

Public finances in Europe: Are they sustainable?

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Abstract: In this paper we aim to analyse the degree of mean reversion of public expenditure, revenue and the difference between them, over GDP for 27 European Union (EU) countries. To gain flexibility in the analysis of the order of integration of the variables we apply fractional integration techniques. In general, we find evidence of mean reversion in all countries.

Key words: Public revenues; Public expenditures; Fractional integration.

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1. Introduction

Since the collapse of Lehman Brothers in 2008, and the breakout of the global financial crisis, many affected countries aimed to reduce their public debt stocks by applying contractionary fiscal policies. The reason behind this was the escalation in the levels of debt amid previously applied countercyclical expansionary policies. There is considerable literature on the degree of fiscal budget sustainability, see next section, which applies tests for the order of integration of fiscal budget over GDP. However, it is important for policy decisions to understand how its components, namely public expenditure and revenue over GDP, in addition to the difference between these, react after a shock.

In this paper we apply fractional integration techniques in order to gain flexibility in the analysis of the order of integration of these macrovariables in a group of 27 EU countries. As far as we know, this is one of the few papers that analyse this issue from a fractionally integrated perspective and the first in the context of the EU countries. If the order of integration is greater than 1, then shocks have permanent effects, whereas if it is less than 1, the effects are only transitory. In the former, policy intervention is necessary to counteract exogenous shocks, whereas in the latter it would only depend on the speed of mean reversion, which is faster the closer the order of integration is to 1. Given that some EU countries have needed bailouts after the collapse of their public balances, the analysis of the mean reversion of fiscal budget and its components has gathered momentum. This is of particular importance since, in a monetary union, there is no possibility to finance public deficits through monetary expansion by the national central banks. Hence the probability of default increases (De Grauwe, 2012).

In a seminal contribution, Bohn (2007) explains that the transversality condition of the intertemporal budget constraint can be satisfied for any arbitrary order of integration of the fiscal deficit, for a sufficiently large discount factor. Hence, one cannot really assess sustainability testing for stationarity of the fiscal deficit. In this paper, we are interested in analysing how the three magnitudes, i.e. expenditure, revenue and the difference between them, over GDP, react after a shock and we call for caution in the non-mean reverting cases.

The contributions of the paper are the following: First we examine the public finances from a time series viewpoint using a novel methodology based on the concepts of long memory and fractional integration. In doing so, we permit a more degree of flexibility than the standard methods that are based on stationarity, $I(0)$, or nonstationarity, $I(1)$, models. Second, there are not empirical papers that use this methodology in the context of the 27 EU countries. Finally, the implications of the shocks using this method are also examined in the paper.

There are many different ways to assess sustainability. The S_0 , S_1 and S_2 indicators are another way to assess it. Our measures are complementary to those, in the sense that rather than looking at the values of debt, we look at how countries accumulate debt. That is, we look into how past flows into the stock of debt affect the speed at which does flows generate. In order words, we analyse if the countries generate debt in an explosive manner. Hence, the values of debt or public deficits may not be very high, but a country might be generating then at a high speed every year, which could be seen as an indication that something is wrong.

The layout of the paper is as follows: Section 2 deals with a brief revision of the literature on this specific issue. Section 3 presents the methodology used in the paper

which is based on fractional integration, making especial emphasis in the fact that this methodology allows for studying in a more flexible way the nature of the shocks which may be transitory or permanent. Section 4 describes the dataset and the results. Finally, Section 5 concludes the paper.

2. Literature review

Sustainability of fiscal policy has been an issue widely addressed in the literature over decades, coming back again to the heart of the debate after the 2008 global financial crisis. Initially, the majority of the empirical works¹ examine this hypothesis for U.S. time series data, either from a univariate approach, testing the non-stationary of budget deficits or public debt by applying different unit root tests (Hamilton and Flavin, 1986; Wilcox, 1989), or from a multivariate approach, assessing the long-run relationship between public revenues and expenditures (Trehan and Walsh, 1988; Hakkion and Rush, 1991; Haug, 1991, 1995; Ahmed and Rogers, 1995; Quintos, 1995; Crowder, 1997; Martin, 2000). Other studies attempt to unify both approaches (Trehan and Walsh, 1991; Berenguer-Rico and Carrión-i-Silvestre, 2011) or suggest alternative methods to test the fiscal sustainability (Bohn, 1998, 2007; Yoon, 2012). We also find works that re-examine this issue, highlighting the importance of allowing for structural breaks in the analysis (Quintos, 1995; Martin, 2000; Cunado et al., 2004; Berenguer-Rico and Carrión-i-Silvestre, 2011) or reaching a certain threshold for a mean-reverting behaviour of budget deficit (Arestis et al., 2004; Payne and Mohammadi, 2006; Cipollini et al., 2009). Examples of empirical literature for other economies are also numerous. We can point out single-country studies, for instance, for the case of

¹ For a comprehensive literature review, see e.g. Afonso (2005) and Paparas et al. (2015).

Australia (Elliot and Kearney, 1988; Olekalns, 2000); *the United Kingdom* (Lusinyan and Thornton, 2011; Fan and Arghyrou, 2012); *Spain* (Bajo-Rubio et al., 2004, 2006, 2014); *Portugal* (Marinheiro, 2006; Correia et al., 2008); *Austria* (Getzner et al., 2001); *Germany* (Greiner et al., 1999, 2006) or *Sweden* (Hatemi-J, 2002), among others, as well as, for a set of countries such as the G-7 (Payne, 1997; Feve and Henin, 2000; Chen, 2014) or some EU/EMU members (Bravo and Silvestre, 2002; Greiner et al., 2004; Afonso, 2005; Argyrou and Luintel, 2007; Cuestas and Staehr, 2013; Afonso and Tovar, 2017). Both the methodology and the main results of such studies are summarized in Table 1.

Focusing on our sample, we can mention some previous works based on EU quarterly data which take into account multiple structural changes and the presence of nonlinearities in the analysis. For instance, Argyrou and Luintel (2007) examine both the strong- and weak-sense of fiscal sustainability for a sample of four EMU economies —*Greece, Ireland, Italy and the Netherlands*— In their research, the authors find evidence that the fiscal policy in all of them is sustainable, detecting the presence of multiple regime shifts, one of which can be attributed to the Maastricht Treaty. In addition, their results point to the existence of a non-linear behavior in the adjustment of fiscal disequilibrium. Other authors such as Cuestas & Staehr (2013) study the persistence of the fiscal balance in percent of GDP of ten Central and Eastern European countries. They find out that in the long term, the series exhibit a mean-reverting behavior after controlling for structural changes, but this scenario is vulnerable and depend, in the medium term, on the effect of global financial crisis. More recently, Chen (2014), using different threshold autoregressive (TAR) models, analyses fiscal sustainability of the debt-GDP ratio for the G-7 and some European countries —*Greece,*

Ireland, Portugal and Spain—. Evidence seems to be mixed, depending on the type of linear or non-linear unit root tests applied. The results from TAR model show for the majority of countries that the government's intertemporal budget constraint holds in the long run. The results from variants of TAR model reveal that the debt–GDP ratios of Canada, Germany, the US and Italy are stationary when a non-linear trend is considered. Finally, Alfonso and Tovar (2017) revisit the relationship between the primary budget surplus and the debt–to–GDP ratio using a sample of eleven Euro–area countries over the period 1999Q1 and 2013Q4. Their results show evidence of sustainability in Belgium, France, Germany, and the Netherlands, highlighting the negative impact of the global financial crises on fiscal sustainability. Table 1 summarizes the literature review in a comprehensive way.

[Include Table 1 about here]

Overall we can say that the evidence is mixed and far from conclusive. The contribution of this paper lies in the analysis of the reaction to shocks not only for the fiscal deficit, but also for its main components, revenue and expenditure as a percentage of GDP. To gain flexibility in the analysis instead of relying on unit root or stationarity tests, we use fractional integration methods which break the dichotomy of integer orders of integration. In this way we may be able to see whether a potential escalating deficit is due to the expenditure side or the revenue side.

3. Methodology

We use techniques which are based on the concept of fractional integration. This basically means that the number of differences required in a time series to render it $I(0)$ stationarity may be a fractional value, allowing thus for a higher flexibility in the

dynamic specification of the data than those models based on classical methods and that only use integer degrees of differentiation, usually 0 or 1. Thus, x_t is said to be integrated of order d , and denoted as $x_t \approx I(d)$ if it can be represented as:

$$(1 - L)^d x_t = u_t, \quad t = 1, 2, \dots, \quad (1)$$

where L is the lag operator (i.e., $Lx_t = x_{t-1}$), and u_t is $I(0)$ (or “short memory”), defined as a covariance stationary process where the infinite sum of the autocovariances is finite. In this context, if $d > 0$, x_t belongs to a wider class of models called “long memory”, so-named because of the strong degree of association between observations which are far away in time. These processes, originally proposed in the 80s by Granger (1980, 1981), Granger and Joyeux (1980) and Hosking (1981) garnered popularity fifteen years later when its use was generalized in the analysis of macroeconomic and financial data (see, e.g. Baillie, 1996; Gil-Alana and Robinson, 1997; Michelacci and Zaffaroni, 2000). The main advantage of this method is that it is more general than the standard methods, in the sense that it includes the standard cases of stationarity, $I(0)$, and nonstationarity, $I(1)$, as particular cases of interest when d is equal to 0 and 1 respectively. Another advantage of this approach is that the fractional differencing parameter will provide us with information about the degree of persistence of the data. Moreover, this is a very flexible approach that permits us to consider nonstationary persistence though mean reverting processes if the differencing parameter is in the range $[0.5, 1)$. In this context, the longer the value of d is, the longer the time the series to be recovered will be, while if d is equal to or higher than 1 shocks will have a permanent nature and strong measures will have to be adopted to recover the original trends.

4. Data and Empirical Results

In this section we describe the dataset and present the results for the fiscal sustainability analysis. The database has been obtained from EUROSTAT and corresponds to quarterly non-financial accounts for general government. The variables studied are total expenditure and total revenue as percentages of gross domestic product. We use unadjusted data (i.e. neither seasonally adjusted nor calendar adjusted data) due to their greater availability for longer time series. Our sample covers 27 EU countries over the period 1999Q1– 2014Q1, for the majority of them.² We only consider countries that have at least 50 observations for each variable, being excluded for this reason, Croatia, with 9 observations (from 2012Q1 to 2014Q1).

Across this section and to allow for some deterministic terms, we consider the following model,

$$y_t = \alpha + \beta t + x_t, \quad (1 - L)^d x_t = u_t, \quad t = 1, 2, \dots, \quad (2)$$

where the errors are assumed to follow in turn a white noise process. Across the tables we display the estimates of d , along with their corresponding 95% confidence bands, for the three cases of i) no deterministic terms, ii) a constant, and iii) a constant and a linear time trend. Table 2 focuses on the expenditure/GDP ratio (in logs); Table 3 on revenue/GDP, while Table 4 on the differences between the two series.

Starting with the expenditure/GDP ratio and looking first at the deterministic terms, we observe that the time trend is required in half of the countries (14), while for

² Countries with data from 1999Q1 to 2014Q1 are: *Austria, Bulgaria, Czech Republic, Denmark, Estonia, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Poland, Portugal, Slovakia, Slovenia, The Netherlands*. For the remaining countries, the initial period for the analysis is: the United Kingdom (1987Q1); Belgium and France (1991Q1); Sweden (1993Q1); Germany, Spain and Cyprus (1995Q1); Romania and Finland (1998Q1) and Malta (2000Q1).

the thirteen remaining, the intercept seems to be sufficient to describe this component. From the fourteen countries where the time trend is required, the time trend coefficient is significantly positive in 10 of them, while in four countries, the time trend is found to be negative (Bulgaria, Germany, Slovak Republic and Sweden).³ Focusing on the estimated values of d , we can look at the second column of Table 5 that reports a summary of Tables 2 – 4 focusing exclusively on the selected models according to the deterministic terms. We see in this table that long memory (i.e., statistical evidence of $d > 0$) is found in 16 of the countries examined. France, Finland and the UK also display large degrees of persistence (with estimates of d respectively of 0.71, 0.69 and 0.64) but the unit root null is in these cases rejected in favor of mean reversion ($d < 1$). At the other extreme, we have 6 countries with significantly negative values of d : Italy (-0.50), Cyprus (-0.29), Portugal (-0.24) and Bulgaria, Hungary and Malta (-0.16). For the remaining countries the $I(0)$ hypothesis cannot be statistically rejected.

[Insert Tables 2 -5 about here]

Next we move to the revenue/GDP ratio. The results for the three cases of no terms, an intercept and an intercept with a linear time trend are displayed in Table 2. We observe in this table that the intercept is required in 12 countries, while the time trend seems to be required in the remaining 15, with 10 positive trends and 5 countries showing a negative slope. The estimates of d in this table are substantially smaller than in the case of the expenditure/GDP ratio, and we only observe 4 countries displaying long memory ($d > 0$) behavior: Sweden (0.71), Slovak Republic (0.32), and Greece and Lithuania (0.23); on the other hand there are eight countries with anti-persistence ($d < 0$)

³ Note that in the context of fractional integration with $d > 0$, the time trend coefficient becomes irrelevant since it tends to a constant in the long run.

behavior, being especially noticeable the cases of Portugal (-0.51), and Romania (-0.50). The remaining countries show I(0) behavior.

Table 3 focuses on the differences between expenditures and revenues (in logs). Starting once more with the deterministic terms, we observe three countries with no deterministic terms (Bulgaria, Denmark and Estonia); there is a group of 11 countries which require an intercept; and the time trend is statistically significant in the remaining 13 (with 9 positive trends and 4 negative ones). Focusing now on the differencing parameter, long memory is found in 15 countries. Large degrees of integration are also obtained in the cases of Denmark (0.60) and the UK (0.42) and anti-persistence is only found in two countries: Italy (-0.29) and Austria (-0.25).

In general it is found that there is no evidence of lack of mean reversion for the countries analysed, with a few exceptions. For the cases of Sweden and Denmark, although we do not find evidence of explosive or unit root behavior, it is important to highlight the slow speed of mean reversion of their fiscal balance, which also may ring some alarm bells.

5. Summary and Conclusions

There has been increasing concern on the sustainability of public deficits in Europe amid the global financial crisis and the Great Recession. The background of this analysis is related to the fact that some European economies have needed bailouts.

With the aim of providing more evidence for policy purposes on the issue of fiscal sustainability in Europe, we have analyzed the order of integration of public expenditure, revenue and the difference between them, over GDP, in Europe.

To keep the analysis simple and focused, we have applied fractional integration techniques in order to analyze the mean-reverting behavior of those three variables. This methodology is more general than the classical one based on integer degrees of differentiation and seems to be more appropriate to analyze the nature of the shocks from a very flexible viewpoint. We then find that these three variables behave in most cases as mean reverting processes, some of them also displaying long memory behavior. The main implication is that shocks will tend to disappear by themselves with no need of strong policy actions to recover the original trends.

The possibility of structural breaks is an issue that has not been taken into account in this paper. This is relevant, especially noting that some authors have argued that fractional integration might be an artificial artifact generated by the presence of breaks not taken into account (see, e.g, Diebold and Inoue, 2001; Granger and Hyung, 2004; etc.). However, given the sample size in our case, the inclusion of breaks would produce subsamples with very few observations invalidating the analysis based on fractional integration. On the other hand, issues such as causality, endogeneity or the omission of relevant variables have not been taken into account in the univariate models presented in this work since our approach was based on examining the statistical properties from the data following the approach of “let the data speak by themselves”. All these questions will be investigated in future papers.

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Table 1: Summary of some empirical works on fiscal sustainability

Author(s)	State(s)	Time period (frequency)	Variables	Tests performed	Sustainability?
Hamilton & Flavin (1986)	U.S.	1962–1984 (annual)	Deficit & debt	<ul style="list-style-type: none"> •Dickey-Fuller test for unit roots •Generalized Flood-Garber test •Restricted Flood-Garber test 	Yes: consistent with the IBC (at 10% significance level)
Trehan & Walsh (1988)	U.S.	1890–1986 (annual)	Deficit, tax smoothing	<ul style="list-style-type: none"> •Dickey-Fuller test for unit roots •Engle-Granger co-integration test •Stock-Watson co-integration test •Barro’s tax smoothing hypothesis 	Yes: consistent with IBC but not with tax smoothing hypothesis.
Wilcox (1989)	U.S.	1960–1984 (annual)	(Un)disco-unted debt	<ul style="list-style-type: none"> •Dickey-Fuller test for unit roots •F-statistic test •Hamilton and Flavin test 	No: Fiscal policy has not been sustainable, contrary to Hamilton and Flavin (1986)
Hakkio & Rush (1991)	U.S.	1950:2–1988:4 (quarterly)	Deficit	<ul style="list-style-type: none"> •ADF unit roots test •Different co-integration tests 	Yes: for the entire sample. No: from 1976:3 to 1988:4
Haug (1991)	U.S.	1960:1–1987:4 (quarterly)	Debt (bond) & Surplus	<ul style="list-style-type: none"> •The co-integration regression Durbin-Watson (CRDW) test • ADF unit roots test 	Yes: variables are stationary in first differences; co-integration tests imply the acceptance of the present value borrowing constraint
Trehan & Walsh (1991)	U.S.	1960–1984 1946–1987 (annual)	Deficit, debt & external investment	<ul style="list-style-type: none"> •Dickey-Fuller test for unit roots •Phillips’ test 	Yes: for the federal government’s budget, the deficit is consistent with sustainability; also, for the external investment.
Ahmed & Rogers (1995)	U.S. & U.K.	1792–1992 1692–1992 (annual)	IBC & IBOC	<ul style="list-style-type: none"> •Phillips-Perron unit roots test •Perron unit roots test •ADF unit roots test •Co-integration & stability tests 	Yes: in the U.S. and U.K., both constraints being satisfied in entire sample.
Quintos (1995)	U.S.	1947:2–1992:3 (quarterly)	Deficit (Breaks)	<ul style="list-style-type: none"> •Phillips & Ploberger (1994) PIC test •ADF unit roots test •Rank constancy test with breaks for co-integration (Quintos, 1994) 	Yes: co-integration is a sufficient condition in the ‘strict’ sense of sustainability and holds only up to 1980. Independently of shifts, deficit is sustainable.
Crowder (1997)	U.S.	1950:1–1994:2 (quarterly)	IBC	<ul style="list-style-type: none"> •ADF unit roots test •Johansen’s (1994) method 	No: expenditures grow faster than revenues as from 1982; this is in the line of Hakkio & Rush (1991), Wilcox (1989) & Quintos (1995)
Payne (1997)	G-7	1949–1994 (annual)	Deficit	<ul style="list-style-type: none"> •ADF unit roots test •Engle-Granger co-integrating regressions. 	Yes: for Germany; for Canada, Italy, U.K. & the U.S., the estimated b’s are significantly less than one. No: for France, Japan & Italy. It is contrary to Owoye (1995)
Bohn (1998)	U.S.	1916–1995 (annual)	Debt & surpluses	<ul style="list-style-type: none"> •Phillips-Perron test; ADF test; KPSS test; different regressions. •Bohn’s test (relationship between primary surpluses & debt ratio) 	Yes: the debt-GDP ratio should be mean-reverting. IBC holds despite the frequent primary deficit.
Greiner & Semmler (1999)	Germany	1955–1994 (annual)	Discounted net debt	<ul style="list-style-type: none"> •Restricted Flood-Garber Test •ADF test for unit roots •AR(2) estimations 	No: in particular, after 1989.
Martin (2000)	U.S.	1947:2–1992:3 (quarterly) as Quintos (1995)	Deficit (Breaks)	<ul style="list-style-type: none"> •Phillips & Ploberger (1994) PIC test & ADF unit roots test based on OLS. •Co-integration with endogenous breaks 	Yes: over the 1947-1992 period, as in Quintos (1995). It is found 3 breaks: 1975:1, 1985:1, & 1987:1
Olekalns (2000)	Australia	1900 – 1994/95 (annual) 1978:3 -1997:4 (quarterly)	IBC (Breaks)	<ul style="list-style-type: none"> •ADF test •KPSS test •Zivot and Andrews (1992) test •Engle and Granger’s (1987) test •Gregory-Hansen (1996) test 	No: there has not been adherence to the IBC but there exist recent budget surpluses; it is detected structural shifts in fiscal policy at the end of World War II and in the 1980s.
Feve & Henin (2000)	G-7	1970–1999 (semi-annual)	Debt & surplus	<ul style="list-style-type: none"> •Feedback ADF unit root test 	Yes: U.S, UK and Japan

				<ul style="list-style-type: none"> • ADF test • AR-OLS test 	No: Germany, France, Italy, Canada.
Getzner et al. (2001)	Austria	1960–1999 (annual)	Debt & surplus	<ul style="list-style-type: none"> • Generalized Flood-Garber test • Restricted Flood-Garber test • ADF test • ARMA processes • Bohn (1998) test 	Yes: stationarity from 1960 to 1974. No: non-stationarity from 1975 to 1999. Thus, structural break in the mid-1970s.
Hatemi-J (2002)	Sweden	1963:1–2000:1 (quarterly)	Taxes & spending	<ul style="list-style-type: none"> • KPSS test • Perron (1989) test • Johansen's VAR • Augmented Granger causality tests 	Yes: consistent with the IBC and feasible with respect to the EMU criteria (bi-directional causality)
Bravo & Silvestre (2002)	11-EU	1960–2000 (annual)	Expenditures & revenues	<ul style="list-style-type: none"> • Dickey-Fuller stationarity tests • Engle-Granger cointegration test • Johansen cointegration trace test • The t-statistic test ($b=1$) 	Yes: in Austria, France, Germany, Netherlands and the UK. No: in Belgian, Denmark, Ireland, Portugal, Italy & Finland.
Cunado et al. (2004)	U.S.	1947:2–2003:1 (quarterly)	Deficit (Breaks)	Fractional processes with breaks: <ul style="list-style-type: none"> • Robinson (1994) Lagrange Multiplier (LM) test • Quasi Maximum Likelihood Estimate of Robinson (1995) test (QMLE) 	Yes: fiscal deficit is mean reverting (an I(d) process with $d<1$) taking into account a break in the mid-1970s.
Arestis et al. (2004)	U.S.	1947:2–2002:1 (quarterly)	Surplus (Breaks)	• Threshold Autoregressive (TAR) model by Caner & Hansen (2001)	Yes: in the long run. Intervention to reduce the deficit only when a certain threshold (-0.313) is reached.
Bajo-Rubio et al. (2004)	Spain	1964–2001 (annual)	Surplus	• Threshold Autoregressive (TAR) model by Caner & Hansen (2001)	Yes: evidence of mean-reverting of deficit once a threshold (-1.90) is reached.
Greiner et al. (2004)	4-EMU	1960–2003 (annual)	Debt & surplus	<ul style="list-style-type: none"> • Bohn's (1998) test • OLS estimations 	Yes: for all economies (France Germany, Italy & Portugal)
Bohn (2005)	U.S.	1792–2003 (annual)	Debt & deficit	<ul style="list-style-type: none"> • ADF test; PP test; & KPSS test. • Regression specification obtained from tax smoothing theories. 	Yes: robust positive response of primary surpluses to fluctuations in the debt-GDP ratio. Link with economic growth.
Afonso (2005)	15-EU	1970–2003 (annual)	Debt (Breaks)	<ul style="list-style-type: none"> • ADF and PP test • Zivot and Andrews's (1992) test • Engle-Granger and Johansen cointegration tests • Gregory and Hansen (1996) cointegration test (regime shift) 	No, for the majority of EU-15 countries, despite of signs of stabilizing of debt-to-GDP ratio at the end of the 1990s. Only Germany, the Netherlands, Finland, Austria, and the U.K show signs of sustainability.
Payne & Mohammadi (2006)	U.S.	1947:1–2003:4 (quarterly)	Deficit (Breaks)	<ul style="list-style-type: none"> • TAR model • Momentum TAR model (MTAR) 	Yes: allowing for an endogenously structural break in 1982:1. Deficit shows symmetric mean-reverting behaviour around the threshold value.
Bajo-Rubio et al. (2006)	Spain	1964–2003 (annual) 1982:1–2004:1 (quarterly)	Expenditures & revenues	<ul style="list-style-type: none"> • Ng-Perron (2001) tests of unit roots • Hansen-Seo (2002) tests of threshold cointegration 	Yes: mean-reverting dynamic behaviour after threshold: 5.30% of GDP for annual data and 7%, for quarterly data. The main consolidation effort was at the end of the first half of the 80s, and 1993–95.
Marinheiro (2006)	Portugal	1852–2003 (annual)	Debt & deficit (Breaks)	<ul style="list-style-type: none"> • ADF test; PP test; & KPSS test. • Engle and Granger test • Johansen maximum likelihood test • Gregory and Hansen test 	Yes: for 1903–2003. No: for 1975–2003. Fiscal policy is unsustainable since 1975.
Greiner et al. (2006)	Germany	1960–2003 (annual)	Debt & Surplus	• Semi-parametric regressions with time depending coefficients as an extension of Bohn's (1998) approach.	Yes: public debt is sustainable as in Greiner et al. (2004).
Argyrou & Luintel (2007)	4-EMU: Greece Italy Ireland & Netherland	1970:1–1998:3 1962:2–1997:4 1957:1–1998:4 (quarterly)	Expenditures & revenues (Breaks)	<ul style="list-style-type: none"> • DOLS and DGLS estimators of the co-integrating vector. • Tests for non-linear fiscal adjustment 	Yes: for all 4 economies, across different time horizons (Maastricht effect)
Correia et al. (2008)	Portugal	1852–2004 (annual)	Expenditures & revenues (Breaks)	<ul style="list-style-type: none"> • ADF test & PP test. • Cointegration tests (Johansen & Saikkonen and Lütkepohl) • Breitung's non-parametric test 	Yes: for 1923–1973 and since 1986. No: for 1852–1922 and 1974–1985. Breitung test and the Bohn test (based on

				•Bohn's test	theoretical model) are useful to detecting unsustainability.
Cipollini et al. (2009)	U.S.	1947:1–2004:4 (quarterly)	Expenditures & revenues (Breaks)	•ADF test & PP test. •Ng & Perron (2001) under GLS •Lagrange multiplier threshold test. •Berkowitz (2001) test	Yes: in the long run. Intervention to reduce the deficit only when a threshold (\$8.859 per capita) is reached. Fiscal adjustments take place via spending cuts. Major shifts: feb-1975, mar-1981, feb-1999
Berenguer-Rico & Carrion-i-Silvestre (2011)	U.S.	1947:1–2007:3 (quarterly) as in Quintos (1995), Martin (2000) & Cunado et al., (2004)	Debt & deficit (Breaks) Unified framework	•Perron–Yabu (2009) test •Gregory and Hansen test •Carrion-i-Silvestre and Sansó test. •Estimation of the multicointegration and I(2) cointegration regressions	Yes: there is a long-run stock–flow relationship between revenues and expenditures with one break by the mid-1990s (1995:4 or 1996:4, depending on the model)
Lusinyan & Thornton (2011)	U.K.	1750–2004 (annual) as in Ahmed & Rogers (1995).	Expenditures & revenues (Breaks)	•Different unit roots tests. •Different cointegration tests: -Gregory and Hansen (1996) test -Johansen (1988, 1991, 1995) test -Johansen et al., (2000) test	Yes: strong evidence of a long-run relationship between revenues and expenditures; some of the main breakpoints are linked to war events.
Yoon (2012)	U.S.	1947:1–2007:3 (quarterly) as in Berenguer-Rico & Carrion-i-Silvestre (2011)	Deficit (Breaks)	•ADF test •Recursive ADF test suggested by Phillips et al. (2011) for explosiveness	Yes: the post-war U.S. budget deficit was explosive. This work should be studied again taking into account a new version of recursive test for multiple episodes of explosiveness.
Fan & Argyrou (2012)	U.K.	1955:1–2006:1 (quarterly)	Expenditures & revenues (Breaks)	•ADF test and PP test. •DOLS and DGLS estimators of the co-integrating vector. •ECM estimations •Bai & Perron (1998) test. •QL-STEEM test	Yes: for the full time sample and subperiods identified, with 3 breaks in the early 1970s & 1980s and late 1990s. No: from 1973 to 1981.
Cuestas & Staehr (2013)	10-EU (Central & Eastern)	1999:1–2010:2 (quarterly)	Budget balance in % of GDP (Breaks)	•Ng–Perron (2001), KSS & Sollis (2009) unit root test. •Lee & Strazicich (2003) unit root test	Yes: in the long run, the series seem to be mean-reverting, after controlling for structural changes, but they also exhibit instability.
Bajo-Rubio et al. (2014)	Spain	1850–2000 (annual)	Debt, surplus, expenditures & revenues	•Ng–Perron tests for unit roots. •Sims–Stock–Watson (1990) tests for Granger-causality. •The impulse-response functions.	Yes: from 1850 to 2000. Intervention is needed if the deficit is over a threshold (around 4.5% of GDP, according to Bajo-Rubio et al., 2010). The results support Escario et al. (2012); Tortella (2000) or Comín (1995, 1996).
Chen (2014)	G-7 & Greece, Ireland, Portugal & Spain	1980:1–2012:4 (quarterly)	Debt imbalance	•Linear unit root tests. •TAR and MTAR unit root tests. •LSTR-TAR and LSTR-MTAR unit root tests.	Yes: in the long run (for TAR and MTAR)
Afonso & Tovar (2017)	11-EMU	1999:1–2013:4 (quarterly)	Debt & surplus	•Different unit root tests. •Johansen–Juselius cointegration test. •Stock–Watson–Shins test. •Toda & Yamamoto (1995) for Granger causality test. •Impulse response functions	Yes: in Belgium, France, Germany, & the Netherlands. Strong importance of expenditure-based fiscal rules

Notes:

- Intertemporal Government Budget Constraint (IBC)
- Intertemporal External Borrowing Constraints (IBOC)
- EMU: European Monetary Union
- ADF test: Augmented Dickey-Fuller (1981) test for the null hypothesis of a unit root.
- PP test: Phillips and Perron (1988) test for the null hypothesis of non-stationarity.
- KPSS test: Kwiatkowski et al. (1992) test for stationarity.
- KSS: Kapetanios, Shin, and Snell (2003) for unit root in the nonlinear STAR framework
- Zivot-Andrews (1992) tests for the null hypothesis of a unit root (and exogenous change)
- Engle-Granger (1987) test of the null hypothesis of no cointegration
- Johansen (1988) maximum likelihood (LM) test
- Gregory and Hansen (1996) test specifies the null hypothesis of non-cointegration
- Carrion-i-Silvestre and Sansó (2006) test, the null is cointegration with one structural break.
- DOLS: Dynamic Ordinary Least Square
- DGLS: Generalized Least Squares
- QL-STEEM: quadratic-logistic smooth threshold error correction model

Table 2: Estimates of d and 95% confidence band on Expenditure/GDP ratio

Country	No regressors	An intercept	A linear trend
U. K.	0.94 (0.82, 1.10)	0.64 (0.56, 0.76)	0.62 (0.52, 0.75)
AUSTRIA	0.94 (0.78, 1.17)	0.06 (-0.07, 0.26)	0.07 (-0.07, 0.27)
BELGIUM	0.97 (0.84, 1.14)	0.42 (0.35, 0.53)	0.42 (0.35, 0.53)
BULGARIA	0.89 (0.74, 1.11)	-0.07 (-0.20, 0.12)	-0.16⁻ (-0.31, 0.07)
CYPRUS	0.82 (0.70, 0.98)	0.12 (0.04, 0.23)	-0.29⁺ (-0.40, -0.12)
CZECH REP.	0.92 (0.77, 1.14)	0.09 (-0.04, 0.25)	0.08 (-0.05, 0.26)
DENMARK	0.93 (0.78, 1.16)	0.49 (0.38, 0.63)	0.46 (0.34, 0.62)
ESTONIA	0.90 (0.75, 1.12)	0.36 (0.26, 0.50)	0.33 (0.21, 0.49)
FINLAND	0.93 (0.78, 1.14)	0.69 (0.58, 0.87)	0.66 (0.52, 0.86)
FRANCE	0.96 (0.84, 1.13)	0.70 (0.58, 0.85)	0.71⁺ (0.60, 0.86)
GERMANY	0.87 (0.74, 1.05)	0.11 (0.01, 0.24)	0.05⁻ (-0.09, 0.31)
GREECE	0.87 (0.72, 1.08)	0.21 (0.12, 0.33)	0.03⁺ (-0.08, 0.18)
HUNGARY	0.93 (0.77, 1.16)	-0.11 (-0.23, 0.11)	-0.16⁺ (-0.31, 0.07)
IRELAND	0.90 (0.73, 1.14)	0.44 (0.36, 0.56)	0.33⁺ (0.19, 0.51)
ITALY	0.90 (0.75, 1.11)	-0.06 (-0.16, 0.08)	-0.50⁺ (-0.63, -0.31)
LATVIA	0.89 (0.74, 1.11)	0.16 (0.05, 0.31)	0.15 (0.02, 0.32)
LITHUANIA	0.90 (0.74, 1.13)	0.25 (0.14, 0.41)	0.26 (0.14, 0.42)
LUXEMBOURG	0.92 (0.76, 1.14)	0.24 (0.11, 0.45)	0.15⁺ (-0.02, 0.41)
MALTA	0.89 (0.73, 1.11)	-0.16 (-0.30, 0.04)	-0.14 (-0.28, 0.06)
NETHERLANDS	0.93 (0.77, 1.16)	0.48 (0.39, 0.54)	0.38⁺ (0.24, 0.55)
POLAND	0.91 (0.76, 1.14)	0.18 (-0.01, 0.45)	0.20 (0.01, 0.49)
PORTUGAL	0.90 (0.76, 1.12)	0.12 (0.04, 0.24)	-0.24⁺ (-0.38, -0.04)
ROMANIA	0.93 (0.76, 1.17)	0.12 (-0.01, 0.36)	0.11 (-0.03, 0.36)
SLOVAK REP.	0.93 (0.78, 1.14)	0.40 (0.31, 0.54)	0.36⁻ (0.25, 0.52)
SLOVENIA	0.87 (0.72, 1.05)	0.23 (0.12, 0.38)	0.19⁺ (0.08, 0.34)
SPAIN	0.88 (0.75, 1.06)	0.16 (0.09, 0.27)	0.13 (0.04, 0.24)
SWEDEN	0.94 (0.81, 1.12)	0.41 (0.29, 0.57)	0.42⁻ (0.29, 0.60)

In bold the significant models according to the deterministic terms. +/- in the last column indicates significant positive/negative trend coefficients.

Table 3: Estimates of d and 95% confidence band on Revenues/GDP ratio

Country	No regressors	An intercept	A linear trend
U. K.	0.93 (0.83, 1.07)	0.10 (0.04, 0.18)	0.03⁺ (-0.04, 0.13)
AUSTRIA	0.90 (0.75, 1.11)	-0.18 (-0.26, -0.08)	-0.28⁻ (-0.39, -0.16)
BELGIUM	0.88 (0.78, 1.03)	-0.38 (-0.44, -0.31)	-0.47⁺ (-0.53, -0.40)
BULGARIA	0.97 (0.80, 1.22)	0.11 (-0.01, 0.30)	-0.18⁻ (-0.36, 0.13)
CYPRUS	0.88 (0.75, 1.06)	0.222 (0.14, 0.32)	-0.01⁺ (-0.10, 0.15)
CZECH REP.	0.93 (0.77, 1.15)	0.03 (-0.11, 0.22)	0.03 (-0.10, 0.21)
DENMARK	0.93 (0.75, 1.16)	0.12 (-0.05, 0.39)	0.12 (-0.05, 0.41)
ESTONIA	0.91 (0.75, 1.13)	0.22 (0.12, 0.36)	0.08⁺ (-0.06, 0.28)
FINLAND	0.96 (0.79, 1.19)	-0.18 (-0.31, 0.06)	-0.18 (-0.31, 0.05)
FRANCE	0.93 (0.81, 1.10)	-0.12 (-0.20, -0.04)	-0.24⁺ (-0.31, -0.13)
GERMANY	0.94 (0.80, 1.13)	-0.06 (-0.12, 0.03)	-0.16⁻ (-0.23, -0.05)
GREECE	0.88 (0.74, 1.08)	0.23 (0.14, 0.37)	0.23 (0.13, 0.37)
HUNGARY	0.92 (0.76, 1.14)	0.11 (0.01, 0.26)	-0.06⁺ (-0.19, 0.15)
IRELAND	0.96 (0.78, 1.22)	-0.29 (-0.42, -0.09)	-0.30 (-0.44, -0.09)
ITALY	0.87 (0.73, 1.07)	-0.22 (-0.31, -0.12)	-0.47⁺ (-0.57, -0.34)
LATVIA	0.94 (0.78, 1.18)	0.13 (-0.02, 0.35)	0.13 (-0.02, 0.36)
LITHUANIA	0.93 (0.76, 1.15)	0.21 (0.09, 0.37)	0.23⁻ (0.11, 0.39)
LUXEMBOURG	0.94 (0.78, 1.16)	0.09 (-0.03, 0.26)	0.09 (-0.03, 0.26)
MALTA	0.89 (0.73, 1.10)	0.03 (-0.08, 0.17)	-0.08⁺ (-0.18, 0.08)
NETHERLANDS	0.95 (0.78, 1.19)	-0.12 (-0.11, 0.11)	-0.12⁺ (-0.23, 0.03)
POLAND	1.06 (0.87, 1.35)	-0.22 (-0.47, 0.34)	-0.21 (-0.51, 0.44)
PORTUGAL	0.88 (0.73, 1.09)	-0.10 (-0.19, 0.03)	-0.51⁺ (-0.64, -0.33)
ROMANIA	0.93 (0.76, 1.17)	-0.50 (-0.66, -0.22)	-0.50 (-0.66, -0.22)
SLOVAK REP.	0.92 (0.77, 1.13)	0.38 (0.30, 0.50)	0.32⁻ (0.20, 0.47)
SLOVENIA	0.92 (0.76, 1.13)	0.02 (-0.10, 0.18)	0.01 (-0.10, 0.15)
SPAIN	0.95 (0.82, 1.15)	0.01 (-0.11, 0.20)	0.00 (-0.12, 0.20)
SWEDEN	0.95 (0.83, 1.13)	0.71 (0.60, 0.85)	0.71 (0.62, 0.85)

In bold the significant models according to the deterministic terms. +/- in the last column indicates significant positive/negative trend coefficients.

Table 4: Estimates of d and 95% bands on Expenditures – Revenues (in logs)

Country	No regressors	An intercept	A linear trend
U. K.	0.41 (0.34, 0.51)	0.42 (0.35, 0.52)	0.41 (0.34, 0.51)
AUSTRIA	-0.09 (-0.16, 0.02)	-0.13 (-0.24, 0.02)	-0.25⁺ (-0.41, -0.04)
BELGIUM	-0.05 (-0.12, 0.04)	-0.04 (-0.09, 0.03)	-0.06⁻ (-0.11, 0.01)
BULGARIA	-0.05 (-0.18, 0.15)	-0.05 (-0.18, 0.15)	-0.10 (-0.23, 0.11)
CYPRUS	0.13 (0.02, 0.27)	0.13 (0.02, 0.27)	0.13 (0.02, 0.27)
CZECH REP.	0.21 (0.02, 0.43)	0.16 (0.01, 0.37)	0.13 (-0.04, 0.35)
DENMARK	0.60 (0.49, 0.75)	0.58 (0.48, 0.72)	0.57 (0.46, 0.72)
ESTONIA	0.09 (-0.05, 0.32)	0.09 (-0.06, 0.32)	0.10 (-0.06, 0.33)
FINLAND	0.31 (0.18, 0.53)	0.29 (0.17, 0.50)	0.16⁺ (0.02, 0.44)
FRANCE	0.01 (-0.07, 0.10)	0.01 (-0.06, 0.09)	0.00 (-0.06, 0.09)
GERMANY	0.10 (0.05, 0.27)	0.08 (0.04, 0.23)	0.12⁻ (-0.03, 0.36)
GREECE	0.14 (0.06, 0.29)	0.23 (0.11, 0.41)	0.01⁺ (0.22, 0.31)
HUNGARY	0.18 (0.05, 0.37)	0.16 (0.05, 0.33)	0.10 (-0.03, 0.30)
IRELAND	0.43 (0.32, 0.57)	0.43 (0.34, 0.55)	0.32⁺ (0.19, 0.50)
ITALY	-0.11 (-0.16, -0.03)	-0.24 (-0.35, -0.07)	-0.29⁺ (-0.43, -0.10)
LATVIA	0.07 (-0.04, 0.24)	0.08 (-0.04, 0.24)	0.06 (-0.07, 0.24)
LITHUANIA	0.27 (0.16, 0.43)	0.29 (0.18, 0.44)	0.26 (0.13, 0.43)
LUXEMBOURG	0.24 (0.11, 0.42)	0.21 (0.09, 0.37)	0.09⁺ (-0.06, 0.30)
MALTA	0.19 (0.03, 0.37)	0.11 (0.00, 0.23)	-0.04⁻ (-0.16, 0.12)
NETHERLANDS	0.31 (0.18, 0.52)	0.34 (0.21, 0.55)	0.26⁺ (0.09, 0.51)
POLAND	0.01 (-0.11, 0.29)	0.01 (-0.25, 0.39)	0.07 (-0.23, 0.51)
PORTUGAL	0.08 (0.00, 0.24)	0.12 (0.00, 0.30)	0.06⁺ (-0.11, 0.27)
ROMANIA	0.20 (0.09, 0.37)	0.21 (0.10, 0.38)	0.20 (0.08, 0.38)
SLOVAK REP.	0.58 (0.43, 0.78)	0.47 (0.33, 0.70)	0.47 (0.32, 0.70)
SLOVENIA	0.21 (0.09, 0.36)	0.21 (0.09, 0.36)	0.17⁺ (0.05, 0.32)
SPAIN	0.36 (0.28, 0.45)	0.37 (0.31, 0.46)	0.36 (0.28, 0.45)
SWEDEN	0.69 (0.58, 0.86)	0.60 (0.50, 0.77)	0.62⁻ (0.52, 0.79)

In bold the significant models according to the deterministic terms. +/- in the last column indicates significant positive/negative trend coefficients.

Table 5: Summary estimates of d for the three series

Country	Exp / GDP	Rev / GDP	Exp - Rev
U. K.	0.64 (0.56, 0.76)	0.03 ⁺ (-0.04, 0.13)	0.42 (0.35, 0.52)
AUSTRIA	0.06 (-0.07, 0.26)	-0.28 (-0.39, -0.16)	-0.25 (-0.41, -0.04)
BELGIUM	0.42 (0.35, 0.53)	-0.47 (-0.53, -0.40)	-0.06 (-0.11, 0.01)
BULGARIA	-0.16 (-0.31, 0.07)	-0.18 (-0.36, 0.13)	-0.05 (-0.18, 0.15)
CYPRUS	-0.29 (-0.40, -0.12)	-0.01 (-0.10, 0.15)	0.13 (0.02, 0.27)
CZECH REP.	0.09 (-0.04, 0.25)	0.03 (-0.11, 0.22)	0.16 (0.01, 0.37)
DENMARK	0.49 (0.38, 0.63)	0.12 (-0.05, 0.39)	0.60 (0.49, 0.75)
ESTONIA	0.36 (0.26, 0.50)	0.08 (-0.06, 0.28)	0.09 (-0.05, 0.32)
FINLAND	0.69 (0.58, 0.87)	-0.18 (-0.31, 0.06)	0.16 (0.02, 0.44)
FRANCE	0.71 (0.60, 0.86)	-0.24 (-0.31, -0.13)	0.01 (-0.06, 0.09)
GERMANY	0.05 (-0.09, 0.31)	-0.16 (-0.23, -0.05)	0.12 (-0.03, 0.36)
GREECE	0.03 (-0.08, 0.18)	0.23 (0.14, 0.37)	0.01 (0.22, 0.31)
HUNGARY	-0.16 (-0.31, 0.07)	-0.06 (-0.19, 0.15)	0.16 (0.05, 0.33)
IRELAND	0.33 (0.19, 0.51)	-0.29 (-0.42, -0.09)	0.32 (0.19, 0.50)
ITALY	-0.50 (-0.63, -0.31)	-0.47 (-0.57, -0.34)	-0.29 (-0.43, -0.10)
LATVIA	0.16 (0.05, 0.31)	0.13 (-0.02, 0.35)	0.08 (-0.04, 0.24)
LITHUANIA	0.25 (0.14, 0.41)	0.23 (0.11, 0.39)	0.29 (0.18, 0.44)
LUXEMBOURG	0.15 (-0.02, 0.41)	0.09 (-0.03, 0.26)	0.09 (-0.06, 0.30)
MALTA	-0.16 (-0.30, 0.04)	-0.08 (-0.18, 0.08)	-0.04 (-0.16, 0.12)
NETHERLANDS	0.38 (0.24, 0.55)	-0.12 (-0.23, 0.03)	0.26 (0.09, 0.51)
POLAND	0.18 (-0.01, 0.45)	-0.22 (-0.47, 0.34)	0.01 (-0.25, 0.39)
PORTUGAL	-0.24 (-0.38, -0.04)	-0.51 (-0.64, -0.33)	0.06 (-0.11, 0.27)
ROMANIA	0.12 (-0.01, 0.36)	-0.50 (-0.66, -0.22)	0.21 (0.10, 0.38)
SLOVAK REP.	0.36 (0.25, 0.52)	0.32 (0.20, 0.47)	0.47 (0.33, 0.70)
SLOVENIA	0.19 (0.08, 0.34)	0.02 (-0.10, 0.18)	0.17 (0.05, 0.32)
SPAIN	0.16 (0.09, 0.27)	0.01 (-0.11, 0.20)	0.37 (0.31, 0.46)
SWEDEN	0.42 (0.29, 0.60)	0.71 (0.60, 0.85)	0.62 (0.52, 0.79)

