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2014

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by

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October 2014

Abstract

This paper investigates the relationship between public capital expenditure and public debt in the European Union (EU) on a panel of fifteen countries over the sample period 1980-2013. We find robust evidence of a negative cointegrating relation, according to which increases in the capital expenditure-GDP ratio cause reductions in the debt-GDP ratio in the long run. Our empirical results suggest that current EU fiscal austerity can trigger upward debt spirals if cuts in total expenditure disregard its composition. Consistently with the "golden rule of public finance", EU fiscal rules should allow for higher levels of capital expenditure in order to foster debt consolidation through growth dividends.

Keywords: Fiscal sustainability, EU, panel cointegration, public expenditure, public debt.

JEL Classification: C23, E62, H62, H63.

Acknowledgements

We are very grateful to Giancarlo Marini for encouraging us to pursue this line of enquiry and for his invaluable advice and support. We thank Luca De Benedictis, Claudio Sardoni and participants at the XXIV Villa Mondragone International Seminar on "Public Debt, Global Governance and Economic Dynamism" for helpful comments and discussions. We remain fully responsible for any mistakes in our analysis.

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1. Introduction

The European sovereign debt crisis of 2009-2012 has led to widespread concerns over the issue of fiscal sustainability in the European Union (EU). The austerity measures prescribed by the Fiscal Compact Treaty, in force since 2013, are regarded by a number of influential European policy makers as the most appropriate "exit strategy" to rule out explosive dynamics in the debt-to-GDP ratio. Fiscal retrenchment appears to be essential to guarantee debt consolidation and preserve governments' solvency. In the present context, with a tax burden close to one half of GDP for several EU countries (Eurostat, 2014) and around the top of the "Laffer curve" (Trabandt and Uhlig, 2011, 2012), expenditure cuts are periodically advocated in order for high debt-to-GDP ratios to embark on dynamic paths leading to the 60-percent Maastricht reference value.

However, the composition of expenditure cuts may critically influence fiscal consolidation processes (*e.g.*, Alesina and Perotti, 1997). In particular, fiscal adjustments characterized by permanent reductions in public capital expenditure to achieve budgetary targets may crowd out the economy's rate of economic growth, consistently with both empirical evidence (Aschauer, 1989; Iwamoto, 1990; Barro, 1991; Easterly and Rebelo, 1993) and endogenous growth models (*e.g.*, Futagami, Morita and Shibata, 1993), hence potentially deteriorating the long-run fiscal position (Yakita, 2008; Kondo, 2012).

Along these lines, EU fiscal rules have historically been questioned since the adoption of the Maastricht Treaty and the Stability and Growth Pact, for they abstract from the so-called "golden rule of public finance" which excludes public investments from the deficit ceiling (*e.g.*, Modigliani *et al.*, 1998; Blanchard and Giavazzi, 2004). In the context of endogenous growth models with productive public capital, the golden rule is found to generate growth-enhancing effects with respect to fixed deficit rules in the spirit of the EU fiscal policy framework (Groneck, 2010).

In this paper we analyze the dynamic relationship between public capital expenditure and public debt in the EU over the period from 1980 to 2013. We employ unit root and panel cointegration estimation methods, allowing for the possibility of endogenous structural breaks, to investigate the scope for convergent debt trajectories induced by fiscal stimulus aimed at enhancing public capital. Our empirical analysis is based on a panel of fifteen countries – EU(15) – which include members of the EU throughout the whole sample period 1980-2013 (Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Luxembourg, Netherlands, and the United Kingdom), countries which joined the EU during the 1980s and 1990s (Finland, Greece, Portugal, and Spain), and Norway, which is closely associated with the EU by its membership of the European Economic Area. We further concentrate on the GIIPS group of countries (Greece, Ireland, Italy, Portugal and Spain), because of the alleged greater fragility of their public finances.

We find strong evidence of a significantly negative cointegrating relationship between public capital expenditure and public debt, evaluated in terms of ratios to GDP, in conjunction with a uni-directional causality whereby capital expenditure Granger-causes debt. These empirical findings apply both to EU(15) and to the subset of GIIPS countries. The evidence for a negative debt response to increases in capital expenditure shows extensive robustness especially from 1993 to 2003, due to the occurrence of structural breaks in the individual series over the early 1990s, when the Maastricht Treaty was approved and entered into force.

Our empirical results have two significant policy implications. First, the EU emphasis on reducing total public expenditure to sustain fiscal adjustments can be counter-productive, since it does not account for the critical link between the composition of public expenditure and the success of a fiscal consolidation plan. Secondly, permanent reductions in the debt-to-GDP ratio would require higher levels of capital expenditure, since they provide governments with "growth dividends" which reinforce the long-term stance of fiscal policy.

The paper is organized as follows. Section 2 sets forth the economic rationales behind the possible occurrence of a negative relationship between public capital expenditure and public debt. Section 3 presents the empirical results based on panel cointegration tests. Section 4 concludes.

2. Capital expenditure and public debt sustainability

Our central purpose in this paper is to infer the scope for strengthening the sustainability of EU public finances through rising public expenditure in assets, such as, for example, investments in technology and infrastructures. It is worth emphasizing that a negative relationship between public capital expenditure and public debt might occur, in theory, when one considers the variables either in levels at constant prices or as ratios to GDP.

For real variables in levels, two opposite indirect mechanisms interact. On the one hand, higher public capital expenditure can enlarge the tax base, due to the implied fiscal stimulus on output (*e.g.*, Tuladhar and Bruckner, 2010), thereby expanding fiscal revenues. On the other hand, higher public capital expenditure can increase the long-run real interest rate, due to the alleged rise in the marginal productivity of private capital (Bruce and Turnovsky, 1999; Groneck, 2010), thus exacerbating the debt service. A necessary condition for real debt to decline is that the first effect prevails on the second.

For variables scaled by GDP, however, a third additional indirect mechanism is also at work. Consistently with the well-established literature mentioned in the Introduction, rising public capital expenditure induces an increase in the long-run growth rate, which *per se* tends to dampen the after-growth real interest rate. It follows that, if the "growth dividend" is sufficiently pronounced to bring

about a negative after-growth real interest rate, the law of motion of the debt-to-GDP ratio turns to be fundamentally altered: intrinsically unstable dynamics are reversed into intrinsically stable dynamics. In this case, "honest" Ponzi games (Buiter, 1985) are even possible: deficits do not necessarily imply increases in the debt-to-GDP ratio, since they can always be financed by growth dividends (*e.g.*, Bohn, 2008).

3. Empirical analysis

3.1. Data

This paper examines public capital expenditure and public debt over the period 1980-2013 and separately over the sub-periods 1980-1991 and 1993-2013, to consider the effects on fiscal policy of the Maastricht Treaty which was signed in 1992 and came into force in 1993. The data on public debt and public capital expenditure have been obtained from the AMECO (Annual Macroeconomic Data) database of the European Commission[1]. The general government public debt is here defined as the sum of all the internal liabilities of the central and regional governments. The variables have been considered both in real terms in 2005 prices, and as ratios to GDP at current market prices. All the data series have been transformed into logarithms in order to allow for possible non-linearities[2] and to achieve stationarity in variance.

Most countries in the sample experienced an increase in public debt and in public capital expenditure in real terms from 1980 to 2013. Since for most countries, however, the increase in capital expenditure was proportionally lower than the increase in public debt, capital expenditure also typically declined as a ratio to GDP. The correlation coefficient between public capital expenditure and debt is negative for almost all the countries in the sample, with the exceptions of Greece (0.62), Spain (0.41), UK (0.21), and the Netherlands (0.05). The largest negative correlations were experienced in Austria (-0.73), Italy (-0.68), and Portugal (-0.59).

Tables 1a and 1b report Augmented Dickey-Fuller, Phillips-Perron (1988) and Kwiatkowsky, Phillips, Schmidt and Shin (1992) tests with a constant and trend for individual unit roots on the ratios of government debt and capital expenditure to GDP. The tests reject the null of non-stationarity for variables (and *vice versa* in case of KPSS tests) in first differences for most of the countries in the sample. The ADF test cannot reject the null hypothesis of a unit root in the case of Ireland, Italy, Luxembourg and Spain, and the PP test cannot reject the null of a unit root for Italy and Spain. These results are in line with those reported by Afonso and Rault (2010) for the period 1970-2006. The first difference of real public debt in Table 2a yields similar results, with the ADF test unable to reject the null of a unit root for Ireland, Luxembourg, Norway and Spain and the PP

[1] The Appendix lists all the variable definitions and their AMECO source codes.
[2] See, *e.g.*, Sarno (2001), Legrenzi and Milas (2013), and Piergallini and Postigliola (2013).

test unable to reject the null of non-stationarity for Spain only. The KPSS test supports the null of stationarity for all countries, for the above mentioned variables. For the capital expenditure-GDP ratio and the real capital expenditure series, all the three sets of test statistics confirm first-difference stationarity for all the countries (the only exception being the PP test for real capital expenditure for Greece: see Table 2b).

Unit root tests therefore confirm that most of the variables under analysis can be regarded as stationary in first differences. Further analyses of the series however show that numerous series exhibited structural breaks over the sample period. We computed the Zivot and Andrews (1992) test for one unknown break point, and the Lumsdaine and Papell (1997) test for two structural breaks in level and trend. When one considers the common breaks for the two tests, structural breaks for the debt-GDP ratio are found for Austria, Belgium, Denmark and Spain in 1993-94, Finland, France and Italy in 1992-94, Germany in 1985-86, and Norway in 2002 (Table 3a). When one looks at the capital expenditure-GDP ratio, structural breaks can be seen for Denmark in 1993-94, Luxembourg in 1992, Ireland, Netherlands and Norway in 1991, France and Spain in 1989-90, Portugal in 1987, and UK in 1998 (Table 3b). A similar picture emerges from the analysis of the series in 2005 prices. Table 3c shows that a break was experienced in the real government debt series in Denmark and Finland in 1993-94, in Luxembourg and Norway in 1991, and in Germany in 1989. From Table 3d, the real expenditure series experienced structural breaks in Belgium and Luxembourg in 1991 and in Finland and Greece in 1986-88.

Most of the structural breaks therefore occurred during the period 1991-94, when the fiscal provisions of the Maastricht Treaty came into force. This is relevant for policy analysis, since the resulting change in the fiscal regime could yield different long-run equilibrium relationships for the variables considered. No significant structural breaks were instead associated with the recent 2007-08 financial crisis.

In addition to individual unit root tests, the panel unit root tests of Levin, Lin and Chu (2002), Breitung (2000), Im, Pesaran and Shin (2003), ADF-Fisher Chi-square, PP-Fisher Chi square, and Hadri (2000) were also implemented (Tables 4a and 4b). Most of these tests also confirm the stationarity of the first-differenced series, both for EU(15) and for the subset of GIIPS countries, with the only exceptions of the Hadri z-statistic for EU(15) and for GIIPS, and of the Breitung t-statistic for GIIPS.

3.2. Public capital expenditure and debt dynamics

Table 5a presents the results of cointegration analysis between public capital expenditure and government debt for the panel of EU(15) countries over the sample period 1980-2013. The null hypothesis of no cointegration is tested both for the variables as ratios to GDP and for variables at constant prices. The Pedroni (1999, 2000, 2004) tests allow for heterogeneity across the individual members of the panel, and for both the long-run cointegrating vectors and the short-run dynamics. Seven statistics, four pooled ("within-dimension") and three group-mean ("between-dimension") are reported. The Fisher tests were proposed by Johansen (1998), and Maddala and Wu (1999). They apply Fisher's (1932) meta-analysis approach to combine *p*-values from independent tests, with *r* being the number of cointegrating vectors under the null. The Kao (1999) test extends the Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) approach, under the assumption of strict exogeneity of the regressors with respect to the errors (see also Bhatt and Scaramozzino, forthcoming).

The only evidence in favour of cointegration from Table 5a comes from the Fisher tests ($r<0$ and $r<1$) and, for real variables, from the Pedroni (1999) panel *v*-statistic. The reason for the rejection of the cointegration relationship lies in the structural breaks in the individual series that occurred during the early 1990s which were discussed in section 3.1, and that took place around the time of the implementation of the Maastricht Treaty. Tables 5b and 5c carry out the cointegration analysis separately for the sub-periods 1980-1991 and 1993-2013. There is weak evidence in favour of cointegration during the first sub-period. The Pedroni panel ADF-statistics and group ADF-statistics and the Fisher tests all reject the null of no cointegration both for variables in ratios and at constant prices: for the former the null is also rejected by the Pedroni panel *v*-statistics and by the Kao (1999) test, whilst for the latter the null is also rejected by the Pedroni panel PP-statistic and the group PP-statistic. The summary results for the post-Maastricht sub-period 1993-2013 are presented in Table 5c. The evidence in favour of cointegration is now much stronger, with almost all tests (with the exception of the Pedroni panel *v*-statistics and group *rho*-statistics) supporting the existence of a long-run relationship between capital expenditures and debt.

Table 5d presents the results for the GIIPS countries over the whole sample period 1980-2013. The evidence in favour of the existence of long-run equilibrium relationships for this sub-set of countries is only weak, with three tests supporting cointegration for the variables in ratios (the Pedroni panel ADF-statistic and the two Fisher tests) and with five tests supporting cointegration for the variables at constant prices (the Pedroni group ADF-statistic and the Kao test, in addition to the previous three tests). The evidence in favour of cointegration is however much stronger over the

more recent sub-period 1993-2013. Table 5e shows that nine out of ten tests are significant for variables in levels, and five out of ten for variables as ratios to GDP.

Table 6 shows Kao's (1999) Fully-Modified OLS coefficients for EU(15) and for the GIIPS countries. The coefficients describe the long-run relationship between the cointegrating variables. The coefficients are negative across all the specifications and the sample periods considered. Their values are always highly significant for the variables as ratios to GDP. The only exception is for GIIPS countries over the post-Maastricht period 1993-2013. When the relationship between the variables is estimated at constant prices, the negative coefficient is only significant for the whole sample of fifteen EU countries for the sub-period 1980-1991 and for the GIIPS countries over 1993-2013. This suggests, as the discussion of Section 2 indicates, that the "growth dividend" is likely to constitute the main channel through which higher capital expenditure strengthens fiscal consolidation. Such a channel explains transparently why higher values of public capital expenditure tend to be associated with systematically lower levels of government debt when the variables are evaluated as ratios to GDP and not at constant prices.

Table 7a presents the results of Granger-causality tests on the direction of the relationship between capital expenditure and debt. Capital expenditure always Granger-causes public debt, both as a ratio to GDP and at constant prices. By contrast, there is no evidence that debt Granger-causes real capital expenditure when the variables are expressed as ratios to GDP but only when they are measured in levels. The inconclusive result for real series, unscaled by GDP, reinforces the view that higher capital expenditure triggers convergent paths for the debt to GDP ratio primarily because it tends, *per se*, to reduce the after-growth real interest rate.

Table 7b presents the Granger-causality results for the GIIPS group of countries. Capital expenditure is strongly confirmed to help predict public debt. The effects of public debt on capital expenditure are now weaker.

Taken in conjunction with the results from Table 6, the Granger-causality tests from Tables 7a and 7b show that higher public capital expenditure tends to be associated with lower, and not with higher, public debt for the sample of countries considered in the analysis. These results are especially important in the light of the current policy debate on the most effective measures to take in order to achieve fiscal consolidation in the European Union.

4. Conclusions

Whereas EU fiscal austerity measures aim to guarantee debt consolidation in the aftermath of the sovereign debt crisis of 2009-2012, this paper provides direct evidence of the stabilizing effects induced by expansions in public capital expenditure. Increases in the ratio of capital expenditure to

GDP cause reductions in the ratio of debt to GDP in the long run. This empirical finding emerges from panel cointegration analysis applied to fifteen EU countries and to the subset of GIIPS countries over the sample period from 1980 to 2013, and appears particularly pronounced over the period from 1993 to 2013.

Therefore, the paper confirms that "fiscal discipline" may be conceptually different from "fiscal austerity": fiscal discipline does not necessarily require expenditure-based fiscal austerity. The paper's results are consistent with the view that the EU fiscal consolidation process should explicitly control for the composition of public expenditure. Rising public investment stimulates the long-run rate of economic growth and thus fosters convergence in debt-GDP ratios, ruling out the possible occurrence of high debt-austerity traps.

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Appendix. Variables definitions and sources.

Original Series	**AMECO codes**
General Government consolidated gross debt, Excessive Deficit procedure (based on ESA 1995) and former definition (linked series) (% of GDP)	UDGGL UDGGF
General Government debt (level)	UDGGL UDGGF
General Government capital expenditure	UIGG UKOG
Gross Domestic Product (current prices)	UVGD
GDP Deflator	PVGD

Table 1a. Stationarity Tests for the First Difference of Government Debt to GDP[1].

Country	Period	**ADF** t-stat	**ADF** P-value	**PP[2]** t-stat	**PP[2]** P-value	**KPSS** LM-Statistic For level Stationarity[c]
Austria	1980-2013	-3.310	0.0227	-3.035	0.0422	0.355601***
Belgium	1980-2013	-3.033	0.0424	-2.995	0.0460	0.378097***
Denmark	1980-2013	-3.237	0.0269	-3.147	0.0330	0.228541***
Finland	1980-2013	-3.792	0.0072	-2.656	0.0926	0.081416***
France	1980-2013	-3.529	0.0135	-3.442	0.0166	0.155890***
Germany	1980-2013	-4.150	0.0028	-4.484	0.0012	0.151124***
Greece	1980-2013	-5.411	0.0001	-5.412	0.0001	0.163692***
Ireland	1980-2013	-1.879	0.3373	-1.963	0.0488	0.226473***
Italy	1980-2013	-2.557	0.1121	-2.557	0.1121	0.183831***
Luxembourg	1980-2013	-1.676	0.4326	-4.703	0.0007	0.500688*
Netherlands	1980-2013	-3.217	0.0281	-3.116	0.0353	0.196689***
Norway	1980-2013	-4.778	0.0005	-4.762	0.0006	0.163463***
Portugal	1980-2013	-2.864	0.0608	-2.871	0.0599	0.303228***
Spain	1980-2013	-2.155	0.2257	-2.204	0.2085	0.132496***
UK	1980-2013	-2.574	0.1088	-1.832	0.0643	0.373120***

Notes:

1. The null hypothesis of all tests is that the series has a unit root except for the Kwiatkowski-Phillips-Schmidt-Shin tests, where the null hypothesis is stationarity around a constant. The lag length in the ADF regression is based on the Schwartz Information criterion with a maximum lag of 7.
2. Bandwidth: Newey-West using a Bartlett Kernel.
3. The critical values provided by Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1) are respectively 0.739 (1 per cent level), 0.463 (5 per cent level) and 0.347 (10 per cent level) for the LM test for level stationarity.

Table 1b. Stationarity Tests for the First Difference of General Government Capital Expenditure to GDP[1].

Country	Period	ADF t-stat	ADF P-value	PP[2] t-stat	PP[2] P-value For Adj-t-stat	KPSS LM-Statistic For level Stationarity[c]
Austria	1980-2013	-6.7800	0.0000	-14.775	0.0000	0.081832***
Belgium	1980-2013	-12.129	0.0000	-11.773	0.0000	0.256586***
Denmark	1980-2013	-3.2646	0.0256	-6.4001	0.0000	0.180110***
Finland	1980-2013	-5.9001	0.0000	-7.0531	0.0000	0.176219***
France	1980-2013	-6.3516	0.0000	-6.5316	0.0000	0.075324***
Germany	1980-2013	-6.6183	0.0000	-14.621	0.0000	0.484848**
Greece	1980-2013	-2.1443	0.0327	-2.0848	0.0374	0.210071***
Ireland	1980-2013	-4.4064	0.0016	-12.578	0.0000	0.245524***
Italy	1980-2013	-9.5802	0.0000	-10.239	0.0000	0.113081***
Luxembourg	1990-2013	-7.1815	0.0000	-7.3456	0.0000	0.120760***
Netherlands	1980-2013	-8.7231	0.0000	-21.591	0.0001	0.500000*
Norway	1980-2013	-4.6389	0.0008	-4.8908	0.0004	0.083621***
Portugal	1980-2013	-6.5228	0.0000	-11.030	0.0000	0.500000*
Spain	1980-2013	-8.3192	0.0000	-8.7200	0.0000	0.344715***
UK	1980-2013	-7.0340	0.0000	-7.4641	0.0000	0.096420***

Notes:

1. The null hypothesis of all tests is that the series has a unit root except for the Kwiatkowski-Phillips-Schmidt-Shin tests, where the null hypothesis is stationarity around a constant. The lag length in the ADF regression is based on the Schwartz Information criterion with a maximum lag of 7.
2. Bandwidth: Newey-West using a Bartlett Kernel.
3. The critical values provided by Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1) are respectively 0.739 (1 per cent level), 0.463 (5 per cent level) and 0.347 (10 per cent level) and 0.347 (10 per cent level) for the LM test for level stationarity.

Table 2a. Stationarity Tests for the First Difference of Real Government Debt (2005 prices)[1].

Country	Period	ADF t-stat	ADF P-value	PP[2] Adj-t-stat	PP[2] P-value For Adj-t-stat	KPSS LM-Statistic For level Stationarity[c]
Austria	1980-2013	-3.9255	0.0051	-3.6762	0.0095	0.080606***
Belgium	1980-2013	-2.0227	0.0538	-2.8282	0.0656	0.389174**
Denmark	1980-2013	-3.5002	0.0148	-2.5832	0.1068	0.260809***
Finland	1980-2013	-3.4115	0.0188	-2.6301	0.0976	0.089390***
France	1980-2013	-3.5007	0.0145	-3.5396	0.0132	0.402596**
Germany	1980-2013	-4.5331	0.0010	-4.3658	0.0016	0.146644***
Greece	1980-2013	-6.4281	0.0000	-8.1481	0.0000	0.500000*
Ireland	1980-2013	-1.8924	0.3315	-1.5615	0.1097	0.313943***
Italy	1980-2013	-4.3926	0.0015	-4.3926	0.0015	0.270087***
Luxembourg	1980-2013	-1.5808	0.4801	-5.4604	0.0001	0.565418*
Netherlands	1980-2013	-4.6455	0.0008	-4.6931	0.0007	0.188150***
Norway	1980-2013	-1.8674	0.3424	-5.3978	0.0001	0.122461***
Portugal	1980-2013	-2.6357	0.0965	-2.7055	0.0841	0.441240**
Spain	1980-2013	-2.0017	0.2847	-2.0651	0.2593	0.184810***
UK	1980-2013	-3.5236	0.0137	-3.5236	0.0137	0.451746*

Notes:

1. The null hypothesis of all tests is that the series has a unit root except for the Kwiatkowski-Phillips-Schmidt-Shin tests, where the null hypothesis is stationarity around a constant. The lag length in the ADF regression is based on the Schwartz Information criterion with a maximum lag of 7.
2. Bandwidth: Newey-West using a Bartlett Kernel.
3. The critical values provided by Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1) are respectively 0.739 (1 per cent level), 0.463 (5 per cent level) and 0.347 (10 per cent level) and 0.347 (10 per cent level) for the LM test for level stationarity.

Table 2b. Stationarity Tests for First Difference of Real General Government Capital Expenditure (2005 prices)[1].

Country	Period	ADF t-stat	ADF P-value	PP[2] Adj t-stat	PP[2] P-value For Adj-t-stat	KPSS LM-Statistic For level Stationarity[c]
Austria	1980-2013	-7.3831	0.0000	-19.8953	0.0001	0.064667***
Belgium	1980-2013	-11.522	0.0000	-12.1726	0.0000	0.500000*
Denmark	1980-2013	-3.8478	0.0063	-7.22843	0.0000	0.452421**
Finland	1980-2013	-6.3081	0.0000	-11.8476	0.0000	0.385399**
France	1980-2013	-5.6303	0.0001	-5.64020	0.0001	0.074498***
Germany	1980-2013	-6.6230	0.0000	-12.8462	0.0000	0.349670**
Greece	1980-2013	-3.7544	0.0081	-1.35829	0.5899	0.251300***
Ireland	1980-2013	-4.3360	0.0019	-11.7875	0.0000	0.204542***
Italy	1980-2013	-9.1403	0.0000	-9.20968	0.0000	0.155646***
Luxembourg	1990-2013	-7.6925	0.0000	-7.99947	0.0000	0.127239***
Netherlands	1980-2013	-8.4787	0.0000	-21.2927	0.0001	0.500000*
Norway	1980-2013	-5.2641	0.0001	-6.81477	0.0000	0.120693***
Portugal	1980-2013	-5.8324	0.0000	-6.35522	0.0000	0.339881***
Spain	1980-2013	-8.8622	0.0000	-8.88172	0.0000	0.300629***
UK	1980-2013	-6.7754	0.0000	-7.17743	0.0000	0.088329***

Notes:

1. The null hypothesis of all tests is that the series has a unit root except for the Kwiatkowski-Phillips-Schmidt-Shin tests, where the null hypothesis is stationarity around a constant. The lag length in the ADF regression is based on the Schwartz Information criterion with a maximum lag of 7.
2. Bandwidth: Newey-West using a Bartlett Kernel c-The critical values provided by Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1) are respectively 0.739 (1 per cent level), 0.463 (5 per cent level) and 0.347 (10 per cent level) and 0.347 (10 per cent level) for the LM test for level stationarity.

Table 3a. Tests for Structural Change in the First Difference of Government Debt to GDP (1980-2013).

		Zivot and Andrews (1992)			Lumsdaine and Papell (1997)				
Country	**Lags**	**t-stat[a]**	**Break date**	**Break Date TB_1**	**Break Date TB_2**	**tstat[b]-value TB_1**	**t[b]-stat value TB_2**	**p[b]-value TB_1**	**p[b]-value TB_2**
Austria	1	-3.6594**	2000	1994	2010	-1.9191	0.2326	0.0675	0.8181
Belgium	1	-3.1389***	2008	1994	2009	-5.8552	2.9855	0.0000	0.0066
Denmark	1	-4.0929**	2000	1994	2006	-6.1490	5.7225	0.0000	0.0000
Finland	0	-5.4080***	1991	1993	2010	-4.7446	2.2642	0.0001	0.0333
France	1	-3.6670*	2006	1993	2007	2.0525	3.4742	0.0517	0.0021
Germany	1	-4.8710***	1995	1985	1996	2.7340	1.9844	0.0118	0.0637
Greece	0	-2.6030	2006	2009	2011	1.5846	-1.930	0.1267	0.0660
Ireland	1	-3.8928	2004	1992	2006	-5.1844	5.2778	0.0000	0.0000
Italy	1	-2.3946	1991	1993	2007	-2.6397	3.6837	0.0146	0.0012
Luxembourg	0	-3.0290***	2008	1989	2007	0.4701	4.9130	0.6427	0.0001
Netherlands	1	-3.3963***	2008	1998	2009	-1.6440	1.3852	0.1138	0.1793
Norway	1	-5.5293***	2006	2002	2007	2.7332	-4.365	0.0108	0.0002
Portugal	1	-3.6745	2007	1999	2008	3.6383	4.4095	0.0014	0.0002
Spain	1	-1.9903	1992	1994	2008	-6.2767	6.8603	0.0000	0.0000
UK	1	-5.0691	2005	1989	2007	0.5400	3.9079	0.5943	0.0007

Notes:

1. The exact critical values are calculated are calculated based on 7,000 replications of a Monte Carlo simulation as described in Zivot and Andrews (1992, p.262) and are respectively -6.68 (1 per cent level), -5.82 (5 per cent level) and -5.37 (10 per cent level).
2. The exact critical values are calculated are calculated based on 7,000 replications of a Monte Carlo simulation as described in Lumsdaine and Papell (1997), and are respectively -8.78 (1 per cent level), -7.47 (5 per cent level) and -6.98 (10 per cent level).
3. *** denotes statistical significance at 1 per cent level of significance, ** denotes statistical significance of the structural break at the 5 per cent level of significance while * denotes statistical significance of the structural break at the 10 per cent level of significance.
4. The Zivot and Andrews test for structural breaks identifies a single possible break in the series. Instead, the Lumsdaine and Papell test identifies two possible breaks. We consider a break in the series to be binding, only when the same break is found in both the tests and are significant.
5. In case of the debt/GDP values for each country, it can be seen that common breaks from the test are found in case of Austria for 1993-94, 1992-1994 for Denmark, 1995-96 for Germany, 1992 for Italy, 1994-1997 for Norway. Since, the common break period is early 1990s we can conclude that in general, a break in the panel of the countries altogether would be between 1992-1994.

Table 3b. Tests for Structural Change in the Ratio of General Government Capital Expenditure to GDP (1980-2013).

		Zivot and Andrews (1992)			Lumsdaine and Papell (1997)				
Country	**Lags**	**t-stat**	**Break date**	**Break date 1**	**Break date 2**	**t-stat TB1**	**t-stat TB2**	**P-value 1**	**P-value 2[b]**
Austria	0	-7.1243***	2004	1986	2005	-4.217	1.432	0.0003	0.1656
Belgium	1	-4.4639	1989	1986	1991	-2.719	2.753	0.0122	0.0113
Denmark	4	-2.9300	2005	1993	2007	-1.662	3.228	0.1099	0.0037
Finland	0	-5.1887***	1997	1996	2001	-4.959	4.854	0.0001	0.0001
France	0	-4.7843***	1996	1989	1997	1.435	-1.09	0.1646	0.2852
Germany	0	-6.4900**	1997	1996	2002	-10.64	10.04	0.0000	0.0000
Greece	1	-2.6298	1990	1989	2011	0.225	6.499	0.8238	0.0000
Ireland	0	-5.1135**	2008	1991	2007	3.901	3.713	0.0051	0.0011
Italy	1	-3.3014**	2003	1987	2004	-3.081	-0.88	0.0053	0.3841
Luxembourg	0	-4.3567**	1988	1992	2003	-2.514	0.397	0.0194	0.6947
Netherlands	0	-5.7229	1997	1991	1999	0.936	-0.33	0.3588	0.7380
Norway	1	-4.0452**	1995	1991	2005	-3.827	3.392	0.0009	0.0025
Portugal	1	-4.8730*	1996	1987	2003	3.653	-3.99	0.0013	0.0006
Spain	1	-3.8449*	1990	1990	2010	1.540	-2.89	0.1372	0.0082
UK	0	-4.2797***	2008	1998	2009	2.332	-3.47	0.0288	0.0021

Notes:

1. The exact critical values are calculated are calculated based on 7,000 replications of a Monte Carlo simulation as described in Zivot and Andrews (1992, p.262) and are respectively -6.68 (1 per cent level), -5.82 (5 per cent level) and -5.37 (10 per cent level).
2. The exact critical values are calculated are calculated based on 7,000 replications of a Monte Carlo simulation as described in Lumsdaine and Papell (1997), and are respectively -8.78 (1 per cent level), -7.47 (5 per cent level) and -6.98 (10 per cent level).
3. *** denotes statistical significance at 1 per cent level of significance, ** denotes statistical significance of the structural break at the 5 per cent level of significance while * denotes statistical significance of the structural break at the 10 per cent level of significance.

Table 3c. Tests for Structural Change in the Real Government Debt (2005 prices) (1980-2013).

	Zivot and Andrews (1992)			Lumsdaine and Papell (1997)					
Country	**Lags**	**t-stat[a]**	**Break date**	**Break Date TB_1**	**Break Date TB_2**	**t-stat value TB1**	**t-stat value TB2**	**P[b]-value TB_1**	**P[b]-value TB_2**
Austria	1	-3.8902***	2003	1986	2006	2.994	2.3008	0.0065	0.0308
Belgium	1	-2.4078	1986	1997	2009	-2.3071	0.0002	0.0304	0.9998
Denmark	1	-4.5065**	1992	1993	2006	-4.8036	4.9997	0.0001	0.0000
Finland	1	-4.7388***	1992	1993	2008	0.616	5.3566	0.5434	0.0000
France	1	-3.5718*	2006	1987	2007	4.744	4.2496	0.0001	0.0003
Germany	1	-3.2524*	1994	1989	2002	3.781	-0.4786	0.0010	0.6367
Greece	0	-3.9735	1988	1986	2007	4.617	3.8536	0.0001	0.0008
Ireland	1	-4.3959**	2005	1991	2007	-3.085	5.5887	0.0052	0.0000
Italy	1	-3.4914**	1993	1985	1994	3.1943	-2.5470	0.0040	0.0180
Luxembourg	1	-3.9676*	2005	1991	2008	7.0824	7.5902	0.0000	0.0000
Netherlands	0	-2.0787**	2000	2001	2009	1.1618	-0.9587	0.1192	0.3476
Norway	0	-3.6941**	2006	1991	2007	3.4792	-4.7617	0.0020	0.0001
Portugal	1	-5.1974*	2006	1985	2007	3.9074	4.4516	0.0007	0.0002
Spain	1	-2.4698**	2005	1994	2008	-2.7135	5.5433	0.0124	0.0000
UK	1	-3.9409	2007	1996	2008	1.1664	5.1322	0.2554	0.0000

Notes:

1. The exact critical values are calculated are calculated based on 7,000 replications of a Monte Carlo simulation as described in Zivot and Andrews (1992, p.262) and are respectively -6.68 (1 per cent level), -5.82 (5 per cent level) and -5.37 (10 per cent level).
2. The exact critical values are calculated are calculated based on 7,000 replications of a Monte Carlo simulation as described in Lumsdaine and Papell (1997), and are respectively -8.78 (1 per cent level), -7.47 (5 per cent level) and -6.98 (10 per cent level).
3. *** denotes statistical significance at 1 per cent level of significance, ** denotes statistical significance of the structural break at the 5 per cent level of significance while * denotes statistical significance of the structural break at the 10 per cent level of significance.
4. The Zivot and Andrews test for structural breaks identifies a single possible break in the series. Instead, the Lumsdaine and Papell test identifies two possible breaks. We consider a break in the series to be binding only when the same break is found in both the tests and are significant.

Table 3d. Tests for Structural Change in the Real General Government Capital Expenditure (2005 prices) (1980-2013).

		Zivot and Andrews (1992)		Lumsdaine and Papell (1997)					
Country	**Lags**	**t-stat**	**Break date**	**Break date 1**	**Break date 2**	**t-stat DT1**	**t-stat DT2**	**P-value DT1**	**P-value DT2[b]**
Austria	0	-7.7396***	2004	1994	2005	-4.795	3.195	0.0001	0.0040
Belgium	1	-4.6341	1989	1986	1991	-1.909	2.262	0.0687	0.0334
Denmark	1	-2.9249	2006	1993	2008	0.686	3.249	0.4992	0.0035
Finland	0	-6.1481	1997	1985	1998	4.000	-2.384	0.0006	0.0257
France	0	-3.5833***	1996	1989	1997	2.308	-0.987	0.0303	0.3338
Germany	2	-6.5608**	1997	1996	2002	-7.907	7.586	0.0000	0.0000
Greece	1	-4.3751	1990	1988	1995	2.885	-2.015	0.0083	0.0557
Ireland	0	-5.1976***	2008	1996	2008	4.924	4.219	0.0001	0.0003
Italy	1	-3.2380**	2006	1998	2007	2.416	-3.917	0.0240	0.0007
Luxembourg	0	-5.6460***	2002	1991	2003	2.190	-1.754	0.0389	0.0927
Netherlands	1	-5.5445**	2008	1996	2002	-3.904	4.6038	0.0007	0.0001
Norway	1	-4.1621**	2000	1988	2002	3.224	1.2484	0.0194	0.2244
Portugal	1	-4.0254*	1997	1987	2003	5.666	-5.371	0.0000	0.0000
Spain	1	-4.1413***	2008	1986	2009	2.977	-4.393	0.0067	0.0002
UK	0	-4.6761***	2008	2001	2009	5.1873	-6.193	0.0000	0.0000

Notes:

1. The exact critical values are calculated are calculated based on 7,000 replications of a Monte Carlo simulation as described in Zivot and Andrews (1992, p.262) and are respectively -6.68 (1 per cent level), -5.82 (5 per cent level) and -5.37 (10 per cent level).
2. The exact critical values are calculated are calculated based on 7,000 replications of a Monte Carlo simulation as described in Lumsdaine and Papell (1997), and are respectively -8.78 (1 per cent level), -7.47 (5 per cent level) and -6.98 (10 per cent level).
3. *** denotes statistical significance at 1 per cent level of significance, ** denotes statistical significance of the structural break at the 5 per cent level of significance while * denotes statistical significance of the structural break at the 10 per cent level of significance.
4. The Zivot and Andrews test for structural breaks identifies a single possible break in the series. Instead, the Lumsdaine and Papell test identifies two possible breaks. We consider a break in the series to be binding only when the same break is found in both the tests and are significant.

Table 4a. Panel Unit Root Tests (EU(15)) (1980-2013).

Panel Data	Levin, Lin & Chu	Breitung t-stat	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square	Hadri Z-stat
Government Debt/GDP	-5.9935 (0.0000)	-3.78995 (0.0001)	-5.9435 (0.0000)	93.3359 (0.0000)	117.632 (0.0000)	7.68810 (0.0000)
Capital expenditure/ GDP	-6.72257 (0.0000)	-1.96109 (0.0249)	-12.7160 (0.0000)	196.794 (0.0000)	1882.22 (0.0000)	8.78881 (0.0000)
Real Debt	-4.99982 (0.0000)	-2.92713 (0.0017)	-4.45810 (0.0000)	72.2731 (0.0001)	331.086 (0.0001)	5.38560 (0.0000)
Real Capital Expenditure	-7.05209 (0.0000)	-2.30042 (0.0107)	-13.0893 (0.0000)	200.281 (0.0000)	1534.26 (0.0000)	7.12414 (0.0000)

Notes:

1. Probabilities for Fisher tests are computed using an asymptotic Chi–square distribution.
2. All other tests assume asymptotic normality.
3. Automatic selection of lags based on SIC, Newey-West bandwidth selection using a Bartlett Kernel.
4. Ten cross-sections used in each test. The Levin, Lin & Chu t test uses 290 observations, Breitung-stat used 280 observations, Im, Pesaran and Shin W-stat, ADF-Fischer chi square used 290 observations, PP-Fischer chi-square used 300 observations. Finally, Hadri-z stat used 310 observations. Hadri z-stat assumes no unit root in the process while the other tests assume unit root as the null.

Table 4b. Panel Unit Root Tests (GIIPS) (1980-2013).

Panel Data	Levin, Lin & Chu	Breitung t-stat	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square	Hadri Z-stat
Government Debt/GDP	-1.07939 (0.1402)	-1.09468 (0.1368)	-1.97301 (0.0242)	19.1127 (0.0389)	34.1077 (0.0002)	4.9985 (0.0000)
Capital expenditure/ GDP	-6.67648 (0.0000)	1.67924 (0.9534)	-11.1846 (0.0000)	119.950 (0.0000)	698.408 (0.0000)	5.09028 (0.0000)
Real Debt	-2.33511 (0.0098)	-0.98982 (0.1611)	-3.92859 (0.0000)	35.1202 (0.0001)	241.643 (0.0000)	3.14924 (0.0008)
Real Capital Expenditure	-2.98446 (0.0014)	1.69503 (0.9550)	-9.52363 (0.0000)	107.903 (0.0000)	255.636 (0.0000)	0.72744 (0.2335)

Notes:

1. Probabilities for Fisher tests are computed using an asymptotic Chi–square distribution.
2. All other tests assume asymptotic normality.
3. Automatic selection of lags based on SIC, Newey-West bandwidth selection using a Bartlett Kernel.
4. Ten cross-sections used in each test. The Levin, Lin & Chu t test uses 290 observations, Breitung-stat used 280 observations, Im, Pesaran and Shin W-stat, ADF-Fischer chi square used 290 observations, PP-Fischer chi-square used 300 observations. Finally, Hadri-z stat used 310 observations. Hadri z-stat assumes no unit root in the process while the other tests assume unit root as the null.

Table 5a. Summary Panel Cointegration (EU15) (1980-2013).

Variables	Pedroni (panel v-statistic)	Pedroni (panel rho-statistic)	Pedroni (panel pp-statistic)	Pedroni (panel ADF-statistic)	Pedroni (group rho-statistic)	Pedroni (group pp-statistic)	Pedroni (group ADF-statistic)	Fisher (r < 0)	Fisher (r < 1)	Kao
Govt Debt/GDP & Capital Exp/GDP	0.895 (0.18)	0.9499 (0.828)	0.2312 (0.5914)	-0.2920 (0.385)	2.3485 (0.990)	1.6032 (0.9456)	-0.0882 (0.4648)	82.51 (0.0000)	53.91 (0.0047)	- 0.79935 (0.2120)
Real Debt & Real Capital Exp	4.220 (0.00)	0.9855 (0.837)	0.4723 (0.6817)	-0.4689 (0.319)	2.3022 (0.989)	1.8367 (0.9666)	0.0870 (0.5347)	78.62 (0.0000)	47.21 (0.0237)	1.17574 (0.1198)

Table 5b. Summary Panel Cointegration (EU15) (1980-1991).

Variables	Pedroni (panel v-statistic)	Pedroni (panel rho-statistic)	Pedroni (panel pp-statistic)	Pedroni (panel ADF-statistic)	Pedroni (group rho-statistic)	Pedroni (group pp-statistic)	Pedroni (group ADF-statistic)	Fisher (r < 0)	Fisher (r < 1)	Kao
Govt Debt/GDP & Capital Exp/GDP	3.859 (0.00)	2.4923 (0.993)	0.9952 (0.8402)	-1.2885 (0.098)	3.2770 (0.999)	0.57523 (0.7174)	-1.2984 (0.0971)	104.6 (0.0000)	80.84 (0.0000)	- 1.97613 (0.0241)
Real Debt & Real Capital Exp	-0.55 (0.71)	0.3344 (0.631)	-1.46686 (0.0710)	-1.5777 (0.057)	0.8666 (0.806)	-2.2845 (0.0112)	-1.47708 (0.0698)	63.66 (0.0003)	54.32 (0.0042)	-1.0301 (0.1515)

Table 5c. Summary Panel Cointegration (EU15) (1993-2013).

Variables	Pedroni (panel v-statistic)	Pedroni (panel rho-statistic)	Pedroni (panel pp-statistic)	Pedroni (panel ADF-statistic)	Pedroni (group rho-statistic)	Pedroni (group pp-statistic)	Pedroni (group ADF-statistic)	Fisher (r < 0)	Fisher (r < 1)	Kao
Govt Debt/GDP & Capital Exp/GDP	-1.65 (0.95)	-6.4283 (0.000)	-5.28514 (0.0000)	-4.9892 (0.000)	-0.7070 (0.239)	-1.9546 (0.0253)	-3.16317 (0.008)	82.48 (0.0000)	53.93 (0.0047)	- 1.9864 (0.0235)
Real Debt & Real Capital Exp	-1.57 (0.94)	-7.2239 (0.000)	-5.65661 (0.0000)	-5.6208 (0.000)	-0.5475 (0.292)	-1.5739 (0.0577)	-2.21056 (0.0135)	59.66 (0.0010)	41.40 (0.0804)	1.78673 (0.0370)

Table 5d. Summary Panel Cointegration (GIIPS) (1980-2013).

Variables	Pedroni (panel v-statistic)	Pedroni (panel rho-statistic)	Pedroni (panel pp-statistic)	Pedroni (panel ADF-statistic)	Pedroni (group rho-statistic)	Pedroni (group pp-statistic)	Pedroni (group ADF-statistic)	Fisher (r < 0)	Fisher (r < 1)	Kao
Govt Debt/GDP & Capital Exp/GDP	0.373 (0.35)	-0.8643 (0.139)	-0.9028 (0.1833)	-1.4305 (0.076)	0.2890 (0.613)	-0.1579 (0.4372)	0.1011 (0.5403)	35.23 (0.0001)	20.76 (0.0228)	- 0.93003 (0.1762)
Real Debt & Real Capital Exp	0.535 (0.29)	-0.329 (0.370)	0.1816 (0.5721)	-0.4689 (0.077)	1.3895 (0.917)	1.6186 (0.9472)	-1.5084 (0.0657)	16.92 (0.0076)	26.39 (0.0032)	1.75481 (0.0396)

Table 5e. Summary Panel Cointegration (GIIPS) (1993-2013).

Variables	Pedroni (panel v-statistic)	Pedroni (panel rho-statistic)	Pedroni (panel pp-statistic)	Pedroni (panel ADF-statistic)	Pedroni (group rho-statistic)	Pedroni (group pp-statistic)	Pedroni (group ADF-statistic)	Fisher (r < 0)	Fisher (r < 1)	Kao
Govt Debt/GDP & Capital Exp/GDP	-0.7738 (0.7805)	-1.7143 (0.0432)	-1.0735 (0.1415)	-1.8474 (0.0323)	0.7530 (0.7743)	0.8362 (0.7985)	-1.9395 (0.0262)	62.75 (0.0000)	16.48 (0.0867)	1.0130 (0.1555)
Real Debt & Real Capital Exp	1.4033 (0.0803)	-2.1141 (0.0172)	-2.3045 (0.0106)	-3.8065 (0.0001)	-0.7728 (0.2198)	-1.4516 (0.0733)	-3.8282 (0.0001)	38.03 (0.0002)	19.56 (0.0337)	-3.1301 (0.0009)

Note:

p-values in brackets.

Table 6. Summary Panel Cointegration (1980-2013) – Kao FMOLS Coefficients.

Variables	EU(15) (1980-2013)	EU(15) (1980-1991)	EU(15) (1993-2013)	GIIPS (1980-2013)	GIIPS (1993-2013)
Govt Debt/GDP & Capital Expenditure/GDP	-0.04818 (0.0001)	-0.16979 (0.0000)	-0.15859 (0.0000)	-0.07169 (0.0062)	-0.02971 (0.4502)
Real Debt & Real Capital Expenditure	-0.03001 (0.1614)	-0.17483 (0.0000)	-0.03737 (0.1863)	-0.03002 (0.2441)	-0.5789 (0.0000)

Note:

p-values in brackets.

Table 7a. Granger Causality Test EU(15) Panel.

Panel Data (EU15)	F-statistic (1980-2013)	F-statistic (1993-2013)
Null Hypothesis: Capital Expenditure/GDP does not Granger Cause Debt/GDP	3.69729 (0.0255)	2.30085 (0.1021)
Null Hypothesis: Debt/GDP does not Granger Cause Capital Expenditure/GDP	0.46977 (0.6254)	0.00561 (0.9944)
Null Hypothesis: Real Capital Expenditure does not Granger Cause Real Debt	6.18080 (0.0000)	15.1377 (0.0000)
Null Hypothesis: Real Debt does not Granger Cause Real Capital Expenditure	3.82761 (0.0005)	9.7320 (0.0000)

Table 7b. Granger Causality Test (GIIPS) Panel.

Panel Data (GIIPS)	F-statistic (1980-2013)	F-statistic (1993-2013)
Null Hypothesis: Capital Expenditure/GDP does not Granger Cause Debt/GDP	10.0059 (0.0019)	2.29256 (0.1068)
Null Hypothesis: Debt/GDP does not Granger Cause Capital Expenditure/GDP	0.01901 (0.8905)	0.20935 (0.8815)
Null Hypothesis: Real Capital Expenditure does not Granger Cause Real Debt	17.5153 (0.0000)	7.83929 (0.0007)
Null Hypothesis: Real Debt does not Granger Cause Real Capital Expenditure	3.05578 (0.0823)	1.05138 (0.3537)

Note:

p-values in brackets.