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Trends and Unit Roots in Greek Real Money Supply, Real GDP and Nominal Interest Rate

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Abstract

This paper presents the results of a unit root investigation of Greek real money supply, real G.D.P. and nominal interest rate, after following a sequential procedure which takes into consideration the effect of the possibly erroneus presence or absence of the trend and/or intercept on the augmented Dickey – Fuller unit root test procedure.

1. Introduction

One of the problems we are facing in the econometric evaluation of economic models using the *Ordinary Least Squares* (OLS) method, is the stationarity of the macroeconomic variables. If the variables are not stationary then the coefficients of the model cannot be estimated via the OLS method since the residuals will not have the desired properties.

Generally in Economics a non-stationary sequence can be reverted into a stationary one by taking the first differences or by removing the deterministic trend. The first method is used when the examined macroeconomic sequences are proved to contain one or more *unit roots*. This group of sequences is known as *difference stationary* while the others are known as *trend stationary*. The specification of the type of stationarity is very important in order to proceed with the econometric evaluation of various economic models, since the detrending of a trend stationary sequence by first differencing results in a misspecification error.

In the present article, covering a period from 1960 to 1994, we will examine the time series of Greek real money supply (m_t), real

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gross domestic product (y_t) and nominal interest rates[1] (R_t) for the presence of a unit root, using the Augmented Dickey – Fuller type tests within the framework developed by J. J. Dolado, T. Jenkinson & S. Sosvilla – Rivero (1990).

2. Methodology

A common procedure used to investigate for the presence of a unit root in a sequence is to apply an *Augmented Dickey – Fuller Test* (ADF – test). If we know that the true data generating process of Y_t is described by one of the following equations:

$$\Delta Y_t = \gamma Y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta Y_{t-1} + u_t \tag{1.1}$$

$$\Delta Y_t = a_0 + \gamma Y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta Y_{t-1} + u_t \tag{1.2}$$

$$\Delta Y_t = a_0 + \gamma Y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta Y_{t-1} + u_t \tag{1.3}$$

where Δ is the first difference operator and t is the time trend we determine the value of k and we use the OLS method to estimate the most appropriate of the above equations. Then we examine the null hypothesis of a unit root in the $\{Y_t\}$ sequence by comparing (at a specific significance level and for T observations) the t – statistic of γ coefficient (T_γ) with the τ critical value in the case of equation (1.1), the τ_μ critical value in the case of equation (1.2) or the τ_τ critical value in the case of equation (1.3)[2].

In order to conduct the ADF test when the true data generating process is unknown, we should first determine the value of param-

[1] [1] The data in nominal terms are taken from the " 2000 – The Greek Economy In Figures " statistical guide. The data in real terms have been calculating using 1970 as the base year. The nominal interest rate is the product between the interest rate of saving deposits and the ratio of the saving deposits to the sum of sight, time & saving deposits.

[2] For the values of these statistics see Wayne Fuller, "Introduction to Statistical Time Series", John Wiley, 1976, page 373.

eter k, i.e. the number of lagged differences of the endogenous variable on the right hand side of equations (1.1), (1.2) or (1.3), since the inclusion of too many lags reduces the power of the test. On the other hand the inclusion of too few lags affects the size of the test. Second, we should choose the appropriate model by which the ADF test will be conducted, since the presence of the constant and / or the trend in the equation used, reduces the power of the test.

In the case where the data generating process of $\{Y_t\}$ is unknown, the procedure that will be followed in order to investigate the presence of a unit root in the examined sequence is presented in figure 1 and it contains the following steps[3,4]

1. We define the value of parameter k of the following equation

$$\Delta Y_t = a_0 + \gamma Y_{t-1} + a_2 t + \sum_{i=1}^{k} \beta_i \Delta Y_{t-1} + u_t \qquad (2)$$

More specifically we initially give a quite big value to k (say k'). Said & Dickey (1984) suggest a value of k' no bigger than $\sqrt[3]{T}$, where T is the number of sample observations. In order to ensure that k' is greater than the true value of k, we may set $k' = \sqrt{T}$. After setting the maximum value of k, we estimate equation (2) for k = 0, …., k' using the O.L.S. method. If T^* is the number of usable observations, $\hat{\sigma}^2 = \sum \hat{u}_t^2$ and π_1 are respectively the residuals sum of squares and the number of estimated coefficients of model (2), that is $\pi_1 = k + 3$, then the determination of k could be based on one of the following information criteria:

***1st* Akaike Information Criterion (AIC):** The AIC criterion is defined as

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[3] We may follow the some procedure in the case of the simple type of Dickey – Fuller test for the presence of a unit root in a given sequence.

[4] For more details on the followed procedure see W. Enders, “Applied Econometric Time Series”, John Wiley, chapter 4, pp 254 – 260.

$$AIC = \ell n\left(\frac{\hat{\sigma}^2}{T^*}\right) + \frac{2\pi_1}{T^*} \tag{3}$$

***2^nd^* Schwartz Bayesian Criterion (SBC):** The SBC criterion is defined as

$$SBC = \ell n\left(\frac{\hat{\sigma}^2}{T^*}\right) + \frac{\pi_1 \ell n\left(T^*\right)}{T^*} \tag{4}$$

Between the k' + 1 estimated models we choose the one with the lowest value of the AIC and/or the SBC information criterion.

In order to determine the value of k we could follow a *general to specific rule.* This method is based on the statistical significance of the estimated coefficients $\hat{\beta}_i$ of equation (2). More specifically we start again by giving to k a quite big value, say $k' = \sqrt{T}$, and we estimate model (2) for k = k'. If $\hat{\beta}_{k'}$ coefficient is statistically significant using the t – Student distribution then we may accept that k = k'. If not, we reduce the value of k by one and we estimate model (2) for k = k' – 1. If $\hat{\beta}_{k'-1}$ coefficient is statistically significant then we may accept that k = k' – 1. If not we keep on reducing the value of k until we reach to a statistically significant OLS estimator $\hat{\beta}_{k^*}$ where $k^* \in$ (0, …., k' – 1). This rule which is based on the t – Student distribution will be denoted as *GSR(t).* Perron (1989,1994) proposes a similar procedure for the selection of k, except that the statistical significance of the last coefficient β_i is based on a t – test using the normal distribution[5]. This last procedure will be denoted as *GSR(z).*

Perron and NG (1994) showed that the information based criteria, that is AIC and SBC, tend to select small values for k, namely 0 or 1, which results in high size distortion. On the contrary a gener-

[5] Perron investigates the statistical significance of βi coefficients at the 10 % significance level. In part III we will investigate the significance of βi coefficients at the 5 % significance level.

al to specific procedure tends to select big values for the parameter k, but as a consequence we have a loss of power.

Once a tentative lag length has been determined, say k^*, diagnostic checking should be conducted for the residuals of the following model

$$\Delta Y_t = a_0 + \gamma Y_{t-1} + a_2 t + \sum_{i=1}^{k} \beta_i \Delta Y_{t-1} + u_t \tag{5}$$

in order to accept this specific value of parameter k. More specifically we will accept that $k = k^*$ only if the residuals of equation (5) appears to be white noise, that is, if the residuals satisfy the following conditions:

$$E\left(u_t\right) = 0 \; \forall t \tag{6.1}$$

$$E\left(u_t^2\right) = \sigma_u^2 \; \forall \tag{6.2}$$

$$Cov\left(u_t, u_{t-h}\right) = Cov\left(u_{t-j}, u_{t-j-h}\right) = 0 \text{ for all h} \tag{6.3}$$

In other words, not only the mean of the residuals must be equal to zero but also the residuals must be homoskedastic and uncorrelated.

2. We use the O.L.S. method to estimate the following model

$$\Delta Y_t = a_0 + \gamma Y_{t-1} + a_2 t + \sum_{i=1}^{k^*} \beta_i \Delta Y_{t-i} + u_t \tag{7}$$

3. We check the validity of the unit root hypothesis, comparing the t - statistic

$$T_{\hat{\gamma}} = \frac{\hat{\gamma}}{\sqrt{Var\left(\hat{\gamma}\right)}}$$

with the critical value τ_τ of Dickey - Fuller. If we have that $T_{\hat{\gamma}} = \tau_\tau$ we reject the null hypothesis and we terminate the followed procedure concluding that the examined sequence has no unit root. If the null hypothesis is not rejected we proceed to step 4.

4. Given that $\gamma = 0$, we check the significance of the trend, i.e. $a_2 = 0$, by comparing the T_{a_2} statistic of equation (7) with the calculated by Dickey & Fuller $\tau_{\beta\tau}$ statistic. More specifically if for a certain significance level $T_{\hat{a}_2} < \tau_{\beta\tau}$ we conclude that $a_2 = 0$. The significance of the trend can also be tested through the following mixed test H_0: $\alpha_2 = \gamma = 0$. This test is carried out with the help of the following statistic

$$F_3 = \frac{\sum \hat{u}_{3t}^2 - \sum \hat{u}_t^2}{\sum \hat{u}_t^2} \times \frac{T^* - k}{2}$$

where $\sum \hat{u}_{3t}^2$: the residuals sum of squares of the following model

$$\Delta Y_t = a_0 + \sum_{i=1}^{k^*} \beta_i \Delta Y_{t-i} + u_{3t} \tag{8}$$

$\sum \hat{u}_{3t}^2$: the residuals sum of squares of equation (7)

T^* : the number of usable observations and

k : the number of estimated coefficients of equation (7)

If the value of F_3 statistic is greater than the calculated by Dickey and Fuller critical value Φ_3, i.e. if $F_3 > \Phi_3$, the null hypothesis is rejected and we test the hypothesis H_0: $\gamma = 0$ following the standardized normal distribution. For a two sided test and at the α % significance level, if the absolute value of T_γ statistic [which results from the estimation of equation (7)] is greater than the critical value Z of the normal distribution, the null H_0: $\gamma = 0$ is rejected and we terminate the procedure concluding that the examined sequence has no unit root. If $|T_\gamma| < Z$ the null H_0: $\gamma = 0$ is not rejected and we conclude that the sequence has a unit root. If the null hypothesis H_0: $\alpha_2 = \gamma = 0$ is not rejected we proceed to step 5.

5. We estimate the following equation

$$\Delta Y_t = a_0 + \gamma Y_{t-1} + a_2 t + \sum_{i=1}^{k^*} \beta_i \Delta Y_{t-i} + u_t \tag{9}$$

and we test the null hypothesis H_0: $\gamma = 0$ through the comparison of T_γ statistic with the calculated by Dickey and Fuller critical value τ_μ. If $T_\gamma < \tau_\mu$ we reject the null hypothesis and we terminate the followed procedure concluding that the examined sequence has no unit root. If the null is not rejected we proceed to step 6.

6. Given that $\gamma = 0$ we check the significance of the constant, i.e. $a_0 = 0$, comparing the calculated $T_{\hat{a}_0}$ statistic of model (9) with the critical value $\tau_{\alpha\tau}$ of Dickey & Fuller. If $T_{\hat{a}_0} < \tau_{\alpha\tau}$ then at a given significance level we accept that $a_0 = 0$. The significance of the intercept may also be checked through the test of the null hypothesis H_0: $\alpha_0 = \gamma = 0$. We conduct this test with the help of the following statistic

$$F_1 = \frac{\sum \hat{u}_{1t}^2 - \sum \hat{u}_t^2}{\sum \hat{u}_t^2} \frac{T^* - k}{2}$$

where $\sum \hat{u}_{1t}^2$: the residuals sum of squares of the following model

$$\Delta Y_t = \sum_{i=1}^{k^*} \beta_i \Delta Y_{t-i} + u_{1t} \qquad (10)$$

$\sum \hat{u}_t^2$: the residuals sum of squares of equation (9)

T^* : the number of usable observations and

k : the number of estimated coefficients of equation (9)

If the value of F_1 is greater than the calculated by Dickey and Fuller[6] critical value Φ_1, we reject the null and we test the null hypothesis H_0: $\gamma = 0$ using the standardized normal distribution. More specifically for a two sided test and at the α % significance level if the absolute value of T_γ statistic [which results from the estimation of

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[6] The critical values of $\tau_{\alpha\tau}$, $\tau_{\beta\tau}$, Φ_1, Φ_2 and Φ_3 statistics are given in tables II ~ VI of D.A. Dickey & W.A. Fuller's article " Likelihood Ratio Statistics For Autoregressive Time Series With A Unit Root", in Econometrica, vol. 49, No 4, July 1981, pages 1057 – 1072. These critical values are calculated for sample sizes of 25, 50, 100, 250, 500 & ∞ observations. Since our sample size (T=35) is closer to 25 than 50 observations, we will use the critical values which have been calculated for T = 25. The conclusions of our analysis remain the same even if we had used the critical values for T = 50.

equation (9)] is greater than the critical value Z of the normal distribution, the null H_0: $\gamma = 0$ is rejected and we terminate the procedure concluding that the examined sequence has no unit root. If $|T_\gamma| < Z$ the null H_0: $\gamma = 0$ is rejected and we conclude that the sequence has a unit root. If $F_1 < \Phi_1$ we accept the null H_0: $\alpha_0 = \gamma = 0$ and we proceed to step 7.

7. We estimate the following model

$$\Delta Y_t = \gamma Y_{t-1} + \sum_{i=1}^{k^*} \beta_i \Delta Y_{t-i} + u_t \qquad (11)$$

and we test the null hypothesis H_0: $\gamma = 0$ comparing the statistic T_γ (which results from the above estimation) with the calculated by Dickey and Fuller critical value τ. If $T_\gamma > \tau$ we accept the existence of a unit root in the examined sequence. On the other hand if $T_\gamma < \tau$ we reject the null hypothesis and we accept the absence of a unit root from the examined equation.

3. Empirical Applications

In the present section we will examine the presence of a unit root in the series of Greek real money supply (M2), real G.D.P. and nominal interest rates, following the methodology developed in the previous section (see figure 1).

We start with the determination of parameter k of equation (2) for real M2 (m_t), real G.D.P. (y_t) and nominal interest rates (R_t). Initially we give to k a value equal to 6 ($\cong \sqrt{35} = \sqrt{T}$) and using the O.L.S. method we estimate for k = 6, …., 0 the following models:

$$\Delta m_t = a_1 + \gamma m_{t-1} + a_2 t + \sum_{i=1}^{k} \beta_i \Delta m_{t-1} + u_t \qquad (12)$$

$$\Delta y_t = a_1 + \gamma y_{t-1} + a_2 t + \sum_{i=1}^{k} \beta_i \Delta y_{t-1} + u_t \qquad (13)$$

$$\Delta R_t = a_1 + \gamma R_{t-1} + a_2 t + \sum_{i=1}^{k} \beta_i \Delta R_{t-1} + u_t \qquad (14)$$

The values of k that will be chosen for each one of the above models must ensure that the residuals are white noise, [that is for the chosen value of k relations (6.1) ~ (6.3) must be satisfied].

The autocorrelation of the residuals will be investigated with the help of the Box – Ljung Q statistic that is given by the following relation:

$$Q(m)=T(T+2)\sum_{n=1}^{m}\frac{\rho_n^2}{T-n} : \quad {}^{2}_{m,\alpha} \tag{15}$$

where ρ_n^2 : the sample autocorrelation of the residuals.

Setting m = T/4 $\cong$ 9, we test the significance of the nine first autocorrelations of the residuals of equations (12) ~ (14), comparing the value of Q(9) statistic with the critical value $\chi^2_{9,0.05} \cong 16{,}919$. If Q(9) < $\chi^2_{9,0.05}$ we accept, at the 5% significance level, that the residuals are not correlated. If not, we increase the value of k by one until we get that value of k for which the Q(9) statistic does not reveal any significant autocorrelation among the residuals.

The homoskedasticity of the residuals of both three equations will be investigated with the help of the following statistic:

$$Q(w)=T(T+2)\sum_{n=1}^{w}\frac{r_n}{T-n} : \quad {}^{2}_{w,\alpha} \tag{16}$$

where r_n: the sample autocorrelation of the squared residuals.

Setting w = T/4 $\cong$ 9, we test the significance of the nine first autocorrelations of the squared residuals of equations (12), (13) & (14), comparing the value of Q(9) statistic with the critical value $\chi^2_{9,0.05} \cong 16{,}919$. If Q(9) < $\chi^2_{9,0.05}$ we accept, at the 5% significance level, that the residuals do not exhibit autoregressive conditional heteroskedasticity (ARCH) or generalized autoregressive conditional heteroskedasticity (GARCH), that is they are homoskedastic.

The values of Q(m) and Q(w) statistics are presented along with their corresponding p – values, for k varying from 0 to 6 and for m = w = 9, at the seventh and ninth row of tables 1, 2 and 3 for equations

(12), (13) & (14) respectively[7]. Moreover at the two first rows of these tables the values of AIC and SBC criteria are presented. At the third and fourth row we are presenting the values of the t – statistics of β_i, i = 0, …., 6, coefficients and their corresponding p – values respectively. On the sixth row the t – statistic of γ coefficient is presented. Finally at the eleventh row the value of Jarque- Bera J statistic is presented. This statistic has the following form:

$$J = \frac{T-k}{6}\left[S^2 + \frac{1}{4}(K-3)^2\right] : \chi^2_{2,\alpha} \qquad (17)$$

where S is the skewness and K is the kurtosis.

If $J < \chi^2_{2,0.05} \cong 5{,}991$, then at the 5% significance level we accept that the residuals are normally distributed[8].

Starting with the sequence of real money supply, the value of parameter k of equation (12) which is chosen according to AIC and SBC information criteria as well as the GSR(t) and GSR(z) rules is equal to 1, that is k = 1 (see table 1). And that because for k = 1 the AIC & SBC criteria are minimized and the absolute value of T_γ is bigger, for a two sided test, than the $t_{29,0.025} \cong 2{,}045$ & $Z_{0,975} \cong 1{,}960$ critical values. For k=1, the residuals of equation (12) are not autocorrelated [since Q(m=9) = 3,9217 < $16{,}919 = \chi^2_{9,0.05}$], they are homoskedastic [since Q(w=9)= 13,312 < $16{,}919 = \chi^2_{9,0.05}$] and they are normally distributed [since J = 1,342 < $5{,}991 = \chi^2_{2,0.05}$]. In other words, for k = 1 the residuals of equation (12) are white noise[9] and consequently we may accept this specific value of parameter k.

On the second step (see figure 2) we estimate of the following equation

[7] The results of these tables were derived with the help of EViews 2.0 package.

[8] Although for small samples the Jarque – Bera J statistic should not be used, we suggestively present it's value in order to determine the normality of the residuals.

[9] The residuals are white noise not only for m = w = 9 but also for m,w = 1, …., 8.

$$\Delta m_t = a_0 + \gamma m_{t-1} + a_2 t + \beta_1 \Delta m_{t-1} + u_t \qquad (18)$$

The resulted value of $\hat{T}_\gamma$ statistic is equal to – 2,662. At the 1%, 5% & 10% significance levels we have that[10,11] $\hat{T}_\gamma$ = – 2,662 > τ_τ and consequently the unit root null in not rejected and we proceed to the next step of our analysis, where we will test the significance of the trend.

The null hypothesis a_2 = 0 is rejected at the 10% significance level[12] (since $\hat{T}_{a\beta\tau} = 2{,}489 > = \tau$). The insignificance of the trend is also confirmed by the F_3 statistic since at 1%, 5% & 10% significance levels[13] we have that F_3 = 3,871 > Φ_3. The null hypothesis a_2 = 0 is not rejected however at the 1% & 5% significance levels when the $\tau_{\beta\tau}$ statistic is used (since for these two significance levels we have that $\hat{T}_{a\beta\tau} = 2{,}489 < = \tau$).

If we accept the significance of the trend, we will search for the presence of a unit root in the real money supply sequence, comparing the T_γ statistic of model (18) with the critical value of the standardized normal distribution[14]. At the 1%, 5% & 10% significance levels we have $\left|\hat{T}_\gamma\right| = 2{,}662 > Z_{\alpha/2}$ and consequently we reject the unit root null.

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[10] The critical values of ττ, τμ & τ statistics where calculated for T = 25, 50, 100, 250, 300 and ∞. In our analysis we use the critical values for T = 25, since the number of our observations is closer to this sample size. The results of all unit root tests in part III remain valid even if we had used the critical values of the statistics for T = 50.

[11] For 25 observations and at the 1%, 5% & 10% levels the critical values of ττ statistic are equal to – 4.38, – 3.60 & – 3.24 respectively.

[12] For 25 observations and at 1%, 5% & 10% levels the critical values of τβτ statistic are equal to 3,74, 2,85 & 2,39 respectively.

[13] The F3 is equal to $\frac{5{,}98\times 10^9 - 4{,}72\times 10^9}{4{,}72\times 10^9}\times\frac{29}{2}\cong 3{,}871$. At 1%, 5% & 10% significance levels and for 25 observations, the critical values of Φ3 are equal to 0,74, 1,08 & 1,33 respectively.

[14] For a two sided test the critical value of the normal distribution at the 1%, 5% & 10% significance is equal to 2,576, 1,960 & 1,645 respectively.

If on other hand we accept the insignificance of the trend, we proceed to the fifth step of the followed procedure where we estimate the following model:

$$\Delta m_t = a_0 + \gamma m_{t-1} + \beta_1 \Delta m_{t-1} + u_t \qquad (19)$$

and we test the significance of the null H_0: $\gamma = 0$ comparing the T_γ statistic with the critical value τ_μ. The $T_{\hat{\gamma}}$ statistic is equal to -1,140 and at the 1%, 5% & 10% significance levels is greater than the τ_μ critical value[15]. This leads us to the acceptance of the unit root null and we proceed with the test of the significance of the constant in model (19).

The significance of the constant will be tested via the comparison of the calculated t – statistic of a_0 coefficient of model (19), which is equal to 2,028, with the critical value $\tau_{\alpha\tau}$ of Dickey – Fuller[16]. Since $T_{\hat{a}_0} = 2{,}028 < \tau_{\alpha\tau}$ at the 1%, 5% & 10% significance levels, we accept that $a_0 = 0$. This conclusion is not confirmed however by the F_1 statistic since at all three significance levels we have that[17] $F_1 = 3{,}089 > \Phi_1$.

If we accept the significance of the constant, the examination of the unit root null will be carried out via the comparison of the T_γ statistic of model (19), with the critical value of the normal distribution. At the 1%, 5% & 10% significance levels we have that $\left|T_{\hat{\gamma}}\right| = 1{,}140 < Z_{\alpha/2}$ and consequently we accept the unit root null.

If we accept the insignificance of the constant, we proceed to the final step of the described in figure 1 procedure, where we estimate the model

$$\Delta m_t = \gamma m_{t-1} + \beta_1 \Delta m_{t-1} + u_t \qquad (20)$$

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[15] At the 1%, 5% & 10% significance levels and for 25 observations, the value of $\tau\mu$ statistic is equal to – 3,75, – 3,00 & – 2,62 respectively

[16] At the 1%, 5% & 10% significance levels and for 25 observations, the value of $\tau_{\alpha\tau}$ is equal to 4,05, 3,20 & 2,77 respectively

[17] At the 1%, 5% & 10% significance levels the critical values of Φ_1 statistic are equal to 0,29, 0,49 & 0,65 respectively. The F_1 statistic is equal to $\frac{6{,}91\times 10^9 - 5{,}73\times 10^9}{5{,}73\times 10^9}\times\frac{30}{2}\cong 3{,}089$.

and we test the significance of the unit root null H_0: $\gamma = 0$, comparing the resulted T_γ statistic (which is equal to 1,363) with the τ critical value of Dickey-Fuller[18]. Since at all three significance levels we have that $T_\gamma = 1{,}363 > \tau$, we accept the unit root null.

The examination for the presence of a unit root in the sequence of real G.D.P. starts with the determination of parameter k of equation (13). From the first two rows of table 2 it is quite obvious that the AIC & SBC information criteria choose a value of k equal to 0, that is k = 0. The same value of k is chosen from the GSR(t) & GSR(z) rules, since the absolute value of the T_γ statistic for k = 6, …., 1, is smaller than $t_{0.025,19} \cong 2{,}093$ and $Z_{0,975} = 1{,}960$. We will accept that k = 0, only if the residuals of equation (13) for this value of k are white noise. Since Q(m) and Q(w) (for m = w = 9) are smaller than $16{,}919 = \chi^2_{9,0.05}$, we conclude that for k = 0 the residuals are not autocorrelated and they are homoskedastic. Moreover the fact that J = 1,382 < $5{,}991 = \chi^2_{2,0.05}$ leads us to the conclusion that the residuals are also normally distributed and consequently they are white noise.

On the second step of the followed procedure we estimate, using the O.L.S. method, for k = 0 the following equation:

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \sum_{i=1}^{k=0} \Delta y_{t-i} + u_t$$

or
$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + u_t \qquad (21)$$

The unit root test will be carried out comparing the resulted from the estimation of equation (21) T_γ statistic (which is equal to - 0,340) with the τ_τ critical value of Dickey - Fuller. Since at the 1%, 5% & 10% significance levels T_γ is greater than the τ_τ critical value, we accept the unit root null and proceed with the test of the significance of the trend, comparing the T_{a_2} statistic from equation (21) with the $\tau_{\beta\tau}$ critical value of Dickey - Fuller. At the 1%, 5% & 10% significance levels we have that $T_{a_2} = 0{,}001 < \tau_{\beta\tau}$ and consequently

[18] At the 1%, 5% & 10% significance levels and for 25 observations, the value of τ is equal to - 2,66, - 1,95 & - 1,60 respectively.

we conclude that $a_2 = 0$. This conclusion is not confirmed however by the F_3 statistic, which is equal to 2,095[19]. And that because at the 1%, 5% & 10% significance levels the F_3 statistic is greater than the Φ_3 critical value.

If we accept the significance of the trend, we will test the significance of the unit root null hypothesis comparing the $T_{\hat{\gamma}}$ statistic of equation (21) with the critical value of the normal distribution. Since $\left|T_{\hat{\gamma}}\right| = 0{,}340 < Z_{\alpha/2}$ for $\alpha = 1\%, 5\% \& 10\%$, we accept the unit root null.

If we accept the insignificance of the trend, we proceed to the fifth step of the followed procedure where we estimate the following model:

$$\Delta y_t = a_0 + \gamma y_{t-1} + u_t \tag{22}$$

The unit root hypothesis will be investigated via the comparison of the resulted from equation (22) T_γ statistic (which is equal to -2,074) with the τ_μ critical value of Dickey - Fuller. Since at the 1%, 5% & 10% significance levels we have that $T_{\hat{\gamma}} > \tau_\mu$, we accept the unit root null hypothesis and proceed with the test of the significance of the constant term, comparing the estimated from model (22) T_{a_0} statistic (which is equal to 4,533) with the $\tau_{\alpha\tau}$ critical value of Dickey - Fuller. At the 1%, 5% & 10% significance levels we have that $T_{a_0} > \tau_{\alpha\tau}$, something that forces us to accept the significance of the constant and proceed with the investigation of a unit root in real G.D.P. sequence, comparing the $T_{\hat{\gamma}}$ statistic with the critical value of the standardized normal distribution. At the 1% significance level we accept the unit root null since $\left|T_{\hat{\gamma}}\right| = 2{,}074 < Z_{\alpha/2}$. The unit root null is rejected however at the 5 % & 10% significance levels since for these two significance levels we have that

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19 The F_3 statistic is equal to $\frac{3{,}36\times 10^9 - 2{,}96\times 10^9}{2{,}96\times 10^9} \times \frac{31}{2} \cong 2{,}095$

$\left|T_{\hat{\gamma}}\right| = 2{,}074 > Z_{\alpha/2}$. The analysis for the real G.D.P. is briefly presented in figure 3.

Having searched the sequences of real money supply and real G.D.P., we will now examine the sequence of nominal interest rate for the presence of a unit root. On the first step of our procedure we will determine the value of parameter k of equation (14) with the help of table 3. From the first two rows of this table we conclude that the value of k that would be selected according to the AIC & SBC information criteria is equal to one.

For k = 1 and m = w = 9 we have that Q(m) = 2,589 & Q(w) = 0,013 are smaller than $16{,}919 = \chi^2_{9,0.05}$. This means that for k = 1 the residuals of equation (14) are not autocorrelated[20] and they are homoskedastic. Moreover the residuals are normally distributed since J = 1,992 < $5{,}991 = \chi^2_{2,0.05}$. It is quite obvious that the residuals for k = 1 are white noise and consequently we may accept this value of parameter k. It must be noted that this specific value of k is chosen by the GSR(t) and GSR(z) rules, since for a two sided test the t – statistic $T_{\hat{\beta}_i}$, i = 6, …. 2, is smaller in absolute value than the $t_{0.025,19} \cong 2{,}093$ and $Z_{0,975} = 1{,}960$ critical values, while the $T_{\hat{\beta}_1}$ statistic is bigger in absolute value than $t_{0.025,19} \cong 2{,}093$ and $Z_{0,975} = 1{,}960$.

In the second step we estimate the following model:

$$\Delta R_t = a_0 + \gamma R_{t-1} + a_2 t + \beta_1 \Delta R_{t-1} \qquad (23)$$

The resulted $T_{\hat{\gamma}}$ statistic is equal to – 3,885. We will test the significance of the unit root null comparing the $T_{\hat{\gamma}}$ statistic with the τ_τ critical value of Dickey – Fuller. At the 5% & 10% significance levels we have that $T_{\hat{\gamma}} = -3{,}885 < \tau_\tau$ which means that the nominal interest rate sequence is I(0), that is there is no unit root in $\{R_t\}$. On the other hand at the 1% significance level we find a unit root in $\{R_t\}$ since $T_{\hat{\gamma}} = -3{,}885 > \tau_\tau$ and consequently we proceed to the fourth step of the test procedure.

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[20] There are no significant evidence of autocorrelation of the residuals not only for m = 9 but also for m = 1, …., 8.

On the fourth step we test the significance of the trend comparing the resulted from the estimation of equation (23) $T_{\hat{a}_2}$ statistic, which is equal to 3,575, with the $\tau_{\beta\tau}$ statistic of Dickey - Fuller. At the 5% & 10% significance levels we have that $T_{\hat{a}_{\beta\tau}} = 3{,}575 > \tau$ and consequently we reach to the conclusion that the trend is significant. This conclusion is also confirmed by the F_3 statistic[21] since at the 1%, 5% & 10% significance levels we have that $F_3 = 7{,}753 > \Phi_3$. At the 1% significance level though we have that $T_{\hat{a}_{\beta\tau}} = 3{,}575 < \tau$ which leads us to the conclusion that the trend is insignificant.

If we accept the significance of the trend, the unit root test will be conducted comparing the $T_{\hat{\gamma}}$ statistic of model (23) with the critical value of the Z normal distribution. Since $\left|T_{\hat{\gamma}}\right| = 3{,}885 > Z_{\alpha/2}$ for $\alpha = 1\%$, 5% & 10%, we reject the unit root null.

If we accept the insignificance of the trend, we proceed to the fifth step of the followed procedure where we estimate the following model:

$$\Delta R_t = a_0 + \gamma R_{t-1} + \beta_1 \Delta R_{t-1} \tag{24}$$

We test for the presence of a unit root in the sequence $\{R_t\}$, comparing the resulted $T_{\hat{\gamma}}$ statistic, which is equal to - 1,397, with the τ_μ critical value of Dickey - Fuller. Since at the 1%, 5% & 10% significance levels we have that $T_{\hat{\gamma}} > \tau_\mu$ we accept the unit root null and proceed to the sixth step, where we test the significance of the constant comparing the resulted from the estimation of equation (24) $T_{\hat{a}_0}$ statistic, which is equal to 1,580, with the $\tau_{\alpha\tau}$ critical value of the Dickey - Fuller. At the 1%, 5% & 10% significance levels we have that $T_{\hat{a}_0} < \tau_{\alpha\tau}$ and consequently we conclude that the intercept is insignificant, that is $a_0 = 0$. This conclusion is not confirmed however by the F_1 statistic[22], since at the 1%, 5% & 10% significance levels we have that $F_1 = 1{,}247 > \Phi_3$ which forces us to accept the significance of the constant.

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[21] The F_3 statistic is equal to $\frac{0{,}002345 - 0{,}001528}{0{,}001528} \times \frac{29}{2} \cong 7{,}753$.

[22] The F_1 statistic is equal to $\frac{0{,}002385 - 0{,}002202}{0{,}002202} \times \frac{30}{2} \cong 1{,}247$.

If we accept the significance of the constant, we conduct the unit root test comparing the $T_{\hat{\gamma}}$ statistic of equation (24). Since at the 1%, 5% & 10% significance levels we have that $\left|T_{\hat{\gamma}}\right|$ = 1,380 < $Z_{\alpha/2}$, we accept the unit root null.

If we do not accept the significance of the constant, we proceed to the last step of the described in figure 1 procedure where we estimate the model:

$$\Delta R_t = \gamma R_{t-1} + \beta_1 \Delta R_{t-1} \tag{25}$$

To test for the presence of a unit root in the case of model (25), we will compare the value of T_{γ} statistic (which is equal to 0,016) with the τ critical value of Dickey – Fuller. Since at the 1%, 5% & 10% significance levels we have that $T_{\hat{\gamma}} = 0{,}016 > \tau$, we accept the null hypothesis of a unit root in the sequence of nominal interest rate. The previously described analysis for the case of nominal interest rate is briefly presented in figure 4.

4. Conclusions

In the present article we followed a mixed strategy (which takes into consideration the effect of the erroneus presence or absence of the trend and/or intercept on the augmented Dickey – Fuller unit root test procedure), in order to determine whether the sequences of Greek real money supply, real G.D.P. and nominal interest rate are trend or difference stationary.

If the tests are carried out at the 1% significance level and the test for the significance of the constant and the trend is based on a t – test, the sequences of real money supply, real G.D.P. & nominal interest rate were proved to have a unit root. If at the same significance level the significance of a_0 and a_2 coefficients is based on an F – test, the sequences of real money supply and nominal interest rate were proved to be trend stationary. On the contrary the sequence of real G.D.P. was proved to have a unit root.

If the tests are carried out at the 5% significance level and the test for the significance of the constant and the trend is based on a t – test, the sequence of real money supply was proved to have a unit root while the sequence of real G.D.P. was proved to be trend stationary. On the contrary, if the significance of a_0 and a_2 coefficients is based on an F – test, then (at the same significance level) the sequence of real money was proved to be trend stationary while the sequence of real G.D.P. was proved to be difference stationary. At the 5% significance level we found no unit root in the sequence of nominal interest rate, regardless of the statistic used in order to determine the significance of the constant and the trend.

Finally at the 10% significance level, the sequence of real G.D.P was proved to be trend stationary when the significance of the constant and the trend is based on a t – test, and it was proved to be difference stationary when the significance of a_0 and a_2 coefficients is based on an F – test. At the same significance level and regardless of the type of the test used in order to determine the significance of the intercept and the trend, the sequences of real money and nominal interest rate were proved to have no unit root.

It is obvious that the described in figure 1 procedure is sensitive not only to the size and the type of the test used in order to determine the significance of the intercept and the trend but to the size of the unit root tests as well. Since it is not quite clear whether there is a unit root in real money supply, real GDP & nominal interest rate or not, we should also conduct a Phillips – Perron test or we should test for the presence of a unit root after we have take into consideration the structural changes which took place in the Greek economy whithin the examined period.

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Table 1: *Lag length selection*

	K		0	1	2	3	4	5	6
m_t	**AIC**		19,20445	**19,02157**	19,11854	19,19645	19,18469	19,21919	19,32821
	SBC		19,33913	**19,20297**	19,34756	19,47400	19,51164	19,59637	19,75642
	GSR(t)	$\hat{T}_{\beta_i}$	~	**3,001497**	−0,313429	0,848924	−1,731068	1,066753	−0,209759
		Prob.	~	0,0055	0,7564	0,4040	0,0968	0,2982	0,8361
	GSR(z)	$\hat{T}_{\beta_i}$	~	**3,001497**	−0,313429	0,848924	−1,731068	1,066753	−0,209759
		$\hat{T}_{\gamma}$	−0,713190	−2,662068	−1,649399	−1,702096	−0,475704	−0,479907	−0,132652
	Residuals	**Q(m)**	5,8296	3,9217	4,2620	3,6698	1,1285	1,4910	1,8263
		Prob.	0,757	0,916	0,893	0,932	0,999	0,997	0,994
		Q(w)	19,215	13,312	10,858	11,263	10,933	11,167	11,500
		Prob.	0,038	0,864	0,950	0,939	0,948	0,942	0,932
		J	0,677883	1,342163	1,445771	1,806162	1,311725	1,236714	1,305612
		Prob.	0,712524	0,511155	0,485350	0,405319	0,518994	0,538829	0,520583

Table 2: *Lag length selection*

K	0	1	2	3	4	5	6

	AIC		**18,45843**	18,54751	18,52171	18,58992	18,61551	18,71906	18,72831
	SBC		**18,59311**	18,72891	18,75073	18,86746	18,94246	19,09625	19,15652
	GSR(t)	$T_{\hat{\beta}_i}$	~	0,331720	-0,697988	0,882676	-1,089406	-0,550153	0,713962
		Prob.	~	0,7425	0,4912	0,3858	0,2873	0,5880	0,4839
	GSR(z)	$T_{\hat{\beta}_i}$	~	0,331720	-0,697988	0,882676	-1,089406	-0,550153	0,713962
y_t		$T_{\hat{\gamma}}$	-0,340049	-0,457884	-0,415425	-0,679614	-0,382700	-0,190174	-0,609840
	Residuals	**Q(m)**	6,2658	5,9911	6,6234	7,2225	3,6677	3,6864	3,4943
		Prob.	0,713	0,741	0,676	0,614	0,932	0,931	0,941
		Q(w)	6,0966	6,2117	4,0150	2,9823	2,4097	3,4611	5,7086
		Prob.	0,730	0,719	0,910	0,965	0,983	0,943	0,769
		J	1,381935	1,522083	0,895385	2,601956	2,702287	1,860719	2,725157
		Prob.	0,501091	0,467180	0,639101	0,272265	0,258944	0,394412	0,256000

Table 3: *Lag length selection*

K	0	1	2	3	4	5	6

	AIC		−9,509460	**-9,737819**	−9,700530	−9,619505	−9,602361	−9,528907	−9,436584
	SBC		−9,374781	**-9,556424**	−9,471509	−9,341959	−9,275415	−9,151722	−9,008375
	GSR(t)	$\mathbf{T}_{\hat{\beta}_i}$	~	**3,284037**	−1,012503	0,027699	−1,376471	0,791587	0,057160
		Prob.	~	0,0027	0,3203	0,9781	0,1819	0,4375	0,9550
	GSR(z)	$\mathbf{T}_{\hat{\beta}_i}$	~	**3,284037**	−1,012503	0,027699	−1,376471	0,791587	0,057160
R_t		$\mathbf{T}_{\hat{\gamma}}$	−2,564020	−3,885035	−2,759004	−2,651267	−2,255387	−2,331900	−2,355893
	Residuals	**Q(m)**	16,247	2,5891	3,2488	3,1392	2,7007	2,5493	2,5426
		Prob.	0,062	0,978	0,954	0,959	0,975	0,980	0,980
		Q(w)	0,0131	0,0137	0,0153	0,0157	0,0163	0,0177	0,0185
		Prob.	1,000	1,000	1,000	1,000	1,000	1,000	1,000
		J	6,498772	1,992307	2,142610	1,986091	0,191107	0,083227	0,146568
		Prob.	0,038798	0,369297	0,342561	0,370447	0,908870	0,959240	0,929337

Figure 1

Figure 2

Figure 3

Figure 4