, in accordance to the findings of the literature, the elasticity of electricity consumption to income is above unity, while electricity is relatively inelastic to financial development and relative energy prices. Trade openness is found to be statistically insignificant in the long-run.

Following the estimation of the cointegrating relationship and the respective elasticities, we apply the Enders and Siklos (2001) threshold adjustment methodology for the first time in the electricity-growth literature. To our knowledge, only Esso (2010) has provided econometric estimates based on a threshold cointegration framework, albeit not using the Enders and Siklos (2001) methodology.

The benefit of the methodology is that it allows the researcher to examine whether positive and negative shocks have a different degree of persistence with respect to the expected duration of equilibrium deviations. In other words, the Enders and Siklos (2001) methodology allows us to examine for any differences in the equilibrium adjustment process, resulting from differences in the nature of the shock. Understanding whether such distinctions exist can prove extremely useful both for policymaking and forecasting purposes. For example, if positive (negative) discrepancies from the long-run equilibrium are eliminated faster than negative ones then the system administrators could better forecast next period's consumption adjusting for the fact that the shock would die out. In contrast, if a positive (negative) discrepancy is eliminated slower, then system administrators would need to accommodate the fact that electricity consumption would remain higher (lower) for a longer period of time.

The results suggest that negative discrepancies from the long-run equilibrium are eliminated more slowly compared to positive shocks. As such, negative shocks would force equilibrium away from its expected path in a more persistent way compared to positive shocks. This suggests that economic recessions could have a more persistent effect on electricity consumption, however, more growth would still lead to higher electricity consumption, as the other regressors adjust faster to positive shocks. This underlines the need for better policies aiming at energy saving and promoting green energy sources. To provide some background on the empirical exercise, the following section provides an overview of the Cypriot energy system, with section 3 presenting the methodology employed in the estimation.

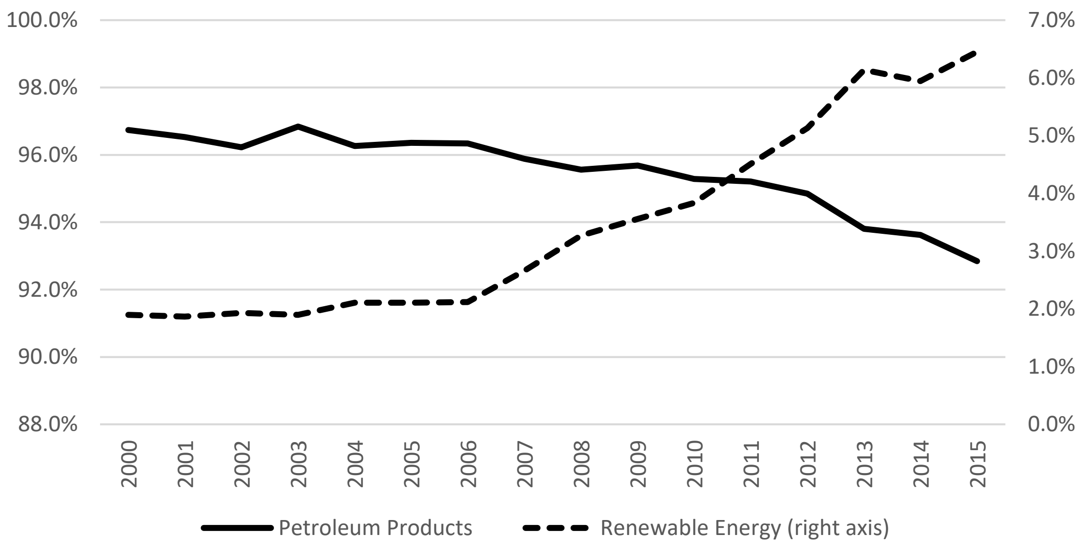
2. *Energy consumption in Cyprus: an overview of the data*

The Cypriot energy system is characterised by its high dependence on imported petroleum products (Koreneos et al.., 2005; Mirasgedis et al., 2004; Zervos et al., 2004; Zachariadis and Hadjikyriakou, 2016) with only marginal decreases recorded since 2005.[1] The island's power plants are mainly powered by fuel oil and while plans for operating plants on natural gas existed these have not yet been implemented. Petroleum products accounted for 92.8% of total inland energy consumption in 2015 with renewable energy accounting for approximately 6.5% (Figure 1). While renewable energy has been on an upwards trend since 2006 its total use is still low especially considering the ample solar energy potential of Cyprus.

Cyprus enjoyed economic growth for approximately 35 years since the Turkish invasion of 1974, which ended with the first post-1974 recession in 2009, followed by another, longer, recession in the 2012-2014 period, culminating with the bail-in of unsecured depositors in the largest bank in the island in 2013 (Michaelides, 2014; Michaelides and Orphanides, 2016; Michail 2021). As a consequence of these economic events, total energy consumption rose by approximately 2% annually in the 2000-2008 period, while it declined by an average of 5.3% per year in the 2009-2013 period. In 2013 alone, electricity consumption registered a 13% decline, as output also declined by 5.4%.

FIGURE 1

Inland consumption of energy as a percentage of total TOE



Source: Eurostat, Table nrg100a

[1] Source: Eurostat tables tsdcc310.

The above short analysis suggests that there is at least an indication of a positive relationship between electricity consumption and GDP growth. To this end, the next section proceeds to provide the methodology to be used for the precise estimation of the electricity-growth relationship.

3. Methodology

a. The standard framework

The relationship between electricity consumption and economic activity in Cyprus can, following the related literature, be examined using the following equation:

$$lnEC_t = a + b_1 lnGDP_t + b_2 lnOP_t + b_3 lnRP_t + b_4 lnFD_t + b_4 \boldsymbol{D_t} + \varepsilon_t \qquad (1)$$

where *ln* represents the natural logarithm, and the residuals ε_t are assumed to be normally distributed. EC_t is the per capita electricity consumption, GDP_t is the per capital real output, OP_t is trade openness defined as the ratio of total imports and exports of goods and services over nominal GDP, RP_t is the relative price of energy to non-energy goods proxied by the ratio of the Brent crude oil price over the GDP deflator and FD_t is the ratio of total domestic loans to GDP. $\boldsymbol{D_t}$ is a vector of dummy variables which, in our case, includes seasonal dummies as well as a dummy to account for the recession period starting from 2012q1 and ending in 2014q4, and the destruction of the Mari power plant (the main power plant in the island) in July 2011.[2]

Economic growth is expected to be the main driving force of electricity (and energy) consumption. Simply put, as the economy grows more electricity will be consumed as result of higher production/income per person.[3] Consequently, countries with higher per capita income are expected to have higher electricity consumption per capita (Keho, 2016).

In contrast, the impact of trade openness on electricity consumption could be either positive or negative, depending on differences in factor endowments and environmental policies. Trade could increase or decrease consumption of electricity depending on whether the country has a comparative advantage in cleaner or dirtier industries. However, trade could also allow for access to energy-efficient technologies and better environmental management practices and hence have a negative impact on electricity consumption (Grossman and Krueger, 1991; Keller, 2004).

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[2] Inter alia, Shahbaz and Feridun (2012), Tang et al. (2013), and Farhani and Solarin (2017) employ similar specifications for the estimation of the energy-growth relationship.
[3] It should be noted that using real GDP could pose some issues given that the increase in income could be disproportionate to the increase in population and hence provide misleading results.

A well-developed financial system is expected to increase energy consumption through a growth-enhancing effect. This is achieved by making it easier for consumers to borrow money, which could then be spent on electricity-consuming durable goods such as home appliances and consumer electronics (Sadorsky, 2011; Islam et al., 2013). However, in combination with foreign trade, financial development could also allow for access to more advanced technologies which could assist in lowering energy consumption (Keho, 2016). Given that both trade and financial development can be misleading if employed at their levels, we scale them with respect to GDP, in order to account for the relative importance of a change in each of these factors. A similar practice has been followed in the literature (Tang et al., 2013; Shahbaz and Feridun, 2012; Farhani and Solarin, 2017).

Relative prices aim to examine whether a price effect exists, i.e. if increases in oil prices (the most-used fuel in Cyprus as the previous section has presented) could have an impact on the consumption of electricity. To account for the overall change in prices, oil prices are scaled relative to non-energy prices such that only changes which do not adhere to the overall price level change will be examined.

In accordance with the above, the coefficient of $lnGDP_t$ is expected to be positive, suggesting that an increase in real per capita output should increase electricity consumption while the coefficient of $lnRP_t$ should be negative, implying that as prices increase consumption should (ceteris paribus) decrease. The signs of the remaining variables could be either positive or negative as argued above and as the results of Tang et al. (2013) and Farhani and Solarin (2017) suggest.

All data were obtained by the Cyprus Statistical Service, while the price of Brent oil was obtained by Thompson Reuters. The sample ranges from 2002Q1 to 2017Q1, covering a full economic cycle, from the boom period of 2006-2008 to the 2012-2014 recession, culminating in the bail-in of unsecured depositors in 2013. The data is transformed into natural logarithms with the first differences viewed as the quarter-on-quarter growth rates.

Before we proceed with the estimation of the cointegrating relationship, we first need to test for the existence of unit roots. Most economic time-series are either I(1) or I(0) and the main econometric benefit of the usual ARDL framework (Pesaran et al., 2001) is that the order of integration of the variables in the cointegrating equation can be either of the two. However, in order for the Engle-Granger approach to be used, all series need to be integrated of order one. To this end, we test for the existence of unit roots in the data, using the GLS-Detrended Dickey-Fuller (GLS-DF) test of Elliot et al.

(1996), in lieu of the Augmented Dickey-Fuller and Phillips-Perron tests which have been shown to have power and size issues (DeJong et al, 1992; Schwert, 2002).[4] The results, presented in Table 1, confirm that all series are integrated of order one, and hence the approach is suitable for use.

TABLE 1

Unit root test

GLS-DF		
H_0: series has a unit root		
Variable	*Level*	*First Difference*
$lnEC_t$	*-0.81*	*-2.63****
$lnGDP_t$	-1.44	-2.61***
$lnOP_t$	-0.39	-7.23***
$lnRP_t$	-1.10	-5.37***
$lnFD_t$	-0.99	-4.97***

Note: *,***, denotes significance at the 10% and 1% level respectively.

The model in equation (1) refers to the long-run relationship between the four variables and electricity consumption. Since it is expected that there will exist a more dynamic representation which also involves a short-term effect, to be able to test it empirically, one needs to incorporate short-run dynamics into the equation.

b. Asymmetric (Threshold) Adjustment

Other than the standard cointegrating equation presented in the previous section, the usual estimation of the effects economic growth can have on electricity consumption, the standard workhorse of empirical studies is the Autoregressive Distributed Lag (ARDL) methodology of Pesaran et al. (2001). However, despite the simplicity of the ARDL methodology, the econometric framework does not allow for the possibility that the equilibrium adjustment term (i.e. the error term in the traditional Engle-Granger framework) could have asymmetric effects.

In general, the presence of asymmetric effects invalidates the standard errors in the ARDL setup, hence jeopardizing inference. In order for the model to be econometrically correct, one needs to account for asymmetry explicitly in the model structure. If adjustment is asymmetric and this is not properly accounted for in the model structure then the model could be mis-specified, leading to erroneous conclusion and incorrect forecasts. To avoid such issues Enders and Siklos (2001) provide an alternative methodology that allows for the possibility that the adjustment coefficient differs with

[4] The Augmented Dickey-Fuller (Dickey and Fuller, 1979), Phillips and Perron (1988) and KPSS (Kwiatkowski, 1992) unit root tests are available upon request.

respect to a specific threshold. Although the methodology has been widely used in energy-related studies,[5] its application in the electricity-growth literature has been, at best, scarce.[6]

The Enders and Siklos (2001) methodology, allows us to examine for any differences in the equilibrium adjustment process which can arise from differences in the nature of the shock. The relative simplicity of this methodology makes it suitable for use in any country, while the importance of measuring the distinction between equilibrium adjustments, resulting from a positive or a negative shock, is paramount both for policymaking and forecasting purposes. The methodology can be applied to a broad range of energy and environmental analyses however, in this paper, we focus on demonstrating its potential for modelling the electricity-growth nexus.

The already existing methodologies aim at measuring oil price asymmetries (e.g. Kilian and Vigfusson, 2011; Hamilton, 2011 and references therein), focus on the short-run effects the relationship. In addition, they are usually bi-variate given that their purpose is to examine the relationship between oil prices and real GDP, which puts an additional restriction to the estimation. In contrast to these, the Enders and Siklos (2001) methodology focuses on the long-run (equilibrium) effects of the relationship (co-movement) between electricity consumption and other explanatory variables. This allows for an examination of the degree at which shocks which force the dependent variable out of the equilibrium path, as predicted by the cointegrating relationship, can differ on the basis of the direction of the shock. In other words, the methodology examines whether the dependent variable's deviations from the equilibrium path, differ in duration depending on whether these are positive or negative.

Before moving to the threshold adjustment methodology, we need to follow Engle and Granger (1987) in order to estimate the long-run relationship, as defined by equation (1).[7] From the basic Engle-Granger setup the estimated residuals, $\widehat{\varepsilon_t}$, obtained from equation (1), assist in formulating a cointegration test such that:

$$\Delta\varepsilon_t = \rho_1\varepsilon_{t-1} + u_t \tag{2}$$

[5] See for example, Chen et al. (2005), Lardic and Mignon (2006), Mohammadi (2009) and Valadkhani (2013).

[6] To our knowledge, only Esso (2010) has provided econometric estimates based on a threshold cointegration framework, albeit not using the Enders and Siklos (2001) methodology.

[7] Although not reported, the presence of a cointegrating relationship was also confirmed using the Johansen and Juselius (1990) approach. However, the Johansen and Juselius (1990) approach does not allow for asymmetric adjustment and hence cannot be employed for such estimations. Cointegration results are available upon request.

where u_t is a sequence of zero-mean, constant-variance iid random variables, such that it is independent of $\widehat{\varepsilon_t}$. Rejecting the null hypothesis of no cointegration implies that the residuals in (1) are stationary with zero mean. In many cases, equation (3) may not be sufficient to capture the dynamic adjustment of $\Delta\varepsilon_t$ towards its long-run equilibrium value. To ensure that the errors (u_t) are zero-mean, (2) is augmented to include lagged changes in the $\{\Delta\varepsilon_t\}$ process such that

$$\Delta\varepsilon_t = \rho_1\varepsilon_{t-1} + \sum_{i=1}^{p-1} \gamma_i \, \Delta\varepsilon_{t-1} + u_t \tag{3}$$

Similar to (2), equation (3) retains the equivalence to original Engle-Granger specification. Through the Granger representation theorem, we know that if $\rho \neq 0$, then (1) and (2) or (3) jointly imply the existence of an error-correction representation of the variables. However, the issue with the above is that these cointegration tests are mis-specified if adjustment is asymmetric. To address this issue Enders and Siklos (2001) consider an alternative specification of the error-correction model, called the threshold autoregressive (TAR) model, which extends (2) and (3) to:

$$\Delta\varepsilon_t = I_t\rho_1\varepsilon_{t-1} + (1 - I_t)\rho_2\varepsilon_{t-1} + u_t \tag{4}$$

$$\Delta\varepsilon_t = I_t\rho_1\varepsilon_{t-1} + (1 - I_t)\rho_2\varepsilon_{t-1} + \sum_{i=1}^{p-1} \gamma_i \, \Delta\varepsilon_{t-1} + u_t \tag{5}$$

In this case, I_t is the Heaviside indicator function which takes the value of 1 if $\widehat{\varepsilon_t} \geq \tau$ and zero otherwise. τ is the threshold value and u_t is a sequence of zero-mean, constant-variance iid random variables, such that it is independent of $\widehat{\varepsilon_t}$. Given that in this case we aim to examine whether positive and negative shocks have a different impact on energy consumption, we set the threshold value to zero, similar to Enders and Siklos (2001).[8]

To examine for threshold asymmetry, we set the threshold indicator as defined above and use equation (3) for the null hypothesis of cointegration and (5) to obtain the F-statistic for the presence of asymmetric effects, under the null that $\rho_1 = \rho_2 = 0$. This statistic is then compared to the critical values in Enders and Siklos (2001). The following section provides the results from this exercise.

[8] In this case there is no policymaker action to smooth out any large changes in the series, hence we abstain from employing the momentum threshold model.

4. Asymmetric Cointegration Estimates

The estimation results from the Enders and Siklos (2001) approach can be found in Table 2. As expected the results are quantitatively different, albeit they convey the same message. In particular, electricity consumption is found to have an elasticity above unity with regards to GDP, a result similar to Zachariadis and Pashourtidou (2007). Relative energy prices is found to have a small but significant negative effect, as expected by the discussion in section 3.1. The size of the coefficient however underlines the fact that electricity consumption in Cyprus is relatively inelastic to changes in oil prices as a result of its high oil dependence. Financial development records a small positive effect, while trade openness is found to be statistically insignificant.[9] Seasonal dummies are also found to be statistically significant with a notable positive impact in the winter (D_1) and summer (D_2) months.

TABLE 2

Engle-Granger long-run elasticities. Dependent variable: electricity consumption

Variable	*Coefficient*	*St. Error*	*t-statistic*
$lnGDP_t$	1.32	0.10	12.99***
$lnOP_t$	0.09	0.06	1.43
$lnRP_t$	-0.06	0.02	2.96***
$lnFD_t$	0.12	0.04	2.89***
D_1	0.09	0.02	5.10***
D_2	-0.02	0.01	-1.46
D_3	0.18	0.02	11.12***
Constant	-11.20	0.86	-12.96***

Note: Estimates of long run relationships between electricity consumption (EC), real GDP (GDP), trade openness (OP), relative prices (RP) and financial development (FD). D_1, D_2, D_3 are dummies for the first, second and third quarter respectively.

Table 3 presents the results from the test for adjustment asymmetry. In particular, the first column in Table 3 shows the estimated equation using the traditional Engle-Granger setup, under equation (4) where the t-statistic of -5.41 (ρ_1) is compared with the Engle-Granger critical values. The respective critical value at the 1% is -4.07, hence confirming the presence of cointegration. However, in testing for asymmetry in the error-correction specification, the second column of Table 4 suggests that, using the critical values of Enders and Siklos (2001) for the Φ and t-Max tests, there is also evidence of asymmetric convergence (ρ_1 and ρ_2). Hence, we

[9] In the Engle-Granger setup, two distinct equations are employed for the estimation (long-run and short-run). As such, dummy variables need to be included in both equations in order to capture seasonal dynamics. In contrast, the ARDL approach uses a single-step equation which does not require the use of seasonal dummies in both the long run and the short run.

proceed with estimating the short-run elasticities for electricity consumption using both the Engle-Granger and the Enders-Siklos setups.

TABLE 3

Threshold Estimates

	Engle-Granger	*Threshold*
ρ_1	-0.88*** (0.16)	-0.94*** (0.25)
ρ_2		-1.01*** (0.24)
γ_1	0.20 (0.13)	0.27 (0.17)
γ_2		0.07 (0.14)
F-statistic (Φ)		10.92
t-max		-3.75

Note: Threshold estimates are based on the Enders and Siklos (2001) critical values and are normally distributed. The existence of a different adjustment path for positive and negative shocks is not rejected at the 1% level. Parentheses are standard errors.

Table 4 shows the results from both specifications. The first column reflects the usual Engle-Granger setup while the second uses the threshold error-correction model of Enders-Siklos. In general, the coefficient estimates do not differ much in the two specifications. The short-run coefficient of the change in real GDP is positive and significant at the 10% level, with its value standing at 0.77. The significance of this term has been known to indicate short-run (or weak) Granger causality in the literature (Zachariadis and Pashourtidou, 2007).

Interestingly, there appear to be no short-run effects from relative prices or financial deepening in the estimation, in either specification. This result can perhaps be attributed to the fact that relative prices require more time for adjustment and hence their impact would be limited to the long-run. A similar rationale holds for financial deepening as increases in loans do not have a direct impact on energy consumption; their impact is mainly through other channels such as increased purchasing ability and consequently energy use. In contrast, openness appears to have some short-run effects. Long-run causality, viewed as the significance of the error-correction term also exists in this case.

The 2011q3 dummy reflecting the destruction of the power station in the Mari area had some short-run impact, but the recession dummy does not appear to have had any significant effect on electricity consumption. The most important finding from Table 4 is that negative discrepancies from the long-run, $(1 - I_t)EC_{t-1}$, are found to be eliminated more slowly ($1/0.58$) compared to positive shocks ($1/0.73$). This can perhaps be attributed to the fact that the independent regressors react faster to positive shocks, and thus help to adjust electricity consumption at its equilibrium level. In addition, as negative shocks are usually associated with recession periods they can be more persistent as a result of the underlying macroeconomic conditions.

The third and fourth columns of Table 4 show the results with GDP as the dependent variable. With regards to the threshold values, it appears that GDP does not record any differences between the disequilibrium persistence when distinguishing between positive and negative shocks, although long-run causality is also present. When turning our attention to the impact of electricity consumption on GDP this is found to be statistically significant albeit with a much smaller elasticity (0.09) compared to reverse relationship. Hence, while short-run (weak) Granger causality also runs from electricity consumption to GDP the impact is much smaller than the opposite case.

TABLE 4

Short-run Elasticities

Variable	*Dependent variable: Electricity Consumption*		*Dependent variable: GDP*	
	Engle-Granger (1)	***Threshold (2)***	***Engle-Granger (3)***	***Threshold (4)***
$\Delta lnGDP_t$	0.78* (0.41)	0.77* (0.41)		
$\Delta lnEC_t$			0.09** (0.04)	0.09** (0.04)
$\Delta lnOP_t$	0.22** (0.10)	0.23** (0.10)	-0.00 (0.03)	-0.00 (0.04)
$\Delta lnRP_t$	-0.05 (0.03)	-0.05 (0.03)	0.00 (0.01)	0.00 (0.01)
$\Delta lnFD_t$	-0.03 (0.15)	-0.00 (0.16)	-0.00 (0.05)	0.00 (0.05)
D_1	0.25*** (0.02)	0.25*** (0.02)	-0.05*** (0.01)	-0.05*** (0.01)
D_2	0.07** (0.03)	0.07** (0.03)	0.04*** (0.01)	0.04*** (0.01)
D_3	0.36*** (0.02)	0.36*** (0.02)	-0.02 (0.02)	-0.02 (0.02)
Constant	-0.16*** (0.01)	-0.16*** (0.01)	0.01 (0.01)	0.01 (0.01)
$Dummy2011q3$	-0.07* (0.04)	-0.07* (0.04)	-0.02 (0.01)	-0.02 (0.01)
$Recession$	-0.02 (0.01)	-0.02 (0.01)	-0.01*** (0.00)	-0.01** (0.00)
EC_{t-1}	-0.66*** (0.14)		-0.19** (0.07)	
$I_t EC_{t-1}$		-0.73*** (0.20)		-0.22** (0.09)
$(1-I_t)EC_{t-1}$		-0.58*** (0.21)		-0.12 (0.13)
Joint-statistics				
ECT&$\Delta lnOP_t$	12.57***		3.29**	
ECT&$\Delta lnRP_t$	12.01***		3.20**	
ECT&$\Delta lnFD_t$	12.69***		3.16*	
ECT&$\Delta lnGDP_t$	11.77***			
ECT&$\Delta lnEC_t$			3.91**	
LM	1.09	0.95	0.13	0.19
RESET	0.43	0.63	0.79	0.97
Normality	0.35	0.41	2.25	2.37
Heteroscedasticity	0.37	0.51	1.22	1.05
CUS(CUS^2)	S(S)	S(S)	S(S)	S(S)
R^2	0.95	0.95	0.89	0.89
Adjusted R^2	0.94	0.94	0.87	0.87

Notes: Parentheses indicate standard errors. *,**,*** indicate significance at the 10%, 5% and 1% level respectively. D_1, D_2, and D_3 are seasonal dummies for the first, second and third quarters of the year. The recession dummy covers the period starting from 2012q1 and ending in 2014q4 while the 2011q3 dummy captures the destruction of the Mari power plant (the main power plant in the island) in July 2011. LM is the Langrange multiplier test distributed as $X^2(1)$. CUS and CUS^2 are the cumulative sum of recursive residuals and the cumulative sum of squares of recursive residuals. S suggests that the estimate is stable. Normality test is based on Jarque-Bera which is distributed $X^2(1)$. RESET is Ramsey's test of functional form, distributed as $X^2(1)$. Heteroscedasticity is the Breusch-Pagan-Geodfrey test, distributed as $X^2(1)$. The sample ranges from 2002q1 to 2017q1, with a total of 57 observations.

The case of a feedback relationship is further supported by the causality tests results located in the second panel of Table 4. Examining for 'strong' Granger causality (Oh and Lee, 2004) by means of jointly testing for the significance of the error-correction term and the other terms is usually conducted within a VECM framework, but is also offered here for illustration purposes. The tests indicate that such form of Granger causality also exists in the data further strengthening the case in favour of the feedback hypothesis, also in line with Zachariadis and Pashourtidou (2007). Nevertheless, the results show that the sensitivity of GDP to electricity consumption is much smaller than the opposite case.

The relevant diagnostic tests can be found in the third panel of Table 5. The models pass all heteroscedasticity, serial correlation, normality and functional form tests. In addition, the high value of the R-squared indicates that the model is indeed a good fit. Overall, the results of this section suggest that the long-run elasticity of electricity consumption to output is greater than unity, a result which is in accordance to both the previous section as well as with the previous literature. In addition, negative shocks appear to be more persistent in the Engle-Granger setup, as the coefficient is 25% larger than the respective coefficient for positive shocks.

5. Conclusions and Policy Implications

The main contribution of this paper is the use, for the first time in the electricity-growth literature, of the Enders and Siklos (2001) methodology that allows the researcher to distinguish between positive and negative shocks from equilibrium. Using this methodology, we find that negative shocks appear to be more persistent than positive ones. Understanding whether such distinctions exist can prove extremely useful for both policymaking and forecasting purposes. For example, if positive discrepancies from the long-run equilibrium are eliminated faster than negative ones then the system administrators could better forecast next period's consumption adjusting for the fact that the positive shock would die out faster. In the case of a negative discrepancy, which is expected to be eliminated at slower pace, system administrators need to accommodate the fact that electricity consumption would remain lower for a longer period.

Further to the above results, this paper confirms that the elasticity of electricity consumption to GDP in Cyprus is greater than unity in accordance to the findings of Zachariadis and Pashourtidou (2007). The results also point out that electricity consumption is inelastic with respect to financial development, which can explain why during the lending boom and bust periods (see Cleanthous et al., 2019) Cyprus did not register higher growth rates of electricity consumption. Most importantly, electricity consumption is highly inelastic with regards to the relative price of energy to non-energy goods in the economy.

The above are consistent with evidence from many countries worldwide (see Menegaki, 2014). Furthermore, the inelasticity of electricity consumption to relative prices is reinforced by the fact that Cyprus does not, at the moment, use a well-diversified fuel mix and hence price variation among households is quite low. This may also be a result of widespread electrification in household appliances and equipment, in line with developments in the international market. The country is on a trajectory of increased economic development, registering growth rates in excess of 3% since 2016, with annual electricity demand is expected to increase by about 6% compared to a 'no climate change' case. Despite its relatively small size, the costs associated with this change in demand are expected to exceed 730 million euros, with welfare losses amounting to more than 150 million euros, according to the findings of Zachariades and Hadjinicolaou (2014).

On the basis of the outlook above, reductions in electricity consumption will require a combination of i) increased deployment of renewable power generation on the supply side with b) improved efficiency of electricity use on the demand side. As IRENA (2015) points out, doubling the share of renewables would deliver about half the required emissions reductions and, along with greater efficiency keep global warming under 2 degrees Celsius. The combination of energy efficiency and renewable energy sources would, as IRENA and C2E2 (2015) note, result in a reduction in energy demand by a quarter by 2030.

For Cyprus, a sustainable and greener future energy path would require the deployment of solar- and wind-powered electricity generation, in order to meet peak requirements, especially in the summer months when a large inflow of tourists is also registered. As the results of this paper suggest, a renewable energy shock, which could lower electricity consumption, could have more persistent effects and hence further promote a greener path.

Such developments would also reduce Cyprus's energy dependence on oil and improve energy security issues, given the high inelasticity of demand to changes in price. An improvement in energy security issues via an increase in greener power sources would, in addition to providing an environmentally-friendlier alternative, also have positive macroeconomic effects as it would safeguard the economy from external shocks (Bhattacharyya, 2011). Consequently, and given the urgent need to address climate change, attention should be devoted to the formulation of policies which would improve energy efficiency and accelerate transition to renewable power generation in order to safeguard both the economy and the environment.

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