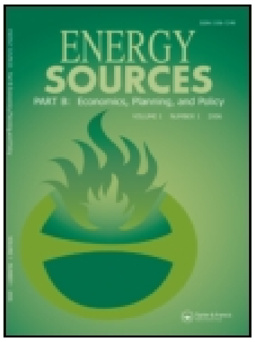

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Energy consumption, CO_2 emissions, economic growth, and foreign trade relationship in Cyprus and Malta

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ABSTRACT

This paper examines the long-run and causal relationship issues between economic growth, carbon emissions, energy consumption, foreign trade ratio, and employment ratio in Cyprus and Malta by using autoregressive distributed lag (ARDL) bounds testing approach of cointegration and error-correction-based Granger causality models. Empirical results over the period 1980–2006 suggest an evidence of a long-run relationship between the variables at 5% significance level only in Malta. Thus, Granger causality models are estimated only for Malta. Results for the existence and direction of Granger causality show that the causality runs from carbon emissions, energy consumption, foreign trade ratio, and employment ratio to economic growth but not vice versa in Malta. The overall results indicate that energy conservation policies, such as rationing energy consumption and controlling carbon dioxide emissions, are likely to have no adverse effect on the real output growth of Malta.

KEYWORDS

ARDL bounds; carbon dioxide emission; Cyprus; economic growth; energy consumption; Malta

1. Introduction

The effects of economic growth on the environmental pollutants have been widely discussed in the economic literature. They have mostly been examined within the framework of environmental Kuznets curve (EKC), which postulates an inverted U-shaped relationship between environmental pollution and per capita income (Abdulai and Ramcke, 2009). Basically there are three research methods in the literature on the relationship between economic growth, energy consumption, and environmental pollutants (Zhang and Cheng, 2009). The first strand focuses on the environmental pollutants and economic growth nexus that is closely related to testing the validity of the EKC (see Dinda, 2004; Stern, 2004). The second method is related to energy consumption and output nexus (see Ozturk, 2010). The third method is the combination of these two methods which examines the relationships between economic growth, environmental pollutants, and energy consumption in the same framework (see Halicioglu, 2009; Zhang and Cheng, 2009; Acaravci and Ozturk, 2010; Ozturk and Acaravci, 2010; Pao and Tsai, 2011). This study extends the third method by including also the effects of foreign trade into the multivariate framework in order to reduce the problems of omitted variable bias in econometric estimation.

According to World Development Indicators (WDI) of The World Bank, Cyprus's share of carbon emissions in the world was 100st place, while Malta was 132nd, and the share of Cyprus in the total world carbon emissions was 0.031% and Malta's was 0.01% in 2007. Therefore, Malta has one of the lowest carbon emission rates per capita within the EU (7.9 tonnes of CO_2 equivalents per capita, compared with an average of 10.4 tonnes for the EU-27).

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There are many studies on this subject for the EU countries. However, no study is found for the Cyprus and Malta. Since it is the first study that attempts to examine this issue, this paper contributes to the existing literature. We investigate both short-run and long-run and causal relationship issues between economic growth, carbon emissions, energy consumption, foreign trade ratio, and employment ratio in two island economies, Cyprus and Malta, by using autoregressive distributed lag (ARDL) bounds testing approach of cointegration and error-correction-based Granger causality models over 1980–2006 period. The rest of the paper is organized as follows. Section 2 presents the methodology and data. Section 3 reports the empirical results. Finally, Section 4 concludes the paper.

2. Methodology and data

To investigate the long-run relationship between carbon emissions per capita, energy consumption per capita, employment ratio (in percent), foreign trade ratio (in percent), and real GDP per capita, we employed the following equation:

$$gdp_t = \alpha + \beta co_t + \theta ec_t + \varphi em_t + \omega ft_t + \varepsilon_t, \quad (1)$$

where *gdp* is real GDP per capita (constant 2,000 US$), *co* is carbon dioxide emissions (metric kilograms per capita), *ec* is energy use (kilograms of oil equivalent per capita), *em* is employment ratio (ratio of total labor force to total population, in percent), *ft* is the foreign trade ratio (ratio of goods traded to GDP, in percent), and ε_t is the error term. The annual time series data are taken for 1980–2006 from the WDI online database. All variables are employed with their natural logarithms form to reduce heteroscedasticity and to obtain the growth rate of the relevant variables by their differenced logarithms.

The long-run and causal relationships between economic growth, carbon emissions, energy consumption, employment ratio, and foreign trade in Cyprus and Malta will be performed in two steps. First, we will test the long-run relationships among the variables by using the ARDL bounds testing approach of cointegration. Second, we will test causal relationships by using the error-correction-based Granger causality models.

2.1. *Cointegration analysis*

The ARDL bounds testing approach of cointegration is developed by Pesaran and Shin (1999) and Pesaran et al. (2001). The ARDL model for the standard log-linear functional specification of long-run relationship between carbon emissions per capita, energy consumption per capita, employment ratio, foreign trade ratio, and real GDP per capita is as follows:

$$\Delta gdp_t = \alpha_1 + \sum_{i=1}^{a1} \phi_{1i}\Delta gdp_{t-i} + \sum_{j=0}^{b1} \beta_{1j}\Delta co_{t-j} + \sum_{k=0}^{c1} \theta_{1k}\Delta ec_{t-k} + \sum_{m=0}^{d1} \varphi_{1m}\Delta em_{t-m} + \sum_{n=0}^{e1} \omega_{1n}\Delta ft_{t-n} + \delta_1 gdp_{t-1} + \delta_2 co_{t-1} + \delta_3 ec_{t-1} + \delta_4 em_{t-1} + \delta_5 ft_{t-1} + \varepsilon_{1t}. \quad (2)$$

where ε_{1t} and Δ are the white noise term and the first difference operator, respectively. The bounds testing procedure is based on the joint *F*-statistic or Wald statistic that is tested the null of no cointegration, $H_0 : \delta_r = 0$, against the alternative of $H_1 : \delta_r \neq 0$, $r = 1, 2, 3, 4, 5$. Narayan (2005) regenerated the set of critical values for the limited data ranging 30–80 observations. With the limited annual data for Cyprus and Malta on variables, this study employs the critical values of Narayan (2005) for the bounds *F*-test rather than Pesaran et al. (2001), because Pesaran et al.'s (2001) critical values are based on large sample sizes.

The second step is to estimate the following long-run and short-run models that are represented in Eqs. (3) and (4) if there is evidence of long-run relationships (cointegration) between these variables:

$$gdp_t = \alpha_2 + \sum_{i=1}^{a1} \phi_{2i} gdp_{t-i} + \sum_{j=0}^{b1} \beta_{2j} co_{t-j} + \sum_{k=0}^{c1} \theta_{2k} ec_{t-k} + \sum_{m=0}^{d1} \varphi_{2m} em_{t-m} + \sum_{n=0}^{e1} \omega_{2n} ft_{t-n} + \varepsilon_{2t}, \quad (3)$$

$$\Delta gdp_t = \alpha_3 + \sum_{i=1}^{a1} \phi_{3i} \Delta gdp_{t-i} + \sum_{j=0}^{b1} \beta_{3j} \Delta co_{t-j} + \sum_{k=0}^{c1} \theta_{3k} \Delta ec_{t-k} + \sum_{m=0}^{d1} \varphi_{3m} \Delta em_{t-m} + \sum_{n=0}^{e1} \omega_{3n} \Delta ft_{t-n} + \psi ECT_{t-1} + \varepsilon_{3t}, \quad (4)$$

where ψ is the coefficient of error correction term (ECT).

2.2. *Causality analysis*

Following Granger (1988), the first step is the estimation of the long-run model for Eq. (1) in order to obtain the long-run relationship as error-correction term (ECT) in the system. The next step is to estimate the Granger causality model with the variables in first differences and including the ECT in the systems. In our case, the vector error correction (VEC) multivariate systems take the following forms:

$$\begin{bmatrix} \Delta gdp_t \\ \Delta co_t \\ \Delta ec_t \\ \Delta em_t \\ \Delta ft_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \end{bmatrix} + \begin{bmatrix} \pi_{11,1} & \pi_{12,1} & \pi_{13,1} & \pi_{14,1} & \pi_{15,1} \\ \pi_{21,1} & \pi_{22,1} & \pi_{23,1} & \pi_{24,1} & \pi_{25,1} \\ \pi_{31,1} & \pi_{32,1} & \pi_{33,1} & \pi_{34,1} & \pi_{35,1} \\ \pi_{41,1} & \pi_{42,1} & \pi_{43,1} & \pi_{44,1} & \pi_{45,1} \\ \pi_{51,1} & \pi_{52,1} & \pi_{53,1} & \pi_{54,1} & \pi_{55,1} \end{bmatrix} \begin{bmatrix} \Delta gdp_{t-1} \\ \Delta co_{t-1} \\ \Delta ec_{t-1} \\ \Delta em_{t-1} \\ \Delta ft_{t-1} \end{bmatrix} + \ldots + \begin{bmatrix} \pi_{11,p} & \pi_{12,p} & \pi_{13,p} & \pi_{14,p} & \pi_{15,p} \\ \pi_{21,p} & \pi_{22,p} & \pi_{23,p} & \pi_{24,p} & \pi_{25,p} \\ \pi_{31,p} & \pi_{32,p} & \pi_{33,p} & \pi_{34,p} & \pi_{35,p} \\ \pi_{41,p} & \pi_{42,p} & \pi_{43,p} & \pi_{44,p} & \pi_{45,p} \\ \pi_{51,p} & \pi_{52,p} & \pi_{53,p} & \pi_{54,p} & \pi_{55,p} \end{bmatrix} \begin{bmatrix} \Delta gdp_{t-p} \\ \Delta co_{t-p} \\ \Delta ec_{t-p} \\ \Delta em_{t-p} \\ \Delta ft_{t-p} \end{bmatrix} + \begin{bmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \\ \psi_4 \\ \psi_5 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \\ \varepsilon_{7t} \\ \varepsilon_{8t} \end{bmatrix}. \quad (5)$$

Using Eq. (5), Granger causal relationships can be examined in three ways: (i) according to Masih and Masih (1996) and Asafu-Adjaye (2000), short-run or weak Granger causalities are detected through the F-statistics or Wald test for the significance of the relavant π coefficients on the first differenced series; (ii) Masih and Masih (1996) point out that another possible source of causation is the ECT in equations. The long-run Granger causalities are examined through the t-test or Wald test for the significance of the relavant ψ coefficients on the lagged error–correction term. (iii) Asafu-Adjaye (2000) emphasizes that the joint test of two sources of causation indicates which variable(s) bear the burden of short-run adjustment to re-establish long-run equilibrium, following a shock to the system. Lee and Chang (2008) referred it as a strong Granger causality test that is detected by joint testing of the significance of the relavant π coefficients on the first differenced series and the significance of the relavant ψ coefficients on the lagged error–correction term.

3. Empirical results

If the order of integration of any of the variables is greater than 1, for example, an $I(2)$ variable, then the critical bounds provided by Pesaran et al. (2001) and Narayan (2005) are not valid. They are computed on the basis that the variables are $I(0)$ or $I(1)$. For this purpose, it is necessary to test for unit root to ensure that all the variables satisfy the underlying assumptions of the ARDL bounds testing approach of cointegration methodology before proceeding to the estimation stage. Leybourne et al. (2005) have also recently noted that weighted symmetric augmented Dickey–Fuller test (ADF-

WS) has good size and power properties when it is compared with the other tests. In order to overcome the low power problems associated with conventional unit root tests, especially in small samples, we therefore employed the ADF-WS of Park and Fuller (1995) and Dickey–Fuller generalized least-squares test (DF-GLS) of Elliot et al. (1996). The results indicate that only foreign trade ratio for Cyprus is stationarity at levels and other variables for Cyprus and Malta are stationarity at the first differences.[1] Thus, we can confidently apply the ARDL methodology to our model for both countries.

According to Pesaran and Shin (1999), the Schwarz Bayesian criterion (SBC) is generally used in preference to other criteria because it tends to define more parsimonious specifications. The ARDL (1,1,0,0,1) models for both countries are estimated and the bounds *F*-test for cointegration suggests only Malta yields evidence of a long-run relationship between carbon emissions per capita, energy consumption per capita, employment ratio, foreign trade ratio, and real GDP per capita at 5% significance level. However, no long-run relationship is found among variables in Cyprus. Thus, the error-correction-based Granger causality model will be estimated only for Malta and it cannot be run to analyze for Granger causal relatioshiops for Cyprus. Estimated ARDL model for Malta has passed several diagnostic tests that indicate no evidence of incorrect functional form, serial correlation, and heteroscedasticity. In addition, the residuals have normal distribution according to the normality test that is based on a test of skewness and kurtosis of residuals (see Table 1).

On the other hand, the stability of the short-run and long-run coefficients is checked through the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests. The CUSUM and CUSUMSQ tests are quite general tests for structural change in that they do not require a prior determination of where the structural break takes place. Figure 1 presents the plot of CUSUM and CUSUMSQ tests statistics that fall inside the critical bounds of 5% significance. This implies that the estimated parameters for Malta are stable over the periods.

Our result of the estimated log-linear long-run coefficient of carbon emissions per capita is positive and statistically significant (0.384). This means that more carbon emissions do not likely reduce the economic growth. It implies the income elasticity of carbon emissions per capita and a 1% increase in carbon emissions per capita will increase real GDP per capita about 0.384%. The estimated log-linear long-run coefficient of energy consumption per capita is positive and statistically insignificant (0.133). The estimated log-linear long-run coefficient of employment ratio and foreign trade ratio are positive and statistically significant (2.384 and 0.719, respectively). Latter results indicate that a higher (or lower) employment ratio or foreign trade ratio likely increase (or

Table 1. Estimated coefficients for Malta.

Variables			Short run		Long run
gdp (−1)			0.826 (0.000)		
Co			0.005 (0.888)		0.384 (0.041)
co (−1)			0.062 (0.051)		
ec			0.023(0.490)		0.133 (0.472)
em			0.416 (0.112)		2.384 (0.001)
ft			0.242 (0.005)		0.719 (0.054)
ft (−1)			−0.116 (0.069)		
Constant			−1.328 (0.095)		7.622 (0.003)
R^2	0.998	NORM	0.437 (0.804)	F_{MALTA}	4.462
SEE	0.015	LM	0.472 (0.492)	F_{CYPRUS}	1.577
RESET	1.522 (0.217)	HET	0.159 (0.690)	*ECT*	−0.174 (0.014)

Note. SEE, standard error of the regression; RESET, Ramsey's RESET test using the square of the fitted values with one degree of freedom; NORM, test for normality of residuals with a χ^2 distribution with two degrees of freedom; LM, Lagrange multiplier test for serial correlation with a χ^2 distribution with four degrees of freedom; HET, test for heteroscedasticity with a χ^2 distribution with one degree of freedom; *ECT*, estimated coefficient of error correction term. F_{CYPRUS} and F_{MALTA} are the ARDL cointegration tests for CYPRUS and MALTA. The critical values for the lower *I*(0) and upper *I*(1) bounds are 3.058 and 4.223 for 5% significance level, respectively (Narayan, 2005, Appendix: Case II).

[1]The results of the unit root tests are available upon request.

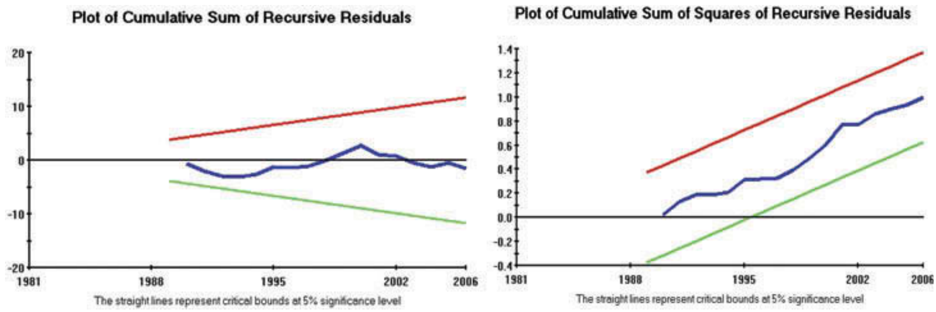

Figure 1. Plot of CUSUM and CUSUM of squares test.

decrease) the real GDP per capita. Finally, the estimated *ECT* is also negative (−0.174) and statistically significant at 5% confidence level. *ECT* indicates that any deviation from the long-run equilibrium between variables is corrected about 17% for each period and takes about six periods to return the long-run equilibrium level (see Table 1).

This study also explores causal relationship between the variables by using error-correction-based Granger causality models which are weak (short-run) Granger causality, long-run Granger causality, and strong Granger causality. The results of both Granger causality models (see Table 2 and Figure 2) can be summarized as follows:

(i) Long-run Granger causality exists only for the real GDP equation.
(ii) There are no short-run (weak) Granger causal evidences between carbon emissions per capita, energy consumption per capita, and real GDP per capita. But there are evidences of a unidirectional strong Granger causal relationship from carbon emissions per capita running to real GDP per capita and a unidirectional strong Granger causal relationship from energy consumption per capita running to real GDP per capita. Although the main source of carbon dioxide emissions is the energy consumption, the other most interesting result is that there is no evidence of short-run and strong Granger causal relationships between carbon emissions and energy consumption.
(iii) There are evidences of a short-run unidirectional Granger causal relationship and a strong unidirectional Granger causal relationship from foreign trade ratio to real GDP per capita.

Table 2. Granger causality test results for Malta.

	Short-run (or weak) causality					Long-run causality
Variables	Δgdp	Δco	Δec	Δem	Δft	$\psi_i, i = 1,2,3,4,5$
Δgdp	–	0.2957 (0.5866)	0.0710 (0.7899)	0.0419 (0.8379)	3.4374** (0.0637)	5.3131* (0.0212)
Δco	0.0716 (0.7898)	–	0.1300 (0.7185)	0.1472 (0.7013)	0.9843 (0.3211)	0.0641 (0.8002)
Δec	0.0005 (0.9821)	0.2201 (0.6390)	–	0.6992 (0.4030)	0.0769 (0.7815)	0.0289 (0.8650)
Δem	0.5124 (0.4741)	0.0463 (0.8297)	1.0648 (0.3021)	–	0.5967 (0.4398)	0.9397 (0.3324)
Δft	0.0025 (0.9602)	0.2380 (0.6256)	3.4446** (0.0635)	2.1936 (0.1385)	–	0.2975 (0.5854)
	Strong causality					
Variables	Δgdp	Δco	Δec	Δem	Δft	
Δgdp	–	6.4287[b] (0.0402)	5.3486[a] (0.0690)	5.6957[a] (0.0580)	6.994[b] (0.0303)	
Δco	0.0814 (0.9601)	–	0.2004 (0.9046)	0.2531 (0.8812)	0.9844 (0.6113)	
Δec	0.0435 (0.9785)	0.5409 (0.7630)	–	0.6998 (0.7048)	0.1401 (0.9323)	
Δem	0.9490 (0.6222)	1.93952 (0.3792)	1.9389 (0.3793)	–	2.0696 (0.3553)	
Δft	0.60009 (0.7405)	1.3420 (0.5112)	3.8152 (0.1484)	2.2785 (0.3201)	–	

Note. The null hypothesis is that there is no Granger causal relationship between variables. Values in parentheses are *p*-values for Wald tests with a χ^2 distribution. Δ is the first difference operator. Optimal lag, based on SBC information criteria test results, is 1. [a]is 10% and [b] is 5% significant levels.

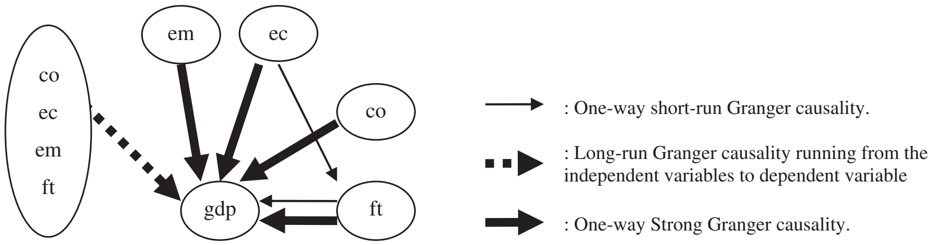

Figure 2. Granger causality relationship flows for Malta.

(iv) While there is an evidence of a strong unidirectional Granger causal relationship from employment ratio to real GDP per capita, there is no evidence of a short-run unidirectional Granger causal relationship from employment ratio to real GDP per capita.
(v) There are no evidences of short-run and strong Granger causal relationships between foreign trade ratio and carbon emissions per capita and employment ratio. But there is an evidence of a unidirectional short-run Granger causal relationship from energy consumption per capita to foreign trade ratio.
(vi) There are no evidences of short-run and strong Granger causal relationships between foreign trade ratio and employment ratio.

The overall results indicate that energy conservation policies, such as rationing energy consumption and controlling carbon emissions, are likely to have no adverse effect on the real output growth of Malta.

4. Concluding remarks

This paper examines the long-run and causal relationship issues between carbon emissions, energy consumption, employment ratio, foreign trade ratio, and economic growth in two Mediterranean islands economies: Cyprus and Malta. For this purpose, ARDL bounds testing approach of cointegration and error-correction-based Granger causality models is employed for 1980–2006 period.

The empirical results show an evidence of a long-run relationship between the variables at 5% significance level only in Malta. However, no long-run cointegration (relationship) is found between the variables in the case of Cyprus. Thus, Granger causality models estimated results only for Malta. Results for the existence and direction of Granger causality models show that the causality runs from carbon emissions, energy consumption, foreign trade ratio, and employment ratio to economic growth but not vice versa in Malta. The overall results indicate that energy conservation policies, such as rationing energy consumption and controlling carbon dioxide emissions, are likely to have no adverse effect on the real output growth of Malta.

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