Unit Root Investigation With Two Breaks Of Greek Velocity (1858-1938)

Erotokritos Varelas, University of Macedonia, Greece

ABSTRACT

In the present article the time series of Greek velocity are investigated for the presence of a unit root, allowing for maximum two breaks which take place at an unknown point in time. This methodology is preferred to conventional Dickey & Fuller tests because the covered time horizon, namely from 1858 to 1938, is characterized by a number of very important events, the nature of which is either economic or historical.

Keywords: Unit root, Breaks, Economic Exploration

INTRODUCTION

The theme of unit roots in macroeconomic time series has received a great amount of theoretical and applied research in the last two decades. The presence or absence of unit roots, to put it in a simple way, helps identifying some features of the underlying data-generating process of a series. If a series has no unit roots, it is characterized as stationary, and therefore exhibits mean reversion in that it fluctuates around a constant long run mean. Also, the absence of unit roots implies that the series has a finite variance which does not depend on time (this point is crucial for economic forecasting), and that the effects of shocks dissipate over time. Alternatively, if the series feature a unit root, they are better characterized as non-stationary processes that have no tendency to return to a long-run deterministic path. Besides, the variance of the series is time-dependent and goes to infinity as time approaches infinity, which results in serious problems for forecasting. Finally, non-stationary series suffer permanent effects from random shocks. As usually denominated in the literature, series with unit roots follow a *random walk.*

The investigation of time series for the presence of a unit root usually precedes the use of several econometric techniques, like ordinary least squares, time series and spectral analysis, co-integration and error correction modeling etc. since the stability of time series or the determination of their order for integration is essential for their application.

The stability of a time series could be graphically examined with a correlogram of its level. More specifically, the rapid (slow) geometrical convergence of the graph on autocorrelation function towards zero is indicative of a stationary (non-stationary) process. The results of this methodology may, however, turn out to be quite questionable. For example, in case of a nearly integrated time series, i.e. a time series which converges to its long – run equilibrium value very slowly, its slow decay autocorrelation function may lead to the false conclusion that the considered time series is non-stationary.

Other procedures, which might be used to determine the presence of a unit root in a time series, are the one proposed (i) by Dickey & Fuller [1979, 1981], (ii) by Kwiatkowski et al [1992] and (iii) by Phillips and Perron [1988] who drew a unit root test using non-parametric statistical methods[1].

Various Dickey – Fuller and Phillips – Perron test statistics are biased toward the acceptance of the unit root null in the presence of structural breaks, i.e. structural breaks reduce the power of unit root test. Therefore, Perron [1989, 1990, 1994, 1997], Zivot & Andrews [1992], Banerjee, Lumsdaine & Stock [1992], Perron & Vogelsang [1992a, 1992b, 1998] have developed tests, in the context of which the significance of unit root null is tested, allowing for a break in a time series and choosing the break date either exogenously or endogenously. Moreover, Lumsdaine & Papell [1997] developed a methodology, in the context of which the unit root hypothesis is investigated allowing for two breaks in a time series with the break dates to be chosen endogenously.

The methodologies, used in the present article, were developed (i) by Perron & Vogelsang [1998] and (ii) by Lumsdaine & Papell [1997]. Covering the period between 1858 and 1938 and using annual data, the time series of Greek velocities (v1,v2,v3) are tested for the presence of a unit root, allowing at most for two breaks that take place at an unknown point in time. The v1 is defined as GDP/M1, where M1 consists of the sum of currency circulation plus sight deposits, the v2 is defined as GDP/M2, where M2 consists of the sum of M1 plus time deposits and v3 is defined as GDP/M3, M3 is the sum of M2 plus savings deposits, respectively. The data is taken from Kostelenos, G.C. "Money and Output in Modern Greece: 1858 – 1938," pp. 25 ~ 28 & 337 ~ 346, 433-436,457-459, *Centre of Planning and Economic Research*, Studies 44, Athens, 1995.

METHODOLOGY

In the context of a K.P.S.S. test, the followed procedure begins with the determination of the following statistic:

$$\widehat{\eta}(\ell) = \frac{T^{-2}}{s^2(\ell)} \sum_{t=1}^{T} S_t^2 \tag{1}$$

where: t = 1 , 2 , …. , T , $\ell = o\left(T^{1/2}\right)$, T : the sample size,

$$S_t = \sum_{i=1}^{t} e_i \tag{2}$$

$$s^2(\ell) = T^{-1} \sum_{t=1}^{T} e_t^2 + 2\,T \sum_{s=1}^{\ell} w(s,\ell) \sum_{t=s+1}^{T} e_t e_{t-s} \tag{3}$$

with:

$$w(s,\ell) = 1 - s/(\ell+1) \tag{4}$$

Given that $\ell = o\left(T^{1/2}\right)$, $\widehat{\eta}(\ell)$ – statistic is calculated for any integer value of ℓ within the interval [0 , 9) and is denoted as $\widehat{\eta}_{\mu}(\ell)$ $\left[\widehat{\eta}_{r}(\ell)\right]$ when the residuals e_t result after the regression of the examined time series on a constant (on a constant and a time trend).

Following Perron [1989, 1990], the trend shifts are modeled by two general groups of models. The first group includes the so called "Additive Outlier" models (AO), which permit sudden occurrence of a break in the trend of a time series. The second group includes the 'Innovational Outlier' models (IO), which allow for a break that is completed slowly over time and not within a time period (like in case of AO models).

Three forms of breaks will be considered. The first (A) and second (B) forms are related with a positive or negative change in the mean and the slope of the examined time series respectively. The third form (C) is referred to a positive or negative change both in the mean and the slope of the time series' trend.

In the context of AO models, the investigation for a unit root in the time series $\left\{Y_t\right\}_{t=1}^{T}$ involves a three step-procedure. In first step, the ordinary least squares (OLS) method is used to estimate one of the following equations[2]:

$$Y_t = \mu^A + \beta^A t + \theta^A DU_t + \tilde{Y}_t \qquad (5)$$

$$Y_t = \mu^B + \beta^B t + \gamma^B DT_t^* + \tilde{Y}_t \qquad (6)$$

$$Y_t = \mu^C + \beta^C t + \theta^C DU_t + \gamma^C DT_t^* + \tilde{Y}_t \qquad (7)$$

$\text{where}: DU_t = 0\,(1) \text{ if } t \le T_B\ (t > T_B), DT_t^* = 0\,(t - T_B) \text{ if } t \le T_B\ (t > T_B), 1 < T_B < T,$ T_B: the potential break date, T: the sample size and $\tilde{Y}_t$: the detrended series.

The second step of the followed procedure involves the estimation of one of the following equations using the OLS method:

$$\tilde{Y}_t^{\ell} = \sum_{i=1}^{k} \omega_i (DT_b)_{t-i} + a^{\ell}\ \tilde{Y}_{t-1}^{\ell} + \sum_{i=1}^{k} c_i \Delta \tilde{Y}_{t-i}^{\ell} + u_t \qquad (8)$$

$$\tilde{Y}_t^B = a^B\ \tilde{Y}_{t-1}^B + \sum_{i=1}^{k} c_i \Delta \tilde{Y}_{t-i}^B + u_t \qquad (9)$$

$\text{where}: (DT_b)_t = 0\,(1) \text{ when } t \ne T_B + 1\ (t = T_B + 1), \ell = A, C\ \&\ k = 0, 1, 2, ...$

In third step and assuming that the residuals of (8) and (9) are not correlated, the significance of unit root null is tested comparing the value of $T_{\tilde{a}^j} = \left(\tilde{a}^j - 1\right) / \text{s.e.}(\tilde{a}^j)$, j = A, B, C with the appropriate critical value. If the value of computed t – statistic is smaller (greater) than the critical value, unit root null is rejected (accepted).

When the trend shift of $\{Y_t\}_{t=1}^{T}$ is gradual, the unit root investigation takes place in two steps. During the first step, one of the following equations is estimated using the OLS method:

$$Y_t = \mu^A + \beta^A t + \theta^A DU_t + d^A (DT_b)_t + a^A Y_{t-1} + \sum_{i=1}^{k} c_i \Delta Y_{t-i} + u_t \qquad (10)$$

$$Y_t = \mu^B + \beta^B t + \gamma^B DT_t^* + a^B Y_{t-1} + \sum_{i=1}^{k} c_i \Delta Y_{t-i} + u_t \qquad (11)$$

$$Y_t = \mu^C + \beta^C t + \theta^C DU_t + d^C (DT_b)_t + \gamma^C\ DT_t^* + a^C Y_{t-1} + \sum_{i=1}^{k} c_i \Delta Y_{t-i} + u_t \qquad (12)$$

In second step and assuming that the residuals of the estimated equation are not correlated, the t – statistic $T_{\tilde{a}^j} = \left(\tilde{a}^j - 1\right) / \text{s.e.}(\tilde{a}^j)$, j = A, B, C is used to determine stationarity of the examined series. More specifically, if the value of $T_{\tilde{a}^j}$ statistic is lower (higher) than the appropriate critical value[3] at a certain significance level, the $\{Y_t\}_{t=1}^{T}$ series is proved to be trend (difference) stationary.

To investigate the stationarity of a time series $\{Y_t\}_{t=1}^{T}$, allowing for two breaks in its deterministic trend that take place at distinct points in time, the analysis of Lumsdaine & Papell [1997] could be followed. The model is described by the following equation:

$$\Delta Y_t = \mu + \beta\, t + a\, Y_{t-1} + \theta_1\, DU1_t + \gamma_1\, DT1_t + \theta_2\, DU2_t + \gamma_2\, DT2_t + \sum_{i=1}^{k} c_i \Delta Y_{t-i} + u_t \qquad (13)$$

where $t = 1, ..., T$, $DU1_t = 0\,(1)$ if $t \le T_b^1$ ($t > T_b^1$), $DU2_t = 0\,(1)$ if $t \le T_b^2$ ($t > T_b^2$),

$DT1_t = 0\,(t - T_b^1)$ if $t \le T_b^1$ ($t > T_b^1$), $DT2_t = 0\,(t - T_b^2)$ if $t \le T_b^2$ ($t > T_b^2$) and

T_b^1 (T_b^2): the point in time that the first (second) break occurs.

The procedure that is followed for the investigation of the unit root hypothesis' validity includes four steps. In the first step, the OLS method is used to estimate (13) for all possible time combinations (T_b^i, T_b^j). The value of parameter k ensures that the residuals u_t are not correlated and its magnitude is determined as in the case of equations (4) ~ (8). It must be noted that this estimation is carried out, assuming 1st that $2 < T_b^1, T_b^2 < T-1$, 2nd the possibility of having two breaks that take place on consecutive dates is ruled out. It is about cases, in which a positive (negative) shock is immediately followed by a negative (positive) one and are considered as one and not two episodes. Thirdly, in case of models AA and CC, the estimation of equation (13), and ensuing from this equation for $\gamma_1 = \gamma_2 = 0$, is carried out for those time combinations (T_b^i, T_b^j) for which i < j. The latter assumption is not adopted in case of model CA. The selected combination of break points (T_b^i, T_b^j) is the one for which the value of $T_{\hat{a}}$ statistic for testing a = 0 is minimized, i.e. for which the possibility of accepting the unit root hypothesis is minimized. This value of $T_{\hat{a}}$ statistic is used in the second step of the followed procedure to determine the stationarity of the examined time series. More specifically, the unit root null is rejected (accepted) when the $T_{\hat{a}}$ statistic is lower (higher) than the appropriate critical value.

HISTORICAL OVERVIEW

In the present section a short review of the historic and economic events is attempted that took place in the period between 1858 and 1938. This time domain, practically, covers a big part of Greek modern history, which is extended between the war of independence (1821 ~ 1831) and the Second World War (1939 ~ 1945). During this period, the Greek history is characterized by major national and economic events, the most significant of which are presented in the context of table 1.

According to the data presented in table 1, there are several years within the covered period, for which the series are expected to be changed in the mean and/or the growth of their trend. In case of velocity v1, a shift in the trend of this series is expected within one of the following years: (a) in 1881 (observation twenty four), (b) in 1884 (observation twenty seven), (c) in 1893 (observation thirty six), (d) in 1897 (observation forty), (e) in 1910, 1912,1913 (observation fifty three, fifty five and six) and (f) in 1922,1923 (observation sixty five, sixty six) and, finally, (f) in 1929 (observation seventy two). In case of velocity v2, and v3 respectively, we expect the same scenario.

Table 1
Main economic and historical events within the period 1858 ~ 1938

Year	Obs.	Event
1864	7	Great Britain ceded the seven Ionian Islands to Greece.
1867	10	Greece joins the Latin Monetary Union. As a result, it was obliged to increase drachma's content in precious metal.
1881	24	Annexation of Thessaly and a part of Epirus by Greece.
1882	25	As a result of country's accession to L.M.U. in 1867, the transformation of Greek monetary system is completed. Old coins and foreign currencies used in transactions are withdrawn.
1884	27	The Greek State issues 11000000 gold coins. The New Drachma is put in circulation and coexists with the Old Drachma.
1886	29	Starting from this year, Greek government enters a period of large scale foreign borrowing to finance the budget deficits.
1893	36	Bankruptcy of Greek economy.
1897	40	Greece losses a part of Thessaly after its defeat in the war against Ottoman Empire. The Great Powers establish an International Financial Control over certain Greek finances and guarantee the payment of the war indemnity to Turkey and the country's foreign debt.
1910	53	Passing of the law 3642 under which drachma entered the classical gold standard.
1912	55	Annexation of Crete by Greece. Outbreak of First Balkan War.
1913	56	Outbreak of 2nd Balkan War. Greece annexes Macedonia and the rest of Epirus.
1916	59	Greece enters First World War. As a result of the dispute between Prime Minister, E. Venizelos, and King Constantine regarding the placing of Greece on the side of Entente, the country had two governments until 1917 when King Constantine left the country.
1919	62	Greece recovers Eastern Macedonia, annexes Western Thrace and participates in the reciprocal exchange of national minorities (Neuilly treaty).
1920	63	In accordance to the treaty of Sevres, Greece obtained Eastern Thrace, North & Central Aegean Islands and the region around the city of Smyrna (in Asia Minor).
1921	64	Greece launches the "Asia Minor" military campaign against Turkey.
1922	65	The "Asia Minor front" collapses Greece is defeated. In accordance to the Lausanne treaty, Greece losses Eastern Thrace and the region around the city of Smyrna. A great number of Greek refugees from Eastern Thrace and Asia Minor enters Greece.
1928	71	Foundation of Central Bank of Greece.
1929	72	The great economic depression.

RESULTS

The stationarity of, v1, v2 and v3 (all measured in real terms and in natural logarithms) will be investigated in the present section with the help of the data presented in tables 2, 3 and 4.The time series 'data are taken from Kostelenos, G.C.[1995],pp.433-436,457-459. In table 2 the estimated values of $\widehat{\eta}_{\mu}(\ell)$ and $\widehat{\eta}_{\tau}(\ell)$ statistics are presented. These two statistics were estimated for different integer values of parameter ℓ ranging from zero to eight. It is quite easy to ascertain that the values of both statistics constitute a negative function of parameter ℓ with their minimum value estimated for ℓ = 8. In other words, the possibility of accepting the level or trend stationarity hypothesis is maximized for $\ell = 8$. Therefore, the KPSS test will be conducted for that specific value of parameter ℓ. The hypothesis of level stationarity is rejected for all time series, since $\hat{\eta}_\mu(8)$ is higher than the given in table 2 critical values at 1%, 5% and 10% significance levels. This is not surprising given the presence of a clear deterministic trend in all three-time series.

Table 2
Estimated values of $\hat{\eta}_\mu(\ell)$ and $\hat{\eta}_r(\ell)$ statistics

	ℓ	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Real v1	$\hat{\eta}_\mu(\ell)$	7.413	3.843	2.611	1.993	1.622	1.375	1.198	1.066	0.964
	$\hat{\eta}_r(\ell)$	0.435	0.237	0.170	0.136	0.115	0.101	0.092	0.085	0.080
Real v2	$\hat{\eta}_\mu(\ell)$	7.654	3.917	2.661	2.031	1.651	1.398	1.217	1.082	0.977
	$\hat{\eta}_r(\ell)$	0.470	0.262	0.191	0.155	0.133	0.117	0.107	0.099	0.093
Real v3	$\hat{\eta}_\mu(\ell)$	7.719	3.750	2.684	2.148	1.666	1.311	1.229	1.182	0.987
	$\hat{\eta}_r(\ell)$	0.348	0.185	0.153	0.114	0.120	0.089	0.182	0.096	0.272

***Note*:** Critical values for $\hat{\eta}_\mu(\ell)$ $[\hat{\eta}_r(\ell)]$ statistic at 1%, 5% and 10% are 0.739 (0.216), 0.463 (0.146) and 0.347 (0.119) respectively.

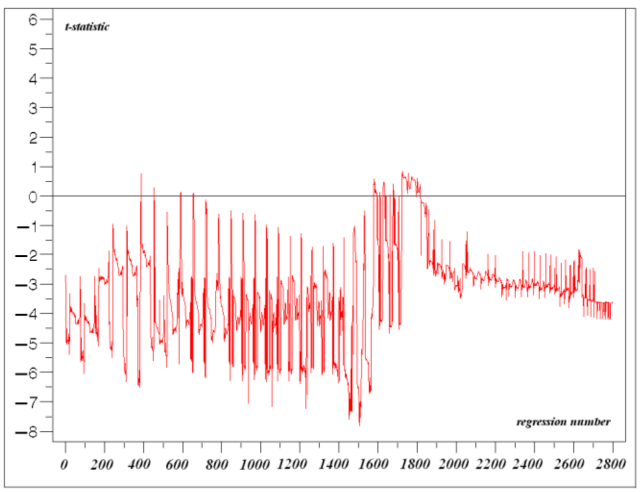
Table 3
Break Point Selection and Test Statistics Estimated via Innovational Outlier C Model

		k	*Estimated Statistic*	*Selected Break Point*		$T_{\hat{a}}$ *Test Statistic*
				Year	*Obs.*	
Real v1	$T_{\hat{a}}^{min}$	0	-4.406	1880	23	-4.346
	$\lvert T_{\hat{\gamma}} \rvert_{max}$	0	3.902	1881	24	-3.365
Real v2	$T_{\hat{a}}^{min}$	0	-3.107	1865	8	-3.507
	$\lvert T_{\hat{\gamma}} \rvert_{max}$	9	3.660	1926	69	-3.088
Real v3	$T_{\hat{a}}^{min}$	0	-3.605	1865	8	-3.672
	$\lvert T_{\hat{\gamma}} \rvert_{max}$	9	2.935	1926	69	-3.270

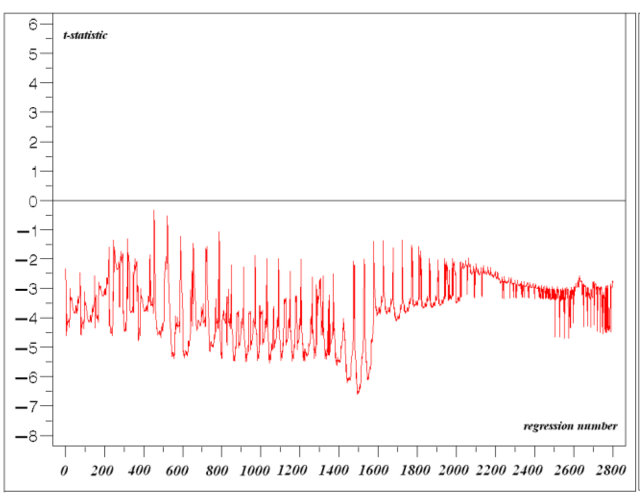
***Note*:** The critical values for testing the unit root null when the break is chosen on the basis of the minimum (absolute maximum) value of $T_{\hat{a}}$ ($T_{\hat{\gamma}}$) statistic at 1%, 5% and 10% significance levels are – 6.32 (– 6.07), – 5.59 (– 5.33) and – 5.29 (– 4.94) respectively (see Perron [1997] in case of $T_{\hat{a}}$ statistic and Perron and Vogelsang [1998] in case of $T_{\hat{\gamma}}$ statistic).

The data presented in table 3 result after the use of innovational outlier C model, which permits the investigation of the unit root hypothesis, allowing for a break in the level and trend of the examined series that takes place in an unknown time point. More specifically, $T_{\hat{a}}^{min}$ and $\lvert T_{\hat{\gamma}} \rvert_{max}$ indicate the minimum value of T_a statistic and the maximum absolute value of T_γ statistic respectively, that were estimated in the context of IO, C model in case of real v1, v2 and v3, for each one of the 79 observations. The reported value of the truncation lag parameter k was selected, using the earlier described general to specific procedure, ensuring that residuals are well behaved, i.e. they are normally and independently distributed. The specified break points by $T_{\hat{a}}^{min}$ statistic, i.e. the minimum statistic used to test whether a = 1, are 1880 in case of real v1 and 1865 in case of real v2 and real v3. Although these break points are quite close to the expected ones on the basis of the historical events presented in table 1, they are quite different to the resulted ones after the use of $\left|T_{\hat{\gamma}}\right|_{max}$ statistic. More specifically, the break points indicated by this statistic are 1881 in case of real v1 and 1926 in case of real v2 and real v3. With the exception of real v1, the determined break points via $\left|T_{\hat{\gamma}}\right|_{max}$ statistic are quite far from the expected ones in all other cases. All the time series are proved to be difference stationary processes, regardless of the used break point selection method, given that the estimated values of T_a statistic are greater than the critical values at 1%, 5% and 10% significance levels. The magnitude of these critical values are presented in the lower part of table 3.

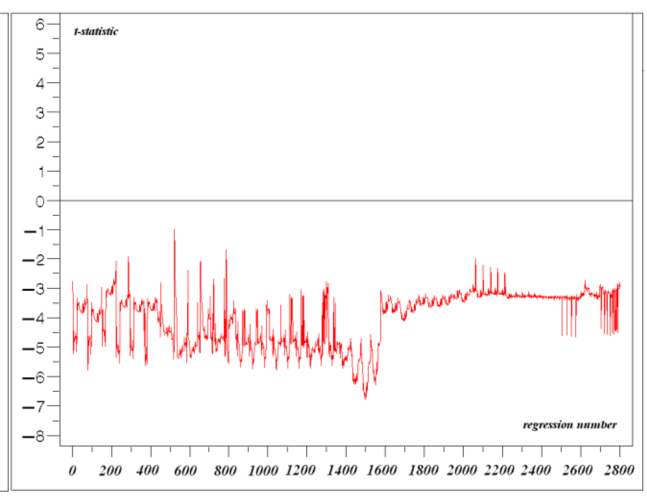
The data presented in table 4 result after the use of CC model, in the context of which the unit root null is tested, allowing for two breaks in the level and trend of the series examined. The stationarity of velocity (v1,v2,v3) will be investigated in the present section with the help of the diagram 1 and table 4. The diagram 1 shows the t statistic of the parameter (*a*) of the equation (13).



a. Velocity M1



b. Velocity M2



c. Velocity M3

Diagram 1

From the diagram 1 we observation can see that the v1 velocity has the minimum t statistic on the 27 and 61 observation. For the v2 velocity the minimum t statistic is on observation 27 and 48. The v3 velocity has the minimum t statistic on observation 27 and 55. To give a better information about the above diagram, let us look table 4.

Table4
Break Points Selection and Estimated Coefficients via CC Model

	k	T_b^1 T_b^2	*Obs.*	*A*	θ_1	γ_1	θ_2	Γ_2
V1	2	1884	27	-1.119	1.894	0.262	-0.969	0.113
		1919	61	(-7.81)	(6.311)	(6.431)	(-3.44)	(5.174)
V2	0	1884	27	-0.701	1.188	0.097	-0.401	0.062
		1906	48	(-6.59)	(4.854)	(4.131)	(-1.95)	(4.054)
V3	0	1884	27	-0.707	1.253	0.084	0.302	0.043
		1913	55	(-6.78)	(5.38)	(4.532)	(1.652)	(3.406)

Note: The critical values for testing the unit root null at 1%, 5% and 10% significance levels are – 7.34, – 6.82 and – 6.49 respectively (see Lumsdaine and Papell [1997]). *t* – statistics in parentheses.

The data presented in table 4 result after the use of CC model, in the context of which the unit root null is tested, allowing for two breaks in the level and trend of the series examined. The break points approved by the minimum value of $T_{\hat{a}}$ statistic for testing a = 0 are 1884 and 1919 in case of v1 velocity. The break points approved by the minimum value of $T_{\hat{a}}$ statistic foe testing a=0 are 1884 and 1906 in case of v2, and 1884 and 1913 in case of v3. The approved break points are quite close to the expected ones. In 1884 the Greek State issues 11000000 gold coins. The New Drachma is put in circulation and coexists with the Old Drachma. In 1919, in accordance to the Treaty of Neuilly Greece recovered Eastern Macedonia and annexed Western Trace. In addition, the Treaty provided for the reciprocal exchange of the populations belonging to the relevant in each case racial minorities. Crete was in 1912 annexed and the first Balkan war broke out. This was followed in 1913 by the second Balkan War, which resulted in the annexation of the rest of Epiros and of Macedonia. The Balkan wars and the First World War yielded wealth, territories, confidence and high expectations. Deposits increased substantially and the Greek economy seemed invulnerable as the drachma remained solidly at par with the gold franc until 1919, although inflation in Greece was much higher than in the UK and in France. Greece had participated in the gold exchange standard since 1910, but due to the handicaps that the war imposed upon trade, as well as to the exchange pegging imposed by the Allies, the system was not allowed to function properly and the Greek currency was kept stable rather than being allowed to depreciate. The imposition of the International Financial Control coincided with a dramatic favourable change of the World economic conjuncture. The development of the Greek merchant steam fleet coincided with (and was partly feed of) the increase of transatlantic emigration (after 1890). The remittances of emigrants and the income created by merchant marine activities soon became very important factors for the balance of payments. The magnitude and the importance of these two kinds of capital transfer were reflected in the accumulation of significant deposits in the Greek Banks. If we take bank deposits as an indicator of the saving propensity of the Greek Economy, we realize that the era which followed the period of the Great Depression, characterized by a rapid growth of the Bank deposits, is one of a growing possibility for the Banking system to enlarge its financing activities. It is important here to add that these savings were not created domestically, but originated from the enterprising Greek Levantine Diaspora, from emigrants in the United States and from those employed in the merchant marine. It is not a coincidence that the Bank of Athens, which was created in the late 19th century, was the first deposit bank in the country and was extensively involved in the Levantine markets.

The conclusion reached after the comparison of $T_{\hat{a}}$ statistic with the critical values presented in the lower part of table 4, is that the unit root null can rejected at all significance levels in case of v1.The velocity v1 is a stationary process. The velocity v2 and the velocity v3 is a stationary process only at 10% level.

CONCLUSIONS

In the context of the present paper and covering the period between 1858 and 1938, the series of Greek velocity is examined for a unit root allowing for maximum two breaks in their trend, that take place at an unknown point in time. The structural breaks are considered to be either instantaneous or gradual and to affect the intercept or the slope or both of them of the examined series. From an historical point of view, there are several dates at which a break might be emerged in the trends of velocity. In our analysis, the trend of the series exhibits a gradual change in both the intercept and the slope of the trend. In this model, the break dates were endogenously determined. Concerning the stationarity of the examined series, the results where contradicting. More specifically, in the context of KPSS test all three definitions of money supply were proved to be trend stationary processes. In the context of CC model, the minimum value of T_a statistic for testing the unit root null was used, in order to determine the combination of break dates in the velocity series. In case of velocity v1 the unit root null can rejected at all significance levels. The velocity v2 and v3 area trend stationary process only at 10 percent level.

NOTES

[1] The asymptotic distribution of Phillips – Perron test is the same as Augmented Dickey – Fuller statistic.

[2] The potential break date T_B is allowed to take any value within the open and not the closed interval (1,T) to avoid the problem of co-linearity during the estimation of equations (5) ~ (9).

[3] The magnitude of the critical values both in case of AO and IO models is affected by the ratio $\lambda = T_B/T \in (0,1)$, the criterion used for the determination of parameter k and the method used to determine the break date (T_B) endogenously.

REFERENCES

1. Banerjee, Anindya; Lumsdaine, Robin L.; Stock, James H.. Recursive and Sequential Tests of the Unit – Root and Trend – Break Hypothesis: Theory and International Evidence, *Journal of Business & Economic Statistics*, 10, 3, July 1992, pp. 271 ~ 87.
2. Dickey, David A.; Fuller, Wayne A.. Distribution of the Estimators for Autoregressive Time Series with a Unit Root, *Journal of the American Statistical Association*, 74, 366, June 1979, pp. 427 ~ 31.
3. Dickey, David A.; Fuller, Wayne A.. Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root, *Econometrica*, 49, 4, July 1981, pp. 1057 ~ 72.
4. Kostelenos, George C. Money and Output in Modern Greece: 1858 – 1938, pp. 25 ~ 31 & 337 ~ 442, *Centre of Planning and Economic Research*, Studies 44, Athens, 1993.
5. Kwiatkowski, Denis; Phillips, Peter C. B.; Schmidt, Peter; Shin, Yongcheol. Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root, *Journal of Econometrics*, 54, 1992, pp. 159 ~ 178.
6. Lazaretou, Sophia. Greek Monetary Retrospect: The Adventures of the Drachma, pp. 16 ~ 21, Bank of Greece Working Paper, No 2, 2003.
7. Lazaretou, Sophia. Government Spending, Monetary Policies and Exchange Rate Regime Switches: The Drachma in the Gold Standard Period .*Explorations in Economic History*,32, 1995,pp.28-50.
8. Lumsdaine, Robin L.; Papell, David H. Multiple Trend Breaks and the Unit – Root Hypothesis, *The Review of Economics and Statistics*, 79, 2, May 1997, pp. 212 ~ 218.
9. NG, Serena; Perron, Pierre. Unit Root Test in ARMA Models with Data – Dependent Methods for the Selection of the Truncation Lag, *Journal of the American Statistical Association*, 90, 429, March 1995, pp. 268 ~ 81.
10. Perron, Pierre. The Great Crash, the Oil Price Shock and the Unit Root Hypothesis, *Econometrica*, 57, 6, November 1989, pp. 1361 ~ 1401.

11. Perron, Pierre. Testing for a Unit Root in a Time Series with a Changing Mean, *Journal of Business & Economic Statistics*, 8, 2, April 1990, pp. 153 ~ 62.
12. Perron, Pierre. Trend, Unit Root and Structural Change in Macroeconomic Time Series, in B. B. Rao, ed., *Cointegration for the Applied Economist*, New York: Mac Millan Press, 1994, pp. 113 ~ 46.
13. Perron, Pierre. Further Evidence on Breaking Trend Functions in Macroeconomic Variables, *Journal of Econometrics*, 80, 2, October 1997, pp. 355 ~ 85.
14. Perron, Pierre; Vogelsang, Timothy J.. Testing for a Unit Root in a Time Series with a Changing Mean: Corrections and Extensions, *Journal of Business & Economic Statistics*, 10 , 4 , October 1992a, pp. 467 ~ 70.
15. Perron, Pierre; Vogelsang, Timothy J.. Nonstationarity and Level Shifts with an Application to Purchasing Power Parity, *Journal of Business & Economic Statistics*, 10, 3, July 1992b, pp. 301 ~ 20.
16. Perron, Pierre; Vogelsang, Timothy J.. Additional Tests for a Unit Root Allowing for a Break in the Trend Function at an Unknown Time, *International Economic Review*, 39, 4, November 1998, pp. 1073 ~ 1100.
17. Phillips, Peter C. B.; Perron, Pierre.. Testing for a Unit Root in Time Series Regression, *Biometrika*, 75, 2, 1988, pp. 335 ~ 46.
18. Zivot, Eric; Andrews, Donald W. K.. Further Evidence on the Great Crash the Oil – Price Shock, and the Unit Root Hypothesis, *Journal of Business & Economic Statistics*, 10, 3, July 1992, pp. 251 ~ 70.

NOTES