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Did the Euro Change the Effect of Fundamentals on Growth and Uncertainty?

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Contributions

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Did the euro change the effect of fundamentals on growth and uncertainty?

Abstract: We present empirical evidence on whether the introduction of the euro has changed the effect of economic fundamentals on the growth rates of euro countries' GDPpc and GDPpc volatility. We find that there is a statistically significant structural break in the impact of increments in government debt on both economic growth and uncertainty. In particular, after adoption of the euro increments in government debt decreased growth and increased uncertainty. These results are robust to a battery of checks, including exclusion of the recent financial crisis period, comparison with non-euro European countries, and controlling for different debt/GDP ratios.

Keywords: currency union; euro zone; fundamentals; GDPpc growth rate; GDPpc growth rate volatility; government debt.

1 Introduction

It is now well known that the primary benefits of monetary union for the members are lower transaction costs and lower inflation. Yet, a currency union also has costs; asymmetric economic shocks and a lack of flexible adjustment mechanisms can offset the economic benefits associated with a common currency [see Baldwin and Wyplosz (2006) and De Grauwe (1992) for an empirical investigation and Eichengreen (1991) for a survey of earlier works]. When members of a

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currency union have heterogeneous preferences on monetary policy, consensus can be hard to achieve.[1] As a consequence, there are likely impacts of economic fundamentals, such as government debt, on both economic growth and economic uncertainty when a country joins a currency union. Adoption of the euro by the first 12 euro zone countries, surely one of the most important events in the recent history of central banking and monetary policy, provides a natural laboratory for testing these questions.

Mundell's (1961) seminal work initiated an important line of research on optimum currency unions. Alesina and Barro (2002), Barro and Tenreyro (2007), and Frankel and Rose (2002) studied the effect of the adoption of a common currency by a set of heterogeneous countries on certain macroeconomic variables, such as volume of trade, price stability, and output.[2] We are not aware of any work that studies the specific question of whether adoption of the euro has changed the structural effect of fundamentals on economic growth and growth volatility. Our goal is to provide empirical evidence on this important question.

We consider the first 12 European countries that adopted the euro and conduct a cross-sectional empirical analysis between 1980 and 2011. We perform two main tests on the hypothesized change of the effect of economic fundamentals after adoption of the euro in 1999. The first test takes the per capita gross domestic product (GDPpc) growth rate as the dependent variable, while the second uses GDPpc growth rate volatility. The regression strategy in both tests follows two steps. We first recuperate the residuals from a panel regression of GDPpc growth rates on country and time fixed effects. A filtered growth rate would not reflect the growth rate from a country's specific economic structure or for a specific year. In the second step, we take these residuals as a proxy of GDPpc growth rates, and the absolute value of the residuals as a proxy of GDPpc growth rate volatilities. In both tests we see whether each coefficient is different and statistically significant before and after introduction of the euro. If coefficients are different, we say that there has been a structural break in the effect of the particular variable.

We find that adoption of the euro introduces a statistically significant structural break in the coefficient that measures the effect of government borrowing on economic growth. Before adoption of the euro, increments in government debt had a positive effect on economic growth, while after adoption increments in debt

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1 See Riboni and Ruge-Murcia (2010).

2 In particular, Alesina and Barro (2002) analyzed the trade-off between volume of trade and price stability in the formation of a currency union; Barro and Tenreyro (2007) investigated the impact of currency unions on bilateral trade and the extent of comovements of prices and outputs; and Frankel and Rose (2002) quantified the effect of common currencies on trade and output.

reduced growth. Both effects are statistically significant, suggesting the existence of a structural break. We have performed some robustness checks, and found that the effect of the growth rate of government debt on economic growth is not driven by the financial and sovereign crisis period of 2008–2011 and that the set of European non-euro countries do not exhibit such a structural break in 1999. In addition, we have performed a similar regression but using robust standard errors (meaning that the estimators of the standard errors are robust to the heteroskedasticty and also to the cross-sectional dependence that characterizes panel data), and the result on a structural break is similar.

These results contribute to the recent literature on government debt and growth. Our paper contributes to the academic debate by focusing on the euro zone countries and controlling for the historical change of their monetary institutions, country and time fixed effects, and other macroeconomic variables.

This literature has switched to examining whether the government debt may influence growth in a non-linear way; see Panizza and Presbitero (2013) for an excellent review of the literature, and the influential papers Reinhart and Rogoff (2010) and Reinhart, Rogoff, and Svastano (2003) for a result where increments in government debt dampen economic growth to countries with high debt/GDPpc levels.[3] Motivated by this debate, we pose the following question: Could it be possible that the structural break we see in the effect of government debt on growth is neither the result of the adoption of the euro, nor the matter of recent financial and sovereign crisis, but can be attributed to crossing the threshold level of debt above which the positive effect of debt on growth changes to negative? We have run several regressions that omit the observations that have a ratio of government debt to GDP above 50%, 70%, 90%, 110%, and 130%. For each of these thresholds, we observe the existence of a statistically significant structural break on the effect of government debt growth on GDPpc growth.

In our analysis of the effect of fundamentals on economic uncertainty we find that there is a structural break in the effect of government debt growth on real GDPpc growth volatility. This break is statistically significant at 1% significance level. Interestingly, this second main result is robust to exclusion of the recent financial and sovereign crisis (2008–2011 period). Furthermore, to test the results we repeat the empirical analysis for the European countries that did not adopt the euro. This test clearly indicates that this structural break is specific to the euro countries, and thus attributable to adoption of the euro. In addition, we checked whether the structural break is robust to using the square of the residuals as another proxy of volatility, and found that results do not qualitatively

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3 See also Afonso and Jalles (2013), Egert (2012), and Minea and Parent (2012).

change. Finally, we have tested whether the statistically significance of the structural break vanishes when condition our regression to a given ratio of government debt to GDP, and found that results do not change for thresholds 50%, 70%, 90%, 110%, and 130%.

The main result of this paper is that the adoption of the euro changed the impact of government debt on both economic growth and uncertainty. The economic intuition behind these effects can be summarized as follows. When the ability of a country to reduce the interests on its debt is reduced (or eliminated), new debt increments may weaken economic growth, particularly when new public investments produce at a rate lower than the debt's real interest rate. Moreover, new debt may increase economic uncertainty since a country that loses the instrument of monetary policy also loses the ability to stabilize the effect of leverage in the economy.

The paper is organized as follows. Section 2 offers a simple model specification that identifies relevant economic fundamentals that affect economic growth and uncertainty. Section 3 presents the data used in the paper. Section 4 presents the empirical analysis of the effect of fundamentals on economic growth. Section 5 presents the empirical analysis of the effect of fundamentals on economic uncertainty in a similar fashion. Section 6 concludes. The Appendix further explains the robustness checks and presents the associated tables and figures. Our robustness checks can be enumerated as follows: (i) exclusion of the financial crisis period 2008–2011; (ii) considering as an additional control variable the real exchange rates; (iii) re-running the main regressions for the non-euro European countries (control group), (iv) re-running the main regressions using estimators of the standard errors robust to the heteroskedasticity and also to the cross-sectional dependence that characterizes panel data, (v) re-running regression on economic uncertainty using instead the square of the residuals as a proxy for GDPpc growth rate's volatility, (vi) re-running the main regressions conditional on a given ratio of government debt to GDP, (vii) Hausman endogeneity test for government debt, and (viii) "cusum" test to see the constancy of the coefficients of each individual Eurozone country.

2 Model specification

Our contribution in this paper is empirical. However, one would like to have a simple model specification that identifies relevant economic fundamentals that affect economic growth, as measured in terms of the growth rate of per capita gross domestic product. We consider a country 1 with a Cobb-Douglas produc-

tion function where the final output is a function of the total factor productivity (A), the amount of labor employed (L), a nondurable intermediate input imported from another country 2 (M), and the amount of government expenditure (G). The economic intuition of input G is that there are productive government expenditures, such as public infrastructure, education, and the health system, that also affect the final level of the final output.[4] We omit transaction costs from the analysis; for a study of the effect of transaction costs on trade in the euro zone, see Tenreyro and Silva (2010). The production function of a representative firm in country 1 in period t is:

$$Y_t = A_t G_t^{\alpha_1} M_t^{\alpha_2} L_t^{1-\alpha_1-\alpha_2}. \tag{1}$$

As is common in the growth literature, the variable Y_t refers to country 1's gross domestic product (GDP) at the end of period t, while the variables on the right-hand side of equation (1) are dated as of the beginning of the period. All variables in (1) are expressed in aggregate real terms. We can write equation (1) in per capita (pc) terms by dividing both sides of the equation by country's population. We will use lower case letters to denote the variables in per capita terms, and rewrite equation (1) as follows:

$$y_t = A_t g_t^{\alpha_1} m_t^{\alpha_2} l_t^{1-\alpha_1-\alpha_2}. \tag{2}$$

We then loglinearize both sides of equation (2) and take the derivative with respect to time, and write:

$$\frac{\dot{y}_t}{y_t} = \frac{\dot{A}_t}{A_t} + \alpha_1 \frac{\dot{g}_t}{g_t} + \alpha_2 \frac{\dot{m}_t}{m_t} + \alpha_3 \frac{\dot{l}_t}{l_t}, \tag{3}$$

where $\dot{x}_t \simeq x_t - x_{t-1}$ denotes the variation with respect to time of a variable $x_t = y_t$, A_t, g_t, m_t, l_t. We can express the per capita government expenditure g_t as a function of new government gross debt b_t, per capita government revenue from taxes τ_t, and per capita debt inherited from the previous period and associated interests $r_t \equiv (1+i_t) b_{t-1}$, where i_t denotes the interest rate at period t on previous government debt.[5] The decomposition obeys the standard government budget constraint. The

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4 See Finn (1998) and Baxter and King (1993) for a similar approach of including G in a standard neoclassical production function.
5 In the literature, government debt is also referred to as "public debt," see Reinhart and Rogoff (2010). Note also that here, as in Barro's (1979) theory, growth rate of debt is independent of the debt-income ratio.

variation of government expenditure with respect to time can then be expressed as $\dot{g}_t = \alpha_3 \dot{b}_t + \alpha_4 \dot{\tau}_t + \alpha_5 \dot{r}_t$. We can then write:

$$\frac{\dot{y}_t}{y_t} = \psi_0 \frac{\dot{A}_t}{A_t} + \psi_1 \frac{\dot{b}_t}{g_t} + \psi_2 \frac{\dot{\tau}_t}{g_t} + \psi_3 \frac{\dot{r}_t}{g_t} + \psi_4 \frac{\dot{m}_t}{m_t} + \psi_5 \frac{\dot{l}_t}{l_t}, \tag{4}$$

where $\psi_0 = 1$, $\psi_1 = \alpha_1 \alpha_3$, $\psi_2 = \alpha_1 \alpha_4$, $\psi_3 = \alpha_1 \alpha_5$, $\psi_4 = \alpha_2$, and $\psi_5 = \alpha_3$. In steady state, GDPpc growth can be expressed as a function of growth rates of government borrowing, revenue, interest on debt, imports, and employment. The main equation that we use in our empirical analysis is the following:

$$\frac{\dot{y}}{y} = \psi_0 \frac{\dot{A}}{A} + \psi_1 \frac{b}{g} \frac{\dot{b}}{b} + \psi_2 \frac{\tau}{g} \frac{\dot{\tau}}{\tau} + \psi_3 \frac{r}{g} \frac{\dot{r}}{r} + \psi_4 \frac{\dot{m}}{m} + \psi_5 \frac{\dot{l}}{l}. \tag{5}$$

Variables $\dot{b}/b$, $\dot{\tau}/\tau$, and $\dot{r}/r$ are multiplied by their respective weight with respect to government expenditure. For instance, the weight of the growth rate of new government borrowing $\dot{b}/b$ is b/g, measured as the percentage of new debt with respect to government expenditure.[6]

Equation (5) shows the effect of fundamentals in growth rates on the GDPpc growth rate. The total factor productivity component in our empirical analysis below corresponds to the intercept in the regression strategy. The second covariate is the weighted growth rate of gross government debt, and, as we will see below, it is the variable that drives our main results. The remaining covariates are derived from the model and will be called "controls." Omitting these "controls" may produce results exaggerating the effect on the growth rate of government borrowing.

We aim to provide the first empirical evidence on whether there has been a structural break in the coefficient of these important economic fundamentals after adoption of the euro. For this, we first rewrite the coefficient ψ_j of a variable j as follows:

$$\psi_j = \begin{cases} \eta_j & \text{for } t \leq 1999, \\ \eta_j + \lambda_j & \text{for } t > 1999. \end{cases}$$

We say that there was a structural break in the effect of gross debt growth on economic growth after 1999 if $\lambda_1 \neq 0$. Similarly, we can define a structural break for the remaining variables.

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6 In our empirical analysis we obtain this ratio by dividing the percentage of gross debt with respect to GDP by the percentage of government expenditure with respect to GDP.

In order to understand the effect of government debt on economic growth and uncertainty when a country gives up its own monetary policy, we draw here the lines of a simple two-period model. Consider a situation where government debt issued in the first period is used only for public investment (transfers to households are not considered), and in the second period there is uncertainty as to realization of the marginal productivity associated with levered government public investment. Also assume that debt monetization is ruled out and there are only two states in the second period. In one state the returns from investing the public levered funds (marginal productivity mp_g) exceed the real interest rate on government borrowing (r), i.e., $mp_g > r$. In the other state the opposite happens, $mp_g < r$, i.e., the returns from the public levered investment are not enough to pay the interest on the debt.[7]

In this setting the country only has its nominal interest rate to try to revert the inequality $mp_g < r$ if a bad shock happens to occur. But once in a currency union, the country's ability to manipulate the interest rate by intervening in the secondary bond market is greatly reduced (now the decision is in hands of a supranational central bank). Then, if the state $mp_g < r$ occurs, issuing new debt becomes a tax, hampering economic growth, and increasing the uncertainty about the profitability of the country's public levered investments.

3 Data

The data comes from the International Monetary Fund's (IMF) Data Outlook Databases. Real GDP is expressed in billions of national currency. Gross debt, government expenditures, and government revenue are expressed in current local currency as a percent of GDP.[8] Imports is measured in percent change and employment in millions of persons. The data on 10-year interest rates on government bonds come from Bloomberg Data Services.

To evaluate the robustness of our results, we will run an additional regression that includes the growth rate of the real effective exchange rate, defined as the nominal effective exchange rate (a measure of the value of a currency against

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7 This second state, although extreme, has been observed in some euro countries during the recent financial crisis (e.g., Ireland, Greece, Spain, and Portugal). We could have considered a less extreme state of nature, where the returns from the public levered investment are not enough to absorb a negative demand shock.

8 Net debt, which captures the difference between gross debt and financial assets held by the government, is hard to compute and rarely comparable across countries, see Panizza and Presbitero (2014).

a weighted average of several foreign currencies) divided by a price deflator or index of costs.[9] The data on exchange rates comes from World Bank.

We obtained the real GDP in per capita terms by dividing the real GDP by the respective country's population (population is measured in millions and is also obtained from the IMF's website). Real per capita gross debt was obtained by multiplying the real per capita GDP by the percentage of gross debt with respect to GDP. In a similar way, we constructed the variables real per capita government expenditure and government revenue. Government expenditure is needed to construct the weights in our regression (5). Interests were obtained by multiplying the 10 year government bond rate of year t by the real per capita gross debt of year t–1. Original data on imports comes in percent change terms, so to obtain the growth rate of per capita imports we subtract the population growth rate from the growth rate of (aggregate) imports. Employment is transformed in per capita terms by dividing it by the population of a country.

All economic variables are then transformed into growth rates, so causal effects must be interpreted in terms of growth rates of the variables. We run the regressions with a time lag of 1 year for the covariate. Using regressions with instantaneous effects (no time lag) would lead to an identification issue; that is, in that case we cannot identify whether fundamentals cause economic growth and uncertainty or whether economic growth and uncertainty cause fundamentals to change.

IMF's data is available at annual frequency. In our analysis the sample runs from 1980 to 2011. There are two reasons why we do not include years 2012 and 2013. First, this time interval puts similar weights to both the pre-euro and the after-euro periods. Second, and more importantly, we found that after 2011 there are important problems of missing data for many variables, such us imports, debt, revenue, and expenditure.

We cover the first 12 euro zone members: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, and Spain.[10] All these countries adopted the euro in 1999, except Greece in 2001. There are other countries that became members of the euro group later, namely Cyprus (2008), Estonia (2011), Latvia (2014), Malta (2008), Slovakia (2009), and Slovenia (2007). We did not include these new members as they contribute to the panel with very few observations (our data goes until 2011 and in the robustness check of the financial crisis we omit the period 2008–2011).

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9 See Edison and Melvin (1990) for a survey of early empirical papers that point out the importance of the effect of exchange rate variability on trade.

10 Andorra, Malta, Monaco, and San Marino are not included in the analysis.

In a robustness check we consider a control group formed by those European countries that did not adopt the euro in the period under consideration. This group is composed by Czech Republic, Denmark, Hungary, Poland, Norway, Sweden, Switzerland, and the UK. There are other European countries that we chose not to include for different reasons. Bulgaria, Croatia and Romania were excluded due to their late structural economic reforms (evidence of this is the late accession to the European Union in 2007, 2013, and 2007, respectively), which suggests that these three countries cannot be thought as having similar economic characteristics as the treatment group (the euro countries). Latvia and Lithuania were excluded due to an important problem of missing data that goes until 1999.

The total number of both cross-sectional and time-series observations in our sample is 384 for the set of euro countries and 256 for the set of European non-euro countries. There are some missing observations for some countries, so in some tests the sample size is reduced. There is data on employment that is missing for Hungary and Poland, and there is data on government debt that is missing for Czech Republic and Hungary.

4 Effect of fundamentals on economic growth

We first describe the methodology we use to examine a possible structural break in the impact of fundamentals on economic growth caused by introduction of the euro. We are mainly interested in the effect of government debt. Following equation (5), the other variables used to explain the growth rate of real GDPpc are the growth rates of real per capita government revenue, real per capita interest on borrowing, per capita imports, and per capita employment. Many of these additional control variables are important indicators that central banks use to determine the health of the economy when setting monetary policy.

4.1 Regression strategy

The regression strategy is based on two intuitive steps. We first estimate residuals from a panel regression of the GDPpc growth rate on country and time fixed-effects. We then take the residuals as a proxy for GDPpc growth rates. The panel regression with country and time fixed effects allows us to filter out the GDPpc growth rate. Thus, the filtered growth rate will not reflect the growth rate of the underlying euro zone country's specific economic structure and a specific year. The panel regression is:

$$\tilde{y}_{it} = \eta_i + \delta_t + v_{it}, \tag{6}$$

where $\tilde{y}_{it} \equiv \dfrac{y_{it} - y_{it-1}}{y_{it-1}}$ represents the level of GDPpc growth rate of country i at time t; y_{it} is the country i real GDPpc at time t; η_i represents country i's fixed effect; and δ_t represents the time t fixed effect. The *permanent* effect of the adoption of the euro should not be reflected by any specific euro zone country's fixed effect or any specific year's fixed effect. Roughly speaking, the residual v_{it} captures an effect that can be attributed neither to the economic structure of country i nor to the economic events associated with a particular year t. Thereafter, we take as a proxy for the real GDPpc growth rate the fitted residual $\hat{v}_{it}$:

$$\hat{v}_{it} = \tilde{y}_{it} - \hat{\eta}_i - \hat{\delta}_t, \tag{7}$$

where $\hat{\eta}_i$ and $\hat{\delta}_t$ are the statistically significant (at a 1% significance level or less) estimates of the country and time fixed-effects.

In the second step and to examine the effect of government debt and other fundamentals on the proxy for GDPpc growth rate before and after adoption of the euro, we run the panel regression:

$$\hat{v}_{it+1} = \mu_i + (\phi_1 + \psi_1 \mathbf{I}_{i,t}) Debt_{i,t} + \sum_{j=2}^{J} (\phi_j + \psi_j \mathbf{I}_{i,t}) X_{j,i,t} + u_{i,t+1}, \tag{8}$$

where μ_i denotes the country-specific effect, $\mathbf{I}_{i,t}$ is a dummy variable that takes a value of 1 if country i adopted the euro in year t or before, and a value of 0 otherwise, and $u_{i,t+1}$ denotes the idiosyncratic error term. The variable of interest to us is country i's weighted growth rate of government debt at time t, here denoted by $Debt_{i,t}$. The growth rates of country i's other potential economic fundamentals (or controls) at time t are denoted by $X_{j,i,t}$, for $j=2, ..., J$.

Our estimation procedure is a two-step procedure that may cause efficiency losses. However, notice that there is no guarantee that the implementation of one-step estimation procedure would lead to better results as the number of parameters to estimate would increase [estimating the parameters of the panel regressions (6) and (7) together] and this could cause some estimation bias.

It is worth noting that in the panel regression (8) the coefficients of the impact of government debt and of the other controls are different before and after adoption of the euro. Before the euro the coefficients are given by ϕ_j and after the adoption by $\phi_j + \psi_j$, for $j=1, ..., J$. If an economic fundamental j has the same effect on the level of GDPpc growth rate before and after adoption of the euro, an equality must hold:

$$\phi_j = \phi_j + \psi_j,$$

and thus the coefficient ψ_j must be equal to zero.

For example, testing whether adoption of the euro has changed the effect of the growth rate of government debt on the level of the GDPpc growth rate is equivalent to testing the null hypothesis:

$$H_0 : \psi_1 = 0, \qquad (9)$$

against the alternative:

$$H_1 : \psi_1 \neq 0. \qquad (10)$$

The rejection of H_0 against H_1 will imply that there is a structural break in the impact of the growth rate of government debt on the level of the GDPpc growth rate due to introduction of the euro. Furthermore, comparison of the sign and the magnitude of the coefficients ϕ_j and $\phi_j + \psi_j$ will identify the direction of the changes and indicate whether the effect strengthens or weakens after adoption of the euro.

4.2 Results and discussion

We use the data to estimate the regression equation (8) and test the null hypothesis (9) against the alternative hypothesis (10). The estimation results are summarized in Table 1. As all economic variables are transformed in the same way (into growth rates) and are without units, the coefficients that measure the impact of fundamentals on GDPpc growth rate are comparable.

Table 1 reports a significant structural break in the effect of growth rate of government debt on economic growth after adoption of the euro. Increments in government debt have a positive effect on GDPpc growth rate before adoption, with a coefficient estimate of 35.48. The effect becomes negative after adoption with a large coefficient estimate equal to –26.90, meaning that an increase in government debt decreases GDPpc growth level. The last two columns indicate that the effects before and after adoption are statistically significant (at 5% and 1% significance levels, respectively), confirming a structural break in the effect of government debt growth on GDPpc growth.

4.2.1 Robustness checks

We have performed several robustness checks to test the validity of the results presented in Table 1. The following results are reported in Table 3 of the Appendix.

Table 1 Estimation results of the impact of economic fundamentals on real per capita GDP growth level, 1980–2011.

GDPpc growth rate level	Coefficient	t-Statistic	Prob.
Gov. Debt	35.48**	2.05	0.040
Gov. Debt*Dummy	−62.38***	−3.02	0.002
Gov. Revenue	87.06**	2.04	0.042
Gov. Revenue*Dummy	−193.87***	−3.01	0.003
Interest on Borrowing	−26.27	−0.38	0.707
Interests on Borrowing*Dummy	49.76	0.65	0.515
Imports	-11.85**	−2.42	0.015
Imports*Dummy	9.51	1.52	0.129
Employment	28.43	0.4	0.690
Employment*Dummy	58.81	0.49	0.625
Const.	−6.73**	−2.01	0.045
R^2 overall (%)	42.49		

This table reports estimation results of the impact of economic fundamentals on GDPpc growth rate level for the period 1980–2011. The results correspond to regression equation (8). The effect of economic fundamental j before adoption of the euro is measured by the coefficient ϕ_j, and after adoption by $\phi_j + \psi_j$. For example, in this table the effect of government debt before adoption of the euro is 35.476, while its effect after the euro is 35.48−62.38=−26.90. The total number of both cross-sectional and time-series observations in our sample is 384.
***Significant at 1% and **significant at 5%.

First, we have run a similar regression using robust standard errors (meaning that the estimators of the standard errors are robust to the heteroskedasticty and also to the cross-sectional dependence that characterizes panel data), and the result on the structural break of the effect of government debt on growth is similar; see the robustness check 1 column. We also found that the structural break is robust to exclusion of the financial and sovereign crisis period (2008–2011),[11] see the robustness check 2 column, and to inclusion of real exchange rate as an additional control variable in the regression (8), see the robustness check 3 column.

Motivated by the recent literature on government debt and growth that examines whether government debt influences growth in a non-linear way (see Panizza and Presbitero 2013), we have run several regressions that omit the observations that have a ratio of government debt to GDP above a given threshold. The thresholds we considered were 50%, 70%, 90%, 110%, and 130%. Results for each of these thresholds are presented in the robustness check 4, 5, 6, 7, and 8 columns. For each of these thresholds, we observe the existence of a statistically significant

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11 We have also checked whether the results change when we drop the European sovereign debt crisis period (2009–2011), and found that results do not change.

structural break on the effect of government debt growth on GDPpc growth level. These results suggest that the structural break we saw in the effect of government debt on growth is the result of the adoption of the euro and cannot be attributed to crossing the threshold level of debt above which the positive effect of debt on growth changes to negative.

4.2.2 Other fundamentals

Government revenue exerts a significant negative effect on economic growth after adoption of the euro. We see later that this significant effect of government revenue is robust to exclusion of the financial and sovereign crisis and to the inclusion of exchange rate as an additional control variable. However, when we run the same regression conditional on different thresholds of the ratios government debt to GDP and government revenue to GDP, we found that the structural break becomes insignificant below thresholds 51% of government debt to GDP and 41% of government revenue on GDP; see the robustness checks 4 and 9 columns of Table 3, respectively.

All other economic fundamentals exhibit no structural break in their impact on GDPpc growth. Imports appear to have a 13% statistically significant effect on economic growth both before and after adoption of the euro with coefficient estimates equal to –11.846 and –2.34, respectively. This result adds to Frankel and Rose's (2002) prediction of a positive effect on trade of the adoption of a common currency. The small coefficient of –2.55 with low statistical significance supports evidence provided by Tenreyro and Silva (2010), who found only a small effect in trade after adoption of the euro.

4.2.3 Comparison with non-euro European countries

One might ask whether the structural break on the effect of government debt growth on GDPpc growth level reported in Table 1 is seen in the non-euro European countries. To investigate this question, we run regression (8) using data on the Czech Republic, Denmark, Hungary, Norway, Poland, Sweden, Switzerland, and the UK. The total number of both cross-sectional and time-series observations in this empirical analysis is 256. The estimation results for the period 1980–2011 are reported in the robustness check 10 column of Table 3. We see that government debt, government revenue, and interest on borrowing have no statistically significant effect on economic growth rate either before or after adoption of the euro. Imports and employment appear to have a statistically significant effect on

economic growth after adoption of the euro. Thus, comparison of the euro and non-euro European countries indicates that our result of the existence of a structural break on the effect of government debt growth on real GDPpc growth is specific to the euro zone countries, with the only exception of imports.

5 Effect of fundamentals on uncertainty

We now proceed to test the hypothesized change of the effect of economic fundamentals on GDPpc growth rate volatility after adoption of the euro.

5.1 Regression strategy

Our investigation of gross domestic product growth rate volatility (economic uncertainty) uses the same variables as those we use to investigate the level of the GDPpc growth rate. For GDPpc growth rate's volatility we consider a linear approximation (first-order Taylor expansion) with the same economic fundamentals and the same data as before. The two-step regression strategy is also similar (Morgan, Rime, and Strathan (2004) follow a similar two-step regression procedure to investigate how integration of bank ownership across states has affected economic volatility within states). We first recuperate the residuals from a panel regression of GDPpc growth rate on country and time fixed effects.

Second, we take the absolute value of these residuals as a proxy of GDPpc growth rate volatility. The panel regression in step one allows us to filter out the GDPpc growth rate volatility from the underlying country's specific economic structure and from a specific year fixed effect – the *permanent* effect of the adoption of the euro should not be reflected by any specific year fixed effect. Formally, we run the panel regression (6). Thereafter, we take as a proxy of real GDPpc growth rate's volatility the absolute value of the residual v_{it}:

$$\widehat{Vol_{it}(g_{it})} \simeq |\hat{v}_{it}| = |g_{it} - \hat{\eta}_i - \hat{\delta}_t|, \tag{11}$$

where $\hat{v}_{it}$ is the fitted residual, and $\hat{\eta}_i$ and $\hat{\delta}_t$ are the statistically significant (at a 1% significance level or less) estimates of the country and time fixed effects, respectively. We have also considered another measure of GDPpc growth rate's volatility given by the square of the residuals, $\widehat{Vol_{it}(g_{it})} \simeq \hat{v}_{it}^2 = (g_{it} - \hat{\eta}_i - \hat{\delta}_t)^2$, and results are similar (see discussion in the next subsection).

In the second step and to examine the effect of government debt and other fundamentals on GDPpc growth rate's volatility before and after adoption of the euro, we run the panel regression:

$$|\hat{v}_{it+1}| = \omega_i + (\beta_1 + \gamma_1 \mathbf{I}_{i,t})Debt_{i,t} + \sum_{j=2}^{J}(\beta_j + \gamma_j \mathbf{I}_{i,t})X_{j,i,t} + \varepsilon_{i,t+1}, \qquad (12)$$

where ω_i is the country-specific effect; $\mathbf{I}_{i,t}$ is a dummy variable that takes a value of 1 if country i adopted the euro in year t, and a value of 0 otherwise; $Debt_{i,t}$ is country i's weighted growth rate of government debt at time t; $X_{j,i,t}$, for $j=2, ..., J$, are growth rates of other potential economic fundamentals in country i at time t; and $\varepsilon_{i,t+1}$ denotes the idiosyncratic error term.

The coefficients of the impact of government debt and of other controls on GDPpc growth rate's volatility before and after adoption of the euro are given by β_j and $\beta_j + \gamma_j$, for $j=1, ..., J$, respectively. If an economic fundamental j has the same effect on GDPpc growth rate's volatility before and after adoption, the equality must hold:

$$\beta_j = \beta_j + \gamma_j,$$

and thus the coefficient γ_j must be equal to zero. For example, testing whether the adoption of the euro has changed the effect of debt on the GDPpc growth rate's volatility is equivalent to testing the null hypothesis:

$$H_0 : \gamma_1 = 0,$$

against the alternative

$$H_1 : \gamma_1 \neq 0.$$

The rejection of H_0 against H_1 will imply there has been a structural break in the impact of government debt growth rate on GDPpc growth rate's volatility attributable to introduction of the euro. Comparison of the sign and the magnitude of the coefficients β_j and $\beta_j + \gamma_j$ will identify the direction of the changes and indicate whether the effect strengthens or weakens after introduction of the euro.

5.2 Results and discussion

After filtering gross domestic product growth rate's volatility using equations (6) and (11), we run regression (12) with all the economic fundamentals. The

estimation results are summarized in Table 2. Since all economic variables are transformed in the same way (into growth rates) and are without units, the estimated coefficients that measure the impact of the fundamentals on GDPpc growth rate's volatility are comparable.

Table 2 reports a significant structural break in the effect of the growth rate of government debt on economic uncertainty after adoption of the euro. Increments in government debt have a negative effect on GDPpc growth rate volatility before adoption, with a coefficient estimate of –22.241. The effect becomes positive after adoption with a large coefficient estimate equal to 35.508, meaning that an increase in government debt increases GDPpc growth rate's volatility. The last two columns indicate that the effect after adoption is statistically very significant, confirming a structural break in the effect of government debt.

5.2.1 Robustness checks

We have performed several robustness checks to test the validity of the results presented in Table 2. The following results are reported in Table 4 of the Appendix.

Table 2 Estimation results of impact of economic fundamentals on GDP growth rate volatility, 1980–2011.

GDPpc growth rate volatility	Coefficient	t-Statistic	Prob.
Gov. Debt	−22.24	−1.51	0.131
Gov. Debt*Dummy	57.75***	3.34	0.001
Gov. Revenue	−49.98	−1.37	0.172
Gov. Revenue*Dummy	122.77**	2.25	0.024
Interest on Borrowing	−10.11	−0.17	0.864
Interests on Borrowing*Dummy	−2.97	−0.05	0.963
Imports	−0.59	−0.14	0.891
Imports*Dummy	−0.49	−0.09	0.927
Employment	−37.19	−0.6	0.547
Employment*Dummy	11.02	0.11	0.916
Const.	29.78***	17.18	0.000
R^2 overall (%)	25.03		

This table reports estimation results of the impact of economic fundamentals on GDPpc growth rate volatility. The dependent variable (proxy of GDPpc growth rate volatility) is given by the absolute value of the residual v_{it} in (6). The results correspond to regression equation (12). The effect of economic fundamental j before adoption of the euro is measured by the coefficient β_j, and after adoption by $\beta_j+\gamma_j$. For example, in this table the effect of government debt before adoption of the euro is −22.241, while its effect after adoption is −22.241+57.749=35.508. The total number of both cross-sectional and time-series observations in our sample is 384. ***Significant at 1% and **significant at 5%.

First, similar results can be obtained if we take the square of the residuals as a proxy of GDPpc growth rate's volatility, see the robustness check 11 column. We have also performed a similar regression using robust standard errors (meaning that the estimators of the standard errors are robust to the heteroskedasticty and also to the cross-sectional dependence that characterizes panel data), and the result is similar; see the robustness check 12 column. Also, this result is robust to exclusion of the financial and sovereign crisis, see the robustness check 13 column, and to inclusion of real exchange rate as an additional control variable in the regression (12), see the robustness check 14 column.

In addition, we have run the regression conditional on a ratio *gov.debt/GDP* below a given threshold. As in the case of economic growth, the thresholds we considered were 50%, 70%, 90%, 110%, and 130%. For each of these thresholds, we observe the existence of a statistically significant structural break on the effect of government debt growth on GDPpc growth rate's volatility, see the robustness check 15, 16, 17, 18, and 19 columns in Table 4, respectively. These additional tests suggests that the structural break observed on the effect of government debt on uncertainty cannot be attributed to crossing a particular threshold level of government debt to GDP.

5.2.2 Other fundamentals

All other economic fundamentals, except government revenue, exhibit no structural break in their impact on GDPpc growth rate's volatility. The structural break in the impact of government revenue on uncertainty is not robust to controlling for real exchange rate, see the robustness check 14 column in Table 4. We also checked whether this structural break is robust to different thresholds for the ratio of government debt to GDP, and found that it becomes insignificant for ratios below 51%, see the robustness check 15 column in Table 4. This additional evidence suggests that the effect of government revenue on uncertainty can be due to crossing a specific threshold level of *gov.debt/GDP*, and not to adoption of the euro.

5.2.3 Comparison with non-euro European countries

We again investigate whether these results can also be seen in the non-euro European countries. We run regression (12) using data on the Czech Republic, Denmark, Hungary, Norway, Poland, Sweden, Switzerland, and the UK. As before, the total number of both cross-sectional and time-series observations is 256.

The estimation results for the period 1980–2011 are presented in the robustness check 20 column of Table 4. Comparison of euro and non-euro European countries indicates that the result of a structural break in the effect of government debt on economic uncertainty is particular to the euro zone countries.

6 Conclusions

The recent European debt crisis sparked a debate on the benefits and costs associated with the European Monetary Union. We contribute to this literature by providing first evidence on the effects of several economic fundamentals on economic growth and uncertainty with adoption of the European single currency. Government debt appears to be the primary variable that exhibits a structural break on both economic growth and uncertainty. The statistical significance of this break is robust to several checks, including exclusion of the financial and sovereign crisis period and comparison with other non-euro European countries.

Our empirical results strongly suggest that future research should consider the idea of creating new permanent institutions that might offset the negative structural changes induced by the adoption of a common currency. De Grauwe (2011) contributes to this debate by arguing that the recent government debt crisis in the Eurozone is due to a failure of economic governance. Luque, Morelli, and Tavares (2014) exploit a theoretical model that explains how an increase in GDPpc volatility in a monetary union brings salience to the extreme options of moving towards a fiscal union versus reverting to autarky. Roughly speaking, without further institutions like a fiscal union, the adoption of the euro by some European countries stands as a big obstacle for the survival of the union as a whole.

Finally, recognize that we take a neutral position in the debate on adoption of the euro, trying not to be swayed by popular arguments in favor of or against the euro. Our only purpose has been to provide the first empirical evidence on the effects of fundamentals on economic growth and uncertainty surrounding its adoption.

Appendix

Robustness checks and tables

To support the main findings in Tables 1 and 2, we conduct several robustness checks:

1. We exclude the financial crisis by focusing on the period 1980–2007.
2. We consider as an additional control variable the real exchange rate defined as the nominal effective exchange rate (a measure of the value of a currency against a weighted average of several foreign currencies) divided by a price deflator or index of costs.
3. We re-run the main regressions (8) and (12) using instead non-euro European countries: Czech Republic, Denmark, Hungary, Norway, Poland, Sweden, Switzerland, and the UK. This exercise helps us see whether the results in Tables 1 and 2 characterize simply the countries of the euro area.
4. We re-run the main regressions (8) and (12) using instead robust standard errors (meaning that the estimators of the standard errors are robust to the heteroskedasticity and also to the cross-sectional dependence that characterizes panel data).
5. We re-run the regression (12) using instead the square of the residuals as a proxy for GDPpc growth rate's volatility.
6. We re-run the main regressions (8) and (12) conditional on a given ratio of government debt to GDP.
7. Hausman test to test for endogeneity of government debt: We use the Hausman test to check whether government debt growth is endogenously determined with GDPpc growth. If endogeneity is present, then OLS estimates will be biased and inconsistent. To test this hypothesis, we use the growth rate of real exchange rate as the instrumental variable. As it is well known in the literature, it is difficult to find a good instrument for this type of regression [see Panizza and Presbitero (2012)]. The real exchange rate is usually argued to be a satisfactory instrumental variable due to its correlation with government debt through its foreign debt component (in the auxiliary regression government debt appears to be positively correlated to the real exchange rate at a 1% statistically significance level). To run the Hausman test we compare two sets of estimates, one that is consistent under both the null and the alternative and another that is consistent only under the null hypothesis. A large difference between the two sets of estimates is taken as evidence in favor of the alternative hypothesis. Our analysis confirms that government debt growth

is not an endogenous variable. Results are reported in Table 5. We refer to the note of Table 5 for the details of this test.

8. Cusum test for the constancy of the coefficients: To test the validity of our structural break results, we use the "cusum" test introduced by Brown, Durbin, and Evans (1975). Using recursive residuals, this test allows a point by point analysis, enabling us to see both the abrupt and gradual changes and also the approximate sample periods in which the changes occur. We take here a standard approach and apply the cusum test to each individual country. We find that there is a break in the year of adoption of the euro for the majority of countries.

The output of the cusum test is a graph. The interpretation is the following. There is no break when the cusum line is close to the horizontal axis (at zero level of the vertical axis). A departure from the horizontal axis indicates that there is a break at the point of departure.

Cusum test

We were not able to apply the cusum test to Luxemburg and the Netherlands due to missing data problems. In particular, for these two countries there are no data between 1980 and 1996 for variables such as government debt, government revenue, and interests. For the rest of the Eurozone countries, the problem of missing data is less important and the cusum test can be performed.

The cusum tests for the residuals (proxy of GDPpc growth rate) of each Eurozone country (except Luxemburg and the Netherlands) are presented in Figures 1–10. This test is done in the context of regression (8). The cusum tests for the absolute value of the residuals (proxy of volatility of GDPpc growth rate) of each eurozone country (except Luxemburg and the Netherlands) are presented in Figures 11–20. This test is done in the context of regression (12).

These figures show that there is a departure of the cusum line from the horizontal axis for the majority of these countries in a small neighborhood of year 1999, except for Greece whose departure is around 2001 (the year when Greece joined the euro).

Our main results of existence of structural breaks in the effect of government debt on both economic growth and uncertainty after introduction of the euro are consistent in all robustness checks.

Table 3 Robustness checks for the impact of economic fundamentals on GDPpc growth level.

Robustness checks GDPpc growth rate level	1	2	3	4	5	6	7	8	9	10
Gov. Debt	35.41	48.08	18.96	62.07	65.31	58.02	46.41	37.18	45.31	5.00
	(0.010)***	(0.017)**	(0.253)	(0.014)**	(0.011)**	(0.016)**	(0.039)**	(0.076)*	(0.471)	(0.977)
Gov. Debt*Dummy	−62.38	−62.67	−42.50	−67.07	−94.26	−93.68	−77.88	−62.86	−141.03	−120.43
	(0.000)***	(0.066)*	(0.032)**	(0.093)*	(0.005)***	(0.003)***	(0.003)***	(0.009)***	(0.054)*	(0.612)
Gov. Revenue	87.06	123.35	59.77	144.06	130.63	118.95	105.06	78.75	148.35	−798.62
	(0.001)***	(0.010)***	(0.148)	(0.025)**	(0.023)**	(0.027)**	(0.042)**	(0.090)*	(0.213)	(0.248)
Gov. Revenue*Dummy	−193.87	−297.83	−142.51	−128.92	−176.33	−188.71	−207.48	−181.79	100.79	697.04
	(0.000)***	(0.000)***	(0.022)**	(0.300)	(0.047)**	(0.023)**	(0.005)***	(0.008)***	(0.563)	(0.369)
Interest	−26.27	−37.76	−42.53	−11.85	−122.63	−66.22	−59.25	−33.94	−298.77	−389.49
	(0.741)	(0.623)	(0.525)	(0.939)	(0.294)	(0.455)	(0.477)	(0.667)	(0.076)*	(0.802)
Interests*Dummy	49.76	50.26	70.7	−29.73	66.84	70.18	89.96	49.89	287.22	−634.95
	(0.535)	(0.867)	(0.331)	(0.917)	(0.642)	(0.544)	(0.325)	(0.558)	(0.113)	(0.832)
Imports	−11.85	−15.30	−9.47	−46.88	−29.61	−30.03	−9.50	−6.18	−13.25	−305.72
	(0.000)***	(0.006)***	(0.045)**	(0.000)***	(0.002)***	(0.001)***	(0.164)	(0.322)	(0.273)	(0.348)
Imports*Dummy	9.50	18.71	7.95	−17.12	0.47	5.42	2.08	2.17	41.16	673.24
	(0.000)***	(0.015)**	(0.186)	(0.224)	(0.967)	(0.620)**	(0.801)	(0.774)	(0.007)***	(0.068)*
Employment	28.43	48.13	12.08	−108.29	17.56	1.87	14.00	29.15	100.90	426.22
	(0.351)	(0.545)	(0.858)	(0.433)	(0.861)	(0.985)	(0.881)	(0.714)	(0.505)	(0.750)
Employment*Dummy	58.80	96.25	102.38	314.78	255.84	239.85	161.19	75.42	−131.86	−3909.70
	(0.551)	(0.551)	(0.369)	(0.125)	(0.127)	(0.139)	(0.290)	(0.559)	(0.712)	(0.025)**
Exchange Rate	n.a.	n.a.	0.17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
			(0.207)							
Exchange Rate*Dummy	n.a.	n.a.	0.38	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
			(0.000)***							
Const.	−6.73	−2.00	−6.79	−13.94	−12.00	−11.69	−9.45	−7.79	−3.48	31.64
	(0.257)	(0.499)***	(0.642)	(0.004)***	(0.001)***	(0.001)***	(0.007)***	(0.022)**	(0.008)***	(0.043)**
R² overall (%)	42.49	41.07	71.39	25.34	26.67	29.46	36.60	33.39	66.94	16.10
Observations	384	336	384	384	384	384	384	384	384	256

(Table 3 Continued)

All results in Table 3 correspond to regression equation (8). As in Table 1 the effect of economic fundamental j before adoption of the euro is measured by the coefficient ϕ_j, and after adoption by $\phi_j + \psi_j$. The last row of the table corresponds to the total number of both cross-sectional and time-series observations in each sample. Below each coefficient we write the p-value in brackets. Statistical significance levels are as follows: ***significant at 1%, **significant at 5%, and *significant at 1%. Table 3 reports the following robustness checks for the impact of economic fundamentals on GDPpc growth rate volatility.

Robustness check 1 reports estimation results of the impact of economic fundamentals on GDPpc growth rate level for the period 1980–2011 when standard errors are robust to the heteroskedasticity and also to the cross-sectional dependence that characterizes panel data.

Robustness check 2 reports estimation results of the impact of economic fundamentals on real per capita GDP growth level when we omit the financial and sovereign crisis (period 1980–2007).

Robustness check 3 reports estimation results of the impact of economic fundamentals on real per capita GDP growth level for the period 1980–2011 and controlling for contemporaneous real exchange rates.

Robustness check 4 reports estimation results of the impact of economic fundamentals on real per capita GDP growth level for the period 1980–2011 when ratio of government debt to real GDP is below 51%.

Robustness check 5 reports estimation results of the impact of economic fundamentals on real per capita GDP growth level for the period 1980–2011 when ratio of government debt to real GDP is below 71%.

Robustness check 6 reports estimation results of the impact of economic fundamentals on real per capita GDP growth level for the period 1980–2011 when ratio of government debt to real GDP is below 91%.

Robustness check 7 reports estimation results of the impact of economic fundamentals on real per capita GDP growth level for the period 1980–2011 when ratio of government debt to real GDP is below 111%.

Robustness check 8 reports estimation results of the impact of economic fundamentals on real per capita GDP growth level for the period 1980–2011 when ratio of government debt to real GDP is below 131%.

Robustness check 9 reports estimation results of the impact of economic fundamentals on real per capita GDP growth level for the period 1980–2011 when ratio of government revenue to real GDP is below 41%.

Robustness check 10 reports estimation results for the set of non-Euro countries of the impact of economic fundamentals on real per capita GDP growth level for the period 1980–2011.

Table 4 Robustness checks for the impact of economic fundamentals on GDPpc growth volatility.

Robustness checks GDPpc growth rate volatility	11	12	13	14	15	16	17	18	19	20
Gov. Debt	−1177.82	−22.24	−28.33	−3.30	−76.20	−63.83	−64.32	−52.97	−43.05	−203.93
	(0.247)	(0.058)*	(0.065)*	(0.819)	(0.001)***	(0.004)***	(0.003)***	(0.005)***	(0.013)**	(0.170)
Gov. Debt*Dummy	3659.92	57.75	63.65	29.88	144.73	116.81	129.75	103.08	81.64	71.12
	(0.002)***	(0.000)***	(0.019)**	(0.082)*	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.723)
Gov. Revenue	−2861.12	−49.98	−57.99	21.75	−158.40	−101.34	−115.79	−99.78	−75.04	−702.69
	(0.257)	(0.127)	(0.125)	(0.548)	(0.014)**	(0.034)**	(0.012)***	(0.022)**	(0.056)*	(0.229)
Gov. Revenue*Dummy	8460.81	122.77	209.41	23.50	168.33	171.57	171.60	192.49	143.49	281.57
	(0.025)**	(0.061)*	(0.001)***	(0.661)	(0.0123)	(0.018)**	(0.012)***	(0.002)***	(0.012)**	(0.668)
Interest	−620.59	−10.11	−0.18	−45.59	−26.82	76.68	54.24	19.26	7.39	465.55
	(0.879)	(0.841)	(0.998)	(0.415)	(0.787)	(0.383)	(0.465)	(0.783)	(0.910)	(0.723)
Interests*Dummy	−804.16	−2.97	108.802	27.62	206.09	−48.77	−39.30	−37.40	−14.31	−563.75
	(0.858)	(0.954)	(0.541)	(0.652)	(0.262)	(0.657)	(0.389)	(0.629)	(0.840)	(0.823)
Imports	−185.34	−0.59	0.15	−7.36	−5.96	−4.60	−2.90	7.28	4.86	427.86
	(0.530)	(0.783)	(0.975)	(0.081)*	(0.558)	(0.594)	(0.733)	(0.217)	(0.372)	(0.120)
Imports*Dummy	−148.61	−0.49	−5.00	9.53	45.90	19.69	15.60	−4.13	−4.60	−46.91
	(0.690)	(0.811)	(0.413)	(0.075)*	(0.000)***	(0.049)**	(0.108)	(0.554)	(0.475)	(0.880)
Employment	−2129.64	−37.19	−43.65	−7.57	110.26	−66.52	−68.11	−64.96	−85.34	−984.71
	(0.616)	(0.339)	(0.486)	(0.896)	(0.325)	(0.429)	(0.415)	(0.406)	(0.203)	(0.383)
Employment*Dummy	1676.18	11.02	−89.75	−50.74	−83.73	−74.92	−67.53	−50.83	37.64	−1956.89
	(0.816)	(0.909)	(0.478)	(0.607)	(0.644)***	(0.595)	(0.626)	(0.696)	(0.733)	(0.184)
Exchange Rate	n.a.	n.a.	n.a.	0.24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
				(0.039)**						
Exchange Rate*Dummy	n.a.	n.a.	n.a.	0.19	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
				(0.000)***						
Const.	1046.80	29.78	27.94	−4.39	35.65	32.92	33.66	32.60	31.49	86.17
	(0.000)***	(0.000)***	(0.000)***	(0.716)	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
R^2 overall (%)	26.59	25.03	15.53	40.67	41.74	20.85	24.12	24.83	25.72	19.31
Observations	384	384	336	384	384	384	384	384	384	256

(Table 4 Continued)

In columns 2–10 of Table 4 the dependent variable (proxy of GDPpc growth rate volatility) is given by the absolute value of the residual. In column 1 the dependent variable (proxy of GDPpc growth rate volatility) is given by the square of the residual. The results correspond to regression equation (12). As in Table 2, the effect of economic fundamental j before adoption of the euro is measured by the coefficient β_j; and after adoption by $\beta_j + \gamma_j$. The last row of the table corresponds to the total number of both cross-sectional and time-series observations in each sample. Below each coefficient we write the p-value in brackets. Statistical significance levels are as follows: ***significant at 1%, **significant at 5%, and *significant at 10%. Table 4 reports the following robustness checks for the impact of economic fundamentals on GDPpc growth rate volatility:

Robustness check 11 reports estimation results of the impact of economic fundamentals on GDPpc growth rate volatility for the period 1980–2011 using squared residuals as a proxy for volatility.

Robustness check 12 reports estimation results of the impact of economic fundamentals on GDPpc growth rate volatility for the period 1980–2011 when standard errors are robust to the heteroskedasticity and also to the cross-sectional dependence that characterizes panel data.

Robustness check 13 reports estimation results of the impact of economic fundamentals on real per capita GDP growth volatility when we omit the financial and sovereign crisis (period 1980–2007).

Robustness check 14 reports estimation results of the impact of economic fundamentals on real per capita GDP growth volatility for the period 1980–2011 and controlling for contemporaneous real exchange rates.

Robustness check 15 reports estimation results of the impact of economic fundamentals on real per capita GDP growth volatility for the period 1980–2011 when ratio of government debt to real GDP is below 51%.

Robustness check 16 reports estimation results of the impact of economic fundamentals on real per capita GDP growth volatility for the period 1980–2011 when ratio of government debt to real GDP is below 71%.

Robustness check 17 reports estimation results of the impact of economic fundamentals on real per capita GDP growth volatility for the period 1980–2011 when ratio of government debt to real GDP is below 91%.

Robustness check 18 reports estimation results of the impact of economic fundamentals on real per capita GDP growth volatility for the period 1980–2011 when ratio of government debt to real GDP is below 111%.

Robustness check 19 reports estimation results of the impact of economic fundamentals on real per capita GDP growth volatility for the period 1980–2011 when ratio of government debt to real GDP is below 131%.

Robustness check 20 reports estimation results for the set of non-Euro countries of the impact of economic fundamentals on real per capita GDP growth volatility for the period 1980–2011.

Table 5 Hausman endogeneity test.

GDPpc growth	Coefficient	t-Statistic	Prob.
Gov. Debt Growth	51.20	0.54	0.592
Gov. Revenue	267.21	2.98	0.003
Interest on Borrowing	−230.87	−1.78	0.077
Imports	6.50	0.84	0.403
Employment	−14.48	−0.08	0.939
Residual_debt	−57.47	−0.59	0.557
Const.	−19.20	−2.32	0.021
R^2 overall (%)	7.49		

Note: We use the Davidson and MacKinnon's (1989) version of the Hausman test by running an auxiliary regression. For this, we have to run two OLS regressions. In a first regression (the auxiliary regression), we regress the suspect variable (government debt growth) on all exogenous variables and instruments and retrieve the residuals (this regression shows that government debt and the real exchange rate are positively correlated at 1% statistically significance level). We then use these retrieved residuals as additional regressors in a second regression that re-estimates the GDPpc growth rate function. Results are reported in Table 5. If the OLS estimates are consistent, then the coefficient on the first stage residuals should not be significantly different from zero. In Table 5 we can see that the test does not reject the hypothesis of consistent OLS estimates at conventional levels (t-statistic =−0.59). Thus, we conclude that government debt growth is not an endogenous variable. There are 264 total panel observations. Variable "Residual_debt" stands for the retrieved residuals from the auxiliary regression.

Cusum test for economic growth
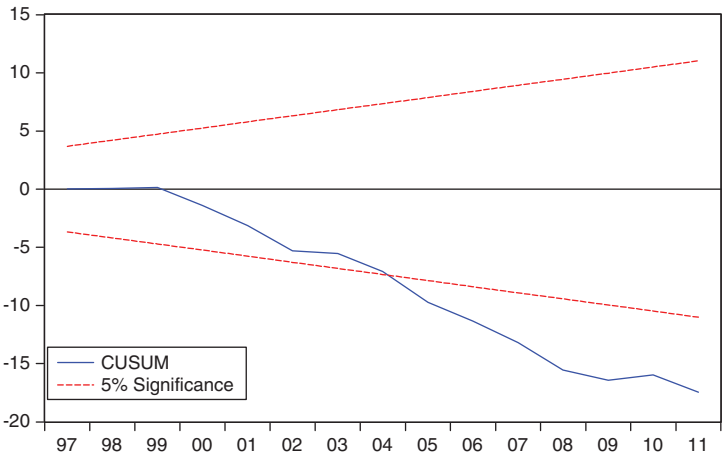
Figure 1 Austria.
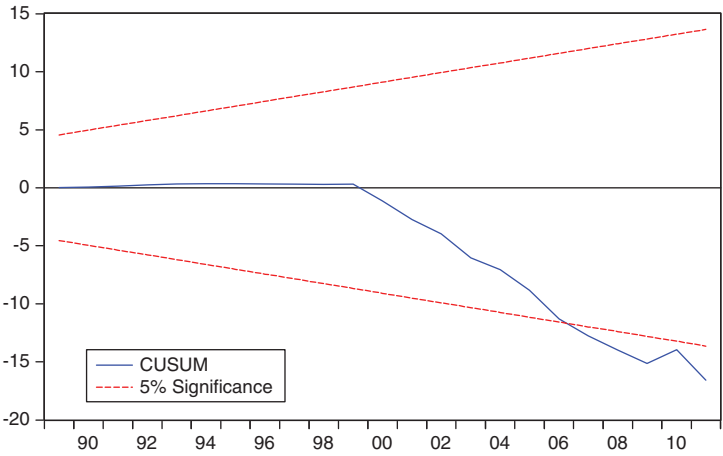
Figure 2   Belgium.
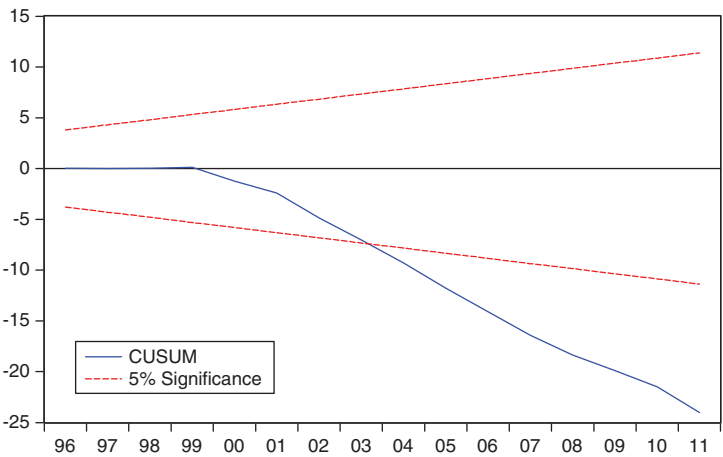
Figure 3   Finland.
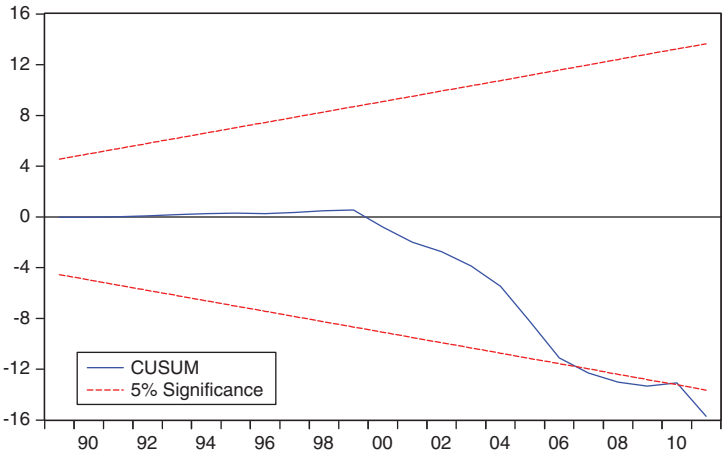
Figure 4 France.
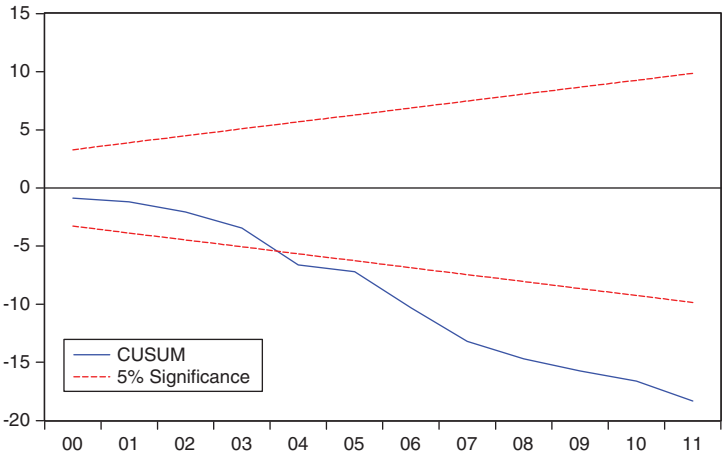
Figure 5 Germany.
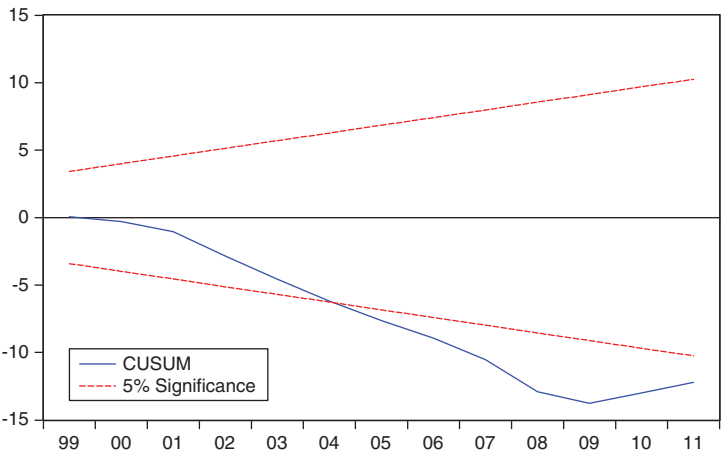
Figure 6 Greece.
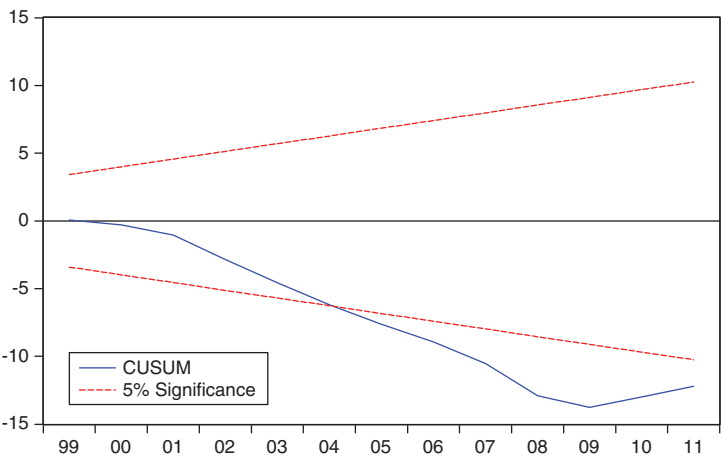
Figure 7 Ireland.
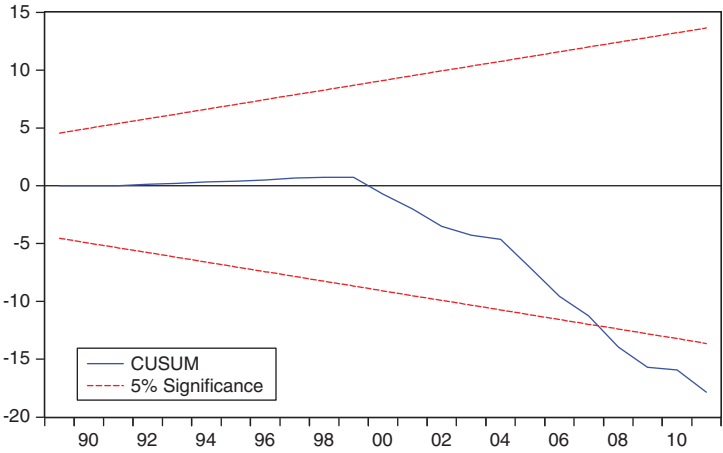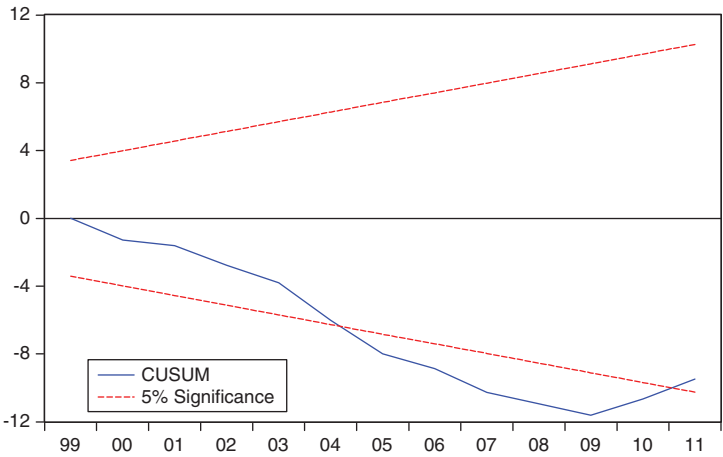
Figure 8   Italy.
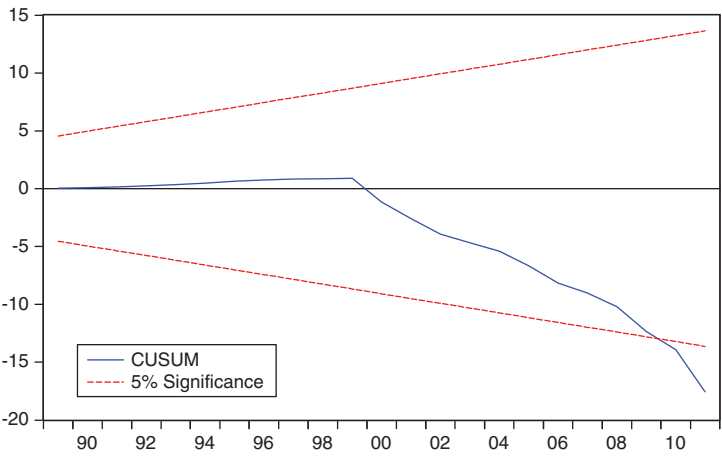

Figure 9   Portugal.

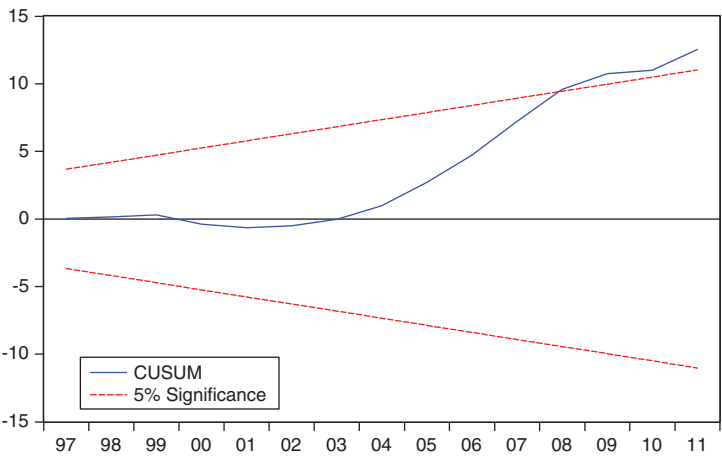**Figure 10** Spain.

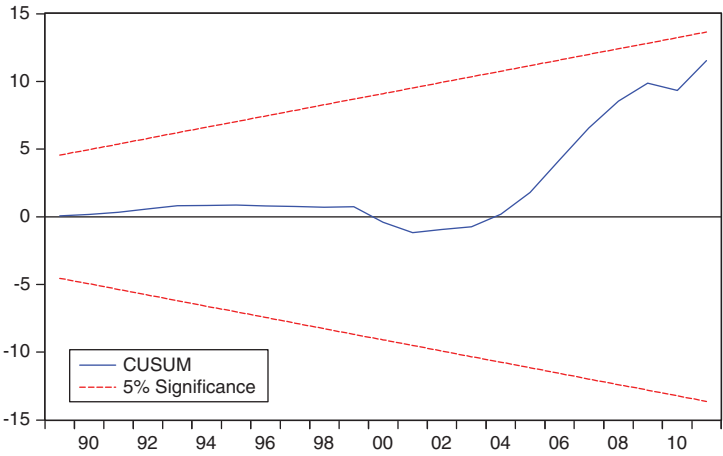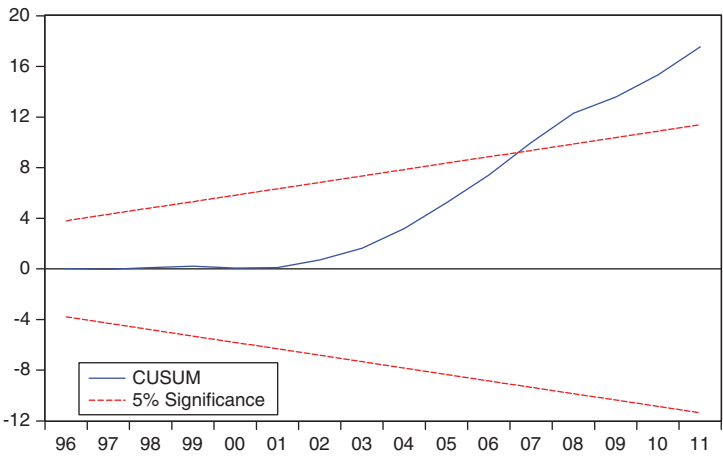## Cusum test for economic uncertainty

Figure 11 Austria.

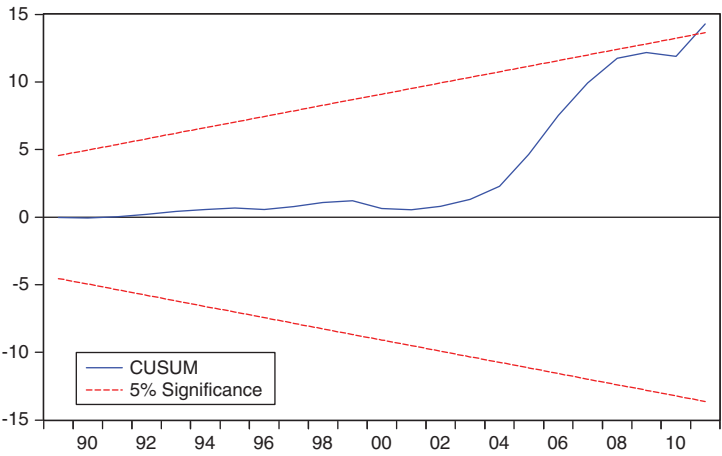**Figure 12**   Belgium.

Figure 13   Finland.

Figure 14 France.
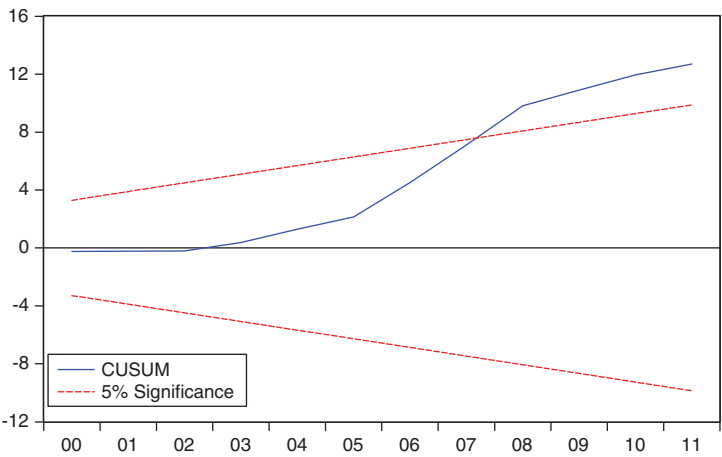
Figure 15 Germany.
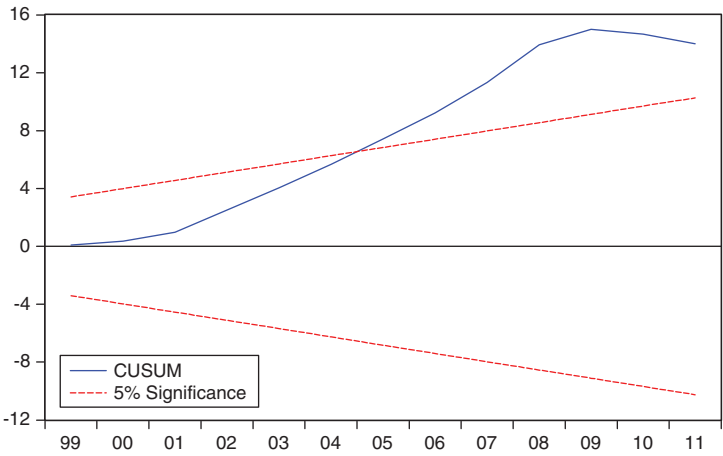
Figure 16   Greece.
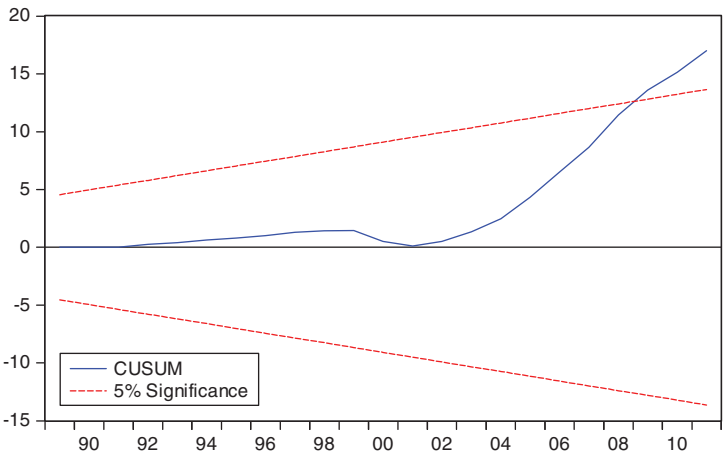
Figure 17   Ireland.
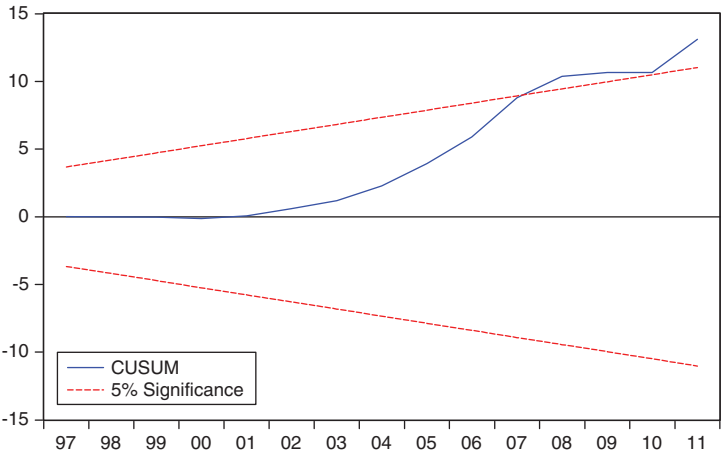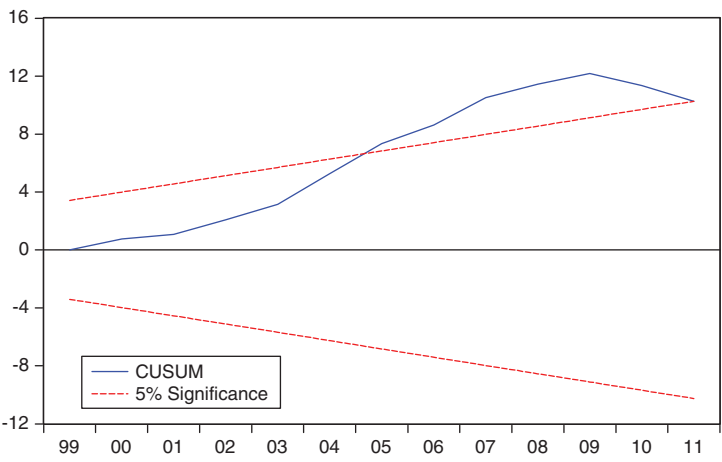
Figure 18   Italy.

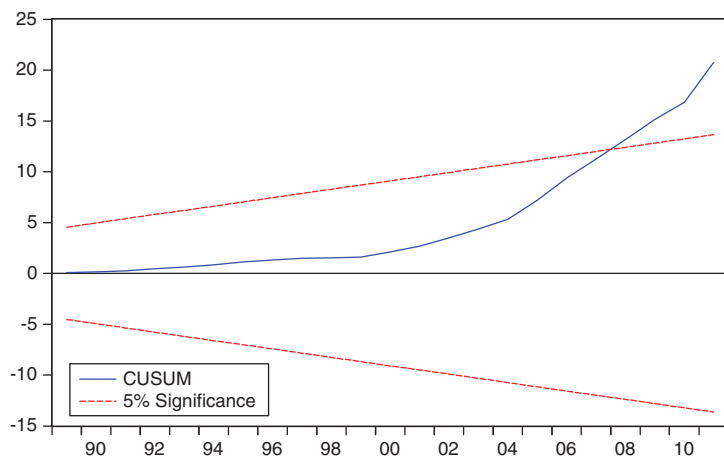**Figure 19**   Portugal.

Figure 20 Spain.

References

Afonso, A., and J. T. Jalles. 2013. "Growth and Productivity: The Role of Government Debt."
    International Review of Economics and Finance 25: 384–407.
Alesina, A., and R. Barro. 2002. "Currency Unions." *Quarterly Journal of Economics* 117:
    409–436.
Baldwin, R., and C. Wyplosz. 2006. *The Economics of European Integration*. 2nd ed. London
    London: McGraw-Hill.
Barro, R. 1979. "On the Determinants of Public Debt." *Journal of Political Economy* 85: 940–971.
Barro, R., and S. Tenreyro. 2007. "Economic Effects of Currency Unions." *Economic Inquiry* 45:
    1–23.
Baxter, M., and R. G. King. 1993. "Fiscal Policy in General Equilibrium." *American Economic
    Review* 83: 315–334.
Brown, R. L., J. Durbin, and J. M. Evans. 1975. "Techniques for Testing the Constancy of
    Regression Relationships Over Time." *Journal of the Royal Statistical Society* 37: 149–192.
Davidson, R. and J. G. MacKinnon. 1989. "Testing for Consistency using Artificial Regressions."
    Econometric Theory 5: 363–384.
De Grauwe, P. 1992. *The Economics of Monetary Integration*. 1st ed. Oxford: Oxford University
    Press.
De Grauwe, P. 2011. "Managing a Fragile Eurozone." *CESifo Forum* 12: 40–45.
Edison, H., and M. Melvin. 1990. "The Determinants and Implications of the Choice of an
    Exchange Rate System." In *Monetary Policy for a Volatile Global Economy,* edited by W.
    Haraf and T. Willett, Washington, DC: American Enterprise Institute.
Eichengreen, B. 1991. "Is Europe an Optimum Currency Area." NBER Working Paper 3579.
Egert, B. 2012. "Public Debt, Economic Growth and Nonlinear Effects: Myth or Reality?" OECD
    Economics Department, Working Papers 993, OECD Publishing.

Finn, M. G. 1998. "Cyclical Effects of Government's Employment and Goods Purchases." *International Economic Review* 39: 635–657.

Frankel, J., and A. Rose. 2002. "An Estimate of the Effect of Common Currencies Unions on Trade and Income." *Quarterly Journal of Economics 117*: 437–466.

Luque, J., M. Morelli, and J. Tavares. 2014. "A Volatility-based Theory of Fiscal Union Formation." *Journal of Public Economics* 112: 1–11.

Minea, A., and A. Parent. 2012. "Is High Public Debt Always Harmful to Economic Growth? Reinhart and Rogoff and Some Complex Nonlinearities." Working Papers 8, Association Francaise de Cliometrie.

Morgan, D. P., B. Rime, and P. Strathan. 2004. "Bank Integration and State Business Cycles." *Quarterly Journal of Economics* 119: 1555–1584.

Mundell, R. A. 1961. "A Theory of Optimum Currency Areas." *American Economic Review* 51: 657–665.

Panizza, U., and A. F. Presbitero. 2012. "Public Debt and Economic Growth: Is There a Causal Effect?" POLIS Working Papers 168, Institute of Public Policy and Public Choice.

Panizza, U., and A. F. Presbitero. 2013. "Public Debt and Economic Growth in Advanced Economies: A Survey." *Swiss Journal of Economics and Statistics* 149: 175–204.

Reinhart, C., and K. Rogoff. 2010. "From Financial Crash to Debt Crisis." *American Economic Review* 101: 1676–1706.

Reinhart, C., K. Rogoff, and M. Svastano. 2003. "Debt Intolerance." In *Brooklyn Papers on Economic Activity*, edited by William Brainerd and George Perry, 1–62.

Riboni, A., and F. Ruge-Murcia. 2010. "Monetary Policy by Committee: Consensus, Chairman Dominance or Simple Majority?" *Quarterly Journal of Economics* 125: 363–416.

Tenreyro, S., and S. Silva. 2010. "Currency Unions in Prospect and Retrospect." *Annual Review of Economics* 2: 51–74.