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SEASONAL ERROR CORRECTION MODELS FOR MACROECONOMIC VARIABLES: THE CASE OF TURKISH ECONOMY [1, 2]

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ABSTRACT

In this research, it has been aimed to examine seasonal long-term relationships and to estimate seasonal error correction model (SECM) which is the second step in the presence of cointegrating relationships for quarterly Gross Domestic Product (GDP), Gross Fixed Capital Formation (INV), Imports (IMP), Consumption of Resident Households (CONS) and Government Final Consumption Expenditures (GOV) variables for Turkey covering 1998Q1-2017Q3 period. HEGY(1990) approach has been utilized for seasonal unit root analyses and seasonal error correction mechanisms have been estimated based on the study of Engle, Granger, Hylleberg, Lee (EGHL) (1993). Findings have revealed that when dependent variable is INV, SECM(3) has worked at 1/2 frequency and 38.9% of deviations from long-run equilibrium in INV variable will be corrected at one period. Based on SECM(2) estimation at ½ frequency, 30.9% of deviations from IMP will disappear at one period under 10% significance level. At ¼ frequency, SECM(1) results for GOV and CONS dependent variables have shown that approximately 55% of deviations from long-run equilibrium in both variables will disappear at one period. ECM has not worked for dependent variable "GOV" at ¾ frequency depending upon the positive value of error correction term. Additively, SECM(2) has been working at ¼ frequency for dependent variable "IMP".

Keywords: EGHL, Gross Domestic Product, HEGY, Seasonal Cointegration, Seasonal Error Correction Model.

JEL Codes: C13, C22, E20.

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MAKROEKONOMİK DEĞİŞKENLER İÇİN MEVSİMSEL HATA DÜZELTME MODELLERİ: TÜRKİYE EKONOMİSİ ÖRNEĞİ

ÖZ

Bu çalışmada Türkiye ekonomisi için 1998Q1-2017Q3 dönemini kapsayan çeyreklik Gayrisafi Yurt İçi Hasıla (GDP), Gayrisafi Sabit Sermaye Oluşumu (INV), İthalat (IMP), Yerleşik Hanehalklarının Tüketimi (CONS) ve Devletin Nihai Tüketim Harcamaları (GOV) değişkenleri arasında mevsimsel eşbütünleşik ilişki olup olmadığının incelenmesi ve eşbütünleşik ilişkinin varlığı durumunda analizin ikinci adımı olan mevsimsel hata düzeltme modellerinin (SECM) tahmin edilmesi amaçlanmıştır. Mevsimsel hata düzeltme mekanizmaları Engle, Granger, Hylleberg, Lee (EGHL) (1993)'nin mevsimsel eşbütünleşme çalışmasına dayanarak tahmin edilmiştir. Mevsimsel eşbütünleşme için serilerin aynı frekanslarda bütünleşik olmaları gerektiğinden mevsimsel birim kök analizleri için HEGY (1990) yaklaşımı kullanılmıştır. ½ frekansında bağımlı değişkenin INV olduğu durumda SECM(3) modeli tahmin edilmiş olup hata düzeltme mekanizmasının çalıştığı tespit edilmiştir. Buna göre yatırımda uzun dönem dengesinden sapmaların yaklaşık %38.9'u bir dönemde düzeltilecektir. 1/2 frekansında SECM(2) tahminlerine göre %10 anlamlılık düzeyinde ithalattaki sapmaların yaklaşık %30.9'u bir dönemde ortadan kalkacaktır. Bağımlı değişkenlerin GOV ve CONS olduğu durumlarda SECM(1) tahminlerine göre ¼ frekansında uzun dönem dengesinde her iki değişkende yaşanan sapmaların yaklaşık %55'inin bir dönemde ortadan kalktığı tespit edilmiştir. ¾ frekansında ise hata düzeltme terimi pozitif çıktığından GOV değişkeni için uzun dönem dengesinden sapmaların dengeye dönmesi kısa dönemde sağlanamamıştır. Bağımlı değişkenin IMP olduğu durumda ise SECM(2) modeline göre hata düzeltme mekanizması ¼ frekansında çalışmaktadır.

Anahtar Kelimeler: EGHL, Gayri Safi Yurt İçi Hasıla, HEGY, Mevsimsel Eşbütünleşme, Mevsimsel Hata Düzeltme Modeli.

Jel Kodları: C13, C22, E20.

INTRODUCTION

As it is well known, most macroeconomic time series are measured at seasonal frequencies and when they represent strong stochastic seasonality features implied by the existence of a seasonal unit root, the usual cointegration test at zero (long-run) frequency does not take long-run relationships between variables at seasonal frequencies into consideration. Starting from the valuable contributions regarding seasonal integration and cointegration analyses provided by Hylleberg, Engle, Granger and Yoo (HEGY) (1990), Engle, Granger, Hylleberg and Lee (EGHL) (1993) have extended the seasonal cointegration approach which is conducted in case two or more series include unit roots at the same seasonal frequencies. As the second step of EGHL (1993) approach, seasonal error correction models (SECMs) are estimated in order to make an obvious distinction between long-run and short run and through these models, speed of adjustment coefficients are detected implying the rate at which deviations from long-run equilibrium are corrected at one period of time, therefore also revealing short-run dynamics between variables. There are many studies which have commonly taken place in the literature by making use of long-run relationships and error correction models for quarterly data.

Kunst (1990) has examined four European countries (Austria, Federal Republic of Germany, Finland and the United Kingdom) and found that these four economies represent strong cointegrating relationships at seasonal frequencies apart from the conventional cointegration at zero frequency proposed by Engle and Granger (1987) when six-dimensional quarterly macroeconomic series (gross domestic product, private consumption, gross fixed investment, exports of goods, real interest rate on bonds and real wage) are considered.

Mills and Mills (1992) have investigated seasonal patterns for quarterly macroeconomic time series of the United Kingdom. In spite of the fact that most variables include both seasonal and non-seasonal unit roots, Mills and Mills (1992) could not have detect any cointegrating relationship for long-run and seasonal frequencies between output and consumption and between output or prices and money.

Eberl (1998) has made a research on money-demand relationships for Germany utilizing from simple–sum and Divisia M3 as alternative monetary measures in a multivariate seasonal cointegration framework. In that research, four different money systems have been examined for 1975-1997 quarterly data through seasonal cointegration approach that was proposed by Kunst and Franses (1998) taking non-diverging seasonal trends feature of data into account and seasonal error correction models have been estimated for each system. All cointegration matrices have been estimated through canonical correlation analysis. As a conclusion, Eberl (1998) has reported that disequilibria from long-run equilibrium in Divisia systems have been corrected at a faster rate when compared to M3 models.

Mithani and Khoon (1999) have tried to investigate the causal relationships between quarterly government revenue and government expenditure in Malaysia covering 1970Q1-1994Q4 period. Before detecting causal relationships, there has been found a cointegrating relationship at semi-annual frequency through the usage of seasonal cointegration approach which was developed by Hylleberg *et al*. (1990) and extended by Engle *et al.* (1993) and seasonal error correction model results have revealed that only revenue responds to budgetary disequilibria by implying a uni-directional causality.

Löf and Lyhagen (1999) have examined long-run relationships among gross domestic product, private consumption, gross fixed investment, exports, real wages and real interest rates variables for Austria, Germany and United Kingdom. In their study, forecasting performances of seasonal cointegration model specifications proposed by Johansen and Schaumburg (1999) and Lee (1992) have also been compared based on the Monte Carlo study and the model specification suggested by Johansen and Schaumburg (1999) has been detected to have a better forecasting performance as general.

Cubadda (2001) has introduced a complex error correction model - that depends on partial canonical correlations - for seasonally cointegrated variables by presenting a reduced rank estimator and has applied the method for quarterly Italian macroeconomic time series which are household consumption, fixed investment and gross domestic product for the period 1973Q2-1997Q1. According to the findings, it has been concluded based on the annual cointegration relationship that the test that depends on the complex error correction model has presented strong evidence that are not detected by the Lee's procedure.

Wu (2004) has aimed to build a foreign trade model of China following the error correction modelling technique -based on the autoregressive distributed lags model- in order to determine the import and export equations clearly for the period of 1992Q1-2004Q3 and findings have revealed a dependence between imports and exports both in the long run and short run. In the long run, exports have responded to imports, world trade and the relative price of exports while imports have been determined by exports and gross domestic product.

Kızılgöl (2011) has investigated about the seasonal cointegrating relationships between quarterly gross domestic product, exports, consumption and investment variables covering the period 1987Q1-2007Q3 using HEGY (1990) and EGHL (1993) tests and detected a cointegrating relationship between gross domestic product and consumption series at ¼ (and ¾) frequency only for the model including both constant and seasonal dummy variables.

More recently, Mert and Demir (2014) have tried to reveal seasonal long-run relationships and estimate seasonal error correction models in the presence of cointegration for quarterly exports and imports series of Turkish economy covering the period of 1969Q1-2014Q1. As a result, one cointegrating vector has been detected at ¼ (and ¾) frequencies and exports of goods have been found to have a positive effect on imports of goods for the current and one-lagged period. Based on this result, seasonal error correction model has been estimated for these quarterly frequencies and findings have shown that seasonal error correction mechanism has worked at only ¼ frequency. In addition, 30% of deviations from long-run equilibrium in imports have been corrected at one period.

This paper has been organised as follows: Section 1 introduces the theoretical approach for bivariate seasonal cointegration and seasonal error correction models (SECMs) briefly, Section 2 presents research findings and the conclusion part presents a brief summary concerning the analysis.

1. THEORETICAL APPROACH

It is well known that many macroeconomic series have a nonstationary pattern in their natures and in case they include seasonal nonstationary patterns, seasonal differencing transaction can eliminate such a pattern in a stochastic seasonal model. By implication, it is vital to detect the kind of seasonality in variables as about to deterministic or stochastic in applying seasonal differencing transaction; since nonstationarity and non-invertibility situations can lead to serious problems in parameter estimation and forecasting (Türe & Akdi, 2005: 3).

In detecting seasonal unit roots, it has been utilized from the most popular HEGY test procedure proposed by Hylleberg *et al.* (1990) which investigates unit roots at all seasonal frequencies as well as at the zero frequency. Depending on the usage of quarterly data in the analysis, seasonal variations in the variables have been removed through the seasonal difference filter $\Delta_4 = (1-L)^4$ where L denotes lag operator $L^j y_t = y_{t-j}$. In Table 1, frequencies & roots and the information of necessary filters corresponding to various frequencies in order to make the variables stationary at given frequency in the case of nonstationarity have been presented for quarterly data.

Table-1: Long Run and Seasonal Frequencies for Seasonal Unit Root Tests in Quarterly Data

Frequency	Period	Cycles/year	Root	Filter	Tested hypothesis H_0: Unit Root
0 Long run	∞	0	1	$(1-L)$	$\pi_1 = 0$
$\frac{\pi}{2}, \frac{3\pi}{2}$ **Annual**	$4; \frac{4}{3}$	1; 3	$\pm i$	$(1+L^2)$	$\pi_3 \cap \pi_4 = 0$
π **Semiannual**	2	2	-1	$(1+L)$	$\pi_2 = 0$

Note. Information on first five columns have been obtained from Diaz-Emparanza & López-de-Lacalle (2006: 7).

According to HEGY test results, the evidence that the series are integrated of the same order at the same frequencies has been revealing the possibility about the presence of a seasonal long-term relationship between the series. In this study, information on whether there is a stationary relation between the non-stationary series or not has been examined based on the seasonal cointegration theory developed by Hylleberg *et al.* (1990) and extended by Engle *et al.* (1993) which performs seperate cointegration analyses for each frequency (Mert & Demir, 2014: 15). By taking the following polynomials into consideration,

$$Z_1 = (1+L)(1+L^2) = (1+L+L^2+L^3) \quad (1)$$

$$Z_2 = -(1-L)(1+L^2) = -(1-L+L^2-L^3) \quad (2)$$

$$Z_3 = -(1-L)(1+L) = -(1-L^2) \quad (3)$$

HEGY (1990) testing equation with a time series y_t that implies a univariate process can be expressed as

$$(1-L^4)y_t = \alpha_1 D_{1,t} + \alpha_2 D_{2,t} + \alpha_3 D_{3,t} + \alpha_4 D_{4,t} + \delta.t + \pi_1 Z_1 y_{t-1} + \pi_2 Z_2 y_{t-1} + \pi_3 Z_3 y_{t-2} + \pi_4 Z_3 y_{t-1}$$
$$+ \sum_{i=1}^{p} \phi_i (1-L^4) y_{t-i} + \varepsilon_{it} \quad (4)$$

where p denotes the number of lagged terms added into the regression in order to make sure about that residuals are white noise, the $D_{i,t}$s represent seasonal dummy variables. Following the given polynomial filters through Equations (1) to (3), seasonal cointegration could be explained for different cycles as follows:

1. Cointegration at the single period cycle

y_t is cointegrated at the long run (corresponding to the root of 1 with the factor of $(1-L)$) if there is a cointegrating vector α_1 such that the residuals u_t from

$$\alpha_1' Z_1 y_t = u_t \quad (5)$$

are stationary.

2. Cointegration at the two period cycles

y_t is cointegrated at the two period (or biannual) cycle (corresponding to the root of -1 with the factor of $(1+L)$) if there is a cointegrating vector α_2 such that the residuals v_t from

$$\alpha_2' Z_2 y_t = v_t \quad (6)$$

are stationary.

3. Cointegration at the four period cycles

y_t is cointegrated at the four period (or annual) cycle (corresponding to the complex roots of $+i$ and $-i$ with the factor of $(1+L^2)$) if there is a cointegrating vector $\alpha_3 + \alpha_4.L$ such that the residuals w_t from

$$(\alpha_3' + \alpha_4' L) Z_3 y_t = w_t \quad (7)$$

are stationary.

In order to build an error correction model taking cointegration cases at all cycles given above into consideration, two criteria should be satisfied. Primarily, a term corresponding to all given possible cases of cointegration must be incorporated into an error correction model. Secondly, integration orders of all variables in the final error correction equation should be zero (that is, $I(0)$). This second criterion is fulfilled through the usage of pre-filtered data Z_{it} instead of original series in the specification of the terms in the error correction equation. Such a general form of the error correction representation which was developed by Hylleberg *et al.* (1990) and Engle *et al.* (1990) has been given as

$$\phi(L)(1-L^4)y_t = \gamma_1 u_{t-1} + \gamma_2 v_{t-1} + (\gamma_3 + \gamma_4 .L)w_{t-1} + \varepsilon_t \quad (8)$$

where γ_i and the cointegrating parameters, α_i may be different at different frequencies. If there are no certain values for α_i proposed by an economic theory in interest, Hylleberg *et al.* (1990) and Engle, Granger, Hylleberg and Lee (1990) suggest a generalisation of the two stage procedure proposed by Engle and Granger (1987) (Hurn, 1993: 313-315).

Hurn (1993) has handled the topic of seasonal cointegration in the context of monetary policy using South African monetary data and defined an error correction representation with two variables case as in Equation (8) where y_t is nominal income and m_t is a monetary aggregate, with the normalization with respect to the former:

$$\begin{aligned}(1-L^4)y_t &= \sum_{i=1}^{m}\beta_i(1-L^4)y_{t-i} + \sum_{i=0}^{n}\delta_i(1-L^4)m_{t-i} + \gamma_1(Z_1 y_{t-1} - \alpha_{12}Z_1 m_{t-1}) + \gamma_2(Z_2 y_{t-1} - \alpha_{22}Z_2 m_{t-1}) \\ &+ (\gamma_3 + \gamma_4 .L)(Z_3 y_{t-1} - \alpha_{32}Z_3 m_{t-1} - \alpha_{41}Z_3 y_{t-2} - \alpha_{42}Z_3 m_{t-2}) + \varepsilon_{1t} \quad (9)\end{aligned}$$

Equation (9) represents the full seasonal error correction model and reduces to the simple error correction representation in the case of cointegration relationship being detected at all cycles implied also by $\alpha_{12} = \alpha_{22} = \alpha_{32} = \alpha$ and $\alpha_{41} = \alpha_{42} = 0$ restrictions (Engle & Granger, 1987; Granger, 1986). By adding the error correcting term $(y_{t-1} - \alpha m_{t-1})$ into the equation up to a maximum of four lags in order to capture the four unit roots to be removed (Hylleberg *et al.*, 1990), the model that will be estimated can be expressed as follows:

$$(1-L^4)y_t = \sum_{i=1}^{m}\beta_i(1-L^4)y_{t-i} + \sum_{i=0}^{n}\delta_i(1-L^4)m_{t-i} + \sum_{i=0}^{3}\gamma_i L^i(y_{t-1} - \alpha m_{t-1}) + \varepsilon_{2t} \quad (10)$$

Another model that will be estimated as a generalization of Equation (9) when there is cointegration at the single period cycle by filtered variables and at all other cycles by one cointegrating parameter with the restrictions $\alpha_{12} = \alpha$, $\alpha_{22} = \alpha_{32} = \alpha_s$ and $\alpha_{41} = \alpha_{42} = 0$ can be written as

$$(1-L^4)y_t = \sum_{i=1}^{m}\beta_i(1-L^4)y_{t-i} + \sum_{i=0}^{n}\delta_i(1-L^4)m_{t-i} + \gamma_1(Z_1 y_{t-1} - \alpha Z_1 m_{t-1})$$
$$+\sum_{i=0}^{2}\gamma_i L^i[(1-L)y_{t-1} - \alpha_s(1-L)m_{t-1}] + \varepsilon_{3t} \qquad (11)$$

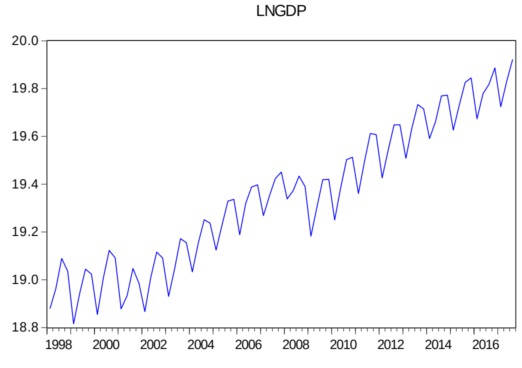
It can be inferred from the general error correction model (9) and this restricted model that seasonal cointegration is applied for the purpose of augmenting the short-run dynamics of the model and the long-run solution does not differ from the original simple error correction model and it can be feasible to estimate the seasonal error correction models expressed by equations (9), (10) and (11) by making use of the Engle-Granger two-step procedure (Hurn, 1993: 315-317) (Sanli, 2015: 109-112).

2. DATA SET AND RESEARCH FINDINGS

In this study, it has been tried to clarify cointegrating relationships between quarterly Gross Domestic Product (GDP) which has been calculated by expenditure approach in chain linked volume, Gross Fixed Capital Formation (INV), Imports of Goods and Services (IMP), Final Consumption Expenditures of Resident Households (CONS) and Government Final Consumption Expenditures (GOV) variables for Turkish Economy covering 1998Q1-2017Q3 period. All data used in the analysis have been extracted from Electronic Data Delivery System (EDDS) of Central Bank of the Republic of Turkey. In the analysis, logarithms of all series have been taken in order to linearize the exponential growth in series and all series have been used as seasonally unadjusted.

In Figure 1, the graphs of all variables have been presented in their logarithmic level forms for implying strong seasonality features of the series.

Figure-1: Logarithmic Level Graphs of GDP, CONS, GOV, IMP and INV Series



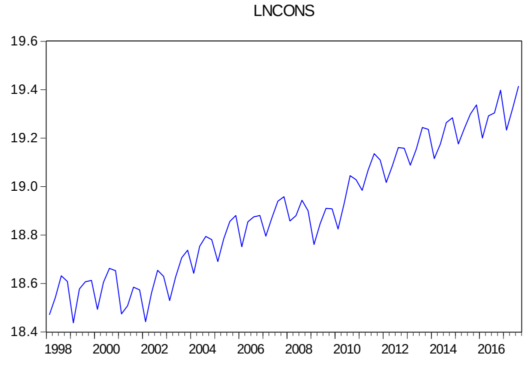
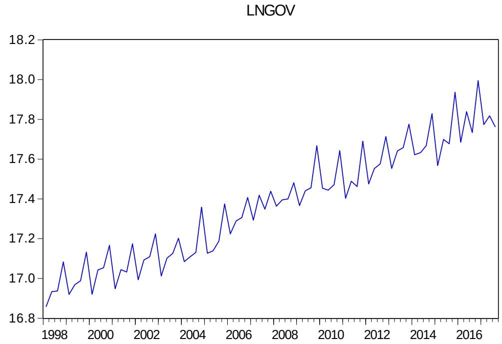
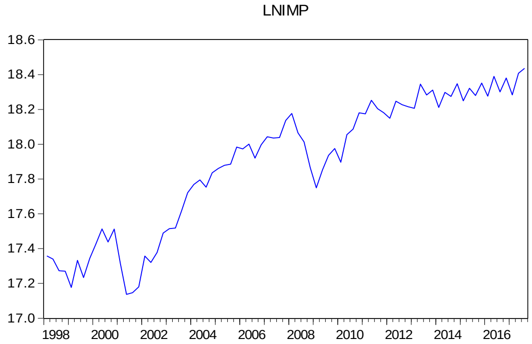
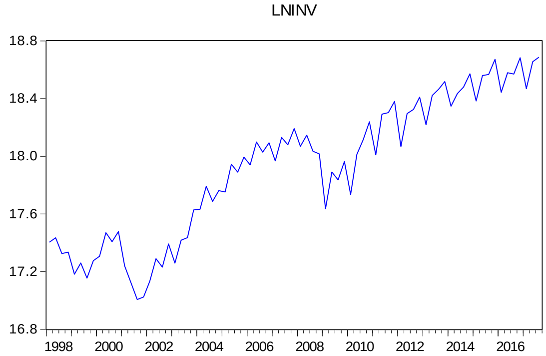


Figure 1 (Continued)







Since series have to be integrated of the same order at the same seasonal frequencies for being able to carry out seasonal cointegration analysis, the first step to reveal seasonal cointegrating relationships between given quarterly variables is to evaluate whether the variables include seasonal unit roots at which frequencies through the most popular Hylleberg *et al.* (HEGY) (1990) seasonal unit root procedure.

In Table 2, HEGY test results at $\theta = 0, \frac{1}{4}, \frac{1}{2}, \frac{3}{4}$ frequencies have been presented for quarterly macroeconomic series for five auxiliary regressions including deterministic components ("constant (C)", "seasonal dummies (SD)" and "trend (T)") and their various combinations. All results in Table 2 have been interpreted at 5% significance level. According to the findings, Table 2 results have shown that all variables include (non-seasonal) unit roots at zero (or long-run) frequency. Semi-annual ½ frequency unit roots have been come across at all variables except LNCONS. While LNINV, LNGDP and LNGOV series have unit roots at semi-annual frequency for only "C + SD" and "C + SD + T" models, LNIMP series include such a root for all five models. On the other hand, seasonal unit roots at quarterly ¼ (and ¾) frequencies have been observed in LNIMP, LNGOV and LNCONS variables for "C + SD" and "C + SD + T" models. The implication of these reported HEGY test results is that it is possible to have cointegration relationships between variables at 0, ½ and ¼ (and ¾) frequencies.

Table-2: HEGY Seasonal Unit Root Test Results for Quarterly Macroeconomic Series

Variables	Deterministic Components in Auxiliary Regressions	Lags	t(π_1)	t(π_2)	t(π_3)	t(π_4)	F (π_3,π_4)
LNGDP	-	1	**2.706 ***	-2.465	-3.890	**-0.985***	8.043
	C	1	**-2.383***	-2.595	-4.111	**-1.053***	8.998
	C + SD	1	**-2.346***	**-2.608***	-3.595	**-0.760***	6.747
	C + T	1	**-1.594***	-2.546	-4.096	**-1.001***	8.880
	C + SD + T	1	**-1.558***	**-2.559***	-3.580	**-0.674***	6.631
LNCONS	-	1	**1.645***	-2.441	-4.347	**-0.956***	9.896
	C	4	**-0.933***	-5.211	-2.388	**-1.173***	3.591
	C + SD	4	**-0.875***	-4.921	**-1.897***	**-0.928***	**2.253***
	C + T	4	**-1.175***	-5.174	-2.379	**-1.121***	3.509
	C + SD + T	4	**-1.188***	-4.908	**-1.897***	**-0.878***	**2.206***
LNINV	-	1	**-0.567***	-2.097	-2.906	-2.462	7.245
	C	1	**-1.492***	-2.013	-2.940	-2.289	6.941
	C + SD	1	**-1.454***	**-1.969***	**-2.996***	-2.402	7.363
	C + T	1	**-1.781***	-2.018	-2.940	-2.234	6.811
	C + SD + T	1	**-1.739***	**-1.976***	**-2.998***	-2.344	7.231
LNGOV	-	1	**2.432***	-2.614	-3.278	**-0.671***	5.554
	C	1	-4.729	-2.524	-3.293	**-0.273***	5.437
	C + SD	1	-4.523	**-2.006***	**-2.928***	**-0.006***	**4.290***
	C + T	1	**-3.069***	-2.570	-3.261	**-0.347***	5.349
	C + SD + T	4	**-2.089***	**-2.780***	**-3.156***	**0.494***	**5.048***
LNIMP	-	2	**-0.516***	**-0.782***	-2.144	-1.892	5.275
	C	2	**-1.605***	**-0.737***	-2.126	-1.725	4.796
	C + SD	2	**-1.592***	**-1.004***	**-2.210***	**-1.651***	**4.881***
	C + T	2	**-0.273***	**-0.732***	-2.141	-1.743	4.744
	C + SD + T	2	**-0.284***	**-0.995***	**-2.220***	**-1.668***	**4.811***

Notes. [1] * denotes insignificant values at 5% level.

[2] t-statistic for π_1 ($t(\pi_1)$) reveals if there is a unit root or not at long-run (or zero) frequency $(H_0:\pi_1=0)$. t-statistic for π_2 ($t(\pi_2)$) tests the existence of the semi-annual unit root $(H_0:\pi_2=0)$ while F- statistic for $\pi_3\cap\pi_4$ $(F(\pi_3,\pi_4))$ tests for a unit root at quarterly frequencies.

[3] -, C, SD and T denote "none (no deterministic component)", "constant", "seasonal dummies" and "trend" respectively.

[4] Critical values have been taken from Hylleberg *et al.* (1990: 226-227) for N=100 observations and 5% level. For zero frequency, critical values are -1.97, -2.88, -2.95, -3.47, -3.53; for semi-annual frequency, they are -1.92, -1.95, -2.94, -1.94, -2.94 and at 95% confidence level, critical values for the 'F' test on ($\pi_3\cap\pi_4$) are 3.12, 3.08, 6.57, 2.98, 6.60 respectively for "- ", "C", "C + SD", "C + T", "C + SD + T" models.

Right choice of lag augmentation may be of vital importance in terms of the power of the test and for this reason, lag augmentation has been given in "Lags" column in order to whiten residuals through lagged values of the given dependent variables as about to be used in auxiliary regressions (Engle *et al*, 1993: 279).

Table-3: Cointegration Test Results at Zero (Long Run) Frequency

	Cointegration Analysis: LNGDP and LNCONS			Auxiliary Regression	Tests for Unit Roots in Residuals	
Regressand	**Coefficient Regressor $LNGDP_{1t}$**	**Deterministic Components Included**	R^2	**Augmentation**	**DW**	**t statistic** $t(\pi_1)$
$LNCONS_{1t}$	0.167588 (3.078155)	C	0.999052	1, 2, 4	1.800443	-3.194069
$LNCONS_{1t}$	0.166476 (3.001575)	C, SD	0.999063	1, 2, 4	1.803338	-3.210807
$LNCONS_{1t}$	0.129206 (2.271444)	C, T	0.999103	1, 2, 4	1.977393	**-7.791350***
$LNCONS_{1t}$	0.128496 (2.218214)	C, SD, T	0.999113	1, 2, 4	1.968413	**-7.800096***
	Cointegration Analysis: LNGDP and LNINV			**Auxiliary Regression**	**Tests for Unit Roots in Residuals**	
Regressand	**Coefficient Regressor $LNGDP_{1t}$**	**Deterministic Components Included**	R^2	**Augmentation**	**DW**	**t statistic** $t(\pi_1)$
$LNINV_{1t}$	0.124625 (2.327621)	C	0.998022	1, 2, 4	1.806793	**-4.887996***
$LNINV_{1t}$	0.130593 (2.296892)	C, SD	0.997965	1, 2, 4, 5	1.795779	**-4.713680***
$LNINV_{1t}$	0.141036 (1.156194)	C, SD, T	0.997965	1, 2, 4, 5	1.794549	**-4.677433***
	Cointegration Analysis: LNGDP and LNGOV			**Auxiliary Regression**	**Tests for Unit Roots in Residuals**	
Regressand	**Coefficient Regressor $LNGDP_{1t}$**	**Deterministic Components Included**	R^2	**Augmentation**	**DW**	**t statistic** $t(\pi_1)$
$LNGOV_{1t}$	0.067823 (2.472562)	C	0.998131	1, 4, 5, 8	1.988328	**-7.693148***
$LNGOV_{1t}$	0.071127 (2.540005)	C, SD	0.998096	1, 4, 8	1.992207	**-7.569225***
$LNGOV_{1t}$	0.025572 (0.777183)	C, SD, T	0.998257	1, 4	1.986581	**-7.560167***
	Cointegration Analysis: LNGDP and LNIMP			**Auxiliary Regression**	**Tests for Unit Roots in Residuals**	
Regressand	**Coefficient Regressor $LNGDP_{1t}$**	**Deterministic Components Included**	R^2	**Augmentation**	**DW**	**t statistic** $t(\pi_1)$
$LNIMP_{1t}$	0.050668 (1.371841)	C	0.996767	1, 2, 4	1.964127	**-8.524644***
$LNIMP_{1t}$	0.050451 (1.336015)	C, SD	0.996775	1, 2, 4	1.964547	**-8.532239***
$LNIMP_{1t}$	-0.018759 (-0.246531)	C, SD, T	0.996830	1, 2, 4	1.964762	**-8.630255***

Note. [1] The auxiliary regression model to be used at zero frequency is $\Delta u_t = \pi_1 u_{t-1} + \sum_{j=1}^{k} b_j \Delta u_{t-j} + e_t$ (with no deterministic components) where u_t denotes the residuals obtained from the cointegration model that will be utilized for estimating this auxiliary regression model (Engle *et al.*, 1993: 289).
[2] The * denotes statistically significant values at 5% significance level.
[3] The values in parentheses represent *t*-statistics.
[4] The null hypothesis states that H_0 : There is no cointegration at zero frequency $(\pi_1 = 0)$.
[5] Critical values have been taken from Engle and Yoo (1987). See Appendix.

Since cointegrating relationships will be analysed between the series that are integrated at the same seasonal frequencies, empirical analyses have been based on transformed series at each frequency and cointegration models have been estimated using ordinary least squares approach. Necessary transformations in order to be able to carry out seasonal cointegration analysis depending upon the study of Engle *et al.* (EGHL) (2003) have been presented as follows:

$$LNGDP_{1t} = (1 + L + L^2 + L^3)LNGDP \quad (12)$$

$$LNGDP_{2t} = -(1 - L + L^2 - L^3)LNGDP \quad (13)$$

$$LNGDP_{3t} = -(1 - L^2)LNGDP \quad (14)$$

$$LNGDP_{4t} = (1 - L^4)LNGDP \quad (15)$$

Transformations given above have been expressed by using LNGDP variable and all other series have been transformed in the same manner by using the same filters given in equations from (12) to (15).

In Table 3, seasonal cointegration analysis results at zero frequency have been presented. $LNGDP_{1t}$, $LNCONS_{1t}$, $LNINV_{1t}$, $LNGOV_{1t}$ and $LNIMP_{1t}$ transformed series preserve long-run (non-seasonal) unit root by excluding seasonal unit roots. In the long run, according to the results of seasonal cointegration analysis interpreted at 5% significance level; while there has been found a cointegrating relationship between LNGDP & LNINV, LNGDP & LNGOV and LNGDP & LNIMP for “C”, “C + SD” and “C + SD + T” models, the cointegrating relationship between LNGDP & LNCONS has been detected for “C + T” and “C + T + SD” models. In addition, even though independent variables in the cointegrating regression have been found to be statistically significant, no cointegrating relationship has been detected between LNGDP & LNCONS for “C” and “C + SD” models.

Table-4: Seasonal Cointegration Test Results at Semi-Annual (½) Frequency

	Cointegration Analysis: LNGDP and LNINV			Auxiliary Regression	Analysis of the residuals	
Regressand	**Coefficient Regressor $LNGDP_{2t}$**	**Deterministic Components Included**	R^2	**Augmentation**	**DW**	***t* statistic** $t\ (\pi_2)$
$LNINV_{2t}$	1.512966 (6.397199)	C, D	0.949721	1, 2, 3, 4, 6, 10	1.894469	**-6.503690***
$LNINV_{2t}$	1.579642 (7.076700)	C, D, T	0.949009	1, 2, 4, 6	1.894032	**-7.151652***
	Cointegration Analysis: LNGDP and LNGOV			**Auxiliary Regression**	**Analysis of the residuals**	
Regressand	**Coefficient Regressor $LNGDP_{2t}$**	**Deterministic Components Included**	R^2	**Augmentation**	**DW**	***t* statistic** $t\ (\pi_2)$
$LNGOV_{2t}$	0.281501 (1.936489)	C, D	0.960674	1	2.022777	**-9.343383***
$LNGOV_{2t}$	0.294174 (1.880107)	C, D, T	0.961940	1, 4, 5	2.013018	**-9.161989***
	Cointegration Analysis: LNGDP and LNIMP			**Auxiliary Regression**	**Analysis of the residuals**	
Regressand	**Coefficient Regressor $LNGDP_{2t}$**	**Deterministic Components Included**	R^2	**Augmentation**	**DW**	***t* statistic** $t\ (\pi_2)$
$LNIMP_{2t}$	0.679634 (4.848388)	C	0.723363	2, 3, 4, 6	1.965862	**-7.822528***
$LNIMP_{2t}$	1.603168 (7.387434)	C, D	0.801073	1, 2, 3, 4	1.890554	**-7.156305***
$LNIMP_{2t}$	1.750969 (8.513290)	C, D, T	0.833498	1, 2, 3, 4, 8	1.714807	**-5.170963***

Note. [1] Only significant lags have been incorporated into the auxiliary regressions to obtain whitened residuals.

[2] The auxiliary regression model to be used at semi-annual frequency is $(\upsilon_t + \upsilon_{t-1}) = \pi_2(-\upsilon_{t-1}) + \sum_{j=1}^{k} b_j(\upsilon_{t-j} + \upsilon_{t-j-1}) + e_t$ (with no deterministic components) where υ_t denotes the residuals obtained from the cointegration model that will be used for estimating this auxiliary regression model (Engle *et al.*, 1993: 290). For critical values see Appendix.

[3] * denotes statistically significant values at 5% significance level.

[4] The null hypothesis states that H_0 : There is no cointegration at semi-annual frequency $(\pi_2 = 0)$.

According to Table 4 which shows seasonal cointegration analysis findings at semi-annual (½) frequency for 5% significance level, cointegrating relationships have been detected between LNGDP & LNINV, LNGDP & LNGOV and LNGDP & LNIMP for "C + SD" and "C + SD + T" models when Engle and Yoo (1987) critical values are taken into consideration. One cointegrating relationship has been found between LNGDP & LNIMP also for the model with "C". In Table 4, $LNGDP_{2t,}$ $LNINV_{2t,}$ $LNIMP_{2t}$ and $LNGOV_{2t}$ transformed series have been formed in a way that will preserve semi-annual frequency unit root while eliminating seasonal unit roots at zero and quarterly frequencies.

Table-5: Seasonal Cointegration Test Results at ¼ (¾) Frequencies

	Cointegration Analysis: LNGDP and LNGOV				Analysis of the residuals		
Regressand	**Coefficient Regressor** **LNGDP$_{3t}$**	**LNGDP$_{3t-1}$**	**Deterministic Components Included**	R^2	***t* statistic** $t\ (\pi_3)$	***t* statistic** $t\ (\pi_4)$	***F* statistic** $\pi_3 \cap \pi_4$
LNGOV$_{3t}$	0.273191 (3.550245)	0.167361 (1.985386)	C	0.869977	**-8.488095***	-1.012981	**37.93986***
LNGOV$_{3t}$	0.259379 (1.720897)	0.011549 (0.077095)	C, D	0.875503	**-7.787641***	-1.645662	**34.99922***
	Cointegration Analysis: LNGDP and LNIMP				**Analysis of the Residuals ‘HEGY’ test**		
Regressand	**Coefficient Regressor** **LNGDP$_{3t}$**	**LNGDP$_{3t-1}$**	**Deterministic Components Included**	R^2	***t* statistic** $t\ (\pi_3)$	***t* statistic** $t\ (\pi_4)$	***F* statistic** $\pi_3 \cap \pi_4$
LNIMP$_{3t}$	0.127862 (1.867544)	0.006022 (0.085036)	C	0.507685	**-7.653489***	0.038278	**29.43219***
LNIMP$_{3t}$	1.110421 (3.902293)	0.068641 (0.214957)	C, D	0.583233	**-6.536573***	-0.708867	**21.93267***
	Cointegration Analysis: LNGDP and LNCONS				**Analysis of the residuals**		
Regressand	**Coefficient Regressor** **LNGDP$_{3t}$**	**LNGDP$_{3t-1}$**	**Deterministic Components Included**	R^2	***t* statistic** $t\ (\pi_3)$	***t* statistic** $t\ (\pi_4)$	***F* statistic** $\pi_3 \cap \pi_4$
LNCONS$_{3t}$	0.728017 (13.35445)	-0.000258 (-0.013056)	C	0.952293	**-5.266582***	**-2.768036***	**23.14049***
LNCONS$_{3t}$	0.725366 (8.698398)	-0.014537 (-0.148567)	C, D	0.952413	**-5.304119***	**-2.750255***	**23.17730***

Note. [1] The auxiliary regression model that is used for determining cointegration at ¼ (and ¾) frequencies can be expressed as

$$(w_t + w_{t-2}) = \pi_3(-w_{t-2}) + \pi_4(-w_{t-1}) + \sum_{j=1}^{k} b_j (w_{t-j} + w_{t-j-2}) + e_t \quad \text{(with no deterministic components)}$$

where w_t denotes the residuals obtained from cointegration model that will be used for estimating the auxiliary regression models (Engle *et al.*, 1993: 290).

[2] * denotes statistically significant values at 5% significance level.

[3] Critical values have been taken from Engle *et al.* (1993). See Appendix for critical values.

[4] The null hypothesis states that H_0 : There is no cointegration at ¼ (and ¾) frequencies $(\pi_3 \cap \pi_4 = 0)$.

In Table 5, seasonal cointegration analysis results at quarterly ¼ (¾) frequencies have been presented. According to this, there has been found a cointegration relationship between LNGDP & LNGOV, LNGDP & LNIMP and LNGDP & LNCONS series at ¼ (and ¾) frequencies for “C” and “C + SD” models at 5% significance level.

Since long-run relationships have been determined at ½ and ¼ (3/4) frequencies, the next step is to estimate seasonal error correction models at these frequencies in order to examine short-term dynamics. The appropriate lag lengths have been identified depending on the Schwarz Information Criterion. As expressed in the theoretical approach, seasonal error correction models have been formed based on the studies proposed by Hylleberg *et al.* (1990) and Engle *et al.* (1993).

Table-6: Seasonal Error Correction Models (SECMs) at ½ Frequency

SECM(3) Results for Dependent Variable: $LNINV_{4t}$				
Independent Variables	**Parameters**	**Coefficients**	**Standard Deviation**	**t statistic**
v_{t-1}	γ_1	**-0.388899**	0.16036	**-2.42519**
$LNINV_{4t-1}$	β_1	0.948735	0.21742	
$LNGDP_{4t-1}$	δ_1	-0.370718	0.52853	
$LNINV_{4t-2}$	β_2	-0.220937	0.24800	
$LNGDP_{4t-2}$	δ_2	0.897332	0.60017	
$LNINV_{4t-3}$	β_3	-0.366652	0.19341	
$LNGDP_{4t-3}$	δ_3	0.023795	0.49142	
SECM(2) Results for Dependent Variable: $LNGOV_{4t}$				
Independent Variables	**Parameters**	**Coefficients**	**Standard Deviation**	**t statistic**
v_{t-1}	γ_1	**-0.136582**	0.09078	-1.50446
$LNGOV_{4t-1}$	β_1	0.269994	0.13803	
$LNGDP_{4t-1}$	δ_1	0.383051	0.22174	
$LNGOV_{4t-2}$	β_2	0.319187	0.12597	
$LNGDP_{4t-2}$	δ_2	-0.126852	0.18097	
SECM(2) Results for Dependent Variable: $LNIMP_{4t}$				
Independent Variables	**Parameters**	**Coefficients**	**Standard Deviation**	**t statistic**
v_{t-1}	γ_1	**-0.308861**	0.16468	**-1.87549**
$LNIMP_{4t-1}$	β_1	1.034797	0.22641	
$LNGDP_{4t-1}$	δ_1	-0.208514	0.54608	
$LNIMP_{4t-2}$	β_2	-0.455109	0.18717	
$LNGDP_{4t-2}$	δ_2	0.466894	0.49864	

In Table 6, seasonal error correction model results at semi-annual frequency have been presented for the cases in which dependent variables are LNINV, LNGOV and LNIMP respectively. When dependent variable is LNINV, the most appropriate lag length that provides non-autocorrelated error term has been chosen as 3 and therefore SECM(3) model has been estimated. Based on the negative and significant value of adjustment coefficient (--0.388899), it has been confirmed that error correction mechanism (ECM) has worked at 5% significance level. According to this result, approximately 38.9% of deviations from long-run equilibrium in INV variable will be corrected at one period of time (here at one quarter) and LNINV series will come to equilibrium after approximately 2.5 periods (1 / 0.38 = 2.63). SECM(2) estimation results for LNIMP series at ½ frequency have revealed that approximately 30.9% of deviations from LNIMP will disappear at one period under 10% significance level and LNIMP will come to equilibrium after 3 periods (1 / 0.30 = 3.33). However, according to SECM(2) results for LNGOV series, error correction mechanism for LNGOV has not been working at both 5% and 10% significance levels due to insignificant speed of adjustment coefficient (-0.136582) with a t-statistic value of -1.50446 although its value is negative.

Table-7: Seasonal Error Correction Models (SECMs) at ¼ (and ¾) Frequencies

SECM(1) Results for Dependent Variable: $LNCONS_{4t}$				
Independent Variables	**Parameters**	**Coefficients**	**Standard Deviation**	**t statistic**
w_{t-2}	γ_1	**-0.550693**	0.19433	**-2.83379**
w_{t-3}	γ_2	-0.152525	0.22269	-0.68491
$LNCONS_{4t-1}$	β_1	0.596268	0.18696	
$LNGDP_{4t-1}$	δ_1	0.203718	0.16302	
SECM(1) Results for Dependent Variable: $LNGOV_{4t}$				
Independent Variables	**Parameters**	**Coefficients**	**Standard Deviation**	**t statistic**
w_{t-2}	γ_1	**-0.548235**	0.11332	**-4.83804**
w_{t-3}	γ_2	0.038148	0.12502	0.30512
$LNGOV_{4t-1}$	β_1	0.375360	0.11596	
$LNGDP_{4t-1}$	δ_1	0.377094	0.11037	
SECM(2) Results for Dependent Variable: $LNIMP_{4t}$				
Independent Variables	**Parameters**	**Coefficients**	**Standard Deviation**	**t statistic**
w_{t-2}	γ_1	**-0.545785**	0.11399	**-4.78810**
w_{t-3}	γ_2	0.154184	0.13201	1.16793
$LNIMP_{4t-1}$	β_1	1.195804	0.18772	
$LNGDP_{4t-1}$	δ_1	-0.548832	0.46437	
$LNIMP_{4t-2}$	β_2	-0.593788	0.15857	
$LNGDP_{4t-2}$	δ_2	0.752295	0.43430	

In Table 7, SECM results have been reported for quarterly frequencies. When dependent variables are LNCONS and LNGOV, SECM(1) estimations have shown that ECM has worked for both models at ¼ frequency with speed of adjustment coefficients -0.550693 and -0.548235 respectively. According to this, approximately 55% of deviations from long-run equilibrium in both variables will disappear at one period. For LNCONS series, SECM has not been working at ¾ frequency depending on statistically insignificant error correction term with a t-statistic value of -0.68491. In addition, SECM has not been working for also LNGOV series at ¾ frequency due to error correction term coefficient with positive value (0.038148). Therefore, deviations in LNGOV series at ¾ frequency have not come to equilibrium level at one period. On the other hand, SECM(2) has been estimated in the case of dependent variable "LNIMP" and SECM has been working with an adjustment coefficient of '-0.545785' at ¼ frequency, but not working at ¾ frequency depending on the positive value of error correction term (0.154184).

CONCLUSION

The objective of this research is to shed a light on seasonal cointegrating relationships of quarterly Gross Fixed Capital Formation (INV), Imports (IMP), Consumption of Resident Households (CONS) and Government Final Consumption Expenditures (GOV) series with Gross Domestic Product (GDP) and subsequently to estimate seasonal error correction models in the presence of cointegration for Turkish economy in the period of 1998Q1-2017Q3. All these macroeconomic variables are of great importance in terms of being crucial factors in the calculation of GDP. In the analysis, at first HEGY (1990) seasonal unit root test has been performed and it has been reported that all variables have non-seasonal unit roots at zero frequency. Bi-annual frequency unit roots have been observed at all variables except LNCONS. While LNGDP, LNINV and LNGOV series have ½ frequency unit root for only "C + SD" and "C + SD + T" models, LNIMP series have this root for all models. In addition, seasonal unit roots at quarterly ¼ (and ¾) frequencies have been detected for LNIMP, LNGOV and LNCONS variables. Based on these findings of the research, HEGY test results have implied the likelihood of having cointegration relationships between above-mentioned variables at 0, ½ and ¼ (and ¾) frequencies and therefore, seasonal cointegration analysis have been carried out depending upon the study of Engle *et al.* (EGHL) (2003) and as the second step of cointegration analysis, bivariate seasonal error correction models have been estimated. Gross fixed capital formation (INV) can be considered as an important component used in GDP calculations which is also regarded as a marker of the future productive capacity of the economy. The strong cointegrating relationship detected at semi-annual frequency between LNINV and LNGDP for 5% significance level has revealed an error correction mechanism performing well which implies that 38.9% of deviations from long-run equilibrium in LNINV variable will be corrected at one quarter and equilibrium level will be reached at a period that is no more than a year (at approximately 2.5 periods). According to cointegration results, LNGDP has a positive effect on gross fixed capital formation with a coefficient of 1.51 at the current period for the model including constant and seasonal dummies and this effect is more (1.58) when trend component is added into the model. As similar to LNINV variable, LNGDP has also affected LNIMP variable –which has a stochastic semi-annual seasonal pattern expressing a cycle for each half year within one year-positively and 30.9% of deviations from LNIMP will be corrected at one period of time under 10% significance level. On the other hand, cointegrating relationships of LNCONS, LNGOV and LNIMP with LNGDP detected at annual unit roots have revealed that LNGDP has a positive effect on LNGOV and LNIMP series at the current and one-lagged periods. While the effect of LNGDP on LNCONS is positive for current period, it is negative for one-lagged period. Furthermore, it has been found that LNGDP has a significant effect on LNCONS for only current period at both "C" and "C + SD" models. ECMs have worked at ¼ frequency for the cases where dependent variables are LNCONS, LNGOV and LNIMP and approximately 55% of deviations from long-run equilibrium in all these series will be corrected at one quarter.

The study has contributed to the literature by revealing the seasonal cointegration relationships between GDP and some macroeconomic variables used in its calculation and seasonal error correction mechanisms which examine short-term dynamics between series.

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APPENDIX: Critical Values for Seasonal Cointegration (for 100 Observations)

Table-8: Critical Values for Seasonal Cointegration at Zero and Semiannual Frequencies

Number of Variables (k=5, N=100)	π_1 ve π_2		
Significance Level	1%	5%	10%
Critical Value	5.18	4.58	4.26

Source: Engle & Yoo (1987: 157).

Table-9: Critical Values for Seasonal Cointegration at ¼ (and ¾) Quarterly Frequencies

N=100	π_3			π_4			$\pi_3 \cap \pi_4$		
Deterministik Bileşen İn cointegrating regression	1%	5%	10%	1%	5%	10%	99%	**95%**	90%
-	-3.94	-3.30	-3.00	-3.01	-2.12	-	10.24	**7.21**	5.91
C	-3.86	-3.27	-2.95	-2.95	-2.08	-	10.15	**7.10**	5.83
C, D	-4.77	-4.12	-3.81	-3.02	-2.14	-	13.26	**10.12**	8.66

Source: (Engle *et al.*, 1993: 293).