A dynamic econometric study of income, energy and exports in Turkey

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Abstract

This study attempts to examine empirically dynamic causal relationships between aggregate output, energy consumption, exports, capital and labour in the case of Turkey using the time series data for the period 1968-2008.
This research tests the interrelationships between the variables using the bounds testing to cointegration procedure. The bounds test results indicate that there exists a long-run relationship between the variables in which the dependent variable is aggregate output. Within this study, three competing sets of hypotheses regarding the relationship between aggregate output, exports and energy consumption are tested. An augmented form of Granger causality analysis is conducted amongst the variables. In the long-run, causality runs interactively through the error correction term from labour, capital, exports and energy consumption to aggregate output. In the short-run, two important bilateral causalities were identified: between energy consumption and aggregate output, between exports and aggregate output. The short-run causality testing reveals further the existence of a unilateral causality running from exports to energy consumption too. The long-run relationship of aggregate output, energy consumption, exports, capital and labour equation is also checked for the parameter stability. The results also provide some important policy recommendations.

Keywords: Aggregate output; energy consumption; capital; labour; cointegration; Granger causality; stability tests; Turkey.

JEL Classifications: Q43, Q53, Q56, C22.

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1. Introduction

Following the pioneering study of Kraft and Kraft [1], there has been a surge of very extensive empirical research on the temporal causality between energy consumption and economic growth. The literature in energy economics has been rapidly populated with the studies on energy-GDP nexus. Payne [2] presents very detailed account of this intensive literature.

Economic theories indicate implicitly existence of the relationship between energy use and economic growth. However, this does not necessarily imply a causal relationship between them. The direction, strength and stability of the relationship between energy consumption and GDP (gross domestic product) play a substantial role in designing the energy policies. For example, if unidirectional causality runs from electricity use to economic growth, reducing energy consumption could lead to a fall in economic growth. On the other hand, if unidirectional causality runs from economic growth to electricity use, decreasing electricity consumption may have little or no adverse impact on economic growth.

Researchers have used several causality tests along with a number of different statistical and econometric techniques to identify whether energy use causes economic growth or whether energy use is determined by the level of output. The results are inconclusive. The results differ even on the direction of causality and the long-term versus short-term impact on energy policy. Initial empirical studies are limited with bivariate cases of energy consumption and GDP. Stern [3] extended this setting into multivariate case by adding capital and labour inputs in order to eliminate omitted variable bias. As indicated by Lutkepohl [4] the exclusion of a relevant variable(s) cause the estimates biased and inconsistent as well as non-causality in a bivariate system.

This study extends this literature to test the relationship between energy consumption, GDP, labour, capital and exports in Turkey using an augmented neo-classical aggregate production model. Incorporating exports into the neo-classical aggregate production model with a view of testing the exports-GDP nexus is initiated by Narayan and Smyth [5], which is also adopted by Lean and Smyth [6]. The neo-classical production model augmented with exports and energy consumption leads to examine the existence of two competing hypotheses simultaneously: energy-GDP nexus and exports-GDP nexus in addition to a supplementary hypothesis between exports and energy consumption.

The dynamic interrelationships amongst the five variables are analyzed using the cointegration technique of Pesaran *et al*. [7] and the Granger causality link both in the short run and the long run.

The remainder of this paper is organized as follows: the next section outlines briefly the literature on the inter-relationships between output, energy consumption and exports. The third section describes the study's model and methodology. The fourth section discusses the empirical results, and the last section concludes.

2. A Brief Literature Review

In a recent literature survey of the energy-GDP nexus, Payne [2] identifies four major hypotheses being tested namely growth, conservation, neutrality and feedback and he concludes that no clear consensus has been achieved.

In the debate of the energy – GDP nexus, the most revealing argument is that energy is an essential input for production because other factors of production such as labour and capital cannot be used without it. Therefore, energy consumption is regarded to be a limiting factor to economic growth. The second strand is based on the neutrality hypothesis, in which energy is neutral to economic growth. The reason of the neutrality of energy to economic growth comes from the fact that the cost of energy is very small as proportion to GDP. Moreover, the impact of energy consumption on economic growth will depend on the structure of the economy and the level of economic growth. As a result of economic growth, production structure is likely to shift towards service sectors, which are not energy intensive activities as discussed in Solow [8] and Denison [9].

The existing Granger causality studies of the energy-GDP nexus for Turkey use generally a bivariate setting apart from Halicioglu [10] and Soytas and Sari [11]. The former study finds evidence of long-run causality, which runs from income to energy use but the latter study provides no such evidence. On the other hand, bivariate studies on the energy-GDP nexus provide inconclusive results, see Table 1.

Table 1. Summary results of the selected empirical works on Energy-Growth Nexus for Turkey

Author (s)	Period	Variables	Method	Causality
Soytas and Sari [12]	1960-1995	E, Y	JC, GC	E→Y
Altinay and Karagol [13]	1960-2000	E, Y	VAR, TY	E→Y
Jobert and Karanfil [14]	1960-2003	E, Y	VAR, TY	None
Halicioglu [11]	1968-2005	E, Y, P, U,	ARDL, GC	Y→E
Lisa and Montfort [15]	1970-2003	E, Y	EG, GC	Y→E
Narayan and Prasad [16]	1960-2008	E, Y	Bootstrap	None
Karanfil [17]	1970-2005	E, Y	JC, GC	None
Erdal *et al*. [18]	1970-2006	E, Y	JC, GC	E↔Y
Soytas and Sari [11]	1960-2000	E, Y, K, L, C	VAR, TY	None

Keys: E (energy consumption), Y (income or output), K (capital), L (labour), C (carbon dioxide emissions), U (urbanization), TY (Toda and Yamamoto), GC (Granger causality), VAR (Vector autoregressive regression), EG (Engle-Granger), JC, (Johansen Cointegration), ARDL (Autoregressive Distributed Lag)

As for the exports-GDP nexus, the prominent view is that exports are seen as engine of economic growth. This discussion has been intensified on empirical grounds since 1970s when developing countries have been involved more in the international trade. Giles and Williams [19] provide a comprehensive survey of more than 150 export-growth applied papers.

According to export-led growth hypothesis, there are a number of channels within trade theory to support the export-led growth hypothesis. For example, export growth leads an increase in demand for the country's output or expansion in exports may promote specialization, which boost the productivity level or export promotion eliminate overvaluation of the domestic currency, or countries with high export/GDP ratios are more open to outside influences and generate externalities such as the incentive to innovate. On the other hand, the competing hypothesis suggests that the trade expansion should be considered as a "handmaiden" successful growth rather than an autonomous engine of growth as argued in Kravis [20]. There is also potential for growth-led exports. For example, Lancaster [21], Krugman [22], Bhagwati [23] suggest that economic growth leads to enhancement of skills and technology with this increased efficiency creating a comparative advantage for the country that facilitates exports. Market failure, with subsequent government intervention, may also result in growth lead exports. It is also possible that there is a feedback relationship between exports and output. According to Helpman and Krugman [24] exports may rise from the realization of economies of scale due to productivity gains; the rise in exports may further enable cost reductions, which may result in further productivity gains. A similar line of argument is put forward by Bhagwati [23] stating that increase trade (irrespective of cause) produces more income, which leads to more trade and so on.

The empirical results generally support the export-led hypothesis. However, there are some inconclusive results in addition to the support for the growth-led hypothesis. In the case of Turkish data, the results appear to be mixed. The summary results of the exports-GDP studies are reported in Table 2.

Table 2. Summary results of the selected empirical works on Exports-GDP Nexus for Turkey

Author (s)	Period	Variables	Method	Causality
Bahmani-Oskooe and Domac [25]	1923-1990	X, Y	JC, GC	X↔Y
Ozmen and Furtun [26]	1970-1995	X, Y	JC, GC	None
Ozturk and Acaravci [27]	1989-2006	X, Y	VAR, TY	X→Y
Halicioglu [28]	1980-2005	X, IP, T	ARDL, GC	X→Y
Bilgin and Sahbaz [29]	1987-2007	X, Y, M, IP	JC, TY, GC	X→Y
Hatemi-J and Irandoust [30]	1960-1997	X, Y	JC, GC	None
Denirhan and Akcay [31]	1966-1966	X, Y, M, ME	EG, TY, JC	Y→X

Keys: X (exports), Y (income or output), IP (Industrial production index)T (terms of trade), M (imports), ME (manufactured exports), TY (Toda and Yamamoto), GC (Granger causality), VAR (Vector autoregressive regression), EG (Engle-Granger), JC, (Johansen Cointegration), ARDL (Autoregressive Distributed Lag)

Finally, there is a third set of competing hypotheses which are based on the relationship between exports and electricity consumption. However, these hypotheses are not derived from any economic theories. One may find exports cause energy use implying that energy saving policies has no adverse impact on export growth. On the other hand, if energy consumption causes exports, reduction in energy use will limit expansion in exports which are considered to be engine of economic growth.

3. Econometric Model and Methodology

A conventional neo-classical one-sector aggregate production function which has been augmented by exports and energy as separate factors of production is expressed in linear econometric form as follows:

$$y_t = \alpha_0 + \alpha_1 e_t + \alpha_2 x_t + \alpha_3 k + a_4 l_t + \varepsilon_t \quad (1)$$

where y_t is aggregate output per capita, e_t is energy consumption per capita, x_t is per capita real exports, k_t is per capita real capital, l_t is labour force participation rate, and ε_t is the regression error term. The lower case letters in equation (1) demonstrate that all variables are in their natural logarithms. Equation (1) also provides the empirical means of testing three competing hypotheses: i) aggregate output and electricity consumption; ii) aggregate output and exports; and iii) exports and electricity consumption.

The recent advances in econometric literature dictate that the long-run relation in equation (1) should incorporate the short-run dynamic adjustment process. It is possible to achieve this aim by expressing equation (1) in an error-correction model as suggested in Engle-Granger [32].

$$\Delta y_t = \beta_0 + \sum_{i=1}^{m1} \beta_{1i} \Delta y_{t-i} + \sum_{i=0}^{m2} \beta_{2i} \Delta e_{t-i} + \sum_{i=0}^{m3} \beta_{3i} \Delta x_{t-i} + \sum_{i=0}^{m4} \beta_{4i} \Delta k_{t-i} + \sum_{i=0}^{m5} \beta_{5i} \Delta l_{t-i} + \gamma \varepsilon_{t-1} + \mu_t \quad (2)$$

where Δ represents change, γ is the speed of adjustment parameter and ε_{t-1} is the lagged error term, which is estimated from the residuals of equation (1). The Engle-Granger method requires all of the variables in equation (1) to be integrated of order one, $I(1)$ and the error term is integrated to be order of zero, $I(0)$ for establishing a cointegration relationship. If some variables in equation (1) are non-stationary, we may use a new cointegration method offered by Pesaran *et al*. [7]. This approach, also known as autoregressive-distributed lag (ARDL), combines Engle-Granger [32] two steps into one by replacing ε_{t-1} in equation (2) with its equivalent from equation (1). ε_{t-1} is substituted by linear combination of the lagged variables as in equation (3).

$$\Delta y_t = \delta_0 + \sum_{i=1}^{n1} \delta_{1i} \Delta y_{t-i} + \sum_{i=0}^{n2} \delta_{2i} \Delta e_{t-i} + \sum_{i=0}^{n3} \delta_{3i} \Delta x_{t-i} + \sum_{i=0}^{n4} \delta_{4i} \Delta k_{t-i} + \sum_{i=0}^{5} \delta_{5i} \Delta l_{t-i} + \delta_6 y_{t-1} + \delta_7 e_{t-1} + \delta_8 x_{t-1} + \delta_9 k_{t-1} + \delta_{10} l_{t-1} + \mu_t \quad (3)$$

Equation (3) can be further transformed to accommodate the one period lagged error correction term (EC_{t-1}) as in equation (4):

$$\Delta y_t = \theta_0 + \sum_{i=1}^{q1} \theta_{1i} \Delta y_{t-i} + \sum_{i=0}^{q2} \theta_{2i} \Delta e_{t-i} + \sum_{i=0}^{q3} \theta_{3i} \Delta x_{t-i} + \sum_{i=0}^{q4} \theta_{4i} \Delta k_{t-i} + \sum_{i=0}^{q5} \theta_{5i} \Delta l_{t-i} + \lambda EC_{t-1} + \mu_t \quad (4)$$

A negative and statistically significant estimation of λ not only represents the speed of adjustment but also provides an alternative means of supporting cointegration between the variables. EC_{t-1} is formed using the long-run coefficient estimates from equation (3). Pesaran *et al's* cointegration approach, also known as bounds testing, has certain econometric advantages in comparison to other single cointegration procedures. They are as follows: i) endogeneity problems and inability to test hypotheses on the estimated coefficients in the long-run associated with the Engle-Granger method are avoided; ii) the long-run and short-run parameters of the model in question are estimated simultaneously; iii) the ARDL approach to testing for the existence of a long-run relationship between the variables in levels is applicable irrespective of whether the underlying regressors are purely $I(0)$, purely $I(1)$, or fractionally integrated; iv) the small sample properties of the bounds testing approach are far superior to that of multivariate cointegration, as argued in Narayan [33].

The bounds testing procedure is based on the Fisher (F) or Wald-statistics and is the first stage of the ARDL cointegration method. Accordingly, a joint significance test that implies no cointegration hypothesis, (H_0: $\delta_6 = \delta_7 = \delta_8 = \delta_9 = \delta_{10} = 0$), against the alternative hypothesis, (H_1: at least one of $\delta_6 .... \delta_{10}$ is different then zero) should be performed for equation (3). The F-test used for this procedure has a non-standard distribution. Narayan [33] computes two sets of critical values for a given significance level with and without a time trend for small samples between 30 to 80 observations. One set assumes that all variables are $I(0)$ and the other set assumes they are all $I(1)$. If the computed F-statistic exceeds the upper critical bounds value, then the H_0 is rejected. If the F-statistic falls into the bounds then the test becomes inconclusive. Lastly, if the F-statistic is below the lower critical bounds value, it implies no cointegration.

Equation (3) provides the short-run and long-run effects simultaneously after the adjustment is completed. The short-run effects between the dependent and independent variables are inferred by the size of δ_{2i}, δ_{3i}, δ_{4i}, and δ_{5i}. The long-run impacts are inferred by the estimates of δ_7, δ_8, δ_9, and δ_{10} that are normalized on estimate of δ_6.

The ARDL cointegration procedure is utilized by researchers in energy studies, see for example ([34, 35, 36]). The ARDL bounds test of cointegration is complemented by Johansen and Juselius's [37] maximum likelihood to provide a sensitivity check on the results.

Since the Johansen and Juselius's [37] multivariate cointegration methodology is fairly well documented, a brief reminder of it is illustrated below:

$$Z_t = \mu + \sum_{i=1}^{s} \Gamma_i Z_{t-i} + e_t \qquad (5)$$

where Z_t represents vector of endogenous $I(1)$ variables i.e., $[y_t, e_t, x_t, k_t, l_t]$, is μ is an vector of constant terms, Γ represents coefficient matrix , s denotes the lag length, and e_t is the residual matrix. All variables in equation (5) are deemed to be potentially endogenous. The cointegrating rank can be found via the trace and the maximal eigenvalue tests. The lag length of the unrestricted VAR (vector autoregresion) structure in equation (5) is decided on the basis of several criteria but AIC, SBC, and the adjusted Likelihood Ratio (LR) test are the most commonly used. Cheung and Lai [38] argues that the critical values of Johansen and Juselius [37] should be scaled in order to allow more appropriate statistical inferences in small samples. The implied scaling factor (SF) is given by the following formula:

$$SF = T/(T - ns) \qquad (6)$$

where T is the effective number of observations, n is the number of variables in the estimated system, and s is the lag parameter.

The Granger representation theorem suggests that there will be Granger causality in at least one direction if there exists a cointegration relationship among the variables in equation (1), providing that they are integrated order of one. Engle and Granger [32] caution that the Granger causality test, which is conducted in the first-differenced variables by means of a VAR, will be misleading in the presence of cointegration. Therefore, an inclusion of an additional variable to the VAR system, such as the error correction term would help us to capture the long-run relationship. To this end, an augmented form of the Granger causality test involving the error correction term is formulated in a multivariate *p*th order vector error correction model.

$$(1-L)\begin{bmatrix} y_t \\ e_t \\ x_t \\ k_t \\ l_t \end{bmatrix} = \begin{bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} d_{11i}d_{12i}d_{13i}d_{14i}d_{15i}d_{16i} \\ d_{21i}d_{22i}d_{23i}d_{24i}d_{25i}d_{26i} \\ d_{31i}d_{32i}d_{33i}d_{34i}d_{35i}d_{36i} \\ d_{41i}d_{42i}d_{43i}d_{44i}d_{45'}d_{46i} \\ d_{51i}d_{52i}d_{53i}d_{54i}d_{55i}d_{56i} \end{bmatrix}\begin{bmatrix} y_{t-i} \\ e_{t-i} \\ x_{t-i} \\ k_{t-i} \\ l_{t-i} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{bmatrix}\left[EC_{t-1}\right] + \begin{bmatrix} v_{1t} \\ v_{2t} \\ v_{3t} \\ v_{4t} \\ v_{5t} \end{bmatrix} \quad (7)$$

$(1-L)$ is the lag operator. EC_{t-1} is the error correction term, which is obtained from the long-run relationship described in equation (1), and it is not included in equation (7) if one finds no cointegration amongst the vector in question. The Granger causality test may be applied to equation (7) as follows: i) by checking statistical significance of the lagged differences of the variables for each vector; this is a measure of short-run causality; and ii) by examining statistical significance of the error-correction term for the vector that there exists a long-run relationship. As a passing note, one should reveal that equation (4) and (7) do not represent competing error-correction models because equation (4) may result in different lag structures on each regressors at the actual estimation stage; see Pesaran *et al.* [7] for details and its mathematical derivation. The recent application of this procedure can be found in [39, 40, 41]. All error-correction vectors in equation (7) are estimated with the same lag structure that is determined in unrestricted VAR framework; see for example, Narayan and Smyth [42]. This study utilizes the latter procedure. Beaudreu [43] provides an extensive framework for Granger causality tests concerning especially energy-GDP nexus.

The existence of a cointegration derived from equation (2) does not necessarily imply that the estimated coefficients are stable, as argued in Bahmani-Oskooee and Chomsisengphet [44]. The stability of coefficients of regression equations are, by and large, tested by means of Chow [45], Brown *et al*. [46], Hansen [47], and Hansen and Johansen [48]. The Chow stability test requires *a priori* knowledge of structural breaks in the estimation period and its shortcomings are well documented, see for example Gujarati [49]. In Hansen [47] and Hansen and Johansen [48] procedures, stability tests require $I(1)$ variables and they check the long-run parameter constancy without incorporating the short-run dynamics of a model into the testing - as discussed in Bahmani-Oskooee and Chomsisengphet [34]. Hence, stability tests of Brown *et al*. [46], which are also known as cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests based on the recursive regression residuals, may be employed to that end. These tests also incorporate the short-run dynamics to the long-run through residuals. The CUSUM and CUSUMSQ statistics are updated recursively and plotted against the break points of the model. Provided that the plots of these statistics fall inside the critical bounds of 5% significance, one assumes that the coefficients of a given regression are stable. These tests are usually implemented by means of graphical representation.

4. Results

Annual data over the period 1968-2008 were used to estimate equation (2) by the Pesaran *et al*. [7] procedure. Data definition and sources of data are cited in the Appendix.

The time series properties of the variables in equation (1) are checked through Augmented Dickey-Fuller (ADF) of Dickey and Fuller [50] and Phillips-Perron [51] unit root-testing procedures to make sure that none the variables are not above integrated order of one. All the series in equation (1) appear to contain a unit root in their levels but stationary in their first differences, indicating that they are integrated at order one i.e., $I(1)$. The results are displayed in Table 3. The visual inspection of the variables in logarithms does not suggest any structural breaks in time-series.

Table 3. Tests for integration[a]

ADF test statistic					Phillips-Peron test statistic				
Variable	Levels	*k* lag	1st Differences	*k* lag	Variable	Levels	*t* lag	1st Differences	*t* lag
y_t	-2.73	3	-3.74*	1	y_t	-1.41	5	-6.15*	5
e_t	-3.26	1	-4.04*	1	e_t	-2.37	5	-3.97*	5
x_t	-2.00	2	-3.75*	1	x_t	-1.78	5	-5.23*	5
k_t	-2.05	2	-3.25*	1	k_t	-1.95	5	-5.40*	5
l_t	-1.38	1	-4.82*	1	l_t	-1.78	5	-8.04*	5

[a] Sample levels 1974-2008 and differences 1975-2008. Rejection of unit root hypothesis, according to McKinnon's [52] critical value at 5 % is indicated with an asterisk. ADF tests include an intercept and a 1 to 5 lagged difference variable and *k* stands for the lag level that maximizes the AIC (Akaike Information Criteria). Phillips-Peron tests have also an intercept and *t* stands for the selected truncation lag level.

Equation (2) was estimated in two stages. In the first stage of the ARDL procedure, the long-run relationship of equation (1) was established in two steps. Firstly, the order of lags on the first-differenced variables for equation (2) was obtained from unrestricted VAR by means of Akaike Information Criterion and Schwarz Bayesian Criterion. The results of this stage are not displayed here to conserve space. Secondly, a bounds F-test was applied to equation (3) in order to establish a long-run relationship between the variables.

In order to avoid a possible lag selection problem at this stage, one may follow the procedure of Bahmani-Oskooee and Goswami [43], which sequentially test the long-run cointegration relationship in equation (2) to test the sensitivity of F-tests to the lag length. This study adopts the second approach which implicitly assumes that equation

(3) is free from a trend due to the differenced variables. In summary, the F- test indicates that there exists one cointegration relationship in which the dependent variable is *y*. Evidence of cointegration among variables also rules out the possibility of estimated relationship being "spurious". The results of the bounds F testing are displayed in Panel A of Table 4.

Table 4. Cointegration test results

Panel A: ARDL bounds cointegration test

	Calculated F-statistics for different lag lengths		
	1 lags	3 lags	5 lags
$F_C(y \mid e,x,k,l)$	1.97	2.56	4.81

Panel B: Johansen cointegration test

Cointegration LR test based on the maximum eigen values of the stochastic matrix, which includes y_t, e_t, x_t, k_t, l_t.

Hypothesized number of cointegrating vectors	Eigenvalue	95% CV	90% CV
None*	49.11	25.81	23.81
At most 1*	24.16	21.20	19.35
At most 2	13.39	16.53	14.89

Notes for the ARDL bounds cointegration test: the critical value ranges of F-statistics with four explanatory variables are 4.42 – 6.25, 3.20 – 4.54 and 2.66 – 3.83 at 1%, 5% and 10% level of significances, respectively. See Narayan [33], p.1988, Case III.
Notes for the Johansen cointegration test: * and ** denote rejection of null hypothesis at 5 % and 10 %, respectively. The critical values (CV) are scaled in accordance to Cheung and Lai [38].

Given the existence of a long-run relationship, in the next step, the ARDL cointegration procedure was implemented to estimate the parameters of equation (2) with maximum order of lag set to 2 to minimize the loss of degrees of freedom.

The long-run results of equation (3) based on SBC criteria are reported in Panel A of Table 5 along with their appropriate short-run results and diagnostics.

The diagnostic test results of equation (3) for short-run estimations are also displayed in Panel C of Table 5. All short-run models pass a series of standard diagnostic tests such as serial correlation, functional form, and heteroscedasticity, except normality.

The robustness of ARDL bounds test of cointegration is checked by the Johansen and Juselius's [37] maximum likelihood cointegration approach. The VAR estimation is conducted at levels of the variables. The optimal lag length is found to be two, based on the AIC model selection criterion. The results from this test are displayed in Panel B of Table 4. As panel B of Table 4 reveals, there exists also one cointegration relationship amongst the variables, which confirm the results of the Peasaran *et al*. [7] cointegration approach.

Table 5. ARDL cointegration results

Panel A: the long-run coefficients Dependent variable y_t			Panel B: the short-run coefficients Dependent variable Δy_t		
Regressors	coefficient	t-ratio	Regressors	coefficient	t-ratio
e_t	0.22	2.39*	Δe_t	0.15	1.96**
x_t	0.02	0.55	Δx_t	0.01	0.53
k_t	0.16	2.60**	Δk_t	0.31	5.60*
l_t	0.53	1.24	Δl_t	0.36	1.16
Constant	7.32	19.77*	EC_{t-1}	-0.68	3.95*

Panel C: the short-run diagnostic test statistics

$\chi^2_{SC}(1)$=1.32	$\chi^2_{FC}(1)$=0.82	$\overline{R}^2$=0.63	DW-statistic=1.93
$\chi^2_N(2)$=7.29	$\chi^2_H(1)$=0.40	RSS=0.04	F-statistic=13.26*

The estimated ARDL model is based on SBC with the lag orders of (1,0,0,1,0). * and ** indicate 5 % and 10 % significance levels, respectively. T-ratios are in absolute values. χ^2_{SC}, χ^2_{FF}, χ^2_N, and χ^2_H are Lagrange multiplier statistics for tests of residual correlation, functional form mis-specification, non-normal errors and heteroskedasticity, respectively. These statistics are distributed as chi-squared variates with degrees of freedom in parentheses. The critical values for $\chi^2(1)=3.84$ and $\chi^2(2)=5.99$ at 5% significance level.

According to the cointegration test results revealed in Table 4, there exists one cointegrating relationship in the form of $[y_t, e_t, x_t, k_t, l_t]$. Therefore, the Granger causality test was conducted to equation (7) as such that only one long-run relationship was estimated with an error correction term. However, the Granger causality tests were applied to other models without the error-correction terms, since one could not ascertain any long-run relationship for the other vectors. The statistical significance of the coefficients associated with the error correction term provides evidence of an error correction mechanism that drives the variables back to their long-run relationship. Table 6 summarizes the results of the long-run and short-run Granger causality. According to the coefficient on the lagged error-correction term, there exists a long-run relationship among the variables in the form of equation (1) as the error-correction term is statistically significant, which also confirms the results of the bounds test.

Table 6 displays that there exists one long-run Granger causality case, which runs interactively through the error-correction terms from energy consumption, exports, capital and labour to the aggregate output. In the case of short-run causality tests, Table 6 reveals there are also two meaningful bidirectional relationships. The first one states that Granger causality between electricity consumption and GDP runs in both directions. The second bilateral causality runs between exports and energy consumption.

Table 6. Results of Granger causality

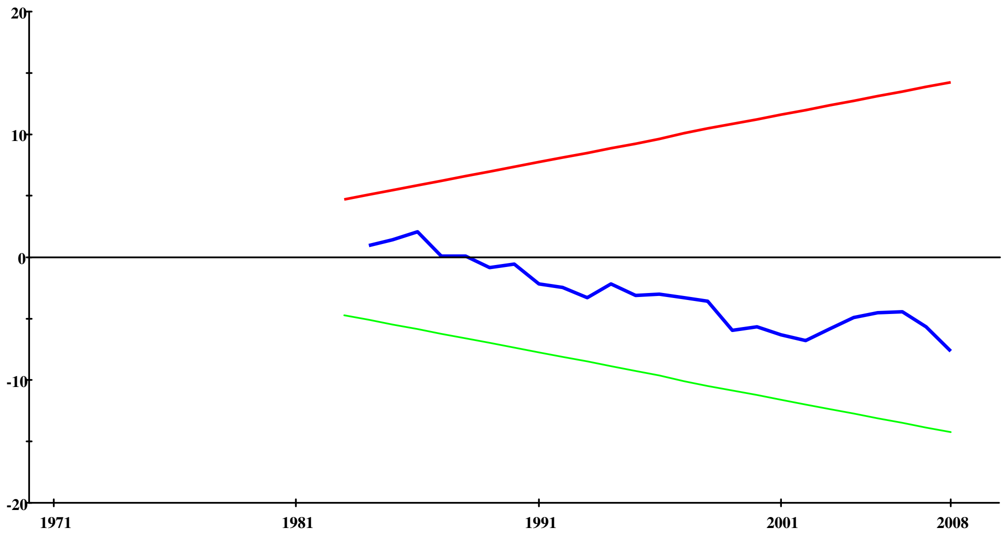
	F-statistics (probability)					
Dependent Variable	Δy_t	Δe_t	Δx_t	Δk_t	Δl_t	EC_{t-1} (*t*-statistics)
Δy_t	-	2.69^{**} (0.08)	2.78^{**} (0.08)	1.26 (0.29)	2.72^{**} (0.08)	-0.35 $(2.15)^{*}$
Δe_t	3.25^{*} (0.05)	-	2.63^{**} (0.09)	0.69 (0.50)	1.62 (0.21)	-
Δx_t	2.82^{*} (0.07)	0.86 (0.43)	-	4.42^{*} (0.02)	0.73 (0.48)	-
Δk_t	3.16^{*} (0.05)	3.59^{*} (0.04)	0.68 (0.51)	-	4.55^{*} (0.02)	-
Δl_t	0.05 (0.94)	0.77 (0.47)	1.58 (0.22)	0.47 (0.62)	-	-

Causality inference : $y \leftrightarrow e$, $y \leftrightarrow$x, $x \rightarrow e$, $l \rightarrow y$, $k \rightarrow y$, $e \rightarrow k$, $l \rightarrow k$.

* and ** indicate 5 % and 10 % significance levels, respectively. The probability values are in brackets. The optimal lag length is 2 and is based on SBC.

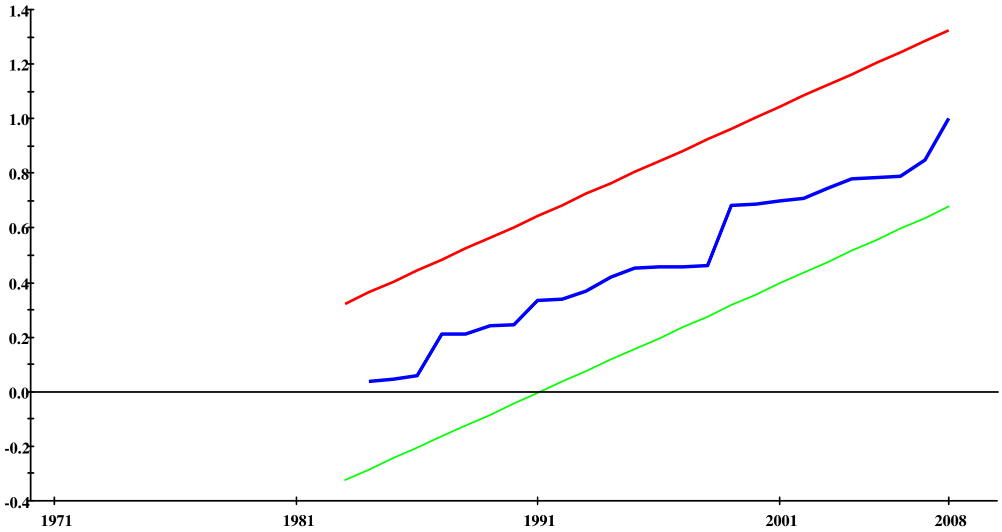
The SBC based error-correction model of equation (3) is selected to implement the CUSUM and CUSUMSQ stability tests. The related graphs of these tests are presented in Figures 1 and 2. As can be seen from Figures 1 and 2, the plots of CUSUM and CUSUMSQ statistics are well within the critical bounds, implying that all coefficients in the error-correction model are stable. Therefore, the estimated model can be used for policy decision-making purposes, such that the impact of policy changes considering the explanatory variables of equation (3) will not cause major distortion in the level of aggregate output, since the parameters in this equation seem to follow a stable pattern during the estimation period.

Figure 1: CUSUM



The straight lines represent critical bounds at 5% significance level

Figure 2: CUSUMSQ



The straight lines represent critical bounds at 5% significance level

5. Conclusions

This study attempted to test multiple hypotheses amongst the aggregate variables of output, energy, exports, capital and labour. To this extent, an augmented form of neo-classical production model is formed. This model is estimated by the cointegration approach of Pesaran et al, suggested a long-run relationship amongst the variables.

The results of augmented Granger causality tests revealed that there is a causality running interactively through the error-correction terms from energy consumption, exports, capital and labour to the aggregate output in the long-run. This implies that energy conservation policies may not be feasible since they will have negative impact on economic activity in the long-run. Moreover, this is particularly important in regards to the current concern that there is a world wide pressure on reducing carbon dioxide (CO_2) emissions, which are commonly accepted as the main source of global warming. This pressure also leads to the restricted use of fossil fuels. In order to avoid falling behind her targets of CO_2 reductions without decreasing the economic growth, Turkey should rapidly invest in energy infrastructure that energy is produced from renewable resources such as hydroelectricity, wind power, hydropower, solar, biofuel etc.

In the short-run, the existence of bilateral causality between energy consumption and GDP suggests that Turkey should implement a dual strategy of investment by investing in electricity infrastructure and by stepping up electricity conservation policies to avoid a reduction in electricity consumption adversely affecting economic growth. In the short-run, there is a unilateral causality running from exports to energy suggesting that energy conservation policies can be expected to have no adverse effect on export growth. This study has also found a feedback relationship in the short-run between exports and economic growth. Therefore economic policies should provide incentives for expanding the scale of economies and efficiency improvements with a view of rising exports. The gains from exports should be invested to research and development activities to reduce the production costs in industries.

Appendix

Data definition and sources

All data are collected from International Financial Statistics of the International Monetary Fund (IMF) [53], World Development Indicators of the World Bank (WB) [54] and Annual Statistics of the Turkish Statistical Institute (TSI) [55].

y is per capita real gross national income in Turkish Lira, in logarithm. Base year is 2000=100. Sources: IMF and TSI.

e is per capita energy consumption in kwh, in logarithm. Source: WB.

x is per capita real exports in Turkish Lira, in logarithm. Base year is 2000=100. Sources: IMF and TSI.

k is per capita gross capital stock in Turkish Lira in logarithm. Base year is 2000=100. Sources: IMF and TSI.

l is labour force participation rate, in logarithm. Source: TSI.

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