Pushing the Limit? Fiscal Policy in the European Monetary Union

Betty C. Daniel  
Department of Economics  
University at Albany  
Albany, NY 12222  
b.daniel@albany.edu

Christos Shiamptanis  
Department of Economics  
Ryerson University  
Toronto, ON M5B 2K3  
christos.shiamptanis@ryerson.ca

October 2011

Abstract

Governments are facing increasing scrutiny over debt and deficits following the worldwide recession and financial crisis which ended in 2009. Additionally, policy makers are confronted with the growing realization that they face fiscal limits on the size of debt and deficits relative to GDP. These fiscal limits invalidate Bohn’s criterion for fiscal sustainability since it allows explosive debt relative to GDP, eventually violating any fiscal limit. The purpose of this paper is to derive restrictions on fiscal policy, necessary for the government to be expected to satisfy fiscal limits in the long-run. We show that the restrictions require that the primary surplus respond large enough to debt. Additionally, since fiscal limits rule out explosive behavior, they imply cointegration between debt and the primary surplus and between the primary surplus and output. We test these two equivalent empirical implications for a panel of ten EMU countries, and find that in the years preceeding the financial crisis, fiscal policy was responsible, in the sense that governments did not expect to violate fiscal limits in the long run.

Key Words: European Monetary Union, monetary policy, fiscal policy, fiscal limits, panel cointegration, error correction

JEL codes: C32, C33, E42, E62, F33

*The authors would like to thank Peter Pedroni for numerous consultations on empirical techniques, as well as Dale Henderson, John Jones and Maurice Roche for helpful discussions. Additionally, thanks are due to seminar participants at the Central Bank of Cyprus, Union College, University of Massachusetts – Dartmouth, and NewYork Camp Econometrics.
1 Introduction

Fiscal authorities are facing renewed scrutiny over government debt and deficits following the worldwide recession and financial crisis that began in 2007. The scrutiny has been especially intense in European Monetary Union (EMU) countries, where fiscal problems have threatened the value of the Euro, and raised the specters of both sovereign default and a breakup of the monetary union. What is "responsible" fiscal policy, and have countries in the EMU been following such a policy? Stated another way, are recent fiscal difficulties due to bad policy or bad luck?

The design of responsible monetary policy has received much more attention than that of responsible fiscal policy. If the objective of monetary policy is inflation stabilization, then consensus is that a monetary authority should follow a rule in which the nominal interest rate is increased more than one-for-one in response to an increase in inflation: the Taylor Rule with the Taylor Principle. Numerous papers estimate Taylor Rules over different periods of time and in different countries, testing whether the interest rate response to inflation is large enough for monetary policies to have been responsible. Leeper (2010) argues that we need to place fiscal policy under the same scrutiny. Specifically, we need to determine criteria for responsible fiscal policy, and then test whether countries meet those criteria.

Responsible fiscal policy must imply sustainability. Early tests of fiscal sustainability (Hamilton and Flavin 1986; Trehan and Walsh 1991) focused on cointegration between gov-
ernment debt and primary surpluses as an indication that current fiscal policy satisfied the intertemporal budget constraint, and hence was sustainable. However, Bohn (2007) argued that sustainability tests based on cointegration were unnecessarily restrictive. This is because a fiscal policy could be sustainable with a growing gap between government debt and the primary surplus, in violation of cointegration. He demonstrated that the government’s intertemporal budget constraint is expected to hold under current fiscal policy if primary surpluses adjust by any positive amount to lagged debt. Therefore, a test for fiscal sustainability is whether the primary surplus responds positively to lagged debt (Bohn 1998, 2008).

However, Bohn’s (1998, 2008) definition of fiscal sustainability clashes with the new and growing literature on fiscal limits (Davig, Leeper, and Walker (2010a,b), Davig and Leeper (2010), Cochrane (2010), Daniel (2010), Sims (1997, 1999), Daniel and Shiamptanis (2011)). This literature recognizes that there is an upper bound on the value of the primary surplus that a country can raise. A fiscal limit is in part due to the Laffer Curve; since taxes are distortionary, there is an upper bound on the level of taxes a country can raise. It also arises due to political will. There is an upper bound on a country’s willingness to tax itself and a lower bound on expenditures on public goods. In the presence of these fiscal limits, explosive debt and primary surpluses, which satisfy the intertemporal budget constraint, do not represent equilibrium paths because they will eventually violate any upper bound. Therefore, a responsible fiscal policy must not only satisfy the intertemporal budget constraint, but also respect fiscal limits, thereby ruling out explosive debt and surpluses.
Bohn (2007) acknowledges that his analysis abstracts from fiscal limits. Therefore, our paper can be viewed as an extension of Bohn, necessary when countries face fiscal limits.

We specify a simple fiscal policy rule, analogous to the Taylor Rule for monetary policy, and derive the restrictions on parameters necessary for fiscal policy to be responsible, defined as satisfying both the government’s intertemporal budget constraint and fiscal limits. Satisfaction of the intertemporal budget constraint requires that the primary surplus respond positively to lagged debt, as in Bohn (1998, 2008). However, a positive response does not assure that the country satisfies its fiscal limits. Satisfaction of fiscal limits adds the requirement that the debt and primary surplus eventually stabilize relative to output. Therefore, the government flow budget constraint, combined with the fiscal rule, must yield a globally stable model. That is, the system is expected to reach a long-run equilibrium, ruling out explosive behavior of the debt and primary surplus relative to output.

The theory implies that there are two equivalent empirically testable criteria to determine whether fiscal policy is responsible. The first is the magnitude of the responsiveness of the primary surplus to lagged debt. We demonstrate that, for the system to be expected to reach the long-run equilibrium in a globally stable model, this responsiveness must be large enough. The second is cointegration. Since the primary surplus and debt are expected to reach a long-run equilibrium in a globally stable model that rules out explosive behavior, consideration of fiscal limits restores cointegration between the primary surplus and debt as a necessary requirement for responsible fiscal policy. When fiscal policy must satisfy fiscal limits in addition to the intertemporal budget constraint, the requirement for cointegration
is not unnecessarily strong.

We conduct tests to assess both criteria using annual data on real debt, real primary surpluses, and real GDP for a panel of ten EMU countries over the period 1970-2006, a sample that ends before the worldwide financial crisis and recession.\footnote{We choose to end the sample before the financial crisis because there were likely to have been substantial changes in fiscal policy over that period.} We find that, prior to the worldwide recession and financial crisis, fiscal policy was adequately responsive to increases in debt and that the data exhibits the required cointegration to imply fiscal responsibility in our panel of ten EMU countries. However, in a stochastic world, responsible fiscal policy is not sufficient to assure the absence of a financial crisis because any country can experience bad luck. Our results imply that recent fiscal problems are primarily due to negative shocks, inclusive of the policy response to those shocks, created by the worldwide financial crisis and recession.

The paper is organized as follows. Section 2 derives the restrictions on the parameters of the fiscal rule necessary for a responsible fiscal policy. Section 3 contains the empirical analysis, and Section 4 provides conclusions.

\section{Derivation of Model Restrictions}

In this section, we consider how fiscal limits affect the criteria for designing a responsible fiscal policy that satisfies both the intertemporal budget constraint and fiscal limits.
2.1 Fiscal Limits

World-wide increases in government debt/GDP ratios have sparked interest in a new literature on fiscal limits, where these limits are endogenous to a country’s economic and political system and have no relation to the limits imposed in the European Monetary Union or any other limits imposed exogenously on a government. These internal fiscal limits recognize that there is an upper bound to the tax revenue that can be raised because taxes are distortionary; explicitly, there is a top to the Laffer Curve. And the political limit on taxation could be reached prior to reaching the top of the Laffer Curve. Additionally, there is a minimum below which transfers or government spending on public goods cannot be reduced. Together these fiscal limits imply an upper bound on the value of primary surpluses, relative to GDP, that a government can generate. The upper bound on primary surpluses in turn implies an upper bound on debt/GDP since agents will not lend if they do not expect primary surpluses to pay the debt. Davig, Leeper, and Walker (2010a,b), Davig and Leeper (2010), and Cochrane (2010) have explored the implications of fiscal limits for inflation, and Daniel (2010) explores their implications for an exchange rate crisis. Sims (1997, 1999) and Daniel and Shiamptanis (2011) consider their implications for price stability in a monetary union.

Bohn’s criteria for fiscal sustainability is derived in the absence of these limits. To illustrate, if we ignore stochastic behavior, and take the simplest model in which the primary surplus relative to GDP responds to only lagged debt relative to GDP ($d_{t-1}$) with coefficient $\alpha$, then we can solve the government’s budget constraint forward to show that the value of
debt relative to GDP $N$ periods into the future is given by

$$d_{t+N} = (1 + i - \alpha)^N d_t,$$

where $i$ is the growth-adjusted interest rate. The criteria for satisfaction of the government’s intertemporal budget constraint is that the present value of debt must be zero in the limit, explicitly

$$\lim_{N \to \infty} \frac{d_{t+N}}{(1 + i)^N} = \lim_{N \to \infty} \left( \frac{1 + i - \alpha}{1 + i} \right)^N d_t = 0.$$

Clearly, $\alpha > 0$ is sufficient to assure intertemporal budget balance. As long as debt/GDP grows more slowly than the growth-adjusted interest rate, its present value is zero in the limit. However, when $i - \alpha > 0$, debt/GDP grows forever, eventually violating any fiscal limit, without violating the government’s intertemporal budget constraint. In the following section, we determine restrictions on the parameters of a simple fiscal rule necessary for policy to satisfy both fiscal limits and intertemporal budget balance.

Leeper (2010) defines the fiscal limit as the point at which the government can no longer raise taxes or reduce spending and transfers. In models without growth and with an exogenous path for government spending and transfers, he models the fiscal limit as a fixed value for taxes. We generalize Leeper and do not assume exogenous government spending and transfers. This leads us to express the fiscal limit in terms of the primary surplus. We assume that there is a limit on the taxes that can be raised and a limit on the amount by which government spending and transfers can be reduced. In a model with output growth
this limit should be increasing with income.\textsuperscript{2} We model the limit as

\begin{equation}
  s_t \leq \phi^{\text{max}} y_t.
\end{equation}

where $s_t$ is the real primary surplus, $y_t$ is real GDP, and $\phi^{\text{max}}$ represents the limit on the primary surplus relative to output.

\subsection*{2.2 Fiscal Policy}

We derive criteria for fiscal policy such that the government’s intertemporal budget constraint holds and fiscal limits are respected. We label this policy responsible fiscal policy. We use a simple specification for fiscal policy, analogous to the Taylor Rule for monetary policy. All variables are expressed in real terms. Our fiscal rule generalizes those originally introduced by Leeper (1991) by allowing the primary surplus ($s_t$) to respond to its own lag, to lagged output ($y_{t-1}$) and to lagged debt ($b_{t-1}$). The fiscal rule is given by

\begin{equation}
  s_t = \beta_1 s_{t-1} + \beta_2 y_{t-1} + \beta_3 b_{t-1} + \nu_t,
\end{equation}

where $\nu_t$ is a mean-zero disturbance representing fiscal shocks. Fiscal shocks reflect both politically-determined shocks to taxes or government spending, and the responses of the fiscal authority to other shocks that affect the economy. The lagged value of the primary surplus is necessary to fit the data. It allows persistence and reflects the desire to smooth the effect of shocks over time. Bohn (1998, 2008) shows that the primary must respond positively to lagged debt for fiscal policy to satisfy the intertemporal budget constraint. In a model with all variables growing, the response to lagged output replaces the constant in Leeper’s fiscal

\textsuperscript{2} Bi’s (2010) model implies that $\phi^{\text{max}}$ is stochastic. Our results would not be affected by this alternative assumption.
policy rule. We test for empirical significance of the coefficients of our fiscal rule, generalized to include the lagged surplus and lagged output.

The government’s flow budget constraint can be expressed as

\[ b_t = (1 + r) b_{t-1} - s_t + \epsilon_t, \]

where \( b_t \) includes publicly held government bonds and the money supply backed by the country’s bonds, and \( \epsilon_t \) represents mean-zero shocks to the real value of debt.\(^3\) We also assume that the real interest rate, \( r \), is exogenously determined in the rest of the world, and as a simplification, assume that it is constant. Substituting for the surplus from equation (2) yields

\[ b_t = (1 + r - \beta_3) b_{t-1} - \beta_1 s_{t-1} - \beta_2 y_{t-1} - \nu_t + \epsilon_t. \tag{3} \]

Together, equations (2) and (3) constitute a dynamic system in the primary surplus and debt as a function of output and stochastic disturbances.

### 2.3 Dynamics

To complete the model, we specify output dynamics. Consistent with our empirical evidence, we specify output to be integrated of order one, giving the system a unit root. Output is determined by

\[ y_t - (1 + g) y_{t-1} = \rho [y_{t-1} - (1 + g) y_{t-2}] + \eta_t, \tag{4} \]

\(^3\) Our focus is on the government’s flow and intertemporal budget constraint, since that is the focus of fiscal policy. However, the requirement that the government’s intertemporal budget constraint be satisfied in equilibrium in a micro-founded model is derived from the combination of the agent’s transversality condition on debt (agent’s intertemporal budget constraint) together with goods market equilibrium.
where \( \rho \) is the autocorrelation in output growth, \( g \) is the average growth of output and \( \eta_t \) is a well behaved output shock. Our assumption, that output is an independent integrated stochastic process, is consistent with a model in which output is driven by integrated exogenous technology shocks. Therefore, we are assuming that the primary surplus has no impact on output. In the macro literature, the sign of this effect is controversial and model specific. Our specification should be viewed as a simplification, which is standard in the literature on fiscal sustainability,\(^4\) and consistent with at least one mainstream macroeconomic model.

The system has a long-run equilibrium in which all variables grow on average at the rate of average growth of output \((g)\). To solve for this equilibrium, quasi-difference equations (2) and (3), to yield

\[
s_t - (1 + g) s_{t-1} = (\beta_1 - 1 - g) s_{t-1} + \beta_2 y_{t-1} + \beta_3 b_{t-1} + \nu_t, \tag{5}
\]

\[
b_t - (1 + g) b_{t-1} = -\beta_1 s_{t-1} - \beta_2 y_{t-1} + (r - g - \beta_3) b_{t-1} + \epsilon_t - \nu_t. \tag{6}
\]

Setting these equations to zero and solving, with shocks taking on their expected values of zero, yields long-run equilibrium relationships

\[
s_t = \varphi y_t \quad \text{and} \quad s_t = \frac{r - g}{1 + g} b_t \tag{7}
\]

where

\[
\varphi = \frac{-\beta_2}{(1 + g) \left[ \frac{\beta_1}{1 + g} + \frac{\beta_3}{r - g} - 1 \right]} < \varphi^{\text{max}}, \tag{8}
\]

and where \( \varphi \) has the interpretation of the long-run value of the primary surplus. In a long-run equilibrium, the primary surplus and debt both grow at the rate of growth of output, and

the primary surplus is proportional to output and to debt, with the factor of proportionality expressed as the growth-adjusted real interest rate.

Using equation (7), then equations (5) and (6) can be rearranged and written in error correction form as

\[ s_t - (1 + g) s_{t-1} = -\frac{\beta_3 (1 + g)}{r - g} \left[ s_{t-1} - \frac{r - g}{1 + g} b_{t-1} \right] - \frac{\beta_2}{\varphi} [s_{t-1} - \varphi y_{t-1}] + \nu_t \]  

(9)

\[ b_t - (1 + g) b_{t-1} = - \left( 1 + g - \frac{\beta_3 (1 + g)}{r - g} \right) \left[ s_{t-1} - \frac{r - g}{1 + g} b_{t-1} \right] + \frac{\beta_2}{\varphi} [s_{t-1} - \varphi y_{t-1}] + \epsilon_t - \nu_t \]  

(10)

The expressions in square brackets are the cointegrating vectors, equivalently the long-run equilibrium relationships, given by equations (7). The error correction form implies that when the system deviates from its long-run equilibrium, the primary surplus and debt both adjust to these deviations. If the adjustment is in the correct direction and large enough, then the system is globally stable. A globally stable system is expected to return to its long-run equilibrium, ruling out explosive behavior. Therefore, a system, which returns to these long-run equilibrium relationships, does not allow the primary surplus to explode relative to output, respecting fiscal limits, and does not allow debt to explode relative to the primary surplus, implying intertemporal budget balance.

To determine the restrictions necessary for global stability, we need to solve the dynamic system, expressed in terms of the cointegrating vectors and the long-run relationship for output. Define \( Y_t \) and \( B_t \) as deviations from cointegrating vectors and \( \Gamma_t \) as the deviation of output from its long-run growth relation according to

\[ Y_t = s_t - \varphi y_t \]
\[ B_t = s_t - \frac{r - g}{1 + g} b_t \]
\[ \Gamma_t = y_t - (1 + g) y_{t-1}. \]

Rewrite the dynamic system, comprised of equations (4), (9), and (10) in terms of \( Y_t \), \( B_t \) and \( \Gamma_t \)

\[
Y_t = \left( 1 + g - \frac{\beta_2}{\varphi} \right) Y_{t-1} - \frac{\beta_3 (1 + g)}{r - g} B_{t-1} - \rho \varphi \Gamma_{t-1} - \varphi \eta_t + \nu_t
\]
\[
B_t = -\frac{\beta_2}{\varphi} \left( \frac{1 + r}{1 + g} \right) Y_{t-1} + \left( 1 + g - \frac{\beta_3 (1 + g)}{r - g} \right) \left( \frac{1 + r}{1 + g} \right) B_{t-1} + \left( \frac{1 + r}{1 + g} \right) \nu_t - \left( \frac{r - g}{1 + g} \right) \epsilon_t
\]
\[ \Gamma_t = \rho \Gamma_{t-1} + \eta_t. \]

Letting \( \theta \) denote the roots of the system above, the characteristic equation is

\[
(\rho - \theta) \left\{ \left[ 1 + g - \frac{\beta_2}{\varphi} \right] - \theta \right\} \left[ \left( 1 + g - \frac{\beta_3 (1 + g)}{r - g} \right) \left( \frac{1 + r}{1 + g} \right) - \theta \right] - \frac{\beta_3 (1 + g) \beta_2}{r - g} \left( \frac{1 + r}{1 + g} \right) = 0
\]

Using equation (8) to substitute for \( \varphi \), the characteristic equation simplifies to

\[
(\theta - \rho) \left[ \theta^2 - (1 + r + \beta_1 - \beta_3) \theta + (1 + r) \beta_1 \right] = 0.
\]

Given that \( \rho \) is less than one\(^5\), the system is globally stable if the remaining roots are also less than one in absolute value. This requires

\[
\beta_3 > r \left( 1 - \beta_1 \right) \quad \text{and} \quad (1 + r) \beta_1 < 1. \quad (11)
\]

In a globally stable system, the values of \( Y_t \), \( B_t \) and \( \Gamma_t \) are expected to approach zero in the limit. Equivalently, deviations from the cointegrating vectors vanish, and the system reaches its long-run relationships, given by equation (7). Equation (11) implies that the
d

\(^5\) The group-mean estimate of \( \rho \) is 0.35
responsiveness of the primary surplus to lagged debt, given by $\beta_3$, must be larger than the real interest rate times one minus the persistence in primary surplus. A positive, but weak response, implies that any initial deviations from cointegrating relationships will explode over time, violating fiscal limits.

Consider the implications of the model solution for the intertemporal government budget constraint and fiscal limits. If the restrictions in equation (11) are satisfied, then the system is expected to reach long-run equilibrium relationships, given by equations (7). These restrictions are sufficient to assure intertemporal budget balance and satisfaction of fiscal limits as long as $\varphi < \varphi^{\text{max}}$, where $\varphi$ is given by equation (8). Alternatively, if the restrictions in equation (11) are not satisfied, then initial deviations from the cointegrating relationships are expected to grow forever. Growth of the primary surplus relative to output violates the fiscal limit, no matter what its value, while growth of deviations of the primary surplus from debt service might or might not violate Bohn's (1998, 2008) criterion for fiscal sustainability. Since responsible fiscal policy must satisfy both fiscal limits and Bohn’s sustainability criterion, necessary criteria for responsible fiscal policy require satisfaction of the restrictions in equation (11). Our solution demonstrates that the cointegrating relationships, equivalently the long-run relationships in equations (7), exist when the restrictions in equation (11) are satisfied. Therefore, we can test our hypothesis of fiscal responsibility using either.

The introduction of fiscal limits brings the literature on fiscal sustainability full circle. Earlier work on fiscal sustainability, summarized by Trehan and Walsh (1991), defined sustainability as satisfaction of the government’s intertemporal budget constraint and argued
that it required a primary surplus responsiveness to debt at least as large as the interest rate. Bohn (1998, 2008) demonstrated that any positive responsiveness would suffice because the intertemporal budget constraint did not require boundedness of the debt. However, fiscal limits require boundedness. When we add boundedness, we restore original criteria that the response of the primary surplus to lagged debt must be large enough. Our magnitudes differ only because we have added additional terms to the fiscal rule. When $\beta_1 = 0$, as assumed in earlier work, our restriction reduces to earlier ones, where primary surplus must respond to lagged debt by more than the real interest rate.

3 Empirical Results

The purpose of the empirical work is to test whether fiscal policy in the EMU was responsible prior to the financial crisis. Our analysis yields two equivalent testable criteria: 1) the existence of cointegrating relationships between the primary surplus and debt, and between the primary surplus and output; and 2) a large enough response of the primary surplus to lagged debt to yield global stability for the dynamic system. Either is sufficient to determine whether fiscal policy was responsible before the crisis. We test both, obtaining consistent results. Additionally, estimation of the parameters of the fiscal rule provides parameter values which other researchers can use to calibrate fiscal policy. We have annual data on the real primary surplus, $s_{it}$, real debt, $b_{it}$, and real GDP, $y_{it}$, for the period of thirty-seven years (1970-2006) for a panel of ten EMU countries.\(^6\)

\(^6\) The countries were chosen based on data availability. They include Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands and Spain. For more details see the Data Appendix.
We use panel techniques to provide estimates of the parameters. Panels increase power, an important feature in a relatively-short time series (37 years). However, for panels to be useful, countries must have some commonality. We assume that if these European countries had enough in common to join a monetary union, then they have enough in common for panel techniques to improve estimates. Mendoza and Ostry (2008) estimate fiscal sustainability, using Bohn’s (1998, 2008) criteria, for a large diverse panel of industrial and emerging markets, a panel which is much more diverse than ours. Additionally, to account for the possible differences across the EMU countries, we use techniques which allow for heterogeneity across the members in the panel.

The model is comprised of variables which can take on positive and negative values, but which also exhibit non-stationary geometric growth. This requires decisions on estimation. The standard way of dealing with geometric trends using logarithms is not available to us since the primary surplus does take on negative values. Bohn (1998, 2008) transforms the variables by dividing by output. We chose not to make this transformation for several reasons. First, such a transformation should eliminate the unit root in the data, invalidating the use of cointegration tests between the primary surplus and debt as a criterion for responsible fiscal policy. Second, the transformation makes the coefficients in the fiscal rule stochastic, depending on the realization of the stochastic growth rate. Third, Bohn (1998, 2008) finds that estimates of the parameters of the fiscal rule, with variables expressed as fractions of output, are sensitive to measures of transitory versus permanent spending.

We follow the earlier literature on sustainability and estimate the model in levels (Hamil-
ton and Flavin, 1986; Trehan and Walsh 1991). This allows us to exploit the time-series characteristics of the data using cointegration methods to obtain super-consistent estimates of the parameters of the cointegrating vectors. Additionally, the error correction specification makes a natural distinction between permanent and temporary changes without the need for developing a separate methodology for measuring transitory spending.

However, estimation in levels does have implications for inferences on magnitudes of parameter values. Estimation in levels carries with it the implicit assumption that the data has a linear trend instead of a geometric trend. Replacing the geometric trend with a linear trend changes the coefficients on the cointegrating relations and introduces constants into the cointegrating relationships and the error correction specification. We derive the cointegrating relationships and the error correction specification with a linear trend in Appendix A, and denote the modified coefficients in the cointegrating vectors with tildes ($\tilde{}$). We show that the criteria for global stability, equations (11), are identical in the two specifications. We also show that, at mean values, the cointegrating relationships with the linear trend are identical to those where growth has a geometric trend.

3.1 Time Series Characteristics of Data

Before we proceed with the estimation of cointegration and error correction, we establish that the variables behave as unit root processes, $I(1)$. We use panel unit root tests, which have more power than the time series unit root tests. Following Im, Pesaran and Shin (2003), we test the null hypothesis that all series in the panel contain a unit root, against the alternative hypothesis that some of the series in the heterogeneous panel are stationary.
The test is based on the average of $N$ individual augmented Dickey-Fuller (1979) (ADF) $t$-statistics. The tests include an individual specific constant and trend. They are computed alternately using one lag, two lags, and heterogeneous numbers of lags across countries, with the lag order estimated using consistent information criteria such as the Akaike and Schwarz criteria. Table 1 reports the results with one lag. All the tests fail to reject the null hypothesis of a unit root in $s_{it}$, $b_{it}$, and $y_{it}$ at the 5 percent level, implying that real primary surplus, real debt and real output are $I(1)$.

### 3.2 Cointegration

Given that the variables in the fiscal rule appear to behave as unit root processes, we test for the existence of long-run equilibrium relationships, which are explicitly derived in Appendix A, using panel cointegration techniques. We estimate the following cointegrating model

$$s_{it} = a_i + \varrho_i x_{it} + e_{it} \quad \text{where} \quad e_{it} = \delta_i e_{it-1} + \mu_{it}$$

and test for the existence of cointegrating relationships between the real primary surplus and real debt, and between the real primary surplus and real GDP. In equation (12), $a_i$ denotes the country specific fixed effects, $s_{it}$ is the real primary surplus, $x_{it}$ is the regressor, $b_{it}$ or $y_{it}$, and $\varrho_i$ is the cointegrating parameter, $r_i$ or $\tilde{r}_i$.\(^8\) Since countries can have different fiscal rules, we model heterogeneity across countries by allowing each country’s policy parameters

---

\(^7\) We also fail to reject the null of a unit root when we use Breitung (2000), Maddala and Wu (1999), Choi (2001) tests, and we reject the null of no unit root when we use Hadri (2000) test. Additionally, we confirm the unit root behavior of the series using panel unit root tests suggested by Breitung and Das (2005), Moon and Perron (2004) and Pesaran (2006), which account for various forms of cross-sectional dependence. The tests are computed using one lag and two lags. For Moon and Perron’s (2004) procedure we use one unobserved factor. All tests include an individual specific constant and trend.

\(^8\) Since we estimate the model in levels, the cointegrating relationships will contain constants, derived in Appendix A.
to differ randomly from the EMU panel policy parameters. Letting $\zeta_i$ be the $i^{th}$ country’s vector of policy parameters, and $\zeta$ the vector of EMU policy parameters, we assume that $\zeta_i = \zeta + \epsilon_{\zeta i}$, where the $\epsilon_{\zeta i}$ have zero-means and constant variances for all $i$.

We begin with two group-mean panel cointegration $t$ tests suggested by Pedroni (1999, 2004). Both tests are residual-based cointegration tests, which test the null hypothesis that the variables of interest are not cointegrated for all the countries in the panel against the alternative hypothesis that there exists a heterogeneous cointegration vector for all the countries in the panel. Under the null hypothesis of no cointegration, the residuals from (12), $\hat{e}_{it}$, are $I(1)$. Denoting the autoregressive coefficient of the $i^{th}$ country’s residuals by $\delta_i$, the group-mean statistics test the null hypothesis of no cointegration, $H_o : \delta_i = 1$ for all $i$, versus the heterogeneous alternative hypothesis, $H_A : \delta_i < 1$ for all $i$. The alternative does not presume the same value for $\delta_i$. The first group-mean test uses semi-parametric corrections, while the second is a parametric ADF test. The tests are extensions of the single time series Phillips-Perron (1988) $t$-test and the ADF $t$-test. We account for cross-sectional dependence and cross-member cointegration by using common time effects. For the semi-parametric

9 The group-mean statistics allow modeling an additional source of potential heterogeneity across individual members of the panel. Moreover, Gutierrez (2003) finds that Pedroni’s tests have higher power than the system test proposed by Larsson, Lyhagen and Lothgren (2001). Additionally, Banerjee, Marcellino and Osbat (2004) show that for small $N$ the size distortions of Pedroni’s tests are lower than those of Larsson and Lyhagen (1999) test.

10 The specifications are given in Appendix C.

11 Common time effects allow us to model a limited form of cross-sectional dependence and cross-member cointegration (which is a form of long-run cross-sectional dependence). Common time effects assume that the cross-sectional dependence correlation between country $i$ and $j$ is identical for all $i, j$. Thus, in the presence of heterogeneous cross-sectional dependence, subtracting off the cross-sectional average does not completely eliminate cross-sectional dependence. The method by which cross-sectional dependence is modeled in panels is still an active area of research. Bai and Ng (2002) and Moon and Perron (2004) consider models in which the error terms have a factor structure in panel unit root tests, however the implications for such factor models have not been studied in the panel cointegration context. Notice though that time effects are a special case of a factor model where there is a single common factor and the response of each country is
test we use the Bartlett kernel and the Newey-West bandwidth selection procedure, and for the parametric ADF-type test, we use the step-down procedure to estimate the number of lags. The results, reported in Table 2, indicate that both tests reject the null hypothesis of no cointegration at the 5 percent level.\textsuperscript{12} Therefore, Pedroni’s tests provide strong evidence that $s_{it}$ and $b_{it}$ are cointegrated and that $s_{it}$ and $y_{it}$ are also cointegrated.

We confirm that there are two cointegrating relations in the trivariate model using the system panel cointegration test proposed by Larsson, Lyhagen and Lothgren (2001). Their test is a panel version of Johansen’s (1988, 1995) full information maximum likelihood method. The null hypothesis is that all of the $N$ countries in the panel have at most $q$ cointegrating relationships among the 3 variables, $H_o : q$ cointegrating relations for all $i$, and the alternative is that all the countries have 3, $H_A : 3$ cointegrating relations for all $i$. This is a sequential procedure where the first test is the null $q = 0$. If this hypothesis is rejected, then the null $q = 1$ is tested. The sequential procedure continues until the null is not rejected or the hypothesis $q = 2$ is rejected. The test is computed using one-lag difference terms and it includes individual specific fixed effects. In Table 3 we verify that there are two cointegrating relations in the model. The panel test statistic indicates that $q = 2$ in the model with three variables $s_{it}$, $b_{it}$ and $y_{it}$. This implies that there is a single stochastic trend in the data for each country, implying that there are cointegrating relations between $s_{it}$ and $b_{it}$, and between $s_{it}$ and $y_{it}$, consistent with previous results.

\textsuperscript{12}We also reject the null of no cointegration at the 5 percent level when we use all seven panel statistics of Pedroni (1999, 2004). Additionally, we reject the null of no cointegration at the 5 percent level when we do not use the common time effects.
Therefore, the data satisfy restrictions necessary for existence of a stationary long-run equilibrium relationship between the primary surplus and debt, and between the primary surplus and output for each country. Stationary long-run equilibrium relationships are consistent with a globally stable model, implying responsible fiscal policy.

### 3.3 Fiscal Response to Debt

Finally, we test whether the magnitude of the response of the primary surplus to lagged debt has been large enough to satisfy restrictions necessary for global stability, given by equations (11). Appendix A provides a derivation of the error correction model, under the assumption in the estimation that the data has a linear trend, as

\[ s_{it} - s_{it-1} = \tilde{\varphi}_i \bar{g}_i - \frac{\beta_3i}{r_i} \left[ s_{it-1} - r_i b_{it-1} + \tilde{\varphi}_i \bar{g}_i \left( \frac{1 + r_i}{r_i} \right) \right] - \frac{\beta_2i}{\tilde{\varphi}_i} \left[ s_{it-1} - \tilde{\varphi}_i \bar{y}_{it-1} + \frac{\tilde{\varphi}_i^2}{\tilde{\varphi}_i} \left( 1 - \frac{\beta_3i}{r_i} \left( \frac{1 + r_i}{r_i} \right) \right) \right] + \nu_{it} \]

where \( \bar{g}_i \) is average linear growth, and \( \tilde{\varphi}_i \) is a combination of the parameters in the fiscal rule and has the interpretation of the long-run value of primary surplus. We estimate the parameters of the above error correction model using a two-step procedure, in which we initially estimate the cointegrating parameters. In the second step, we estimate the coefficients on the error correction terms.

To estimate the cointegrating parameters, we use Pedroni’s (2000, 2001) group-mean fully modified OLS (FMOLS) procedure for cointegrated panels, which is based on equation (12). The group-mean FMOLS procedure accommodates the heterogeneity that is typically

---

\textsuperscript{13}Bohn (2008) considers a similar equation with \( x_{it} \) given by debt, using over two centuries of US data on the primary surplus, output, and debt. His real data series have severe heteroskedasticity, due to two centuries of
present both in the transitional serial correlation dynamics and in the long-run cointegrating relationships. It is a semi-parametric approach that adjusts for the effects of endogenous regressors and short-run dynamics of the errors.\textsuperscript{14} We use the Bartlett kernel and the Newey-West bandwidth selection procedure as suggested by Pedroni (2000). The results, in Table 4, indicate that the group-mean panel estimate for the real interest rate is 4.22 percent ($r = 0.0422$) and the group-mean panel estimate for the long-run value of primary surplus is 3.80 percent ($\bar{\varphi} = 0.0380$).\textsuperscript{15}

In the final step we consider estimation of the group-mean panel fiscal policy parameters $\beta_1$, $\beta_2 \bar{\varphi}$, and $\beta_3 r$. It is important to recognize that the residuals in equation (13) could be autocorrelated in the data. If so, then the residuals could be correlated with the right-hand-side variables, biasing estimates of the coefficients on the error correction terms. Therefore, we use Sims’ (1980) likelihood ratio test to determine the appropriate number of lags to fully capture the dynamics for each country. For some countries, the test implies that equation (13) is appropriately specified. However, for others, an additional lag is chosen. Therefore, to be sure that we are not omitting relevant lags and thereby biasing estimates of coefficients, growth in real GDP. He reduces, but does not eliminate, these problems by dividing by real GDP. Standard deviations for real variables are 64 to 98 times as high in the second period as in the first. For variables expressed as a fraction of GDP, this number falls to something a little larger than 2. We have a very different data set from Bohn’s – a relatively short time dimension and ten countries. The shorter time dimension implies that we do not have Bohn’s heteroskedasticity problem. Ratios of standard deviations in the second half of the sample relative to the first half average to something less than 2, similar to his adjusted data.\textsuperscript{14}Since FMOLS is designed to reduce bias associated with short-run dynamics and the estimates in the $I(1)$ model are super-consistent, it is not necessary to add stationary variables, like HP-filtered measures of the data, as in Bohn’s model with stationary data (2008).\textsuperscript{15}The FMOLS results are robust to the choice of kernel and bandwidth. We obtain almost identical estimates when we use the Parzen and quadratic spectral (QS) kernels and the Andrews (1991) bandwidth selection procedure. Additionally, we obtain similar estimates when we use the group mean dynamic OLS (DOLS) procedure of Pedroni (2004) and the two-step estimator of Breitung (2005).
we estimate the model with an additional lag. \(^1\)

\[
\begin{align*}
    s_{it} - s_{it-1} &= \tilde{\varphi}_i \tilde{g}_i - \frac{\beta_3 i}{r_i} (\tilde{B}_it) - \frac{\beta_2 i}{\tilde{\varphi}_i} (\tilde{Y}_it) + \pi_{1i} (s_{it-1} - s_{it-2} - \tilde{\varphi}_i \tilde{g}_i) \\
    &+ \pi_{2i} \left( b_{it-1} - b_{it-2} - \frac{\tilde{\varphi}_i \tilde{g}_i}{r_i} \right) + \pi_{3i} (y_{it-1} - y_{it-2} - \tilde{g}_i) + \nu_{it}.
\end{align*}
\]

(14)

where \(\tilde{B}_it\) and \(\tilde{Y}_it\) are the cointegrating vectors given by their linear counterparts and \(\tilde{g}_i\) is the average growth rate, all derived in the Appendix A. A persistent, but negative fiscal shock, perhaps created by a war, would imply a negative error in the first cointegrating relationship and rising lagged debt, implying a negative correlation between the two terms. Therefore, failure to include the lagged change in debt could bias the estimate on the coefficient on the error correction terms.\(^2\)

Now, consider estimation of the coefficients on the error correction terms in equation (14). First, we use the estimated cointegrating parameters of the real interest rate and long-run value of the primary surplus to construct the error correction terms for each country, yielding an equation in which all the variables are stationary. Asymptotically, the fact that we use the estimated error correction terms rather than the true error correction terms in (14) does not affect the standard properties of our estimates due to the super-consistency.

\(^1\)The additional dynamics do not change the first criterion for stability, \(\frac{\beta_3 i}{r_i} > 1 - \beta_{1i}\), but modify slightly the second one. This becomes \(\beta_{1i} \left( 1 + r_i \left( \frac{\pi_{2i} + r_i (\pi_{1i} - 1)}{2 \pi_{2i} + r_i (2 \pi_{1i} - 1)} \right) \right) < 1.\)

\(^2\)Using long US samples of one and two centuries that highlight the role of wars, Bohn (2008) expresses the fiscal rule in terms of the surplus and debt as a fraction of output, and finds it necessary to add HP-filter measures of transitory values of the variables to distinguish between the response of the surplus to permanent and transitory shocks and reduce "omitted variables bias." Transitory, but persistent government spending, as associated with a war, would be accompanied by rising debt implying that the residual would be low when debt is high relative to the surplus. The error correction model deals with this by adding lagged changes of the model variables. In this example the lagged change in debt would be high in a war and would play the role of Bohn’s transitory military spending, and the lagged change in output would play the role of Bohn’s HP-filtered output.
properties of the estimator of the cointegrating relationships.\textsuperscript{18} After constructing the error correction terms, we estimate the coefficients of the error correction model, augmented with lagged changes in variables, providing estimates for $\beta_1$, $\frac{\beta_2}{\varphi}$, and $\frac{\beta_3}{r}$. We use the group-mean procedure recommended by Pesaran and Smith (1995).\textsuperscript{19}

Table 5 indicates that the panel estimates are: $\beta_1 = 0.4911$, $\frac{\beta_2}{\varphi} = -0.1188$ and $\frac{\beta_3}{r} = 0.6277$. Each coefficient is statistically significant at the 5% level, and $\frac{\beta_3}{r}$ is statistically significantly larger than $1 - \beta_1$.\textsuperscript{20} We also present parameter estimates for each individual country in Table 6. Our inference for each country’s fiscal policy is weaker. We find that each country’s $\frac{\beta_3}{r_i}$ is larger than $1 - \beta_{1i}$, although standard errors are generally too large to yield significance for each member in the panel. The large individual-country standard errors illustrate the reasons for using panel estimation instead of time series estimation in a relatively short sample. Although the individual country results are not significant, signs are correct, providing some individual country corroboration for our panel results.\textsuperscript{21}

At first glance the estimated coefficient on output, or equivalently on the long-run primary surplus, $\beta_2$, might seem to have the wrong sign. An alternative and equivalent expression of the error correction model is more intuitive. Using results in Appendix A, the fiscal rule in


\textsuperscript{19}They show that when the parameters of interest are heterogeneous, the group-mean procedure provides consistent estimates, whereas the pool panel procedures give inconsistent estimates.

\textsuperscript{20}We obtain almost identical estimates when we use the hierarchical Bayes estimator of Hsiao, Pesaran and Tahmiscioglu (1999) and the weighted estimator of Swamy (1980) (also referred as the empirical Bayes estimator).

\textsuperscript{21}Our results also satisfy the second condition necessary for global stability, $\beta_1 \left(1 + r \left(\frac{\pi_2 + r(\pi_1 - 1)}{2\pi_2 + r(2\pi_1 - 1)}\right)\right) = 0.5035$ which is less than 1.
equation (13) can also be written as

\[ s_{it} - s_{it-1} = (1 - \beta_{1i}) (\bar{\varphi}_i y_{it-1} - s_{it-1}) + \frac{\beta_{3i}}{\bar{r}_i} (r_i b_{it-1} - \bar{\varphi} y_{it-1}) + \nu_{it} \]

which implies that primary surplus increases whenever primary surplus is below its long-run value and whenever the debt service is above its long-run value. As shown in the Appendix A, the criterion \( \frac{\beta_{3i}}{\bar{r}_i} > 1 - \beta_{1i} \) is equivalent to \( \frac{\beta_{3i}}{\bar{\varphi}_i} < 0 \). Given that \( \bar{\varphi}_i > 0 \), the value for \( \beta_{3i} \) must be negative.

We have not allowed estimates of the parameters of the error correction model to change as the monetary union has evolved over time. However, if the coefficients in the cointegrating relationships had changed and no account were taken for the change, then we should not have rejected the null of no cointegration.\(^\text{22}\) The values for the coefficients on the error correction terms could have changed. To test for a change in \( \beta_1, \frac{\beta_2}{\bar{\varphi}}, \) and \( \frac{\beta_3}{\bar{r}} \), we break the sample into two sub-periods, the pre-Maastricht era (1970 – 1993) and the post-Maastricht era (1994 – 2006).\(^\text{23}\) Table 7 shows that \( \frac{\beta_3}{\bar{r}} > 1 - \beta_1 \) in both sub-samples, although standard errors are too high to yield significance.\(^\text{24}\) The split sample evidence suggest that the primary surplus is sufficiently responsive to debt to imply that fiscal policy is responsible in both sub-samples.\(^\text{25}\)

In summary, our group-mean panel results imply that primary surpluses in the EMU countries have been sufficiently responsive to lagged debt to satisfy the criteria for responsible

\(^{22}\) For example, assume that there is an unmodelled change in \( \bar{\varphi} \). The residuals in (12) will be non-stationary and cointegration would be rejected.

\(^{23}\) The Maastricht Treaty began on November 1, 1993.

\(^{24}\) The sub-samples are not long enough to allow reliable inference. Most of our panel techniques require the time series dimension to be substantially larger than the cross-section dimension, and we lose this when we split the sample.

\(^{25}\) Alfonso (2005) and Annett (2006), who use a similar EMU data set and other empirical techniques, do not find evidence for a change in the fiscal policy after the signing of the Maastricht Treaty.
fiscal policy. When we reduce the size of the sample, either by estimating individual-country fiscal rules or by splitting the sample, we retain the magnitudes necessary for responsibility, but they are not always significant.

4 Conclusion

The first contribution of the paper is theoretical. It establishes criteria for responsible fiscal policy, where we define responsible policy as a policy rule that is expected to satisfy both the government’s intertemporal budget constraint and fiscal limits. Responsible fiscal policy must imply non-explosive debt relative to the primary surplus and a non-explosive primary surplus relative to GDP. We specify fiscal policy as a rule and determine the restrictions on parameter values necessary to assure non-explosive behavior. We find that the response of the primary surplus to debt must be large enough to render the system, expressed as long-run equilibrium deviations (equivalently cointegrating vectors), globally stable. This modifies Bohn’s (1998, 2008) condition, in which he defines a sustainable fiscal policy in the absence of fiscal limits as one which satisfies the government’s intertemporal budget constraint. Our additional criterion that fiscal policy satisfy fiscal limits, requires a larger response of the primary surplus to government debt. Moreover, consideration of fiscal limits restores cointegration as a requirement for responsible fiscal policy, since debt, the primary surplus, and GDP must reach stable long-run equilibrium relationships with each other. These results imply two equivalent empirically testable criteria for responsible fiscal policy. The first is cointegration, and the second is the magnitude of the responsiveness of the
primary surplus to lagged debt in the fiscal rule.

Our theoretical contribution brings the literature on fiscal sustainability full circle. Trehan and Walsh (1991) summarized requirements for fiscal policy to satisfy the government’s intertemporal budget constraint as those which we present to satisfy both the intertemporal budget constraint and fiscal limits. Bohn (2007) argued that those requirements were too strong to satisfy the government’s intertemporal budget constraint alone. We show that adding fiscal limits restores those original criteria.

The second contribution of the paper is empirical. We test for cointegration, and we estimate the parameters of the fiscal rule for a panel of ten EMU countries over the period of 1970-2006, using panel techniques that allow for heterogeneity across the countries. We find that over the sample period, the data exhibits the required cointegration and the required responsiveness of the primary surplus to lagged debt for fiscal policy to have been responsible. However, even a country following a responsible fiscal policy can experience bad luck, when a string of negative fiscal shocks, together with the policy response to those shocks, reduces the primary surplus. This analysis implies that the recent financial turmoil in several EMU countries is a consequence of severely negative shocks rather than irresponsible fiscal policy rules.
Appendix
A. Model with a Linear Trend

The model consists of equations (2), and (3), but the equation for output growth is expressed as

\[ y_t - y_{t-1} - \bar{g} = \rho [y_{t-1} - y_{t-2} - \bar{g}] + \eta_t, \]  

(15)

where \( \bar{g} \) is the average change of output, such that \( \frac{\Delta \bar{g}}{\bar{g}} = g \). To solve for long-run equilibrium changes, first difference equations (2) and (3) and drop time subscripts to yield

\[ \Delta s = r \Delta b = \bar{\varphi} \Delta y = \bar{\varphi} \bar{g} \]

where

\[ \bar{\varphi} = \frac{-\beta_2}{\beta_1 + \beta_3/r - 1} < \varphi^{\text{max}}, \]

and where \( \bar{\varphi} \) has the interpretation of the long-run value of the primary surplus with linear trend. Since output changes on average by \( \bar{g} \), the primary surplus changes on average by \( \bar{\varphi} \bar{g} \), and debt changes on average by \( \frac{\bar{\varphi}}{r} \). Differentiating and subtracting the linear trend in the surplus and debt from equations (2) and (3), respectively, yields

\[ s_t - s_{t-1} - \bar{g} \bar{\varphi} = (\beta_1 - 1) s_{t-1} + \beta_2 y_{t-1} + \beta_3 b_{t-1} - \bar{g} \bar{\varphi} + \nu_t \]

(16)

\[ b_t - b_{t-1} - \frac{\bar{g} \bar{\varphi}}{r} = -\beta_1 s_{t-1} - \beta_2 y_{t-1} + (r - \beta_3) b_{t-1} - \frac{\bar{g} \bar{\varphi}}{r} + \epsilon_t - \nu_t \]

(17)

To solve for long-run equilibrium relationships, set the equations above equal to zero, with disturbances at their expected values of zero, to yield

\[ s_t = r b_t - \bar{\varphi} \bar{g} \left( \frac{1 + r}{r} \right) = \bar{\varphi} y_t - \frac{\bar{\varphi}^2 \bar{g}}{\beta_2} \left( 1 - \frac{\beta_3}{r} \left( \frac{1 + r}{r} \right) \right) \]

(18)
Therefore, compared with the theoretical model, which has a geometric trend, the empirical
model, estimated with a linear trend over the finite sample, yields cointegrating vectors
with constants and different coefficients. At mean values, the cointegrating relationships are
identical to those in the model with a geometric trend.

To prove this, express the first equilibrium relationship at the mean as

\[
\bar{s} = r\bar{b} - \bar{g}\varphi \left(\frac{1 + r}{r}\right) = r\bar{b} - \Delta\bar{s} - \Delta\bar{b}
\]

Dividing both sides by \(\bar{b}\) yields

\[
\frac{\bar{s}}{\bar{b}} = r - \left(\frac{\Delta\bar{s}}{\bar{s}}\right) - \frac{\Delta\bar{b}}{\bar{b}}
\]

Since

\[
\left(\frac{\Delta\bar{s}}{\bar{s}}\right) = \frac{\Delta\bar{b}}{\bar{b}} = g
\]

\[
\bar{s} = \frac{r - g\bar{b}}{1 + g}.
\]

(19)

The second cointegrating vector is obtained by setting equation (16) equal to zero, with
shocks at their expected value of zero. Evaluating at the mean yields

\[
(\beta_1 - 1)\bar{s} + \beta_2\bar{y} + \beta_3\bar{b} - \bar{g}\varphi = 0.
\]

Substitute for \(\bar{b}\) from equation (19) and use \(\bar{g}\varphi = \Delta\bar{s}\) to yield

\[
(\beta_1 - 1)\bar{s} + \beta_2\bar{y} + \beta_3\frac{1 + g}{r - g}\bar{s} - \Delta\bar{s} = 0.
\]

Dividing by \(\bar{y}\) and rearranging yields

\[
\left(\beta_1 - 1 + \beta_3\frac{1 + g}{r - g}\right)\frac{s}{y} + \beta_2 - \left(\frac{\Delta s}{\bar{s}}\right)\left(\frac{s}{\bar{y}}\right) = 0.
\]
Using $\frac{\Delta s}{s} = g$ yields

\[
\left( \beta_1 - 1 - g + \beta_3 \frac{1 + g}{r - g} \right) \frac{s}{\bar{y}} + \beta_2 = 0
\]

\[
\bar{s} = \left( \frac{-\beta_2}{\beta_1 + \beta_3 \left( \frac{1+g}{r-g} \right) - (1+g)} \right) \bar{y} = \varphi \bar{y}.
\]

Using equations (16), (17), and (18), the error correction model can be expressed as

\[
s_t - s_{t-1} = \varphi \bar{g} - \frac{\beta_3}{r} \left( s_{t-1} - rb_{t-1} + \varphi \bar{g} \left( \frac{1+r}{r} \right) \right) - \frac{\beta_2}{\varphi} \left( s_{t-1} - \varphi y_{t-1} + \frac{\varphi^2 \bar{g}}{\beta_2} \left( 1 - \frac{\beta_3}{r} \left( \frac{1+r}{r} \right) \right) \right) + \nu_t
\]

(20)

\[
b_t - b_{t-1} = \frac{\varphi \bar{g}}{r} - \left( 1 - \frac{\beta_3}{r} \right) \left( s_{t-1} - rb_{t-1} + \varphi \bar{g} \left( \frac{1+r}{r} \right) \right) + \frac{\beta_2}{\varphi} \left( s_{t-1} - \varphi y_{t-1} + \frac{\varphi^2 \bar{g}}{\beta_2} \left( 1 - \frac{\beta_3}{r} \left( \frac{1+r}{r} \right) \right) \right) - \nu_t + \epsilon_t
\]

(21)

Defining deviations from cointegrating vectors and long-run relationships as,

\[
\tilde{Y}_t = s_t - \varphi y_t + \frac{\varphi^2 \bar{g}}{\beta_2} \left( 1 - \frac{\beta_3}{r} \left( \frac{1+r}{r} \right) \right)
\]

\[
\tilde{B}_t = s_t - rb_t + \varphi \bar{g} \left( \frac{1+r}{r} \right)
\]

\[
\tilde{\Gamma}_t = y_t - y_{t-1} - \bar{g}.
\]

we can rewrite the dynamic system in terms of the cointegrating vectors and the long-run relationship of output as

\[
\tilde{Y}_t = \left( 1 - \frac{\beta_2}{\varphi} \right) \tilde{Y}_{t-1} - \frac{\beta_3}{r} \tilde{B}_{t-1} - \varphi \rho \tilde{\Gamma}_{t-1} + \nu_t - \varphi \eta_t
\]

\[
\tilde{B}_t = - (1+r) \frac{\beta_2}{\varphi} \tilde{Y}_{t-1} + \left( 1 - \frac{\beta_2}{r} \right) (1+r) \tilde{B}_{t-1} + (1+r) \nu_t - r \epsilon_t
\]

\[
\tilde{\Gamma}_t = \rho \tilde{\Gamma}_{t-1} + \eta_t
\]

28
Substituting for $\tilde{\varphi}$, the characteristic equation is identical to that for the theoretical model with the geometric trend. Therefore, the requirements for global stability are identical. The requirement that $\frac{\beta_3}{r} > 1 - \beta_1$ is simply the requirement that

$$\frac{-\beta_2}{\tilde{\varphi}} = \beta_1 + \beta_3 / r - 1 > 0.$$  

The loading on the second error correction term in equation (20) must be positive.

**B. Data Appendix**

Nominal primary surplus, nominal GDP and GDP deflator are from the OECD database. The nominal debt is also from OECD database and for missing years data is obtained from the ECB’s AMECO database. The sample consists of annual data from 1970-2006 for Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands and Spain. For Luxembourg and Portugal there was not data available for a lot of years. For Germany we use the data for West Germany before unification and Germany after unification. The real values of the variables for each country are obtained by dividing the nominal values by the GDP deflator.

For the nominal primary surplus we use the general government primary balances (OECD Annex Table 29) and for nominal debt we use the general government gross financial liabilities (OECD Annex Table 33).

**C. Panel Cointegration Statistics (Pedroni (1999))**

1. Group mean $t$–*statistic* (semi-parametric):

$$N^{-1/2} \bar{Z}_{t,N,T} \equiv N^{-1/2} \sum_{i=1}^{N} \left( \hat{\sigma}_2^2 \sum_{t=1}^{T} \hat{e}_{i,t}^2 \right)^{-1/2} \sum_{t=1}^{T} (\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} - \hat{\omega}_i)$$
2. Group mean \( t \)-statistic (parametric):

\[
N^{-1/2} \tilde{Z}_{tN,T}^* \equiv N^{-1/2} \sum_{i=1}^{N} \left( \sum_{t=1}^{T} \tilde{s}_i^{*2} \tilde{e}_{i,t-1} \right)^{-1/2} \sum_{t=1}^{T} (\tilde{e}_{i,t-1} \Delta \hat{\epsilon}_{i,t})
\]

where

\[
\hat{\omega}_i = \frac{1}{T} \sum_{s=1}^{k_i} \left( 1 - \frac{s}{k_i + 1} \right) \sum_{t=s+1}^{T} \hat{\mu}_{i,t} \hat{\mu}_{i,t-s}, \quad \hat{s}_i^2 = \frac{1}{T} \sum_{t=1}^{T} \hat{\mu}_{i,t}^2, \quad \hat{\sigma}_i^2 = \hat{s}_i^2 + 2\hat{\omega}_i, \quad \hat{s}_i^{*2} = \frac{1}{T} \sum_{t=1}^{T} \hat{\mu}_{i,t}^{*2}
\]

and where the residuals \( \hat{\mu}_{i,t} \) and \( \hat{\mu}_{i,t}^* \) are obtained from the following regressions:

\[
\hat{e}_{i,t} = \hat{\delta}_i \hat{e}_{i,t-1} + \hat{\mu}_{i,t} \quad \text{and} \quad \hat{e}_{i,t} = \hat{\delta}_i \hat{e}_{i,t-1} + \sum_{k=1}^{K_i} \hat{\delta}_{i,k} \Delta \hat{e}_{i,t-k} + \hat{\mu}_{i,t}^*
\]

and \( \hat{e}_{i,t} \) are the residuals from equation (12).
<table>
<thead>
<tr>
<th>Test statistic</th>
<th>( s_{it} )</th>
<th>( b_{it} )</th>
<th>( y_{it} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{IPS} )</td>
<td>-1.06</td>
<td>1.70</td>
<td>2.42</td>
</tr>
<tr>
<td>( t_{BD-rob} )</td>
<td>-1.24</td>
<td>-0.30</td>
<td>-0.95</td>
</tr>
<tr>
<td>( t_{MP-a} )</td>
<td>-0.49</td>
<td>-0.69</td>
<td>1.13</td>
</tr>
<tr>
<td>( t_{MP-b} )</td>
<td>-0.40</td>
<td>-0.79</td>
<td>0.64</td>
</tr>
<tr>
<td>( t_{CIPS} )</td>
<td>-2.13</td>
<td>-1.70</td>
<td>-1.46</td>
</tr>
</tbody>
</table>

Note: \( t_{IPS} \) is the group mean \( t \)-statistic proposed by Im, Pesaran and Shin (2003), \( t_{BD-rob} \) is the OLS robust \( t \)-statistic proposed by Breitung and Das (2005), \( t_{MP-a} \) and \( t_{MP-b} \) are the \( t \)-statistics based on the factor model proposed by Moon and Perron (2004) and \( t_{CIPS} \) is the test proposed by Pesaran (2006). They all test the null of a unit root against the alternative of stationarity. All tests are computed using one lag and they include individual specific constants and trends. The test statistics with ** reject the null of a unit root at the 5 percent level. For the \( t_{IPS} \), \( t_{BD-rob} \), \( t_{MP-a} \) and \( t_{MP-b} \) tests, the null is rejected if \( t < -1.64 \) and for the \( t_{CIPS} \) test, the null is rejected if \( t_{CIPS} < -2.85 \).
Table 2: Residual Based Panel Cointegration Tests

<table>
<thead>
<tr>
<th>Test Statistics</th>
<th>$s_{it}$ and $b_{it}$</th>
<th>$s_{it}$ and $y_{it}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group mean $t$ (semi-parametric)</td>
<td>-4.22**</td>
<td>-4.54**</td>
</tr>
<tr>
<td>Group mean $t$ (parametric)</td>
<td>-4.53**</td>
<td>-4.83**</td>
</tr>
</tbody>
</table>

Note: See Appendix C for details. The statistics are distributed standard normal. They test the null hypothesis of no cointegration against the alternative of cointegration. All the tests include individual specific fixed effects and common time effects. The test statistics with ** reject the null hypothesis at the 5 percent level. The 5 percent critical value is -1.64.

Table 3: System Based Panel Cointegration Tests

<table>
<thead>
<tr>
<th>$s_{it}$, $b_{it}$, $y_{it}$</th>
<th>$q = 0$</th>
<th>$q = 1$</th>
<th>$q = 2$</th>
<th>Cointegrating relations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel test</td>
<td>14.26**</td>
<td>7.77**</td>
<td>0.81</td>
<td>2</td>
</tr>
</tbody>
</table>

Note: The panel cointegration statistic tests the null hypothesis that there are $q$ cointegrating relationships against the alternative that there are 3 cointegrating relationships. The test includes individual specific fixed effects. The test statistics with ** reject the null at 5 percent level. The panel test has a 5 percent critical value of 1.64. The moments used for the panel test are tabulated in Shiamptanis (2008).
Table 4: Panel Estimates of the Cointegrating Parameters

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>ϕ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficients</td>
<td>0.0422**</td>
<td>0.0380**</td>
</tr>
<tr>
<td>Standard Errors</td>
<td>(0.0061)</td>
<td>(0.0076)</td>
</tr>
</tbody>
</table>

Note: r and ϕ are the group-mean panel FMOLS estimates of real interest rate and the long-run value of primary surplus. The estimates are based on the Bartlett kernel and the Newey-West bandwidth selection procedure. They include individual specific effects. The ** indicate statistical significance at the 5 percent level. The 5 percent critical value is 1.96.

Table 5: Panel Estimates of the Fiscal Parameters

<table>
<thead>
<tr>
<th></th>
<th>$\beta_1$</th>
<th>$\frac{\beta_2}{\varphi}$</th>
<th>$\frac{\beta_3}{r}$</th>
<th>$\pi_1$</th>
<th>$\pi_2$</th>
<th>$\pi_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficients</td>
<td>0.4911**</td>
<td>-0.1188**</td>
<td>0.6277**</td>
<td>0.0607</td>
<td>-0.0911**</td>
<td>0.1888**</td>
</tr>
<tr>
<td>Standard Errors</td>
<td>(0.0766)</td>
<td>(0.0452)</td>
<td>(0.0845)</td>
<td>(0.0688)</td>
<td>(0.0387)</td>
<td>(0.0706)</td>
</tr>
</tbody>
</table>

Note: $\beta_1$, $\frac{\beta_2}{\varphi}$ and $\frac{\beta_3}{r}$ are the group-mean panel estimates for the loadings on the error correction terms. $\pi_1$, $\pi_2$ and $\pi_3$ are the group-mean panel estimates for the coefficients on the lagged change in surplus, the lagged change in debt and the lagged change in output, respectively. The ** indicate statistical significance at the 5 percent level.

Table 6: Country Estimates of the Fiscal Parameters
<table>
<thead>
<tr>
<th></th>
<th>$\beta_1$</th>
<th>$\frac{\beta_2}{2}$</th>
<th>$\frac{\beta_2}{\tau}$</th>
<th>$\pi_1$</th>
<th>$\pi_2$</th>
<th>$\pi_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>0.5213***</td>
<td>-0.1477</td>
<td>0.6264</td>
<td>0.1141</td>
<td>-0.0283</td>
<td>0.2748***</td>
</tr>
<tr>
<td></td>
<td>(0.1699)</td>
<td>(0.7081)</td>
<td>(0.7088)</td>
<td>(0.1697)</td>
<td>(0.1269)</td>
<td>(0.1191)</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.5354***</td>
<td>-0.4561**</td>
<td>0.9207**</td>
<td>-0.3064**</td>
<td>-0.2452**</td>
<td>0.1411</td>
</tr>
<tr>
<td></td>
<td>(0.1518)</td>
<td>(0.1813)</td>
<td>(0.2027)</td>
<td>(0.1543)</td>
<td>(0.0829)</td>
<td>(0.1476)</td>
</tr>
<tr>
<td>Finland</td>
<td>0.4307**</td>
<td>-0.0026</td>
<td>0.5719</td>
<td>0.0005</td>
<td>-0.2282</td>
<td>0.4643**</td>
</tr>
<tr>
<td></td>
<td>(0.1501)</td>
<td>(0.8788)</td>
<td>(0.8637)</td>
<td>(0.1896)</td>
<td>(0.1428)</td>
<td>(0.1891)</td>
</tr>
<tr>
<td>France</td>
<td>0.0124</td>
<td>-0.0117</td>
<td>0.9992</td>
<td>0.4368**</td>
<td>-0.1968**</td>
<td>0.3413**</td>
</tr>
<tr>
<td></td>
<td>(0.2011)</td>
<td>(1.4847)</td>
<td>(1.5030)</td>
<td>(0.1469)</td>
<td>(0.0811)</td>
<td>(0.1377)</td>
</tr>
<tr>
<td>Germany</td>
<td>0.3379</td>
<td>-0.1524</td>
<td>0.8145</td>
<td>0.1539</td>
<td>-0.0795</td>
<td>0.0283</td>
</tr>
<tr>
<td></td>
<td>(0.2138)</td>
<td>(1.4243)</td>
<td>(1.4579)</td>
<td>(0.1876)</td>
<td>(0.1254)</td>
<td>(0.0766)</td>
</tr>
<tr>
<td>Greece</td>
<td>0.7763</td>
<td>-0.1154</td>
<td>0.3392</td>
<td>-0.0205</td>
<td>0.0254</td>
<td>-0.0609</td>
</tr>
<tr>
<td></td>
<td>(0.1302)</td>
<td>(0.2737)</td>
<td>(0.2935)</td>
<td>(0.1845)</td>
<td>(0.0673)</td>
<td>(0.1312)</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.3340**</td>
<td>-0.1759</td>
<td>0.8419**</td>
<td>0.1917</td>
<td>-0.2114**</td>
<td>0.1434</td>
</tr>
<tr>
<td></td>
<td>(0.1732)</td>
<td>(0.1768)</td>
<td>(0.2114)</td>
<td>(0.1634)</td>
<td>(0.1045)</td>
<td>(0.0895)</td>
</tr>
<tr>
<td>Italy</td>
<td>0.7430**</td>
<td>-0.0840</td>
<td>0.3410</td>
<td>0.1101</td>
<td>0.0076</td>
<td>-0.1785</td>
</tr>
<tr>
<td></td>
<td>(0.1322)</td>
<td>(0.2330)</td>
<td>(0.2847)</td>
<td>(0.1905)</td>
<td>(0.0444)</td>
<td>(0.1539)</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.5129</td>
<td>-0.0011</td>
<td>0.4882</td>
<td>0.1170</td>
<td>0.0176</td>
<td>0.4215</td>
</tr>
<tr>
<td></td>
<td>(0.0766)</td>
<td>(0.0452)</td>
<td>(0.0845)</td>
<td>(0.0688)</td>
<td>(0.0387)</td>
<td>(0.0706)</td>
</tr>
<tr>
<td>Spain</td>
<td>0.7067**</td>
<td>-0.0406</td>
<td>0.3339</td>
<td>-0.1906</td>
<td>0.0280</td>
<td>0.3130**</td>
</tr>
<tr>
<td></td>
<td>(0.1329)</td>
<td>(0.4130)</td>
<td>(0.3736)</td>
<td>(0.1708)</td>
<td>(0.0643)</td>
<td>(0.1356)</td>
</tr>
</tbody>
</table>
Note: The ** indicate statistical significance at the 5 percent level.

**Table 7: Panel Estimates of the Fiscal Parameters Before and After Maastricht Treaty**

<table>
<thead>
<tr>
<th></th>
<th>$\beta_1$</th>
<th>$\frac{\beta_2}{\phi}$</th>
<th>$\frac{\beta_3}{r}$</th>
<th>$\pi_1$</th>
<th>$\pi_2$</th>
<th>$\pi_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Maastricht</td>
<td>0.3205**</td>
<td>-0.0060</td>
<td>0.6855</td>
<td>0.0854</td>
<td>-0.1831**</td>
<td>0.1212</td>
</tr>
<tr>
<td></td>
<td>(0.1219)</td>
<td>(1.3239)</td>
<td>(1.2825)</td>
<td>(0.1079)</td>
<td>(0.0451)</td>
<td>(0.0685)</td>
</tr>
<tr>
<td>Post-Maastricht</td>
<td>0.3186**</td>
<td>-0.0501</td>
<td>0.7315</td>
<td>0.0909</td>
<td>-0.0521</td>
<td>0.3302**</td>
</tr>
<tr>
<td></td>
<td>(0.1425)</td>
<td>(1.5249)</td>
<td>(1.4951)</td>
<td>(0.0935)</td>
<td>(0.0759)</td>
<td>(0.1318)</td>
</tr>
</tbody>
</table>

Note: The ** indicate statistical significance at the 5 percent level.
References


[31] Leeper, Eric (2010), "Monetary Science, Fiscal Alchemy," manuscript, University of Indiana.


