Fiscal Sustainability of Eurozone Governments: An Empirical Review of the Past Decade

Astrid Ayala1 & Szabolcs Blazsek1

1 School of Business, Universidad Francisco Marroquín, Guatemala

Correspondence: Szabolcs Blazsek, School of Business, Universidad Francisco Marroquín, Edificio de la Escuela de Negocios, 4to nivel, 6 Calle final, zona 10, 01010 Ciudad de Guatemala, Guatemala. Tel: 502-2338-7783. E-mail: sblazsek@ufm.edu

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Abstract

We provide an empirical review of fiscal sustainability of Eurozone governments by using quarterly data on debt to Gross Domestic Product (GDP) and primary deficit to GDP over the period 1999 to 2010. We verify the conditions of fiscal sustainability, defined by the government’s present value borrowing constraint, by applying unit root tests that involve one, two, or multiple structural breaks. We select the best performing model of structural breaks and group Eurozone governments with respect to fiscal sustainability.

Keywords: European Monetary Union, public finances, structural breaks, global financial and economic crises

1. Introduction

In the 1990s, the European Union (EU) countries established the Economic and Monetary Union (EMU or Eurozone, henceforth) and adopted the Euro as a common currency. The EU member states have accepted various criteria, the so-called ‘Maastricht convergence criteria’, for the entrance to the Eurozone. The Maastricht public finance criteria have been included in the Stability and Growth Pact (SGP). In the SGP, the member states of the EMU committed themselves to strict public financial rules: a maximum government debt to Gross Domestic Product (GDP) of 60% and a maximum budget deficit to GDP of 3%. The European Commission (EC) has been responsible for enforcing the SGP and verifying the quality of statistical data reported by national governments. In 1998, 11 EU member states had met the Maastricht criteria, and the Eurozone initiated with the official launch of the Euro on 1 January 1999 with the following member states: Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. Since 1999 other EU-member states have joined the EMU: Greece in 2001; Slovenia in 2007; Cyprus, Malta and Slovakia in 2008; Estonia in 2011; Latvia in 2014.

The present article is motivated by the fact that several governments of the Eurozone have experienced high deficit and an increasing level of public debt as a consequence of the 2008 subprime mortgage crisis of the United States (US) and the subsequent global economic and financial meltdown. This has initiated debates about fiscal sustainability, crisis management and the prevention of future crises in the Eurozone. See Gros and Mayer (2010), and Marzinotto, Pisani-Ferry, and Sapir (2010). Due to the global development of financial markets experienced in the past decades, financial institutions and governments have become significantly interrelated. Consequently, an indebted national government may affect negatively the financial sector. On the other hand, a financial sector with large losses, for example due to an outsized real estate bubble, may generate default of public finances. See Dabrowski (2010), Gros (2010), and Lachman (2010). Several authors report that the sovereign debt crisis for some countries of the Eurozone has been related with the significant and unsustainable debt accumulation of the private sector (e.g., Ireland and Spain), while in other countries with the governments’ mismanagement of public finances (e.g., Greece and Portugal). See De Grauwe (2010), Gros (2010), Arghyrou and Tsoukalas (2011), Featherstone (2011), and Mamadouh and van der Wusten (2011).

We provide an empirical analysis of Eurozone government debt sustainability based on historical data. We use different unit root tests for the debt to GDP and primary deficit to GDP to evaluate the fiscal sustainability of Eurozone governments over the past decade. These unit root tests may involve one, two, or multiple structural breaks. Our framework extends the classical test of fiscal sustainability of Hamilton and Flavin (1986), where the Augmented Dickey-Fuller (ADF, 1979) unit root test is applied. The tests proposed in this article may have
more statistical power in periods of economic crisis than the ADF test. Furthermore, they estimate breakpoint
dates endogenously, providing additional information about the evolution of fiscal ratios and fiscal sustainability.
The statistical findings presented in this article provide an empirical review of government finances from 1999 to
2010. The results reported show how the evolution of fiscal ratios may have affected sovereign debt investors’
beliefs about government debt sustainability and sovereign credit risk in the Eurozone over the past decade.

The remaining part of this article is organized as follows. Section 2 describes the economic foundation of fiscal
sustainability tests: the government’s present value borrowing constraint. Section 3 reviews the fiscal
data applied. Section 4 summarizes the classical ADF test results on fiscal sustainability. Section 5 reports the
extended unit root test results on fiscal sustainability. Robustness analysis results are reported in Section 6.
Finally, we summarize and conclude in Section 7.

2. Fiscal Sustainability

In the existing literature, several papers argue that the government is subject to a present value borrowing
constraint (e.g., Hamilton & Flavin,1986; Trehan & Walsh, 1991; Alfonso & Rault, 2007; Hallett & Lewis,
2007), which establishes that the present value of the current stock of sovereign debt is identical to the present
value of future fiscal balances. The government’s borrowing constraint can be derived as follows. The current
sovereign debt level, \( B_t \), can be expressed as the sum of the debt in the previous period, the corresponding
interest payments, \( \mathcal{R}B_{t-1} \) and the current primary deficit, \( PD_t \):

\[
B_t = (1 + r_t)B_{t-1} + PD_t \tag{1}
\]

Dividing this equation by the GDP denoted by \( G_t \), we get

\[
\frac{B_t}{G_t} = \frac{B_{t-1}(1 + r_t)}{G_{t-1}(1 + g_t)} + \frac{PD_t}{G_t} \tag{2}
\]

where \( g_t \) denotes the GDP growth rate. It can be derived from these equations that the government’s present
value borrowing constraint at \( t = 0 \) for an infinite time horizon is given by

\[
b_0 = \lim_{t \to \infty} b_t \left( \frac{1 + r_t}{1 + g_t} \right)^{-t} - \sum_{t=1}^{\infty} pd_t \left( \frac{1 + r_t}{1 + g_t} \right)^{-t} \tag{3}
\]

where \( b_t = B_t/G_t \) and \( pd_t = PD_t/G_t \). The present value borrowing constraint has been used to define the
concept of fiscal sustainability in the literature. Moreover, it has also motivated statistical tests of fiscal
sustainability, since fiscal sustainability requires both \( b_t \) and \( pd_t \) to be non-explosive according to Equation
(3).

Several authors have proposed the application of unit root tests for fiscal variables to verify fiscal sustainability
(e.g., Hamilton & Flavin 1986; Trehan & Walsh 1991; Alfonso & Rault, 2007). Hamilton and Flavin (1986) use
ADF unit root tests to verify the sustainability of US government debt. Trehan and Walsh (1991), in a unit root
test framework, state: ‘We call a budget process sustainable if the expected present discounted value of the
implied future stock of debt converges to zero.’ Furthermore, Alfonso and Rault (2007) state that the stationarity
of government debt is a required for the fiscal sustainability of EU governments. Using different unit root tests,
these authors conclude that: ‘Sustainability of a given fiscal position requires that all national debt be eventually
repaid. The debt ratio must be non-explosive and must ultimately converge on some finite limit.’

3. Sovereign Debt and Deficit Data

We use data on quarterly public debt to GDP and primary deficit to GDP ratios for the period 1990 to 2010
obtained from the Eurostat Statistics Database of the EC. Since the quarterly deficit to GDP ratios exhibit
significant seasonality effects, we use the Holt-Winters exponential smoothing method to remove the seasonality
component from these data (see Holt, 1959; Winters, 1960). The list of countries analyzed, the corresponding
period observed for each state and some descriptive statistics for debt to GDP and smoothed primary deficit to
GDP data are presented in Tables 1 and 2, respectively. In this article, we focus on the 17 member states which
joined the Eurozone before 2014.

Table 1 shows that the debt to GDP ratio is heterogeneous within the Eurozone. Greece has the maximum value
of debt to GDP (142.80%), while Estonia presents the lowest debt to GDP ratio (3.40%) over the sample period.
Table 1 also shows that the countries with the highest mean debt to GDP ratio are Italy (110.34%), Greece
(108.60%) and Belgium (100.78%). Moreover, the highest standard deviations (SDs) of debt to GDP over the
period analyzed are exhibited by: Ireland (17.91%), Portugal (12.29%) and Greece (11.67%), reflecting
substantial changes in the public debt levels over the period 2000 to 2010.
Table 2 exhibits that the statistics of the smoothed primary deficit to GDP ratio are very different in each country of the Eurozone. Ireland has the maximum value of primary deficit to GDP (29.53%), while Finland presents the lowest deficit to GDP ratio (-9.24%) over the sample period. Table 2 also shows that the countries with the highest mean deficit to GDP ratio are Slovakia (2.39%), Portugal (2.14%) and Greece (2.01%). Moreover, the highest SDs of deficit to GDP over the period analyzed are exhibited by: Ireland (9.02%), Spain (6.09%) and Greece (4.20%), evidencing high volatility in the government deficit to GDP levels during the last decade.

<table>
<thead>
<tr>
<th>Country</th>
<th>Start</th>
<th>End</th>
<th>T</th>
<th>Mean</th>
<th>Med</th>
<th>Max</th>
<th>Min</th>
<th>SD</th>
<th>Skew</th>
<th>Kurt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>68.582</td>
<td>69.700</td>
<td>72.700</td>
<td>60.700</td>
<td>3.298</td>
<td>-0.930</td>
<td>-0.122</td>
</tr>
<tr>
<td>Belgium</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>48</td>
<td>100.783</td>
<td>99.650</td>
<td>120.100</td>
<td>84.200</td>
<td>9.500</td>
<td>0.273</td>
<td>-0.786</td>
</tr>
<tr>
<td>Cyprus</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>63.068</td>
<td>64.000</td>
<td>73.000</td>
<td>48.300</td>
<td>6.450</td>
<td>-0.615</td>
<td>-0.355</td>
</tr>
<tr>
<td>Estonia</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>5.100</td>
<td>5.000</td>
<td>7.200</td>
<td>3.400</td>
<td>0.941</td>
<td>0.373</td>
<td>-0.168</td>
</tr>
<tr>
<td>Finland</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>40.975</td>
<td>41.450</td>
<td>48.400</td>
<td>30.000</td>
<td>4.285</td>
<td>7.128</td>
<td>1.153</td>
</tr>
<tr>
<td>France</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>48</td>
<td>64.821</td>
<td>64.800</td>
<td>82.900</td>
<td>56.400</td>
<td>7.285</td>
<td>1.153</td>
<td>0.763</td>
</tr>
<tr>
<td>Germany</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>65.764</td>
<td>65.700</td>
<td>83.200</td>
<td>58.300</td>
<td>5.299</td>
<td>0.898</td>
<td>1.370</td>
</tr>
<tr>
<td>Greece</td>
<td>2000 Q4</td>
<td>2010 Q4</td>
<td>41</td>
<td>108.602</td>
<td>104.700</td>
<td>142.80</td>
<td>97.300</td>
<td>11.669</td>
<td>1.636</td>
<td>1.756</td>
</tr>
<tr>
<td>Ireland</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>39.741</td>
<td>32.600</td>
<td>96.200</td>
<td>24.700</td>
<td>17.906</td>
<td>1.894</td>
<td>2.873</td>
</tr>
<tr>
<td>Italy</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>48</td>
<td>110.335</td>
<td>109.050</td>
<td>119.60</td>
<td>103.60</td>
<td>4.381</td>
<td>0.629</td>
<td>-0.568</td>
</tr>
<tr>
<td>Malta</td>
<td>2000 Q4</td>
<td>2010 Q4</td>
<td>41</td>
<td>65.361</td>
<td>65.300</td>
<td>73.300</td>
<td>48.200</td>
<td>6.500</td>
<td>-0.020</td>
<td>-0.854</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1999 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>5.320</td>
<td>52.400</td>
<td>63.100</td>
<td>45.300</td>
<td>7.897</td>
<td>1.153</td>
<td>0.763</td>
</tr>
<tr>
<td>Portugal</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>63.095</td>
<td>60.550</td>
<td>93.000</td>
<td>48.200</td>
<td>12.285</td>
<td>0.841</td>
<td>-0.091</td>
</tr>
<tr>
<td>Slovakia</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>38.816</td>
<td>38.550</td>
<td>51.700</td>
<td>25.800</td>
<td>7.897</td>
<td>0.555</td>
<td>-1.193</td>
</tr>
<tr>
<td>Slovenia</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>27.870</td>
<td>27.200</td>
<td>38.000</td>
<td>21.900</td>
<td>4.081</td>
<td>1.357</td>
<td>1.554</td>
</tr>
<tr>
<td>Spain</td>
<td>2000 Q1</td>
<td>2010 Q4</td>
<td>44</td>
<td>48.539</td>
<td>48.700</td>
<td>61.000</td>
<td>35.300</td>
<td>7.854</td>
<td>-0.081</td>
<td>-1.238</td>
</tr>
</tbody>
</table>

Description: The scale of the data series is in percentage points. The columns Start and End show the first and last quarter observed for each country, respectively. Mean, Med, Max, Min, SD, Skew and Kurt denote sample size, median, maximum, minimum, standard deviation, skewness, and kurtosis, respectively.
4. Classical Test of Fiscal Sustainability

We study the fiscal sustainability of Eurozone governments by testing if government debt to GDP and primary deficit to GDP ratios are stationarity or explosive over the period 1990 to 2010. We perform different unit root tests for these fiscal ratios. The null hypothesis, H₀ of these tests is that fiscal data form an unstable unit root process, while according to the alternative hypothesis, H₁ fiscal ratios are covariance stationary. See the definitions of covariance stationary and unit root processes in Hamilton (1994).

In the remaining part of this article, \( y_t \) is used to denote both debt to GDP and primary deficit to GDP ratios.

The initial unit root test employed is the ADF test with a constant term. The ADF test is performed by estimating the following regression model:

\[
\Delta y_t = \delta Z_t + \varphi y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t
\]  

where \( \Delta y_t = y_t - y_{t-1} \) denotes the first difference of \( y_t \), the deterministic terms are given by \( Z_t \), augmentation terms, \( \Delta y_{t-j} \) with \( j = 1, \ldots, k \), are added to eliminate possible serial correlation and \( e_t \) is an i.i.d. error term with zero mean and finite variance.

The first column of Tables 3 and 4 presents the ADF test statistics for debt to GDP and primary deficit to GDP, respectively. These tables show that the unit root null hypothesis can be rejected only for Austria for both fiscal ratios. Therefore, according to the approach of Hamilton and Flavin (1986), the evolution of the debt to GDP ratio is not compatible with fiscal sustainability for the other 16 member states of the Eurozone. We conclude that 16 countries from the 17 EMU states have unsustainable public finances according to the ADF test.

Table 3. Unit root tests with constant term for the government debt to GDP ratio

<table>
<thead>
<tr>
<th>Country</th>
<th>ADF</th>
<th>( R^2 )</th>
<th>LS (2004)</th>
<th>( T_B )</th>
<th>( R^2 )</th>
<th>LS (2003)</th>
<th>( T_{1B} )</th>
<th>( T_{2B} )</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>-3.431**</td>
<td>43.08%</td>
<td>-3.689**</td>
<td>2005 Q3</td>
<td>54.22%</td>
<td>-4.375**</td>
<td>2005 Q3</td>
<td>2007 Q2</td>
<td>59.51%</td>
</tr>
<tr>
<td>Belgium</td>
<td>-2.197(UR)</td>
<td>57.91%</td>
<td>-2.856(UR)</td>
<td>2009 Q3</td>
<td>60.15%</td>
<td>-3.299***</td>
<td>2003 Q3</td>
<td>2007 Q4</td>
<td>60.87%</td>
</tr>
<tr>
<td>Cyprus</td>
<td>-2.216(UR)</td>
<td>6.33%</td>
<td>-2.457(UR)</td>
<td>2003 Q3</td>
<td>14.39%</td>
<td>-2.950*</td>
<td>2005 Q3</td>
<td>2007 Q3</td>
<td>15.64%</td>
</tr>
<tr>
<td>Estonia</td>
<td>-1.418(UR)</td>
<td>16.37%</td>
<td>-2.762(UR)</td>
<td>2007 Q3</td>
<td>29.85%</td>
<td>-3.532**</td>
<td>2004 Q4</td>
<td>2008 Q3</td>
<td>42.59%</td>
</tr>
<tr>
<td>Finland</td>
<td>-1.089(UR)</td>
<td>4.41%</td>
<td>-2.781(UR)</td>
<td>2008 Q3</td>
<td>37.60%</td>
<td>-4.376***</td>
<td>2003 Q3</td>
<td>2007 Q1</td>
<td>40.85%</td>
</tr>
<tr>
<td>France</td>
<td>0.629(UR)</td>
<td>12.78%</td>
<td>-4.026**</td>
<td>2007 Q1</td>
<td>37.60%</td>
<td>-2.063(UR)</td>
<td>2004 Q3</td>
<td>2005 Q4</td>
<td>27.37%</td>
</tr>
<tr>
<td>Germany</td>
<td>1.680(UR)</td>
<td>8.25%</td>
<td>-2.484(UR)</td>
<td>2008 Q4</td>
<td>28.99%</td>
<td>-3.234**</td>
<td>2009 Q1</td>
<td>2009 Q4</td>
<td>31.10%</td>
</tr>
<tr>
<td>Greece</td>
<td>2.148(UR)</td>
<td>19.65%</td>
<td>-1.953(UR)</td>
<td>2004 Q3</td>
<td>23.39%</td>
<td>-2.063(UR)</td>
<td>2004 Q3</td>
<td>2005 Q4</td>
<td>27.37%</td>
</tr>
<tr>
<td>Ireland</td>
<td>2.202(UR)</td>
<td>24.94%</td>
<td>-2.344(UR)</td>
<td>2009 Q2</td>
<td>42.08%</td>
<td>-2.758(UR)</td>
<td>2002 Q3</td>
<td>2009 Q2</td>
<td>56.12%</td>
</tr>
<tr>
<td>Italy</td>
<td>-1.546(UR)</td>
<td>49.89%</td>
<td>-3.026(UR)</td>
<td>2007 Q4</td>
<td>46.46%</td>
<td>-3.842***</td>
<td>2002 Q3</td>
<td>2008 Q4</td>
<td>67.02%</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>0.658(UR)</td>
<td>-1.72%</td>
<td>-2.109(UR)</td>
<td>2008 Q3</td>
<td>77.99%</td>
<td>-2.656(UR)</td>
<td>2003 Q4</td>
<td>2008 Q3</td>
<td>73.88%</td>
</tr>
<tr>
<td>Malta</td>
<td>-1.980(UR)</td>
<td>11.17%</td>
<td>-2.124(UR)</td>
<td>2006 Q1</td>
<td>17.02%</td>
<td>-2.267(UR)</td>
<td>2004 Q3</td>
<td>2006 Q1</td>
<td>15.12%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>-1.445(UR)</td>
<td>2.02%</td>
<td>-1.787(UR)</td>
<td>2008 Q3</td>
<td>77.44%</td>
<td>-3.037</td>
<td>2001 Q3</td>
<td>2008 Q3</td>
<td>81.25%</td>
</tr>
<tr>
<td>Portugal</td>
<td>3.296(UR)</td>
<td>17.95%</td>
<td>-2.673(UR)</td>
<td>2009 Q1</td>
<td>21.26%</td>
<td>-2.967*</td>
<td>2009 Q1</td>
<td>2009 Q3</td>
<td>25.43%</td>
</tr>
<tr>
<td>Slovakia</td>
<td>-1.790(UR)</td>
<td>1.17%</td>
<td>-2.075(UR)</td>
<td>2007 Q2</td>
<td>18.51%</td>
<td>-2.613(UR)</td>
<td>2005 Q1</td>
<td>2007 Q4</td>
<td>34.39%</td>
</tr>
<tr>
<td>Slovenia</td>
<td>-0.917(UR)</td>
<td>5.12%</td>
<td>-2.026(UR)</td>
<td>2009 Q1</td>
<td>27.83%</td>
<td>-2.479(UR)</td>
<td>2005 Q1</td>
<td>2009 Q3</td>
<td>18.26%</td>
</tr>
<tr>
<td>Spain</td>
<td>-1.383(UR)</td>
<td>63.17%</td>
<td>-2.722(UR)</td>
<td>2008 Q4</td>
<td>78.18%</td>
<td>-2.909*</td>
<td>2003 Q2</td>
<td>2008 Q4</td>
<td>70.05%</td>
</tr>
</tbody>
</table>

Description: Augmented Dickey-Fuller (ADF). Lee and Strazicich (LS). Unit Root (UR). \( T_B \) and \( T_{1B} \) denote the quarter of the structural change. Bold numbers indicate the model with the highest adjusted R-squared, \( R^2 \), value for each country. The adjusted R-squared is computed by \( R^2 = 1 - (1 - R^2)(1 - T)/(1 - k - T) \), where \( R^2 \) corresponds to the R-squared of the regressions of Equations (4) and (5). Moreover, \( T \) is the sample size and \( k \) denotes the number of parameters in each equation. Bold numbers indicate the model with the highest \( R^2 \) value. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.
Table 4. Unit root tests with constant term for the smoothed primary deficit to GDP ratio

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>-3.219***</td>
<td>24.86%</td>
<td>-3.865***</td>
<td>2004 Q1</td>
<td>30.60%</td>
<td>-4.730***</td>
<td>2004 Q1</td>
<td>2009 Q1</td>
<td>43.47%</td>
</tr>
<tr>
<td>Belgium</td>
<td>-0.771(UR)</td>
<td>72.33%</td>
<td>-1.853(UR)</td>
<td>2003 Q1</td>
<td>73.57%</td>
<td>-2.571(UR)</td>
<td>2005 Q1</td>
<td>2009 Q1</td>
<td>78.21%</td>
</tr>
<tr>
<td>Cyprus</td>
<td>-1.998(UR)</td>
<td>60.17%</td>
<td>-5.193***</td>
<td>2005 Q1</td>
<td>68.97%</td>
<td>-5.890***</td>
<td>2003 Q4</td>
<td>2008 Q4</td>
<td>72.24%</td>
</tr>
<tr>
<td>Estonia</td>
<td>-2.259(UR)</td>
<td>35.94%</td>
<td>-3.515*</td>
<td>2006 Q4</td>
<td>39.55%</td>
<td>-3.811***</td>
<td>2007 Q4</td>
<td>2009 Q3</td>
<td>44.47%</td>
</tr>
<tr>
<td>Finland</td>
<td>-2.143(UR)</td>
<td>80.77%</td>
<td>-5.634***</td>
<td>2008 Q4</td>
<td>86.43%</td>
<td>-6.892***</td>
<td>2001 Q4</td>
<td>2009 Q1</td>
<td>89.42%</td>
</tr>
<tr>
<td>France</td>
<td>-1.599(UR)</td>
<td>83.57%</td>
<td>-3.267*</td>
<td>2007 Q1</td>
<td>85.94%</td>
<td>-3.862***</td>
<td>2001 Q2</td>
<td>2009 Q2</td>
<td>86.73%</td>
</tr>
<tr>
<td>Germany</td>
<td>-2.109(UR)</td>
<td>41.17%</td>
<td>-3.937***</td>
<td>2009 Q3</td>
<td>58.67%</td>
<td>-4.723***</td>
<td>2000 Q4</td>
<td>2008 Q3</td>
<td>67.58%</td>
</tr>
<tr>
<td>Greece</td>
<td>-1.971(UR)</td>
<td>25.71%</td>
<td>-3.014(UR)</td>
<td>2009 Q2</td>
<td>31.30%</td>
<td>-3.465***</td>
<td>2004 Q3</td>
<td>2009 Q2</td>
<td>21.26%</td>
</tr>
<tr>
<td>Ireland</td>
<td>2.706(UR)</td>
<td>52.62%</td>
<td>-1.737(UR)</td>
<td>2008 Q3</td>
<td>62.32%</td>
<td>-2.415(UR)</td>
<td>2003 Q4</td>
<td>2006 Q3</td>
<td>63.18%</td>
</tr>
<tr>
<td>Italy</td>
<td>-1.354(UR)</td>
<td>59.74%</td>
<td>-3.356*</td>
<td>2002 Q4</td>
<td>64.86%</td>
<td>-3.924***</td>
<td>2001 Q1</td>
<td>2009 Q1</td>
<td>69.96%</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>-2.385(UR)</td>
<td>62.76%</td>
<td>-4.292***</td>
<td>2001 Q3</td>
<td>66.55%</td>
<td>-4.824***</td>
<td>2003 Q1</td>
<td>2009 Q2</td>
<td>66.91%</td>
</tr>
<tr>
<td>Malta</td>
<td>-2.544(UR)</td>
<td>19.90%</td>
<td>-2.554(UR)</td>
<td>2002 Q3</td>
<td>17.76%</td>
<td>-3.197**</td>
<td>2003 Q2</td>
<td>2008 Q1</td>
<td>33.83%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>-2.144(UR)</td>
<td>51.49%</td>
<td>-3.747***</td>
<td>2008 Q2</td>
<td>52.04%</td>
<td>-4.218***</td>
<td>2001 Q2</td>
<td>2009 Q2</td>
<td>58.45%</td>
</tr>
<tr>
<td>Portugal</td>
<td>-2.417(UR)</td>
<td>38.13%</td>
<td>-2.277(UR)</td>
<td>2008 Q3</td>
<td>41.17%</td>
<td>-2.868*</td>
<td>2003 Q4</td>
<td>2008 Q3</td>
<td>39.26%</td>
</tr>
<tr>
<td>Slovakia</td>
<td>-2.161(UR)</td>
<td>60.65%</td>
<td>-3.081(UR)</td>
<td>2002 Q4</td>
<td>61.04%</td>
<td>-3.879***</td>
<td>2002 Q1</td>
<td>2009 Q1</td>
<td>64.24%</td>
</tr>
<tr>
<td>Slovenia</td>
<td>-2.600(UR)</td>
<td>30.71%</td>
<td>-2.627(UR)</td>
<td>2008 Q1</td>
<td>28.63%</td>
<td>-2.803*</td>
<td>2001 Q2</td>
<td>2009 Q1</td>
<td>31.53%</td>
</tr>
<tr>
<td>Spain</td>
<td>-0.836(UR)</td>
<td>66.91%</td>
<td>-4.140**</td>
<td>2008 Q4</td>
<td>76.86%</td>
<td>-5.228***</td>
<td>2003 Q2</td>
<td>2009 Q1</td>
<td>91.72%</td>
</tr>
</tbody>
</table>

Description: Augmented Dickey-Fuller (ADF). Lee and Strazicich (LS, henceforth, 2004) have addressed the problem of spurious rejection of $H_0$ by introducing unit root tests with and without one and two breaks, respectively, considering structural break(s) under the null hypothesis. The LS tests applied in this article allow for structural change(s) in the model’s constant term. Moreover, these structural breakpoint dates are identified endogenously in these tests. In the LS (2003, 2004) tests, the following equation is estimated:

5. Extended Tests of Fiscal Sustainability

The financial, economic and public debt crises in the Eurozone of the last years implied structural breaks in public finance ratios in several countries. These motivate the application of more general unit root tests that account for structural changes in the public finances of Eurozone member states. The unit root tests with structural breaks considered in this article verify a weaker form of fiscal sustainability since they imply non-stationary time series under both $H_0$ and $H_1$ hypotheses. However, they may evidence stationary behavior around the estimated structural change dates when the $H_0$ unit root hypothesis is rejected, which would imply predictable fiscal time series. Moreover, the extended unit root tests proposed in this article identify the dates of structural changes over the period 1990 to 2010 in an endogenous manner.

In the following, we briefly review existing unit root tests that incorporate structural changes. There are several unit root tests in the econometric literature which consider the possibility of one structural break in the data series. Perron (1989) considers a unit root test with one structural break with known (exogenous) breakpoint date. This paper has been extended by Zivot and Andrews (1992) who determine the structural breakpoint date endogenously. Additional works that estimate the time of the break endogenously in unit root tests are Perron (1997) and Vogelsang and Perron (1998).

Lee and Strazicich (LS, henceforth, 2004) argue that one important issue regarding these endogenous break point unit root tests is that they omit the possibility of a unit root with break under the null hypothesis. Therefore, spurious rejections of $H_0$ may occur, questioning the statistical validity of these tests. Furthermore, unit root tests with a single structural break do not take into account that several changes may occur in the level of the variable of interest. This fact has motivated Lumsdaine and Papell (1997) to extend the analysis of Zivot and Andrews (1992) to include two structural breaks. However, Lumsdaine and Papell (1997) have not considered structural breaks under the null hypothesis in their model. Therefore, spurious rejections may occur as it was noted previously.

LS (2004) and LS (2003) have addressed the problem of spurious rejection of $H_0$ by introducing unit root tests with one and two breaks, respectively, considering structural break(s) under the null hypothesis. The LS tests applied in this article allow for structural change(s) in the model’s constant term. Moreover, these structural breakpoint dates are identified endogenously in these tests. In the LS (2003, 2004) tests, the following equation is estimated:
\[
\Delta y_t = \delta' \Delta Z_t + \varphi \Delta \hat{S}_{t-1} + \sum_{j=1}^{k} c_j \Delta S_{t-j} + e_t
\]
(5)

where \( \hat{S}_t = y_t - \varphi_1 - Z_t \delta \) and \( \varphi_1 = y_t - Z_1 \delta \). The \( \delta \) parameters denote coefficients estimated by a regression of \( \Delta y_t \) on \( \Delta Z_t \). Moreover, \( k \) augmentation terms, \( \Delta S_{t-j} \) with \( j = 1, \ldots, k \), are included to correct for serial correlation of the error terms \( e_t \). See LS (2004) for the selection of the number of augmentation terms, \( k \) in Equation (5). In LS (2004), \( Z_t = (1, t, D_t)' \) and \( \Delta Z_t = (1, \Delta D_t)' \). Therefore, this model includes one date of structural change in the constant parameter. In LS (2003), \( Z_t = (1, t, D_{t1}, D_{2t})' \) and \( \Delta Z_t = (1, \Delta D_{t1}, \Delta D_{2t})' \). Thus, this specification considers two different dates of structural changes in the constant parameter.

The unit root test results and the quarters of structural changes estimated by these models are shown in Tables 3 and 4 for the debt to GDP and deficit to GDP ratios, respectively. In order to choose the most appropriate model for the EMU fiscal data, we have computed the adjusted R-squared, \( R^2_a \), for the test equation of the ADF and LS (2003, 2004) unit root tests. Table 3 and 4 report these metrics, indicating the best model by bold numbers. We can see in Tables 3 and 4 that the \( R^2_a \) of the ADF test is lower than the model performance metric of LS (2003, 2004) in all cases. This confirms the application of structural changes when public finances of the Eurozone are analyzed over the period 1999 to 2010. In the following, we focus on the implications of the best econometric model identified by the highest \( R^2_a \) estimates for each country.

Tables 3 and 4 for debt to GDP and deficit to GDP, respectively, report the number of structural changes and the corresponding breakpoint dates. For the debt to GDP variable, one structural break is found for Cyprus (2008 Q2), Luxembourg (2008 Q3), Malta (2006 Q1), Slovenia (2009 Q1) and Spain (2008 Q4). Moreover, two dates of structural changes in debt to GDP are evidenced for the rest of the Eurozone states. For the deficit to GDP variable, one structural break is estimated for Greece (2009 Q2) and Portugal (2008 Q3). For the rest of the EMU countries, two breaks are found in the deficit to GDP time series.

We find breaking level stationary debt to GDP for the following governments: Austria, Belgium, Estonia, Finland, France, Germany, Italy, and the Netherlands. These countries represent a suddenly increased and then stabilized level of debt to GDP. On the other hand, breaking level unit root process is found for government debt to GDP for Cyprus, Greece, Ireland, Luxembourg, Malta, Portugal, Slovakia, Slovenia, and Spain. In these countries, the debt to GDP time series is explosive according to the breaking level unit root tests. Furthermore, the best performing unit root test evidences breaking level unit root deficit to GDP for Greece, Ireland, and Portugal. For other EMU states, we find breaking level stationary deficit to GDP process.

6. Robustness Analysis

The unit root test results reported in Tables 3 and 4 show that, in several cases, the model with two structural breaks has the highest \( R^2_a \) value. However, unit root tests with more than two structural breaks may explain better the evolution of the fiscal variables. To verify the robustness of the results for the unit root test with two structural breaks, we employed a unit root test with three structural breaks, extending the framework of LS (2003). We estimated Equation (5) with \( Z_t = (1, t, D_{t1}, D_{2t}, D_{3t})' \) and \( \Delta Z_t = (1, \Delta D_{t1}, \Delta D_{2t}, \Delta D_{3t})' \). The critical values of this test are obtained by 5000 replications of the model in a way similar to LS (2003). We perform the test with three structural breaks for the countries where the LS (2003) model has the highest \( R^2_a \) value. In the testing procedure, we use the \( T_{1B} \) and \( T_{2B} \) dates estimated by the LS (2003) model (see Tables 3 and 4), while \( T_{3B} \) is determined endogenously. This approach is similar to the idea of Bai and Perron (1998), who test for \( l \) versus \( l+1 \) breaks conditioning on the locations of \( l \) breaks. See also Bai and Perron (2003) and Wang and Zivot (2000). Furthermore, conditioning on two previously estimated breaks, reduces the computation time substantially. We find that the \( R^2_a \) of the three-break unit root test is lower than the \( R^2_a \) of the two-break test for all governments. Therefore, two breakpoints are preferred to three breakpoints according to the \( R^2_a \) metric.

7. Summary and Conclusions

We use different unit root tests to assess fiscal sustainability of all member states of the Eurozone over the period 1999 to 2010. We apply different unit root tests for sovereign debt to GDP and primary deficit to GDP ratios to verify the conditions of fiscal sustainability derived from the government's present value borrowing constraint. The classical ADF test has not evidenced fiscal sustainability for 16 of the 17 EMU member states. However, this test does not consider the possibility of structural breaks. Therefore, we have considered the unit root tests involving structural breaks, as suggested by LS (2003, 2004). These tests include one or two structural changes in the fiscal variables to capture shifts in public finances over the crisis period. The specifications proposed by LS (2003, 2004) have shown better performance than the ADF test when comparing the \( R^2_a \) model selection metric of the different formulations. The LS (2003, 2004) tests identify endogenously the dates of structural changes for both the debt to GDP and primary deficit to GDP variables. We have tested for multiple structural
breaks and have found that models with one or two structural breaks are superior according to the $R^2_0$ measure. Based on the unit root test results, we classify the EMU governments into three groups:

a) Explosive debt to GDP and deficit to GDP governments: Greece, Ireland, and Portugal.

b) Explosive debt to GDP and breaking level stationary deficit to GDP governments: Cyprus, Luxembourg, Malta, Slovakia, Slovenia, and Spain.

c) Breaking level stationary debt to GDP and deficit to GDP governments: Austria, Belgium, Estonia, Finland, France, Germany, Italy, and the Netherlands.

These results provide an empirical review of sovereign debt sustainability from 1999 to 2010 for the Eurozone. The statistical tests involving structural changes identify the breakpoint dates and they can be used to forecast the evolution of future government debt to GDP and primary deficit to GDP in the Eurozone states. The results reported show how the evolution of fiscal ratios may have affected sovereign debt investors’ beliefs about government debt sustainability and sovereign credit risk in the Eurozone over the past decade. Furthermore, these results provide a clear insight on the correlation between fiscal sustainability of Eurozone countries and the EMU sovereign debt crisis.

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References


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