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Public Sector Debt Dynamics: The Persistence and Sources of Shocks to Debt in Ten EU Countries*

Massimo Antonini†, Kevin Lee†† and Jacinta Pires†††

Abstract

This paper characterises the time series properties of debt:GDP ratios in ten EU countries over the period 1982-2009. It establishes that shocks to debt ratios persist and measures the size and source of the permanent effects of shocks as they evolve over time. The analysis shows that debt dynamics in the EU10 are complicated, involving important inter-country interactions and protracted adjustment periods of the order of ten years. We find evidence of asymmetries in the effects of different forms of 'fiscal consolidation', with unanticipated reductions in government spending having a more permanent effect than unanticipated increases in government revenue. Unanticipated business cycle fluctuations also have important long-term effects on the ratio.

Keywords: Public sector debt, debt:GDP ratio, debt sustainability, persistence

JEL Classification: C32, D84, E32.

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1 Introduction

There has been considerable attention focused on public sector debt levels and debt sustainability in recent years. Debt:GDP levels rose dramatically in many countries following the measures taken to deal with the recent financial and economic crisis, from around 65% at the beginning of 2008 to nearer 80% at the end of 2009 in the EU for example.[1] Concern has been expressed over many countries' ability to service such high debt levels both in the media and in the financial markets and, within the EU countries, rescue packages totalling some 920 billion euro were agreed in May 2010 to protect against the fears of sovereign debt default and state insolvency. In September 2010, wide-ranging legislation was introduced to reinforce the economic governance of the EU, strengthening the principles behind the Stability and Growth Pact, allowing for more detailed surveillance of EU countries' fiscal and other macro-economic policies over the business cycle and for stronger enforcement of sanctions against member states failing to comply with the newly-defined concept of prudent fiscal policy-making.[2]

Given the political and economic significance of the issues surrounding public-sector debt management, the empirical literature investigating public sector debt dynamics at the macroeconomic level is surprisingly sparse. There is a voluminous theoretical literature concerned with the characteristics of optimal fiscal policies but this often relates only loosely to explanations of observed public sector debt levels over the long run or over the cycle. As discussed below, there have been various attempts to relate the time series properties of debt levels to debt sustainability and there is, of course, continuous and detailed analysis of the sustainability of public finances in EU countries provided by the European Commission (see, for example, European

[1] To place these figures in context though, we note that debt burdens in the EU rose from around 35% in 1980 to around 75% in the mid- 1990's.

[2] For details, see the statement by the Economic and Financial Affairs Directorate of the European Commission "A new EU economic governance - a comprehensive Commission package of proposals" at http://ec.europa.eu/economy_finance/articles/eu_economic_situation/2010-09-eu_economic_governance_proposals_en.htm.

Commission, 2009, 2010). But, as noted in Trehan and Walsh (1991), the interpretation of the empirical findings in the early time series work was controversial, while the analyses of debt sustainability are typically based on complicated and potentially contentious structural models that are difficult to interpret. Further, much of this work has focused on countries taken in isolation or in turn and it is often difficult to identify the effects of the cross-country interdependencies that are so important to understanding debt sustainability in the eurozone and many other parts of the world.[3]

This paper provides a simple characterisation of the time series properties of the debt:GDP ratios in ten EU countries over the period 1982-2009. It establishes that shocks to debt ratios persist over time and focuses on measuring the size and source of the permanent shocks to the debt ratios. The paper also provides "persistence profiles" which characterise the effects of the permanent shocks on countries' debt as the effects evolve over time. The analysis is undertaken in the context of a multivariate VAR so that the interdependencies between countries' debt ratios are properly taken into account. The analysis shows that public sector debt dynamics in the EU10 are complicated, involving important inter-country interactions and protracted adjustment periods, of the order of ten years, in response to shocks. Shocks to economic growth have direct and permanent effects on the ratio which accumulate over time to contribute to the complexity of public debt dynamics. We also find evidence of asymmetries in the effects of different forms of 'fiscal consolidation', with unanticipated reductions in government spending having a more permanent effect than unanticipated increases in government revenue.

The layout of the paper is as follows. Section 2 provides a brief review of the literature concerned with the time series characterisation of public sector debt dynamics and describes the modelling techniques we use to measure the size of the permanent effects of shocks to debt and to obtain the associated persistence profiles. Section 3

[3]Notable exceptions include Feve and Henin's (2000) analysis of debt in the G7 economies and Afonso and Rault's (2010) analysis of debt:GDP ratios in the EU.

presents the results of the analysis of innovations in debt ratios applied to the EU10 countries, ignoring the nature of the shocks at first and then focusing on the source of shocks. Section 4 concludes.

2 Public Sector Debt Dynamics

2.1 Debt over the Business Cycle

The time series properties of the debt:GDP ratio depend on the characteristics of the shocks hitting the economy and the way government policy reacts to those shocks. In turn the government reaction is determined by its objectives and constraints, including its ability to generate revenues and to sell public bonds. In recent years a large number of countries have adopted various types of fiscal rules (IMF, 2009). These self-imposed constraints aim principally at ensuring long-term sustainability of public finances, although in some cases other objectives -e.g. keeping the size of the public sector relatively small- also played a role. Often the rules explicitly state ceilings for the debt:GDP and deficit:GDP ratios; Eurozone countries are subject to the Stability and Growth Pact (SGP), which limits the deficit:GDP ratio to 3% and the debt:GPD ratio to 60%, for example.

The 60% limit in the SGP is of the order of magnitude suggested in Aiyagari and McGrattan (1998).[4] They provide a model in which heterogeneous agents are subject to idiosyncratic shocks and borrowing constraints. The latter imply that government debt is not neutral, and enhances the ability of individuals to smooth income. The optimal debt policy optimises trade-offs between consumption smoothing, crowding out, wealth redistribution and work disincentives. Their numerical exercises (calibrated on the US economy) suggest that a debt:GDP ratio in the region of 66% would maximise welfare (although welfare losses are small throughout the range 40%-100%). [5]

[4] Although we are not claiming that this is how that ceiling was calculated.

[5] Interestingly, Reinhart and Rogoff's (2010) analysis of long samples of data for many countries

If the model of Aiyagari and McGrattan is a good approximation of reality, the debt:GDP ratio should be stationary around the optimal level. Alternative models, however, suggest that the optimal level of debt will have a unit root. Using a model in which Ricardian equivalence holds, Barro (1979) argued that the optimal fiscal policy implies smoothing out intertemporally the burden of taxation. This implies that the effect of a temporary positive shock on government spending, say, will be a relative small but persistent increase in taxation rather than an higher but short-lived increase that matches the increase in expenditure. As a result, the level of debt will be permanently higher, indicating unit root properties in the debt series. In full stochastic general equilibrium models Schmitt-Grohé and Uribe (2004), and Leith and Wren-Lewis (2006) also find that an optimal fiscal policy implies that public debt follows a random walk. From a theoretical perspective, the high persistence result hinges on the assumptions of no crowding out and incomplete asset markets. In models with complete asset markets, the government can issue state contingent debt to smooth the burden of taxation across states rather than over time. The optimal policy then implies that the level of debt is as persistent as the shocks (Lucas and Stokey, 1983; Aiyagari et al. 2002). Thus the theoretical literature is somewhat inconclusive on the behaviour of public debt over the business cycle even when a fully optimising government is assumed, although Marcet and Scott (2009) have recently argued that the empirical evidence from the analysis of the persistence of US debt yields more support to Barro's hypothesis than to Lucas and Stockey's.

The discussion above suggests that the debt:GDP ratio may have a unit root. But even in models based on optimising governments, there is a recognition that debt cannot grow without bounds. For example, to derive their main results, Aiyagari et al. (2002) impose exogenous limits on the value the stock of debt. Other authors try to explain the limits to debt accumulation within the model. In the literature on strategic default, where debt repudiation is an option for the borrower limits to debt levels are

indicates that debt ratios in excess of 90% have substantial effects on growth.

determined by the optimum lending strategies (see, for example, Eton and Gersovitz, 1981, Cohen and Sachs, 1986; or Arellano, 2008). An alternative explanation of the determinants of deficits and debt, stresses the importance of political economy considerations. This vast literature is surveyed by Alesina and Perotti (1995) and Eslava (2006). One may then conjecture that debt:GDP ratios are likely to display a unit root within a certain range of values, although their behaviour may change significantly at more extreme value.[6]

A further element that is likely to make the statistical properties of the series we study even more complex is the high level of interdependence among European countries. In countries that are closely integrated through trade, cyclical fluctuations in one country will be very quickly reflected in those of the other countries. Discretionary and automatic fiscal responses to the common elements of cyclical fluctuations will be reflected in similar movements in debt:GDP ratios. With integrated financial markets, a bond-financed fiscal expansion in one country increases the total supply of bonds and raises the interest rate faced by that country and by all other countries if bonds issued by different sovereigns are seen as substitutes. Interest payments and debt:GDP ratios in all countries rise. Further spillovers may be present when solvency is an issue. When one country's solvency is in question, investors may fear a run on other highly indebted governments. Interest rates on these bonds can rise sharply while yields on less indebted countries' bonds may fall. And, in the context of a monetary union, a further channel may operate through the "fiscal theory of the price level." This theory argues that unsustainable fiscal policies result in the central bank loosing control over inflation despite a commitment to an explicit target. Anticipation of future inflation would raise nominal interest rates for all countries, including those with sustainable policies. These influences from one country to another mean that the effects of shocks to the debt ratio in one country is very likely to permeate across

[6] In our empirical work we assume that the time-series properties of the data do not change, i.e. that the observed levels are within the range just alluded to.

countries and the cumulative effects of the feedbacks can generate larger and more prolonged adjustments.

Given that the theoretical literature fails to offer sharp and uncontroversial predictions of how fiscal policy would or should look like, it is perhaps not surprising that applied work has often focused on the least controversial aspect included in most theoretical models; namely the intertemporal budget constraints. A large literature has developed, that tries to derive and test empirically testable implications of the constraint. For example, Hamilton and Flavin (1986)'s early tests of government solvency involved checking the stationarity of the deficit and debt processes, but Trehan and Walsh (1991) and Bohn (2007) demonstrate that the debt or debt:GDP series can be integrated of *any order* without violating the intertemporal budget constraint. The intuition is that household's optimising behaviour requires that the expected discounted value of the stock of debt converges to zero in the long run. When this transversality condition is satisfied, the existing level of debt must be equal to the expected discounted sum of future surpluses. When the time series of surpluses is stationary, the expected discounted sum of future surpluses is stationary, and the budget constraint is satisfied only if the debt series is also stationary (this is the case analysed by Hamilton and Flavin). However, the assumption that the surplus is stationary is unnecessarily restrictive and more generally, the time series of debt can be integrated of any order and remain sustainable. This is because the n-period ahead forecast of the level of debt increase at most as a polynomial of time of order n, while the discount factor increases exponentially. Hence their ratio will converge to zero (Bohn, 2007).

2.2 Characterising Public Sector Debt Dynamics

The discussion in the previous section suggests that characterising public sector debt dynamics is not straightforward. Countries' debt:GDP ratios are each likely to show unit root properties and are likely to be related to each other. An important feature of the series is their long-run properties so that the 'persistence' of shocks (measuring the infinite-horizon effect of a shock to the ratio) is a key statistic. But the dynamic paths are likely to be complex so that it is also useful to characterise the time path of the effects of shocks.

The dynamics of debt:GDP ratios in a group of countries can usefully be modelled through a simple vector autoregression (VAR) explaining the growth in the ratio of each country in terms of its own recent past and the past values of the growth in the ratios in related countries. The persistence of shocks to the countries' ratios can be investigated using the measures developed in Lee, Pesaran and Pierse (1992, 1993) and the time paths of the effects of shocks can be investigated through the persistence profiles described in Lee and Pesaran (1993). Here, denoting the (logarithm of) debt:GDP ratio in country i at time t by b_{it}, and assuming that b_{it} is integrated of order 1 (I(1)), we can characterise the time series of the countries' ratios by the Wold representation:

$$\Delta \mathbf{b}_t = \boldsymbol{\mu} + \mathbf{C}(L)\boldsymbol{\varepsilon}_t \tag{2.1}$$

where $\mathbf{b}_t = (b_{1t},\ b_{2t},..., \ b_{mt})'$ is the $m \times 1$ vector containing the debt ratios for the m countries of interest, $\boldsymbol{\mu}$ is a vector of constants representing mean growth rates, $\mathbf{C}(L) = \mathbf{I} + \mathbf{C}_1 L + .. + \mathbf{C}_p L^p$ is a p-order matrix polynomial in the lag operator L, $\mathbf{C}_j$ are $m \times m$ matrices of parameters and $\boldsymbol{\varepsilon}_t$ is the $m \times 1$ one-step-ahead forecast errors in $\Delta \mathbf{b}_t$ given information on lagged values of $\Delta \mathbf{b}_t$. The $\boldsymbol{\varepsilon}_t$ are serially uncorrelated with mean zero and covariance $\boldsymbol{\Omega}$. The representation in (2.1) will be valid whether or not there is cointegration among the individual b_{it} series, although its presence will imply restrictions on the long-run matrix $\mathbf{C}(1)$ and, where the model is approximated in estimation through a finite order VAR, the cointegrating vectors should be included in the model to avoid misspecification.

The representation in (2.1) can capture complicated cross-country interdependencies, including the effect of innovations to countries' debt that are correlated contemporaneously (through $\mathbf{\Omega}$) and the feedbacks across the countries' debt ratios over time (through the $\mathbf{C}_i$), and so provides a very useful vehicle with which to describe debt-dynamics. It is, of course, subject to the usual limitation of multivariate time series models that there are an infinite number of MA representations of this type and that a structural interpretation of the innovations or parameters requires (a typically large number of) identifying restrictions provided by economic theory. On the other hand, the simple reduced form representation of (2.1) can be readily used to describe the way in which the $\boldsymbol{\varepsilon}_t$ innovations are propagated over time if we are simply interested in characterising the countries' debt dynamics.

Specifically, following Lee and Pesaran (1993), we note that important features of debt dynamics will be captured by the $m \times m$ matrix $\mathbf{P}$ whose (i,j)-th element is given by

$$\rho_{ij} = \frac{\mathbf{e}_i'\mathbf{C}(1)\mathbf{\Omega}\mathbf{C}(1)'\mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{C}(0)\mathbf{\Omega}\mathbf{C}(0)'\mathbf{e}_i)(\mathbf{e}_j'\mathbf{C}(0)\mathbf{\Omega}\mathbf{C}(0)'\mathbf{e}_j)}}, \qquad i,j = 1,...,m, \qquad (2.2)$$

where $\mathbf{e}_i$ is the $m \times 1$ selection vector with unity in its i-th element and zeros elsewhere. The "persistence matrix" $\mathbf{P}$ provides a variance-based measure of the infinite-horizon effect of shocks to the system. It is most easily interpreted by considering the measures $P_i = \sqrt{\rho_{ii}}$ based on its diagonal elements. These measures shows the size of the permanent effect on debt in county i of a shock to the system that causes debt in that country to rise by 1% on impact. [7] In the univariate case, the measure coincides with the "impulse-based" measure of persistence, describing the infinite horizon effect of a 1% shock to the variable, and the two concepts are clearly related therefore. However, the variance-based measure has the advantage that it does not require, and

[7] The focus throughout the analysis, including below where shocks of particular types are considered, is on the effects of system-wide shocks. This recognises that, in the context of inter-related economies like those of the EU, decisions that effect debt in one country effect debt ratios in all countries even if the decisions are taken unilaterally.

indeed is invariant to, the identifying assumptions necessary to provide structural meaning to the shocks in an impulse response analysis conducted in a multivariate setting (see Lee and Pesaran, 1993, for further discussion). The moving average representation at (2.1) accommodates the possibility that the instantaneous effect of shocks are gradually eroded over time so that the persistence measure can be close to or equal to zero (as it would be if the debt ratio series was actually stationary). The P_i therefore provides a continuous measure of the extent of the permanent effect of shocks to country i's debt, elaborating in a useful way on the usual dichotomous characterisation between I(0) and I(1) series.[8]

The derivation of the P_i measures suggest two straightforward extensions to provide further insight on the persistent effects of shocks. First we note that the time-profile of the effect of shocks measured by P_i at the of the infinite-horizon can be readily traced over time, defining $\mathbf{P}(n)$ as the matrix whose (i,j)-th element is given by

$$\rho_{ij}(n) = \frac{\mathbf{e}_i'\mathbf{H}(n)'\mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{C}(0)\boldsymbol{\Omega}\mathbf{C}(0)'\mathbf{e}_i)(\mathbf{e}_j'\mathbf{C}(0)\boldsymbol{\Omega}\mathbf{C}(0)'\mathbf{e}_j)}}, \tag{2.3}$$

where $\mathbf{H}(n) = \left(\sum_{i=0}^{n} \mathbf{C}_i\right) \boldsymbol{\Omega} \left(\sum_{i=0}^{n} \mathbf{C}_i\right)'$ for $n = 0, 1, \ldots\ldots$ Here, the $\mathbf{H}(n)$ capture the size of the permanent effects of the shocks as they accumulate over time up to period n. Clearly, the $\mathbf{P}(n)$ converge to the persistence matrix $\mathbf{P}$ as $n \rightarrow \infty$ and the "persistence profiles", defined by the individual country-specific measures $P_i(n) = \sqrt{\rho_{ii}(n)}$, also converge to P_i as $n \rightarrow \infty$. These profiles will provide a useful characterisation of public sector debt dynamics which again avoids the need for any potentially contentious structural assumptions necessary in impulse response analysis.

The second extension, again described in detail in Lee and Pesaran (1993), allows

[8] As noted above, debt increases can be sustainable even if they are stationary so that it would be incorrect to make a one-to-one correspondence between sustainability and zero persistence. On the other hand, we also noted that, realistically, rising debt levels become increasingly hard to tolerate politically and in the financial markets so that countries' are more vulnerable to solvency problems if increases in debt have large permament effects. In this sense, then, the persistence measures also provide an index of "debt unsustainability".

for a decomposition of the shocks to debt in the simple Wold representation of (2.1) so that we might describe the way in which different types of system-wide shocks impact on countries' debt and how their effects are propagated over time. Specifically, suppose $\mathbf{x}_t$ is a vector of EU-wide aggregates that will impact, in different ways and over different time scales, on debt in the EU economies; the vector might include EU output growth, say, so that we can explicitly consider the effect of a slowdown in growth on the individual countries' debt ratios. Assume that the innovations in these aggregates are given by

$$\mathbf{v}_t = \mathbf{x}_t - \mathbf{\Gamma}\mathbf{z}_t \tag{2.4}$$

with mean zero and variance $\mathbf{\Psi}$ and where the $\mathbf{\Gamma}$ are fixed parameters and the $\mathbf{z}_t$ are a set of predetermined variables. Then we can generalise (2.1) to write

$$\Delta\mathbf{b}_t = \boldsymbol{\mu} + \mathbf{D}(L)\mathbf{v}_t + \mathbf{C}(L)\boldsymbol{\varepsilon}_t, \tag{2.5}$$

where $\mathbf{D}(L) = \mathbf{I} + \mathbf{D}_1 L + .. + \mathbf{D}_q L^q$ is a matrix of lag polynomials capturing the effects of the identified system-wide shocks and the $\boldsymbol{\varepsilon}_t$ are now interpreted as 'other, unidentified' innovations to debt assumed to be uncorrelated with the $\mathbf{v}_t$. In this case, the matrix $\mathbf{P}(n)$ is defined by its (i,j)-th element in a way that can be decomposed:

$$\rho_{ij}(n) = \rho_{Sj}(n) + \rho_{Oij}(n) \tag{2.6}$$

where

$$\rho_{Sij}(n) = \frac{\mathbf{e}_i'\mathbf{F}(n)'\mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{H}(0)\mathbf{e}_i)(\mathbf{e}_j'\mathbf{H}(0)'\mathbf{e}_j)}} \quad , \rho_{Oij}(n) = \frac{\mathbf{e}_i'\mathbf{G}(n)'\mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{H}(0)\mathbf{e}_i)(\mathbf{e}_j'\mathbf{H}(0)\mathbf{e}_j)}},$$

$\mathbf{F}(n) = \left(\sum_{i=0}^{n}\mathbf{D}_i\right)\mathbf{\Psi}\left(\sum_{i=0}^{n}\mathbf{D}_i\right)'$ $\mathbf{G}(n) = \left(\sum_{i=0}^{n}\mathbf{C}_i\right)\mathbf{\Omega}\left(\sum_{i=0}^{n}\mathbf{C}_i\right)'$, and $\mathbf{H}(n) = \left(\sum_{i=0}^{n}\mathbf{D}_i\right)\mathbf{\Psi}\left(\sum_{i=0}^{n}\mathbf{D}_i\right)' + \left(\sum_{i=0}^{n}\mathbf{C}_i\right)\mathbf{\Omega}\left(\sum_{i=0}^{n}\mathbf{C}_i\right)'$ for $n = 0, 1, ...$ The profiles described by $P_{Si}(n) = \sqrt{\rho_{Sii}(n)}$ and $P_{Oi}(n) = \sqrt{\rho_{Oii}(n)}$ summarise the effects of the identified EU-wide shocks and the unidentified shocks on each countries' debt, and the scaling reflects the size of the identified and unidentified shocks on impact (but with their total impact effect still equal to unity).

3 Public Sector Debt in the EU10

This section provides estimates of the multi-country model of debt dynamics described in the previous section for ten EU countries over the period 1982-2009. The countries are Belgium, Denmark, Germany, France, Italy, Netherlands, Austria, Portugal, Finland and the UK (the 'EU10'), which constitute the EU countries for which data was available on a consistent basis over the sample period. Details of the series are provided in the Data Appendix. In what follows, we provide an overview of the data focusing on the unit root properties of the debt:GDP series. We then report the results obtained from estimated multi-country models of debt:GDP growth, describing the characterisation of the series through various estimated VAR models and the associated persistence profiles.

3.1 Data overview

Figure 1 plots the debt:GDP series for each of the EU10 countries over the last thirty years or so. The countries' experiences are clearly distinct both in terms of the levels of debt:GDP (ranging from as low as 14% in Finland at the beginning of the sample to as high as 135% in Belgium in the mid-nineties, for example) and in terms of the evolution of the series over time. However, the simple average of the ratios across the countries has a reasonably clear pattern which provides some context: the average ratio starts at its lowest level of 48% in 1982 and rises through a period of high government spending in the eighties to a peak of 75% in 1995 before falling back to 59% in 2007. The financial crisis saw large rises in the ratio during the final two years of the sample, with the average rising to 64% in 2008 and 72% in 2009.

Tables 1.1 and 1.2 present Augmented-Dickey Fuller (ADF) unit root tests on debt:GDP and growth of debt:GDP. Table 1.1 demonstrates that the unit root hypothesis cannot be rejected for debt:GDP levels in any country or using any order of augmentation in the ADF test. Following Im, Pesaran and Shin (2003), the IPS tests statistic shows the standardised value of the mean of the ADF statistics across countries. When compared to the standard normal distribution, the IPS statistic provides a more powerful test of the unit root based on all of the countries taken together and, in this case, the more powerful test confirms the conclusion of the individual countries. The ADF tests for the growth of debt:GDP in Table 1.2 present a more mixed picture considering the country-specific results in isolation. But the IPS test statistics reject the unit root at all lag-lengths providing strong evidence to reject the unit root hypothesis in growths.

In Tables 2.1 and 2.2, we present the corresponding Cross-sectional Augmented Dickey-Fuller(CADF) tests for unit roots on both level and growth of debt:GDP ratios. These tests augment the underlying ADF regressions with lagged differences of the cross-section average, thereby taking into account the cross-sectional interdependencies across countries' debt:GDP ratios that are likely to exist in this context; see Pesaran (2007). The findings of Table 1.1-1.2 are confirmed: tests carried out on the level of debt:GDP cannot reject the hypothesized unit root for any country considered individually for almost any lag-length, and the overall result is confirmed by the cross-sectional IPS (CIPS) test statistics; and for the growths, there is rejection of the null at 5% significance level for 7 out of 10 countries for at least one of the CADF tests, and the CIPS tests rejects the null for lag orders up to three. Taken together, the results provide strong evidence to reject a unit root in the debt:GDP ratio and to treat the growth of debt:GDP as a stationary variable for all countries.

3.2 The Multi-country model

The characterisation of the EU10's debt:GDP data , and the analysis of the persistent effects of shocks to these, is provided by the following simple regression models estimated for each country and stacked in each case to obtain a multi-country VAR:

$$M_2 \quad : \qquad \Delta b_{it} = \alpha_i + \sum_{s=1}^{r} \beta_{s,ii}\, \Delta b_{i,t-s} + \sum_{s=1}^{r} \gamma_{s,i}\, \Delta b_{-i,t-s} + \varepsilon_{it}, \;\; i = 1, ..., m \tag{3.7}$$

$$M_3 \quad : \qquad \begin{array}{c}\text{a restricted version of } M_2\text{, where variables with coefficients with a} \\ \text{t-ratio below unity (in absolute value) are excluded}\end{array} \tag{3.8}$$

$$M_4 \quad : \qquad \Delta b_{it} = \alpha_i + \sum_{s=1}^{r} \beta_{s,ii}\, \Delta b_{i,t-s} + \varepsilon_{it}, \qquad i = 1, ..., m \tag{3.9}$$

$$M_5 \quad : \qquad \Delta b_{it} = \alpha_i + \varepsilon_{it}, \qquad i = 1, ..., m \tag{3.10}$$

A completely unrestricted VAR model (M_1) would be one in which Δb_{it} was regressed on its own lags and on the lags of debt growth in all the other countries individually. But estimation of such a model, even with a relatively short lag order, is impractical given the length of data series available. Our most general model is therefore Model M_2 which is a VAR of order r which explains Δb_{it} in terms of lagged debt growth in country i and lags of debt growth in the rest of the EU10 zone, denoted by $\Delta b_{-i,t} = \sum_{j=1, j\neq i}^{m} \Delta b_{j,t}$. Model M_3 imposes restrictions on M_2 by excluding insignificant variables to obtain a more parsimonious characterisation of the data. M_4 is also a restricted version of M_2, imposing mr restrictions on M_2 by removing the aggregate debt:GDP growth rates from the regressions to exclude the possibility of capturing cross-country interactions. Model M_5 represents the simplest model in which (log) debt to GDP ratio in each country is represented by a random walk with drift.

The four models were estimated for the EU10 over the period 1982-2009 using Full Information Maximum Likelihood (FIML). Log-likelihood values and likelihood ratio tests are reported in Table 3. Tests to judge the order of the lag necessary to capture the time series properties of the data in Model M_2 suggested including two lags of individual country and aggregate debt:GDP growth i.e., r=2. The total number of estimated parameters, not including those in the variance-covariance matrix, is 50 which is clearly very highly-parameterised. Model M_3 is more parsimonious, having dropped variables with t-ratios of less than unity, and the likelihood ratio test establishes the legitimacy of the restrictions imposed: the test statistic takes the value of 7.5 and is compared to the χ^2_{15} distribution. In contrast, models M_4 and M_5 are easily rejected against both M_3 and M_2, establishing that these latter models capture the dynamics of debt:GDP series well (compared to a benchmark random walk model) and that it is important to explicitly take into account the cross-country interactions in the model to capture these dynamics.

Having calculated the individual country regressions and stacked these into a VAR, the model can be inverted to obtain the corresponding moving average model described in (2.1) and the associated persistence measures. Table 4 reports the estimates of individual countries' and aggregate persistence measures defined in (2.2) based on models M_2 and M_3. All the persistence measures are estimated reasonably precisely, with the measures based on M_3 slightly better defined following the elimination of insignificant variables as described above. The persistence measure for the EU10 taken together, based on our preferred model M_3, takes the value 2.87, indicating that a shock that causes the debt:GDP ratio to rise by 1% on impact will cause the ratio to rise by 2.87% at the infinite horizon. This is based on the historical time series and so takes into account the effects of the shock as they are propagated over time including all the macroeconomic adjustment mechanisms and feedbacks that have operated historically (including the subsequent effects on growth, interest rates, government spending plans, and so on). To place the value of 2.87 in perspective, the rise in the average debt:GDP ratio across the EU10 from 64% to 72% observed in 2009 would translate into a long term rise in the ratio to 87% if the whole of the initial change was the result of an unanticipated shock, assuming that there are no further shocks and that the EU10's macroeconomic response is the same as it has been in the past.

The measures in the Table also show that there is considerable variability in the persistence of shocks across countries, with measures of persistence ranging from 1.57 for Portugal to 3.52 for the UK based on our preferred model M_3, for example. This variability is illustrated graphically in Figure 2 which shows each country's persistence profile, as defined in (2.3), scaled to show the effect of a shock that causes the debt:GDP ratio to rise by 1% on impact. The profiles trace out the effects of shocks to ratios as they evolve over time as well as describing the infinite horizon effect and therefore show that there are substantial difference in the dynamic response to shocks as well as in the ultimate effect. The effects of shocks in some countries appear reasonably smooth and monotonic, but there are many countries in which the short-run effects exceed the long run effect reflecting the complexity and delays involved in the macroeconomic and policy responses to unanticipated movements in the debt ratio. The effects of the shocks are also very prolonged in all countries, with the profiles settling to their long-run levels only after around ten years. The fact that countries tend to stabilize at the new level at more or less the same time reflects the importance of the feedbacks from debt growth in the rest of the EU10 to each individual country, emphasising once again the importance of the interactions across countries.

It is worth noting that the persistence measures of Table 4 and the associated profiles in Figure 2 are all scaled to show the effect of a shock which causes the debt:GDP ratio to rise in that country by 1% on impact. They provide a good characterisation of the dynamic effects of shocks, therefore, but do not in themselves provide information on the shocks that have impacted on countries' ratios in practice. Figure 3 provides some information on this by plotting the Beveridge-Nelson (BN) trends in the debt:GDP ratio based on the estimate of model M_3 alongside the actual ratios themselves. The BN trend associated with the model in (2.1) is defined by $\widetilde{\mathbf{b}}_t = \widetilde{\mathbf{b}}_{t-1} + \boldsymbol{\mu} + \mathbf{C}(1)\boldsymbol{\varepsilon}_t$ so that it evolves through time accumulating the infinite-horizon effect of the innovations to the series. It is effectively the infinite-horizon forecast of the series obtained once the effects of past shocks have worked their way through the system and in the absence of any subsequent innovations. The BN trend is therefore readily interpreted as the 'steady-state' debt:GDP ratio at each point in time.

Figure 3 shows the estimated values of the BN trends based on the parameters and estimated residuals obtained from the estimated model M_3 obtained across the EU10.[9] To locate the trends in levels, it is assumed in the figure that debt:GDP ratios were all at steady-state in the year 2000.[10] The figure illustrates the changes in the BN trend over the sample (based on $\widehat{\boldsymbol{\mu}} + \widehat{\mathbf{C}}(1)\widehat{\boldsymbol{\varepsilon}}_t$) and so reflects both the size of the persistence measures in each country and the size of the shocks the countries have experienced. The figures show a decline in the steady-state levels of the ratio over the thirty -year sample for most of the EU10 countries but the implications of the measures taken to deal with the financial and economic crisis of recent years for the increase in the steady-state debt:GDP ratios in most countries are very striking. Steady state ratios rose by 35 percentage points on average across the EU10 over the final two years of the sample, rising from 60% to 82% in Germany, for example; from 65% to 106% in France; from 94% to 142% in Italy; from 60% to 90% in Portugal; and from 41% to 89% in UK.

3.3 The source of shocks

This section focuses on the decomposition of shocks and their contribution to persistence following the discussion around (2.4) and (2.5). The analysis takes as its start point model M_2 where the shock in (3.7) has been decomposed into p different types

[9] The model provides the BN trends for b_{it}, the logarithm of the debt:GDP ratio. These are transformed to obtain the measures of the ratios themselves.

[10] This is a relatively arbitrary assumption although it can be argued that most countries were close to their steady-state in the run up to, or at least shortly after, the adoption of the Stability and Growth Pact in 1997.

of identified shock, $\upsilon_{j,t}$, $j = 1, .., p$, and an unidentified $\widetilde{\varepsilon}_{it}$ shocks as follows:

$$\tilde{M}_2: \qquad \Delta b_{it} = \alpha_i + \sum_{s=1}^{r} \widetilde{\beta}_{s,ii} \Delta b_{i,t-s} + \sum_{s=1}^{r} \widetilde{\gamma}_{s,i} \Delta b_{-i,t-s} + \sum_{j=1}^{p} \sum_{s=0}^{r} \delta_{i,js} \upsilon_{j,t-s} + \widetilde{\varepsilon}_{it}, \qquad i = 1, ..., m, \tag{3.11}$$

where $m = 10$ and $r = 2$, as before, and p is the number of explicitly identified shocks. In what follows, we consider four types of explicitly-identified shocks impacting on variables that affect directly the evolution of the debt:GDP ratio; namely, shocks to interest payments in the EU10 (G_t^r); shocks to EU10 output (Y_t); shocks to EU10 primary government expenditure (G_t^E); and shocks to EU10 government revenue (R_t). We identified the shocks from simple specifications regressing each variable on its own lag as follows:

$$\Delta x_{j,t} = \lambda_{0j} + \lambda_{1j} \, \Delta x_{j,t-1} + \upsilon_{j,t}, \qquad j = 1, ..., 4, \tag{3.12}$$

where $x_{j,t}$ is the (logarithm of) G_t^r, Y_t, G_t^E and R_t in turn. Model $\widetilde{M}_2$ consists of (3.11) and (3.12) which can be estimated jointly using FIML. Model $\widetilde{M}_3$ is similar but obtained following a specification search in which lagged variables with coefficients with t-values below unity (in absolute value) were removed from (3.11) to improve parsimony. In either case, the estimated model can be inverted to obtain the estimate of the moving average form of (2.5) and the estimates of the associated persistence profiles described in (2.6).

Table 5 shows the results of the decomposition of the countries' and aggregate persistence measures by type of shock obtained on the basis of the estimated version of model $\widetilde{M}_3$. The 'total' persistence measures given in the final column are broadly comparable to those in Table 4, if not slightly higher, with the persistence of shocks to the EU10-area as a whole taking a value of 3.01 (standard error 0.53) compared to the corresponding value of 2.87 (0.69) in Table 4. The individual country-specific measures are also broadly similar across the two tables.

In terms of the source of shocks, we see that the identified shocks, taken together, have broadly the same persistence as the other 'unidentified' shocks (with measures of 3.14 and 2.76 at the EU10-area level respectively). There is considerable variation between the persistence measures of the identified shocks however: the shocks to income and to primary expenditure have large and statistically significant persistence measures (at 2.89 and 1.74 respectively), while the shocks to interest payments and to primary revenues are small and statistically insignificant (at 0.44 and 0.65 respectively). There is evidence, therefore, of significant asymmetries in the effects of different forms of 'fiscal consolidation', with reductions in government spending having a more permanent effect than increases in government income. Unanticipated business cycle fluctuations which directly change the ratio on impact also have permanent, long-term effects but unanticipated changes in interest payments do not seem to play a major role in causing persistent shifts in debt:GDP ratios.

4 Concluding Comments

The paper provides an empirical characterisation of the time series properties of debt:GDP ratios in the EU10 countries since the early eighties. The evidence is that the effect of shocks to debt ratios involves complicated cross-country dynamics, with adjustments in response to a shock taking up to ten years and with the ratio often overshooting its long-run level in the short-run. Ultimately, the long-run effect of a shock is to raise the ratio permanently, with the final effect being around three times the effect of the initial shock across the region. Different types of shock are found to have different long-run effects, though, with shocks identified as relating to government spending and to output growth having large persistent effects and shocks to interest payments and to government revenues having less persistent effects.[11]

[11] This suggests that a long-lived fiscal consolidation requires countries to contain their spending rather than increase taxation. See Alesina and Ardagna (1998).

The evolution over time of the debt:GDP ratio is the outcome of a complicated set of inter-related decisions involving governments' tax and spending ambitions and their need to satisfy their intertemporal budget constraint, the public's willingness to hold debt and the ability to pay based on economic growth. A more structural model would require a description of, at least, the interplay between debt, output, and interest rates at home and abroad. The time series model of this paper provides a reduced form characterisation of this outcome reflecting the way these decisions have played out historically. It provides a simple but persuasive characterisation of the data, and captures well the long phases of rising and falling debt:ratios observed over the last thirty years. It also suggests that the reaction to the recent financial and economic crisis will see debt:ratios in the EU countries at levels substantially higher than have been observed for some time.

Data Appendix

The data source for all series is AMECO. Definitions of the variables in the paper are given below. All variables are based on individual country data. These are used directly in the case of the debt:GDP variable and aggregated to obtain EU10-area measures for the other variables. The aggregation procedure followed AMECO's procedure and includes simple or weighted aggregation depending on the variable.

- B_{it} : Debt:GDP ratio, defined as General government consolidated gross debt (excessive deficit procedure (based on ESA 1995) and former definition (linked series)) expressed as a percentage of GDP at market prices (excessive deficit procedure); AMECO code: 1.0.319.0.UDGGL

- G_t^r : EU-10 Real government interest expenditure is defined as the ratio of nominal government interest expenditure (defined as Revenue Interest-General Government - ESA1995, in ECU/EUR; AMECO code: 1.0.99.0.UYIG) and the GDP price deflator(defined as Price deflator GDP at market market prices, ECU/EUR; AMECO code:3.1.99.0.PVGD)

- Y_t : EU-10 Real output is defined as the ratio of nominal GDP (defined as GDP at current market prices: reference level for excessive deficit procedure, ECU/EUR; AMECO code: 1.0.99.0.UVGDH) and the GDP price deflator (defined as above).

- G_t^E : EU-10 Real government primary expenditure is defined as the ratio of nominal General Government Total expenditure (ESA1995), excluding interest payments(in ECU/EUR; AMECO code: 1.0.99.0.UUTGI) and the GDP price deflator(defined as above).

- R_t : EU-10 Real government revenue is defined as the ratio of nominal Government Total revenue (ESA 1995) in ECU/EUR (AMECO code: 1.0.99.0.URTG) and the GDP price deflator(defined as above).

Table 1.1
Augmented Dickey-Fuller Tests for Unit Roots on National Debt:GDP Ratios, 1984-2009

	ADF(1)	ADF(2)	ADF(3)	ADF(4)
Belgium	-2.07	-2.03	-1.54	-1.50
Denmark	-2.46	-1.96	-1.47	-1.77
Germany	-2.43	-2.64	-2.51	-2.43
France	-2.36	-2.41	-1.93	-2.09
Italy	-1.88	-1.75	-1.73	-2.00
Netherlands	-1.93	-2.02	-1.76	-2.04
Austria	-2.98	-2.47	-2.41	-1.55
Portugal	-0.77	-0.58	-0.61	-0.37
Finland	-2.91	-1.38	-1.97	-2.20
UK	-2.43	-0.79	-0.80	-1.15
Mean (IPS test stat)	**-2.22 (-0.18)**	**-1.80 (1.06)**	**-1.67 (1.47)**	**-1.71 (1.03)**

Notes: The variables are all in logarithms. ADF(p) statistics are computed using ADF regressions with an intercept, a linear time trend and p lagged differences of the dependent variable. The 1%, 5% and 10% critical values are -4.38, –3.60 and -3.24. The IPS test statistic is the normalised value of the mean of the ADF statistics and is compared to the standard normal distribution. A '*' denotes significance at the 10% level, '**' denotes significance at the 5% level and '***' denotes significance at the 1% level.

Table 1.2
Augmented Dickey-Fuller Tests for Unit Roots in the Growth of National Debt:GDP Ratios, 1984-2009

	ADF(0)	ADF(1)	ADF(2)	ADF(3)
Belgium	-2.02	-1.86	-1.80	-1.87
Denmark	-2.48	-2.75*	-3.22**	-2.42
Germany	-3.33**	-2.74*	-2.71*	-2.58
France	-2.34	-2.22	-2.60	-2.39
Italy	-2.01	-2.23	-2.07	-1.69
Netherlands	-3.55**	-2.98*	-2.29	-1.88
Austria	-2.80*	-2.90*	-2.38	-3.11**
Portugal	-4.16***	-3.68**	-3.27**	-2.45
Finland	-2.10	-3.95***	-2.22	-1.99
UK	-0.30	-1.75	-1.48	-1.53
Mean (IPS test stat)	**-2.51*** (-3.71)**	**-2.71*** (-4.38)**	**-2.40*** (-3.43)**	**-2.19*** (-2.60)**

Notes: The variables are all in logarithms. ADF(p) statistics are computed using ADF regressions with an intercept and p lagged differences of the dependent variable. The 1%, 5% and 10% critical values are -3.75, –3.00 and -2.63. The IPS test statistic is the normalised value of the mean of the ADF statistics and is compared to the standard normal distribution. A '*' denotes significance at the 10% level, '**' denotes significance at the 5% level and '***' denotes significance at the 1% level.

Table 2.1
Cross-Sectionally Augmented Dickey-Fuller Tests for Unit Roots on National Debt:GDP Ratios, 1984-2009

	CADF(1)	CADF(2)	CADF(3)	CADF(4)
Belgium	-4.36*	-3.82	-2.16	-1.53
Denmark	-3.21	-2.53	-0.02	0.57
Germany	-1.64	-0.60	-0.38	-0.26
France	-3.13	-1.86	-1.84	-1.37
Italy	-1.32	-1.23	-1.08	-1.52
Netherlands	-2.31	-1.22	-1.07	-1.24
Austria	-4.66*	-3.22	-3.31	-2.42
Portugal	-1.61	-1.51	-2.96	-2.84
Finland	-3.14	-0.87	-1.12	-1.04
UK	-0.74	-1.03	-2.13	-2.93
Mean (CIPS test stat)	**-2.61**	**-1.79**	**-1.61**	**-1.46**

Notes: The variables are all in logarithms. CADF(p) statistics are computed using ADF regressions with an intercept, a linear time trend, p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The 1%, 5% and 10% critical values are -6.40, -4.88 and -3.99. The CIPS test statistic is the cross-section mean, compared to the distribution described in Pesaran (2007) where 1%, 5% and 10% critical values are -3.15, -2.85 and -2.79. A '*' denotes significance at the 10% level, '**' denotes significance at the 5% level and '***' denotes significance at the 1% level.

Table 2.2
Cross-Sectionally Augmented Dickey-Fuller Tests for Unit Roots in the Growth of National Debt:GDP Ratios, 1984-2009

	CADF(0)	CADF(1)	CADF(2)	CADF(3)
Belgium	-2.51	-2.09	-2.18	-2.43
Denmark	-4.02**	-3.84*	-5.30***	-2.25
Germany	-2.79	-2.40	-1.64	-1.09
France	-4.74**	-3.62*	-2.00	-2.70
Italy	-3.79*	-2.43	-1.57	-1.19
Netherlands	-4.11**	-2.85	-2.08	-1.76
Austria	-2.44	-3.34*	-2.06	-2.36
Portugal	-4.11**	-3.72*	-2.78	-1.90
Finland	-2.82	-4.38**	-1.33	-1.42
UK	-1.32	-0.88	-0.54	-1.49
Mean (CIPS test stat)	**-3.27*****	**-2.96*****	**-2.15***	**-1.86**

Notes: The variables are all in logarithms. CADF(p) statistics are computed using ADF regressions with an intercept, p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The 1%, 5% and 10% critical values are -5.75, -3.95 and -3.25. The CIPS test statistic is the cross-section mean, compared to the distribution described in Pesaran (2007) where 1%, 5% and 10% critical values are -2.60, -2.25 and -2.12. A '*' denotes significance at the 10% level, '**' denotes significance at the 5% level and '***' denotes significance at the 1% level.

Table 3
Maximised Log-Likelihood Values

Variable	*LLF*	*N*	$\chi^2(r)$
M_2	544.05	50	-
M_3	540.30	35	M_3 *vs* M_2: 7.5 (15)
M_4	523.12	30	M_4 *vs* M_3: 34.37^{***} (5) M_4 *vs* M_2: 41.86^{***} (20)
M_5	464.60	10	M_5 *vs* M_4: 89.66^{***} (20) M_5 *vs* M_3: 151.4^{***} (25) M_5 *vs* M_2: 158.9^{***} (40)

Notes: Models M_2 –M_5 defined in the text and estimated over the period 1982-2009. LLR is the maximised log-likelihood value; N is the number of estimated coefficients; and $\chi^2(r)$ is the likelihood ratio test statistic relating to the *r* restrictions imposed on model M_i to get to model M_j. A '*' denotes significance at the 10% level, '**' denotes significance at the 5% level and '***' denotes significance at the 1% level.

Table 4
Individual Countries' and Aggregate Persistence Measures

	Models	
Country	M_2	M_3
Belgium	2.29 (0.54)	2.50 (0.31)
Denmark	1.57 (0.19)	1.63 (0.16)
Germany	1.82 (0.33)	1.93 (0.27)
France	2.14 (0.61)	2.44 (0.37)
Italy	3.04 (1.18)	3.40 (0.77)
Netherlands	2.49 (1.20)	2.65 (1.08)
Austria	2.17 (0.59)	2.31 (0.29)
Portugal	1.33 (0.16)	1.57 (0.17)
Finland	1.64 (0.22)	1.86 (0.28)
UK	3.58 (2.36)	3.52 (2.41)
EU10-area	**2.40** **(0.90)**	**2.87** **(0.69)**

Notes: Results relate to Models M_2 and M_3 defined in the text and estimated over the period 1982-2009. Individual countries' persistence measures are estimated using (2.2) and the aggregate persistence measure is obtained using vector **w**, a vector of ones, in place of **e**i and **e**j. Bracketed figures are asymptotic standard errors calculated using analytic derivates. The formulae used are given in Appendix B of PPL.

Table 5
Decomposition of Individual Countries' and Aggregate Persistence Measures by Type of Shock

Country	Macro Shocks					Other Shocks	Total
	DintExp	Dy	DExp	DRev	Total Macro		
Belgium	0.18 (0.67)	1.87 (1.07)	0.59 (0.68)	0.28 (1.11)	2.23 (0.42)	2.31 (0.36)	2.28 (0.37)
Denmark	0.40 (0.61)	0.89 (1.06)	1.15 (0.71)	0.33 (1.09)	1.68 (0.47)	1.35 (0.22)	1.43 (0.24)
Germany	0.59 (0.32)	2.60 (0.59)	1.89 (0.44)	0.06 (0.52)	3.94 (0.52)	2.14 (0.40)	3.64 (0.70)
France	0.09 (0.51)	2.90 (0.95)	2.05 (0.66)	0.52 (0.85)	3.57 (0.74)	2.49 (0.42)	3.22 (0.63)
Italy	0.80 (1.67)	4.44 (2.65)	1.99 (2.08)	4.47 (2.39)	3.63 (1.64)	5.76 (1.28)	4.81 (1.24)
Netherlands	1.17 (0.84)	1.92 (1.73)	0.23 (1.33)	0.88 (1.47)	1.36 (1.01)	1.85 (0.41)	1.76 (0.49)
Austria	0.34 (0.85)	1.91 (1.60)	2.14 (1.11)	0.24 (1.39)	2.96 (1.22)	1.91 (0.39)	2.24 (0.61)
Portugal	0.31 (0.43)	2.15 (0.88)	0.56 (0.67)	0.07 (0.69)	2.15 (0.80)	1.46 (0.22)	1.79 (0.49)
Finland	0.46 (0.50)	2.66 (1.01)	2.59 (0.77)	1.19 (0.85)	3.43 (0.90)	1.85 (0.32)	2.72 (0.68)
UK	1.15 (0.81)	5.36 (1.65)	1.65 (1.19)	0.82 (1.25)	4.91 (1.67)	2.66 (0.75)	3.89 (1.17)
EU10-area	**0.44 (0.51)**	**2.89 (0.86)**	**1.74 (0.60)**	**0.65 (0.87)**	**3.14 (0.58)**	**2.76 (0.44)**	**3.01 (0.53)**

Notes: Results relate to Model M_3 defined in the text and estimated over the period 1982-2009. Individual countries' persistence measures are estimated using (2.6) and the aggregate persistence measure is obtained using vector **w**, a vector of ones, in place of **e**i and **e**j. Bracketed figures are asymptotic standard errors calculated using analytic derivates. The formulae used are given in Appendix B of PPL.

Figure 1
Countries' Debt:GDP ratios

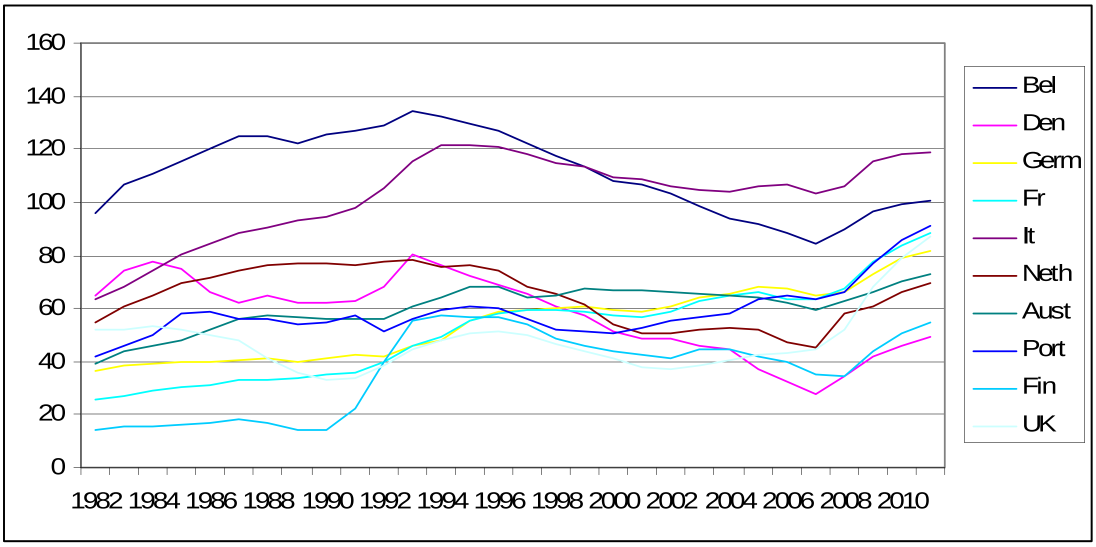

Figure 2
Persistence Profiles measures

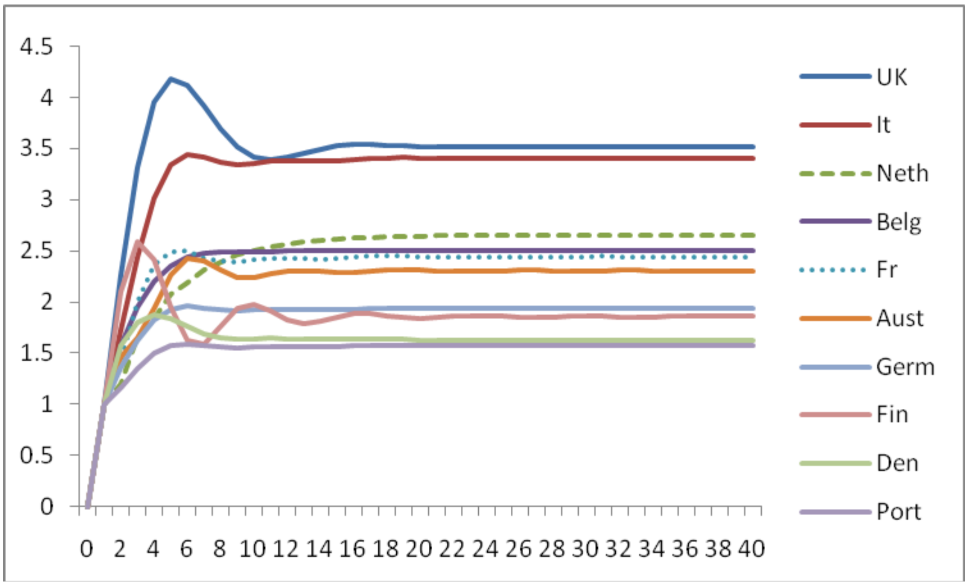

Figure 3
Countries' Debt:GDP ratios (__) and Beveridge-Nelson Trends (- - -)

References

1. Afonso, A. and C. Rault, (2007), "What Do We Really Know about Fiscal Sustainability?", **Review of World Economics (Weltwirtschaftliches Archiv), Springer**, 145(4), 731-755.

2. Aiyagari, S.R., A. Marcet, T.J. Sargent and J. Seppälä, (2002), "Optimal Taxation without State-Contingent Debt", **Journal of Political Economy**, 110(6), 1220-1254.

3. Aiyagari, S.R. and E.R. McGrattan, (1998), "The Optimum Quantity of Debt", **Journal of Monetary Economics**, 42, 447-469.

4. Alesina, A. and S. Ardagna (1998), "Tales of fiscal adjustment", Economic Policy, 13(27), 487-545.

5. Alesina, A. and R. Perotti, (1995), "The Political Economy of Budget Deficits", **IMF Staff Papers**, 1-31.

6. Barro, R.J., (1979), "On the Determination of the Public Debt", **Journal of Political Economy**, 87(5), 940-971.

7. Bohn, H., (1995), "The Sustainability of Budget Deficits in a Stochastic Economy" **Journal of Money Credit and Banking**, 27(1), 257-271.

8. Cohen, D. and J. Sachs, (1986), "Growth and External Debt under Risk of Debt Repudiation", **European Economic Review**, 30, 529-560.

9. Eslava, M. (2006), "The Political Economy of Fiscal Policy: Survey", **Inter American Development Bank Working Paper**, 583.

10. European Commission, (2009), "Sustainability Report 2009", **European Economy**, 9/2009

11. European Commission, (2010), "Public Finances in EMU - 2010", **European Economy**, 4/2010

12. Feve, P. and P.-Y. Henin, (2000), Assessing Effective Sustainability of Fiscal Policy within the G7", **Oxford Bulletin of Economics and Statistics**, 62, 2, 175-195

13. Hakkio, G.S. and M. Rush, (1991), "Is the Budget Deficit 'Too Large'?", **Economic Enquiry**, XXIX, 429-445.

14. Hamilton, J.D. and M.A. Flavin, (1986), "On the Limitations of Government Borrowing: A Framework for Empirical Testing", **American Economic Review**, 76(4), 808-819.

15. Im, K.S., M.H. Pesaran and Y. Shin, (2003), "Testing for Unit Roots in Heterogenous Panels", **Journal of Econometrics**, 115, 53-74.

16. IMF, (2009), "Fiscal Rules - Anchoring Expectations for Sustainable Public Finance. "

17. Lee, K.C. and M.H. Pesaran, (1993), "Persistence profiles and Business Cycle fluctuations in a Disaggregated model of U.K. Output Growth", **Ricerche Economiche**, 47, 293-322.

18. Lee, K.C., M.H. Pesaran and R.G. Pierse, (1992), "Persistence of Shocks and their Sources in a Multisectoral Model of UK Output Growth", **Economic Journal**, 102, 411, 342-356.

19. Lee, K.C., M.H. Pesaran and R.G. Pierse, (1993), "Persistence, Cointegration and Aggregation: A Disaggregated Analysis of Output Fluctuations in the US Economy", **Journal of Econometrics**, 56, 57-88.

20. Leith, C., and S. Wren-Lewis, (2006), "Fiscal Sustainability in a New Keynesian Model", **World Economy and Finance Working Paper Series**, 006.

21. Lockwood, B., A. Philippopoulos, and A. Snell, (1996), "Fiscal Policy, Public Debt Stabilisation and Politics: Theory and UK Evidence", **Economic Journal**, 106, 894-911.

22. Lucas, R.E. and N.L. Stokey, (1983), "Optimal Fiscal and Monetary Policy in an Economy without Capital", **Journal of Monetary Economics**, 12, 55-93.

23. Marcet, A. and A. Scott, (2009), "Debt and Deficit Fluctuations and the Structure of Bond Markets", **Journal of Economic Theory**, 144, 473-501.

24. Pesaran , M.H., (2007), "A Simple Panel Unit Root Test In The Presence Of Cross Section Dependence", **Journal of Applied Econometrics**, 22, 2, 265-312.

25. Reinhart, C. and K. Rogoff, (2010), "Growth in a Time of Debt", **American Economic Review**, 100, 2, 573-578.

26. Schmitt-Grohé, S., and M. Uribe, (2004), "Optimal Fiscal and Monetary Policy under Sticky Prices", **Journal of Economic Theory**, 114, 198-230.

27. Trehan, B. and C.E. Walsh, (1991), "Testing Intertemporal Budget Constraints: Theory and Applications to the U.S. Federal Budget and Current Account Deficits", **Journal of Money, Credit and Banking**, 23, 2, 206-223.

28. Wilcox, D. (1989), "The Sustainability of Government Deficits: Implications of the Present-Value Borrowing Constraint", **Journal of Money, Credit and Banking,** 21, 3, 291-306.