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## **GREEK BUDGET DEFICITS, STRUCTURAL BREAKS AND THE CONCEPT OF SUSTAINABILITY: NEW ECONOMETRIC EVIDENCE**

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**Abstract:** This paper attempts to investigate the concept of the sustainability of Greek fiscal policy. Several procedures to test such sustainability have been proposed in the relevant literature, which focuses on the univariate properties of the public deficit and on the presence of a long-run relationship between government spending and revenues. Our empirical analysis uses an approach proposed by Martin (2000) and is based on a cointegration model allowing for multiple endogenous breaks in both the intercept and slope parameters. The methodology produces an inference about the value of the cointegrating parameters, as well as the size and the timing of shifts in the relationship. Practical advantages arising from the estimation of models with structural changes are, among others, the identification of events that may have fostered the structural changes and better forecasts when the most recent regime is used.

The results reveal that the Greek public deficit is sustainable, in the weak sense of the term. The above findings imply possible future problems and call for fiscal reforms.

**Key words:** Budget deficit; Cointegration; Structural breaks; Sustainability

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### 1. INTRODUCTION

The budget deficit constitutes a major fiscal indicator of a country's macroeconomic position. According to the Keynesian view, expansionary spending increases budget deficits and borrowing with desirable counter-cyclical and growth effects. On the other hand, according to the neoclassical view, a government deficit will be matched by a

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parallel shift in private savings since consumers, who are assumed to have perfect foresight, will fully anticipate additional future taxes due to increased current revenue and expenditure (Ricardian Equivalence Theorem).

Budget deficits have resulted in the enhanced borrowing of governments with developed countries focusing mainly on domestic borrowing whereas developing countries borrow both domestic and foreign funds. In both cases, higher deficits, especially those of the developing countries, have resulted in debt accumulation over the years. This has led countries to an ongoing need for fiscal consolidation and discipline, that is, to run sustainable deficits. In fact, the sustainability of fiscal policies dominates the agenda of economic policy in most countries.

The most widely accepted definition of fiscal sustainability is based on the concept of inter-temporal budget constraint which requires that the discounted value of debt reaches zero at the limit. In this context, the possible interdependence between government spending and revenues should be analysed in order to select the proper strategy of fiscal consolidation.

Regarding Greece, the concept of fiscal sustainability has always been of major importance for two main reasons: first, the fiscal imbalances which appeared in the late 1970s and 1980s had a negative effect on growth and, second, Greece had to meet the Maastricht convergence criteria in order to become a member of the European Monetary Union (EMU). This means that the Greek authorities had to pursue sustainable fiscal deficits to prevent an excessive build up of debt. Besides, after accession to the EMU Greece faced the need to keep this debt within the required limits.

The concept of sustainability has been broadly analysed in the respective literature. A number of empirical efforts pay attention to the integration order of deficit and debt processes and suggest that the condition for fiscal sustainability is the stationarity,  $I(0)$ , of the examined series (Hamilton and Flavin, 1986) or that the discounted debt process is  $I(0)$  without drift (Wilcox, 1989). Other research papers investigate the existence of cointegration between public revenue and expenditures as an alternative condition for fiscal sustainability (Hakkio and Rush, 1991; Smith and Zin, 1991; Trehan and Walsh, 1988, 1991). Quintos (1995) introduced the concept of 'strong' and 'weak' conditions for fiscal sustainability.

With regard to the Greek case, Corsetti and Roubini (1991) found evidence that the Greek public debt is unsustainable. Makrydakis *et al.* (1999) established that the Greek public debt is unsustainable if there is no allowance of fiscal policy regime shifts. In contrast, Argyrou (2004), considering a nonlinear debt adjustment and structural breaks in fiscal policy, concludes that the Greek public debt is sustainable. Using cointegration techniques for a sample of selected European countries, Papadopoulos and Sidiropoulos (1999) provided evidence of sustainable deficits for the Greek economy.

In the context of cointegration methodology, this paper uses the model recently proposed by Martin (2000) which allows for multiple endogenous breaks in both the intercept and slope parameters and re-examines the concept of sustainability. Given that the relative literature provides contrasting evidence regarding the Greek case, we consider that the use of such an advanced empirical approach, though computationally demanding, is justified in the sense that it would shed more light on and validate the accuracy of previous empirical findings. Besides, the empirical analysis uses government spending and revenues as ratios over GDP (Haug, 1995; De Castro and Hernandez de Cos, 2002) since government authorities are mainly concerned with the dynamics of different budget items relative to the overall size of the economy.

The rest of the paper is organised as follows: the next section presents a summary of Greek fiscal policy performance. Section 3 discusses the theoretical issues explaining the use of the cointegration framework for analysing deficit sustainability. Section 4 presents certain methodological issues and Section 5 reports the empirical findings. Concluding remarks are given in the last section.

## 2. GREEK DEFICITS AND HISTORICAL PERSPECTIVES<sup>1</sup>

The Greek fiscal policy was quite conservative up until 1976. Up to 1980 the share of government spending in GDP (G/GDP) remained under 30%. By European standards this was a low percentage for that year; however, it was in the same range as average spending in Europe in 1960. Between 1980 and 1985, the share of public spending in GDP rose by a remarkable 12.5% of GDP. The increase continued over the next decade and by 1995 the G/GDP ratio had reached almost 50%, a high percentage even by European standards. An interesting element of this growth is that much of the increase was due to transfers to the private sector, as well as to interest payments on the growing public debt. This was common to other European countries as well. On the other hand, government consumption or real expenditure changed only a little.

The growth in Greek public spending closely paralleled that of most European countries, but with a lag of some 20 years. In fact, while in most European countries the explosive growth of spending largely occurred during the 1960-80 period, in Greece this happened in the 1980-95 period. By the end of this period, Greece's spending as a share of GDP was in line with (or higher than) that of many continental European countries. In spite of the very high spending growth, a genuine welfare state was not created.

Shifting our attention from the spending to the revenue side of the budget, the ratio of tax revenue to GDP (R/GDP) was low up until 1980. However, from 1980 until 2000 this ratio increased by almost 19 percent or about one percent of GDP per year. Most likely

<sup>1</sup> For a detailed presentation see Manessiotis and Reischauer (2001).

this increase was a world record. Such an increase inevitably leads to questions regarding the impact on the economy.

As a result, and despite the partial recovery of public debt in the 1990s after a tighter fiscal policy, Greece was unable to meet the relevant criteria for EMU qualification and was not among the first-wave EMU participants in January 1999.

### 3. THEORETICAL ISSUES

Consider the following budget constraint:

$$\Delta b_{t+1} = i_t b_t + g_t^* - r_t,$$

where  $b_t$  is the stock of debt at the end of period  $t-1$  in nominal terms,  $g_t^*$  is nominal public expenditure excluding interest payments,  $r_t$  are nominal public revenues, and  $i_t$  is the average nominal interest rate on the debt in period  $t-1$ . The total public expenditures are

$$g_t = i_t b_t + g_t^*.$$

However, according to De Castro and Hernandez de Cos (2002) few or no conclusive results can be drawn from variables that show an upward trend if the economy shows a similar pattern, that is, the relevant variables must be considered by taking into account the size of the economy. Thus, using the variables as percentages of GDP and focusing on the burden that public debt imposes on the economy, the budget constraint in period  $t$  and the definition of total public expenditures, both in GDP terms, are now

$$\Delta B_{t+1} = \lambda_t B_t + G_t^* - R_t \quad (1)$$

$$G_t = \lambda_t B_t + G_t^* \quad (1a)$$

where the uppercase letters indicate the same variables in terms of GDP, and  $\lambda_t = (i_t^* - h_t)/(1 + h_t)$ , which can be understood as the addition to the net debt due to the real ex-post interest rate ( $i_t^*$ ) over the real GDP growth rate ( $h_t$ ). Taking  $\lambda_t$  as stationary around a mean  $\lambda$ , (1) can be expressed as

$$\Delta B_{t+1} = \lambda B_t + G_t^{**} - R_t \quad (2)$$

where  $G_t^{**} = G_t^* + (\lambda_t - \lambda)b_t$ . Solving forward (2), we obtain

$$B_t = \sum_{s=0}^{\infty} (1 + \lambda)^{-(s+1)} (R_{t+s} - G_{t+s}^{**}) + \lim_{s \rightarrow \infty} (1 + \lambda)^{-(s+1)} B_{t+s+1} \quad (3)$$

Taking the expectations in (3), the hypothesis that the government is subject to the intertemporal borrowing constraint can be expressed as

$$B_t = E_t \sum_{s=0}^{\infty} (1 + \lambda)^{-(s+1)} (R_{t+s} - G_{t+s}^{**}) \tag{3a}$$

which is mathematically equivalent to the transversality condition

$$E_t \lim_{s \rightarrow \infty} (1 + \lambda)^{-(s+1)} B_{t+s+1} = 0.$$

This implies that, for a process to be sustainable, the current debt must equal the expected present value of future surpluses.

Next, taking first differences in (3) and using (2) and (1a) yields to the following expression:

$$G_t - R_t = \sum_{s=0}^{\infty} (1 + \lambda)^{-(s+1)} (\Delta R_{t+s} - \Delta G_{t+s}^{**}) + \lim_{s \rightarrow \infty} (1 + \lambda)^{-(s+1)} \Delta B_{t+s+1} \tag{4}$$

where the left-hand side of (4) represents the public deficit. In order to impose a constraint analogous to (3a) the following transversality condition should hold:

$$E_t \lim_{s \rightarrow \infty} (1 + \lambda)^{-(s+1)} \Delta B_{t+s+1} = 0.$$

So far, testing for sustainability aims to verify whether this transversality condition in the government budget constraint holds. The relevant tests pay special attention to integration orders of deficit and debt processes, and to the underlying stochastic structures as well as to the existence of cointegration relationships between revenues and expenditures. In this context, the method employed by Trehan and Walsh (1988) consists of testing the stationarity of  $\Delta B_t$  in various forms, or alternatively the stationarity of  $G_t - R_t$ . This procedure implies testing cointegration between revenues and expenditures when the cointegrating vector (1,-1) is imposed.

Alternatively, Hakkio and Rush (1991) suggested that the sustainability of the debt stock can be evaluated by estimating the regression

$$R_t = \alpha_1 + \beta_1 G_t + u_t \tag{5}$$

where<sup>2</sup>  $\beta_1 \leq 1$  and testing to see whether  $R_t$  and  $G_t$  form a cointegrating relation. More specifically, it can be shown that (Quintos, 1995):

- i) the deficit is 'strongly' sustainable if and only if the I(1) processes  $R_t$  and  $G_t$  are cointegrated and  $\beta_1 = 1$ ;

<sup>2</sup> Note that  $\beta_1 > 1$  is not consistent with a deficit since revenues are growing at a faster rate than (interest inclusive) expenditures.

- ii) the deficit is 'weakly' sustainable if  $R_t$  and  $G_t$  are cointegrated<sup>3</sup> and  $0 < \beta_1 < 1$ ; and  
 iii) the deficit is unsustainable if  $\beta_1 \leq 0$ .

Strong sustainability means that the budget constraint holds with the undiscounted debt process,  $B_t$ , being  $I(1)$ . Weak sustainability means that the constraint holds, but with  $B_t$  exploding at a rate which is less than the growth rate of the economy which is approximated by the mean real interest rate. Although the latter situation is consistent with sustainability, it may well have implications for the ability of the government to market its debt and it is therefore the less desirable scenario. An unsustainable deficit is one which implies that  $B_t$  is exploding at a rate equal to or in excess of the growth rate of the economy, such that the intertemporal budget constraint is violated.

#### 4. METHODOLOGICAL ISSUES

Following Martin (2000), in order to accommodate  $m$  shifts in the parameters of the cointegration model, we define the following model:

$$R_t = x_t' \beta + u_t \quad (6)$$

$$G_t = \alpha + G_{t-1} + v_t \quad (7)$$

where  $x_t' = (1, i(r_1)_t, \dots, i(r_m)_t, G_t, G(r_1)_t, \dots, G(r_m)_t)'$ , with

$$i(r_k)_t = \begin{cases} 0 & \text{for } t \leq r_k \\ 1 & \text{for } t > r_k \end{cases} \quad k = 1, 2, \dots, m \quad (8)$$

$$G(r_k)_t = \begin{cases} 0 & \text{for } t \leq r_k \\ G_t & \text{for } t > r_k \end{cases} \quad k = 1, 2, \dots, m \quad (9)$$

and  $\beta = (\alpha_1, \alpha_2 - \alpha_1, \dots, \alpha_{m+1} - \alpha_m, \beta_1, \beta_2 - \beta_1, \dots, \beta_{m+1} - \beta_m)'$ .

The error structures in (6) and (7) are specified as

$$\begin{pmatrix} \phi(L) & 0 \\ 0 & \psi(L) \end{pmatrix} \begin{pmatrix} u_t \\ v_t \end{pmatrix} = \begin{pmatrix} \varepsilon_t \\ \eta_t \end{pmatrix} \quad (10)$$

where  $\phi(L)$  and  $\psi(L)$  are defined as finite order polynomials in the lag operator  $L$ , and  $(\varepsilon_t, \eta_t)'$  is a disturbance vector, assumed to be bivariate Normal.

<sup>3</sup> Quintos (1995) showed that cointegration is not a necessary condition for weak sustainability. However, the interpretation of  $\beta_1$  is unclear in this case.

In examining the cointegration properties of  $R_t$  and  $G_t$  in equation (6), the following reparameterisation may be used (Zivot and Phillips, 1994):

$$\phi(L) = 1 - \rho_1 L - \rho_2 L\Delta - \dots - \rho_p L^{p-1}\Delta \quad (11)$$

where  $\Delta = 1 - L$ ,  $\rho_1 = \phi_1 + \phi_2 + \dots + \phi_p$  and  $\rho_k = \sum_{i=k}^p \phi_i$ , ( $\phi_i$  are the coefficients of the polynomial  $\phi(L)$ ). An inference concerning the presence of cointegration between the two  $I(1)$  processes,  $R_t$  and  $G_t$ , can be based on the marginal posterior density function for  $\phi_1$ , with a test of cointegration based upon a comparison of  $\Pr(\phi_1 < 1)$  and  $\Pr(\phi_1 \geq 1)$ .

The whole inferential approach used by Martin (2000) is Bayesian, with results being based on Markov chain Monte Carlo posterior simulators. More specifically, the marginal posterior mass functions for the breakpoints,  $r_k$ ,  $k=1, 2, \dots, m$ , provide the basis for estimating the timing of the parameter shifts. The marginal densities for  $(\alpha_{k+1} - \alpha_k)$  and  $(\beta_{k+1} - \beta_k)$ ,  $k=1, 2, \dots, m$ , provide the basis for both point and interval estimates of the magnitude of the intercept and slope shifts respectively;  $\alpha_1$  and  $\beta_1$  represent the parameters of the pre-shift cointegrating relationship, with point and interval estimates of them being produced via their respective marginal posteriors.

The null of  $H_0: \beta_1 = 1$  against the alternative  $H_1: \beta_1 \neq 1$  is tested by determining whether the value of unity is contained in an appropriate Highest Posterior Density (HPD) interval<sup>4</sup> for  $\beta_1$ . Conditional on the acceptance of  $\beta_1 = 1$ , evidence of small and offsetting values for  $(\beta_{k+1} - \beta_k)$ ,  $k=1, 2, \dots, m$ , can be considered as evidence in favour of  $\beta_1 = 1$  for the full period. To test  $H_0$  against the one-sided and bounded alternative  $H_1: 0 < \beta_1 < 1$ , a posterior odds test is applied (Chib, 1995).

## 5. EMPIRICAL ANALYSIS

### 5.1 Data and Integration Analysis

The empirical analysis is carried out using annual data for Greece, on government spending (G) and revenues (R), taken as ratios over GDP. The use of ratios to GDP is based on the consideration that, for the sake of economic interpretation, such transformations really take the size of the economy into account (De Castro and Hernandez de Cos, 2002). Data were obtained from the IFS (International Financial Statistics) database and cover the 1956 to 2000 period<sup>5</sup>.

<sup>4</sup> An HPD interval is an interval with the specified probability coverage whose inner density ordinates are not exceeded by any density ordinates outside the interval.

<sup>5</sup> Although the time period is long and there could be possible inconsistencies in the construction of the data series used, we should mention that they are of a structural nature rather than a methodological one. For instance, on the revenues side we have the adoption of the Common External Tariff (1981), the elimination of the differential tax treatment of all imported goods versus domesti-

As a first step in the analysis, we tested for the order of integration of the two series. To this end, we used a modified version of the Phillips and Perron (1988) tests proposed by Ng and Perron (2001) which try to solve the main problems present in the conventional tests for unit roots. Table 1 shows the results of the two tests,  $\overline{MZ}_\alpha^{GLS}$  and  $\overline{MZ}_1^{GLS}$ . Evidently, the null hypothesis of nonstationarity for the two series in levels cannot be rejected independently of the test; and the presence of two unit roots is clearly rejected at the usual significance levels. Accordingly, both series would be I(1). Similar results are obtained if we use the GLS-detrended Dickey-Fuller test (Elliot, Rothenberg, and Stock, 1996). Finally, the KPSS test (Kwiatkowski, Phillips, Schmidt, and Shin, 1992), which tests the null hypothesis of stationarity, corroborates the above findings.

It should be noted that, in order to make the model defined by (6) and (7) estimable, the specification of the processes  $u_t$  and  $v_t$ , and more specifically the explicit specification of the polynomials  $\phi(L)=\rho(L)$  and  $\psi(L)$  is required. Thus, in the empirical implementation, the autoregressive polynomials are specified as  $\phi(L)=\rho(L)=1-\rho_1L$  and  $\psi(L)=1$ , via the posterior information criterion of Phillips and Ploberger (1994).

Following Martin (2000), the empirical results presented in the next two sub-sections are produced from a total of 5,100 iterations of the relevant Markov Chain Monte Carlo simulation scheme, with the initial 100 discarded and only every 10<sup>th</sup> iterate used in producing the final estimated marginals and odds ratios. The results differ only negligibly when the number of iterations varies.

### 5.2 Cointegration Model with No Structural Breaks

In order to trace out the impact of allowing for endogenous breaks, in the first step we present results for the full sample period with no breaks estimated, in which case the cointegration model defined in (6) and (7) reduces to

$$R_t = \alpha_1 + \beta_1 G_t + u_t \quad (12)$$

$$G_t = \alpha_1 + G_{t-1} + v_t \quad (13)$$

The results are presented in Table 2 in the appendix under the heading 'Model 1'. An ADF test and a test that concerns parameter  $\beta_1$ , are also included in the table.

cally produced ones (1984-1989), the introduction of Value Added Tax (1987), the harmonisation of the three traditional excise taxes (tobacco, fuels and alcoholic beverages) with EU regulations etc. On the expenditure side, there has been a substantial increase in the amount of transfers and their direction from urban to rural households (mainly after 1981). It is also worth mentioning the duplication of the number of civil servants between 1980 and 2000. All these may constitute structural changes and justify the employed empirical methodology, which accounts for possible structural breaks. More details can be found in Manessiotis and Reischauer (2001).

The results from Model 1 provide overwhelming evidence of cointegration over the full-sample period, with the ADF test leading to the rejection of a unit root in the residuals. However, the Bayesian modal estimate of  $\beta_1$ , 0.480, is clearly less than one, with the 95% HPD interval for  $\beta_1$  excluding unity. The posterior odds ratio for testing  $H_0: \beta_1=1$  against the alternative  $H_1: 0 < \beta_1 < 1$  is less than one, implying the rejection of the null hypothesis. These results suggest that the deficit is only weakly sustainable over the full-sample period.

### 5.3 Cointegration Model with Structural Breaks

The results obtained from Model 1 are relatively deficient given the evidence of structural shifts in Figure 1. The results in Table 3 in the appendix from 'Model 2' refer to the estimation of the model (6)-(7). Graphs of the corresponding marginals are presented in Figures 2 to 4. An initial analysis had indicated the presence of three shift points. Thus, equation (6) is estimated with  $m=3$  imposed. The evidence in favour of cointegration over the full period, with parameter shifts now accommodated, is still conclusive although less overwhelming than in the no-breaks case. The marginal mass functions for the  $r_k$  pinpoint breaks in 1979, 1986, and 1995. The two latter breaks are ascribed 99.2% and 53.4% probability, respectively. The mass function for  $r_1$  ascribes a probability of 46.5% to 1979, although with a probability of almost 38% associated with 1978, a total probability of 84.5% is assigned to a break during the years 1978 and 1979.

With regard to identification of the detected break dates, we could mention the following points: i) the break around 1979 could be justified as the cumulative effect of Greek fiscal policy actions since 1974, such as income redistribution policies, the nationalisation of large private companies, the undertaking by the central government of the burden of servicing the debt obligations of certain public enterprises etc. (Makrydakis *et al.*, 1999); ii) the 1986 break could be attributed to Simitis' consolidation programme (1986-87); and iii) the break around 1995 coincides with the beginning of a period characterised by dramatic changes in the manner the monetary and banking sector operated due to the upcoming participation of the country as a full member in the EMU and the need for fiscal consolidation according to the Maastricht criteria.

The modal point estimates of Model 2 indicate that the most substantial shifts occur in the intercept term. By adding the modal estimates of the three intercept shifts,  $(\alpha_2 - \alpha_1)$ ,  $(\alpha_3 - \alpha_2)$ , and  $(\alpha_4 - \alpha_3)$ , to the estimate of the initial intercept,  $\alpha_1$ , an estimate of the implied intercept after the third break is obtained (i.e.  $-0.162+0.189-0.162-0.288$ ). This result ( $-0.423$ ) suggests a net decline of about 261% in the level of regression over the sample period.

The estimation of the slope and slope shift parameters of Model 2 is less accurate than that of the intercept parameters, as evidenced by the wider HPD intervals reported in

Table 3. The point estimate of the pre-shift  $\beta_1$  is 0.700, with the 95% HPD interval excluding unity. This latter fact, combined with the fact that the HPD intervals for all three slope shifts,  $(\beta_2 - \beta_1)$ ,  $(\beta_3 - \beta_2)$ , and  $(\beta_4 - \beta_3)$ , cover zero, can be viewed as evidence in favour of a slope of less than one over the full-sample period. Consideration of the modal point estimates alone suggests that the implied slope coefficient after the third break is 0.441. This is obtained by adding the modal estimates of the three slope shifts,  $(\beta_2 - \beta_1)$ ,  $(\beta_3 - \beta_2)$ , and  $(\beta_4 - \beta_3)$  to the estimate of the initial slope,  $\beta_1$ , i.e.  $0.441=0.700-0.763+0.095+0.409$ . The main point here is that the most substantial shifts are confined to the level of the deficit series and not to the slope. With these level shifts accommodated, the evidence for a slope shift and, hence, a change in the nature of the sustainability, is relatively weak.

## 6. CONCLUDING REMARKS

This paper has presented new evidence regarding the sustainability of the Greek budget deficit. Our empirical analysis was based on a cointegration model proposed by Martin, with an allowance being made for multiple endogenous breaks in both the intercept and slope parameters. The methodology produces an inference about the value of the cointegrating parameters as well as the size and timing of shifts in the relationship. The results are jointly produced and, as such, are not subject to the usual pre-test biases. Further, they are based on the full sample and, therefore, are less affected by degrees of freedom problems encountered in subsample analyses.

More specifically, the empirical findings indicated that the relationship between real revenue and real expenditure over the 1956 to 2000 sample period is a cointegrating one, with three shifts having occurred, in 1979, 1986, and 1995. The highest probability mass (99.2%) was assigned to a shift in 1986, thus, identifying the implementation of the two-year 'stabilisation programme'. Overall, the most substantial shifts seem to have occurred in the level of the regression. In addition, the slope estimation indicated that the initial, pre-break situation of weak sustainability is maintained throughout the full sample period, despite relatively small deviations.

As mentioned in the theoretical section of the paper, weak sustainability, according to Quintos' terminology, means that the intertemporal budget constraint holds, but with the undiscounted debt process exploding at a rate which is less than the growth rate of the economy. In other words, weak sustainability refers to a situation in which the debt-to-GDP ratio continues to increase, although the intertemporal budget constraint might be satisfied and thus, from an economic point of view, the underlying fiscal policy cannot be indefinitely maintained.

In the near future, Greek fiscal policy will have to deal with longer-term problems such as the social security system, privatisations and the large public debt. Thus, our empiri-

cal findings referring to weak sustainability imply some possible future problems for marketing the Greek public deficit and call for fiscal reforms.

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## APPENDIX

TABLE 1: Unit root and stationarity tests

Variables		Ng-Perron unit root tests		GLS Dickey-Fuller test	KPSS test
		$\bar{M}Z_{\alpha}^{GLS}$	$\bar{M}Z_t^{GLS}$		
Levels	G	-5.801	-1.649	-2.695	0.799
	R	-9.533	-2.163	-2.984	0.243
First differences	$\Delta G$	-23.855	-3.422	-6.289	0.072
	$\Delta R$	-32.822	-3.961	-4.261	0.114

### Notes

- 1) The critical values for the trended case and the 5% level of significance are -17.3, -2.91 (Ng and Perron, 2001, Table 1), -3.19 (Elliot, Rothenberg, and Stock, 1996, Table 1), and 0.146 (Kwiatkowski, Phillips, Schmidt, and Shin, 1992, Table 1), respectively for the four tests. The null hypothesis for the first three tests is that the respective series has a unit root while the null hypothesis for the fourth test is that the respective series is stationary.
- 2) The autoregressive truncation lag has been selected using the Akaike information criterion.

TABLE 2: Cointegration model with no parameter shifts estimated (Model 1)

Parameters	Marginal modal estimates	95% HPD intervals
Intercept ( $\alpha_1$ )	0.079	(0.024 0.188)
Slope ( $\beta_1$ )	0.480	(0.230 0.770)
G drift ( $\alpha$ )	0.005	
Cointegration tests: Prob( $\rho_1 < 1$ ) = 0.991, ADF = -3.877		
$H_0 : \beta_1 = 1$ versus $H_1 : \beta_1 < 1$ : Posterior odds ratio = 0.00129		

**Notes**

- 1) The point estimates of intercept and slope parameters are marginal posterior modes. The figures in the third column are 95% HPD intervals.
- 2) The ADF test statistic leads to rejection of the null hypothesis of a unit root in the OLS residuals at the 5% significance level.
- 3) A posterior odds ratio which is less than unity leads to rejection of the null hypothesis that  $\hat{a}_1=1$ .

TABLE 3: Cointegration model with intercept and slope shifts estimated (Model 2)

Parameters	Marginal modal estimates	95% HPD intervals
Intercept ( $\alpha_1$ )	-0.162	(-1.392 1.257)
Intercept shift 1 ( $\alpha_2 - \alpha_1$ )	0.189	(0.068 0.432)
Intercept shift 2 ( $\alpha_3 - \alpha_2$ )	-0.162	(-0.378 0.270)
Intercept shift 3 ( $\alpha_4 - \alpha_3$ )	-0.288	(-0.757 0.180)
Slope ( $\beta_1$ )	0.700	(-0.200 0.870)
Slope shift 1 ( $\beta_2 - \beta_1$ )	-0.763	(-1.100 1.080)
Slope shift 2 ( $\beta_3 - \beta_2$ )	0.095	(-0.491 0.657)
Slope shift 3 ( $\beta_4 - \beta_3$ )	0.409	(-1.100 1.377)
G drift ( $\alpha$ )	0.005	
Cointegration test: Prob( $\rho_1 < 1$ ) = 0.934		
Marginal breakpoint estimates:	1979 (0.465)	
	1986 (0.992)	
	1995 (0.534)	

**Notes**

- 1) The point estimates of the parameters are marginal posterior modes. The figures in the third column are 95% HPD intervals.
- 2) The point estimates of the breakpoints are marginal modes. The figures in parentheses in the last panel of the table are the marginal probability masses associated with the modes.

FIGURE 1: Revenues (REV) and government spending (EXP) as a percentage of GDP

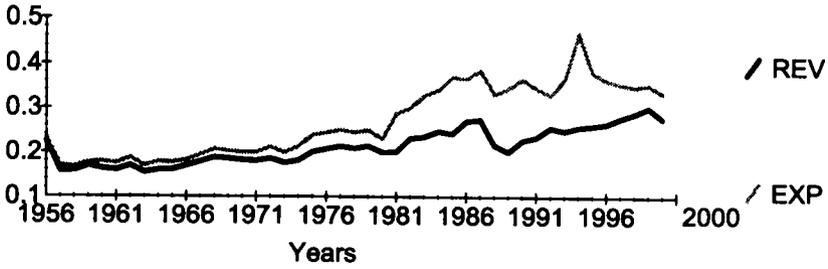


FIGURE 2: Marginal posterior mass function for breakpoint 1

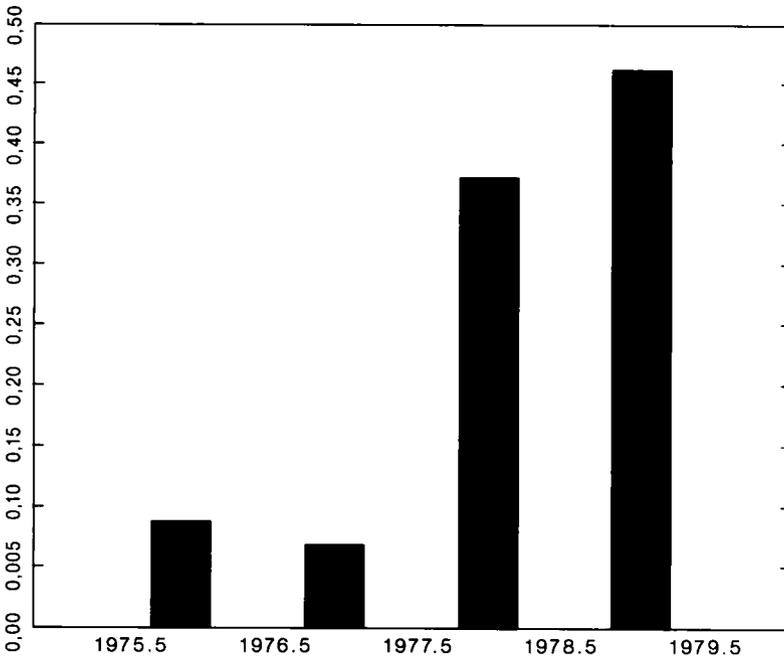


FIGURE 3: Marginal posterior mass function for breakpoint 2

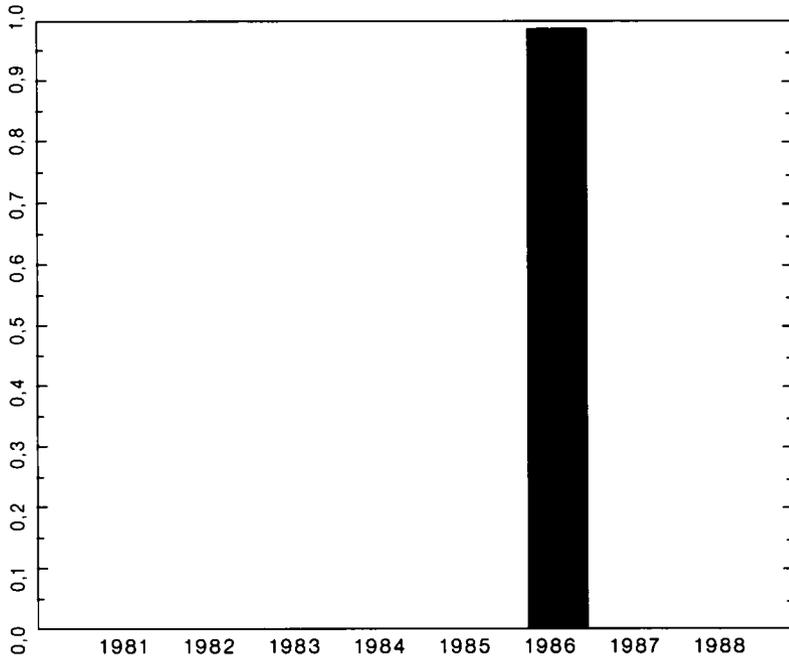


FIGURE 4: Marginal posterior mass function for breakpoint 3

