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

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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 the effect of increments in debt on economic growth exhibits a structural break in 1999. A robustness check attributes this break to the financial crisis, however. There is also a statistically significant structural break in the impact of increments in government debt on economic uncertainty. This result is robust to a battery of robustness checks, including exclusion of the recent financial crisis period and comparison with non-euro European countries.

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

JEL classification: E02, E52, F00, F02, F15, F33, F34, F36, F42.

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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 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.

Our approach in empirical. 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 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 square 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 the introduction of the euro. If coefficients are different,

[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.

we say that there has been a structural break in the effect of the particular variable.

We do 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 1999, increments in government debt had no significant impact on economic growth, while after adoption of the euro a 1 percentage point increment in debt reduced growth by 4.3 percent. The effect of the growth rate of government debt on economic growth, however, seems to be driven by the financial crisis period of 2008-2011. Thus, we cannot relate this structural break in the impact of government debt on economic growth only to adoption of the euro.

Our work is empirical in its nature and contributes to the academic debate on the relation between public debt and growth by focusing on the euro zone countries and controlling for the historic changes in their monetary institutions. Note that our analysis also controls for country and time fixed effects and for other important variables, such as interest rate, savings, public revenues, inflation, employment, trade, and exchange rate.

On the other hand, before 1999 a 1 percentage point increment in government debt reduced the volatility of the GDPpc growth rate (uncertainty) by more than 10 percent, while the same increment increased uncertainty after adoption of the euro by more than 12 percent. These effects are large and of opposite signs, and statistically significant, supporting the existence of a structural break. The economic intuition behind these effects can be summarized as follows. When new government debt happens to be denominated in a common currency, a member of that currency union can no longer (perfectly) affect the nominal value of its debt through monetary policy. Thus, when the mechanisms available to a country to reduce the burden of debt are reduced (or eliminated), new debt increments may weaken economic growth, particularly when new public investments produce at a rate lower than the debt's 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.

Interestingly, this second main result on a structural break in the effect of increments in government debt on economic uncertainty is robust to exclusion of the recent financial crisis (2008-2011 period). Thus, this result is robust to the recent sovereign debt crisis that affected many of the 12 sample countries in the panel that we consider. 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.

All other economic fundamentals, except for imports, exhibit no structural break in their impact on GDPpc growth and its volatility. Imports exhibit a statistically significant structural break for the level of the GDPpc growth rate. This break is such that the coefficient after the

euro adoption is 0.005. This result is consistent with predictions made by Frankel and Rose (2002) on the positive effect of the adoption of a common currency on trade and income. Moreover, the low coefficient supports the evidence provided by Tenreyro and Silva (2010), who find only a small increase in trade after adoption of the euro. Our robustness checks indicate that the statistically significant structural break in the coefficient of imports is robust to the exclusion of the financial crisis period, nor is it seen in the set of non-euro European countries.

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 empirical analysis of the effect of fundamentals on economic growth. There, we discuss the data and regression strategy, summarize the main findings, and check the robustness of the results. Section 4 presents the empirical analysis of the effect of fundamentals on economic uncertainty in a similar fashion. Section 5 concludes. The Appendix further explains the robustness checks, namely (i) exclusion of the financial crisis period 2008-2011; (ii) considering as additional control variables the exchange rates between the U.S. dollar and each euro zone country's currency; and (iii) re-running the main regressions for the non-euro European countries (control group).

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 (GDPpc). To this aim, we follow the seminal work on optimal currency unions by Alesina and Barro's (2002). The final output in their model is a function of the total factor productivity (A), the amount of labor employed (L), and nondurable intermediate inputs, both produced nationally and imported from another country. For the latter, we consider one intermediate input produced by country 1, denoted by K and with associated price μ_t^1, and one intermediate input *imported* from country 2, denoted by M. 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). We add government expenditure (G) as an additional input variable to the production function. The economic intuition is that there are productive government expenditures, such as public infrastructure, education, and the health system, that also affect the final level of GDPpc. The production function of a representative firm in country 1 in period t is:

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

As is common in the growth literature, the variable Y_t refers to country 1's production (GDPpc) 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. Notice that we can express government expenditure G_t as a function of new government debt B_t,[3] government revenue from taxes T_t, gross national savings (GNS) S_t, and the debt inherited from the previous period and associated interests $R_t \equiv (1+i_t)B_{t-1}$, where i_t denotes the period t interest rate on previous government debt. The decomposition obeys the standard government budget constraint $G_t + R_t = B_t + T_t$, where the left hand side of the equation is the expenditure side and the right hand side is the revenue side. After some algebra (see the Appendix), we are able to obtain the main equation that we use in our empirical analysis. GDPpc growth is expressed as a function of previous year growth rates of government borrowing, revenue, interest on debt, savings, imports, prices, and employment.

$$\frac{\dot{Y}_t}{Y_t} = \psi_0 \frac{\dot{A}_t}{A_t} + \psi_1 \frac{B_t}{G_t}\frac{\dot{B}_t}{B_t} + \psi_2 \frac{T_t}{G_t}\frac{\dot{T}_t}{T_t} + \psi_3 \frac{S_t}{G_t}\frac{\dot{S}_t}{S_t} + \psi_4 \frac{R_t}{G_t}\frac{\dot{R}_t}{R_t} + \psi_5 \frac{\dot{M}_t}{M_t} + \psi_6 \frac{\dot{\mu}_t^1}{\mu_t^1} + \psi_7 \frac{\dot{L}_t}{L_t}, \qquad (2)$$

where $\dot{X}_t \equiv \frac{dX_t}{dt}$ denotes the variation with respect to time of a representative variable $X_t = Y_t, A_t, B_t, T_t, S_t, R_t, M_t, \mu_t^1, L_t$. Variables $\dot{B}_t/B_t$, $\dot{T}_t/T_t$, $\dot{S}_t/S_t$ and $\dot{R}_t/R_t$ are weighted by their respective weight with respect to government expenditure. For instance, the weighted growth rate of new government borrowing $\frac{B_t}{G_t}\frac{\dot{B}_t}{B_t}$ is measured as the percentage of new debt with respect to government expenditure. This is consistent with our measure of variables B_t and G_t as a percentage of national GDPpc.

Equation (2) shows the effect of fundamentals on the GDPpc growth rate. The growth rate of total factor productivity in our empirical analysis below corresponds to the intercept in the regression strategy. The second covariate is the weighted growth rate of government borrowing, and, as we will see below, it is the variable that drives our main results. The remaining covariates are derived from the growth model presented above and will be called "controls." Omitting these "controls" may produce results exaggerating the effect on the growth rate of government borrowing. Our analysis omits any endogeneity issues arising between debt, revenues, and interest rate.[4]

Our goal in the empirical sections below are to determine the sign of the coefficients in equation (2). For this exercise, we must pay attention to variables such as government debt, interest on previous debt, and imports, whose nominal value depends on monetary policy (through prices) and exchange rates. We expect such variables to experience a structural break after 1999, once debt and imports from other euro countries became denominated in euros.

[3] 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.

[4] See also Barro's (1974) and Barro (1979).

Our general goal is to provide the first empirical evidence on whether there has been a structural break in the coefficient of the important economic fundamentals after 1999. For this, we first reinterpret the elasticity parameters α_j, $j = 1, 2$ as follows:

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

We say that there was a structural break in the effect of government borrowing on economic growth experiences in 1999 if its coefficient in equation (2), $\psi_1 = \frac{\alpha_3}{1-\alpha_1}$, is such that $\lambda_1 \neq 0$, $\lambda_3 \neq 0$, or both. Similarly, we can define a structural break for the remaining covariates.

A plausible explanation of why government debt may experience a structural break is the following. Exchange rate policy affects the value of government debt issued in terms of a foreign currency (sovereign bonds).[5] By adjusting the exchange rate appropriately, a country can reduce the value of its debt, and thus alleviate the burden of debt. When a country enters a common currency arena, however, the exchange rate between this country and the other countries in the common currency is fixed, so there is no mechanism available for this country to stabilize the specific shocks to the countries of the currency area. (To evaluate the robustness of our results, we run additional regressions that include the growth rate of the exchange rate between the currency of each country in the common currency area and the U.S. dollar; 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.)

Without exchange rate responses in a common currency, the interest rate becomes the key tool to hedge country-specific shocks. That is, when a country adopts a common currency, the only remaining way for the country to affect the value of its debt is via monetary policy, but as we argue below, the effect of this action is at best imperfect.

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. We assume an economy 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

[5] The value of the debt depends on whether a country can influence the value of the currency in which the debt is denominated. To see this, we can rewrite gross government borrowing B_t as a function of the exchange rate X_t as $B_t = \tilde{B}_t / X_t$, where $\tilde{B}_t$ is new borrowing in terms of the foreign currency, e.g., the issuance of sovereign bonds. It may also happen that government debt $\tilde{B}_t$ is issued in terms of the country's own national currency. If so, country 1 can reduce the burden of debt by printing money, also called "debt monetization", only if it has its own monetary policy. Then, one can interpret the ratio $1/X_t$ as the government's cost of issuing new debt, and find that $B_t = \tilde{B}_t / X_t$ is reduced when the government monetizes its debt.

public investment. In the simplest scenario there are two states in the second period. In one state the returns from investing the public levered funds (marginal productivity mp_g) exceed the interest rate on government borrowing (r), i.e., $mp_g > r$, and in the other 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.[6]

If the country is subject to a common currency, the monetary policy mechanism it has available to reduce the burden of the debt via price levels is imperfect at least from the individual country's point of view.[7] In that case, if the state $mp_g < r$ happens to occur, issuing new debt becomes a tax, hampering economic growth. Moreover, when there are no monetary policy tools, a positive probability of occurrence of the second state of nature ($mp_g < r$) increases the uncertainty of a stable growth path for the country. A country with its own national currency can use monetary policy actively to offset the shock by reducing the interest rate r. Such a country has the ability to monetize its debt and reverse the inequality, making public investments profitable, and thus boosting economic growth. This possibility also mitigates the uncertainty about the profitability of the country's public levered investments.

3 Effect of Fundamentals on Economic Growth

We first describe the data and 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 (2), the other variables used to explain the growth rate of real gross domestic product per capita are the growth rates of government revenue, gross national savings, interest on borrowing, imports, inflation, and 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.

3.1 Data

The data on real GDPpc come from the International Macroeconomic Data Set of Economic Research Service (ERS). The data on 10-year interest rates on government bonds come from

[6] 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.

[7] A standard channel to reduce the burden of government debt is by creating inflation. Sims (2012) points out that "joining the Euro meant that countries gave up the cushion of country-specific inflation impacts on debt burden".

Bloomberg Data Services. The data on remaining variables are from the International Monetary Fund (IMF) database. In a robustness check of the regression we add exchange rates between the U.S. dollar and each euro zone country's currency. The data on exchange rates comes from EconStats.[8]

The IMF's data are available at annual frequency. In our analysis the sample runs from 1980 to 2011 - this time interval puts similar weights to both the pre-euro and the after-euro periods. We cover the first 12 euro zone members: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxemborg, Netherlands, Portugal, and Spain.[9] The total number of both cross-sectional and time-series observations in our sample is 384. There are some missing observations for some countries, so in some tests the sample size is reduced. All the economic variables are first 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 one year for the covariate. Thus, the results should be interpreted as causalities and not correlations. 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.

3.2 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:

$$g_{it} = \eta_i + \delta_t + \upsilon_{it}, \tag{3}$$

where $g_{it} \equiv \frac{Y_{it}-Y_{it-1}}{Y_{it-1}}$ 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

[8] In March 1979 the European Community introduced what was known as the European Exchange Rate Mechanism (ERM) to reduce exchange rate variability and achieve monetary stability in Europe. This was to prepare European countries for the creation of the Economic and Monetary Union with its single currency.

[9] Some other Eurozone countries are not included in our analysis because of missing data. Most of these countries had Communist regimes and did not make data publicly available. Other small countries such as Andorra, Malta, Monaco, and San Marino are not included in the analysis.

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 υ_{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 $\hat{\upsilon}_{it}$:

$$\hat{\upsilon}_{it} = g_{it} - \hat{\eta}_i - \hat{\delta}_t, \tag{4}$$

where $\hat{\eta}_i$ and $\hat{\delta}_t$ are the estimates of the country and time fixed-effects, respectively. 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:

$$\hat{\upsilon}_{it+1} = \mu_i + (\phi_1 + \psi_1 \mathbf{I}_{i,t})\, Debt_{i,t} + \sum_{j=2}^{J} \left(\phi_j + \psi_j \mathbf{I}_{i,t}\right) X_{j,i,t} + u_{i,t+1}, \tag{5}$$

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 $j = 2, ..., J$.

It is worth noting that in the panel regression (5) 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:

$$H_0 : \psi_1 = 0, \tag{6}$$

against the alternative:

$$H_1 : \psi_1 \neq 0. \tag{7}$$

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.

As it is usual in empirical work, see Frankel and Rose (2002), we run regressions with and without controls and try to be conservative in our interpretation. Results of a first simple regression with the growth rate of government debt as the only independent variable appear in Table 1. We see a clear statistically significant structural break after 1999. Before adoption of the euro the effect of government debt growth rate on GDPpc growth rate is not significant, but after it the effect is negative. In particular, a 1 percentage point increase in government debt after the euro reduced the GDPpc growth rate by 3.527 percent.

[TABLE 1 HERE]

3.3 Results and Discussion

We use the data to estimate the regression equation (5) and test the null hypothesis (6) against the alternative hypothesis (7). The estimation results are summarized in Table 2. 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 2 HERE]

Table 2 reports a statistically insignificant effect of government debt on the GDPpc growth rate before adoption of the euro. With introduction of the euro, however, there is a structural break in the impact of government debt that is statistically significant even at the 1% significance level. That is, after 1999 a 1 percentage point increment in government debt reduces economic growth by more than 4 percent. This result is robust to the inclusion of the exchange rates between the U.S. dollar and each euro zone country's currency, see Table 4, but not to exclusion of the recent financial crisis, see Table 3.

Reinhart and Rogoff (2010) and Reinhart, Rogoff, and Savastano (2003) attribute the fact that increments in government debt dampened economic growth to the high debt/GDPpc levels. Our paper contributes to the academic debate on the relation between the growth rate of government debt and economic growth by focusing on the euro zone countries and controlling for the historical change of their monetary institutions, country and time fixed effects, and for other macroeconomic variables.

Government revenue exerts no significant effect on economic growth either before or after 1999. We see later that this insignificant effect of government revenue is robust to exclusion

of the financial crisis and to the inclusion of exchange rate as an additional control variable. Thus, these results suggest government revenue plays no part in a structural break on economic growth.

Gross national savings also have no significant effect on economic growth either before or after the euro, meaning that we cannot reject the null hypothesis (6) for GNS. Its lack of statistical significance is robust to exclusion of the financial crisis or inclusion of exchange rate in the regression (5).

Interest on previous debt exhibits a significant structural break with adoption of the euro, with a negative coefficient of -0.360. This statistically significant structural break in the effect of interests on previous debt is robust to inclusion of exchange rate as an additional control variable, but not to exclusion of the financial crisis.

Imports appear to have a statistically significant effect on economic growth both before and after adoption of the euro with coefficient estimates equal to -0.104 and 0.005, respectively. This result is consistent with the predictions of Frankel and Rose (2002) on the positive effect of the adoption of a common currency on trade. The small coefficient of 0.005 also supports evidence provided by Tenreyro and Silva (2010), who find only a small increase in trade after adoption of the euro. Our robustness exercise indicates that the effect of imports accounted is robust to exclusion of the financial crisis period, but it disappears and becomes statistically insignificant before and after the euro once we control for the growth rate of exchange rates.

Inflation has a very statistically significant and negative effect on economic growth only before adoption of the euro. Thus, we find no evidence of a structural break in this effect, even when we exclude the financial crisis period or include the exchange rate as an additional control variable. However, we find that the non-euro European countries experience a structural break after 1999 in the impact of inflation on economic growth.

Finally, the employment growth rate has no statistically significant effect on the GDPpc growth rate at any time. This result is confirmed when we exclude the financial crisis period and when we include the growth rate of exchange rates.

3.4 Non-Euro Countries

One might ask whether the results reported in Table 2 are seen in the non-euro European countries. To investigate this question, we run regression (5) using data on the Czech Republic, Denmark, Hungary, Norway, Sweden, Switzerland, and the United Kingdom. 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 Table 5. We see that government debt, government revenue, gross national savings, interest on borrowing, imports, and employment, have no statistically significant effect on economic growth rate either before or after 1999. Thus, these fundamentals exhibit no structural break with adoption of the euro. Inflation, however, exhibits a structural break in its effect on the level of the growth rate of GDPpc, reducing economic growth after 1999 for the non-euro countries.

Comparison of the euro and non-euro European countries indicates that our results are specific to the euro zone countries, with the only possible exception of inflation.

4 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 in 1999.

4.1 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 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 similar also. (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 square 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 (3). Thereafter, we take as a proxy of real GDPpc growth rate volatility the square of the residual υ_{it}:

$$\widehat{Vol_{it}\left(g_{it}\right)} \simeq \hat{\upsilon}_{it}^{2} = \left(g_{it} - \hat{\eta}_{i} - \hat{\delta}_{t}\right)^{2}, \tag{8}$$

where $\hat{\upsilon}_{it}$ is the fitted residual, and $\hat{\eta}_{i}$ and $\hat{\delta}_{t}$ are the estimates of the country and time fixed effects, respectively.[10]

[10] We have also consider another measure of GDPpc growth rate volatility given by the absolute value of the residuals, $\widehat{Vol_{it}\left(g_{it}\right)} \simeq |\hat{\upsilon}_{it}| = \left|g_{it} - \hat{\eta}_{i} - \hat{\delta}_{t}\right|$, and the results are quite similar.

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

$$\hat{v}_{it+1}^2 = \omega_i + (\beta_1 + \gamma_1 \mathbf{I}_{i,t})\, Debt_{i,t} + \sum_{j=2}^{J} \left(\beta_j + \gamma_j \mathbf{I}_{i,t}\right) X_{j,i,t} + \varepsilon_{i,t+1}, \tag{9}$$

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 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 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 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 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.

We first provide a simple regression using the growth rate of government debt as the only independent variable. The results are presented in Table 6. From this, we see that there is a statistically significant structural break in the impact of government debt on economic uncertainty after 1999. Before introduction of the euro, government debt had a negative effect on the volatility of the GDPpc growth rate. This effect became positive and moreover was amplified after adoption of the euro.

[TABLE 6 HERE]

4.2 Results and Discussion

After filtering gross domestic product growth rate volatility using equations (3) and (8), we run regression (9) with all the economic fundamentals. The estimation results are summarized in Table 7. 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 7 HERE]

Table 7 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 -10.526. The effect becomes positive after adoption with a large coefficient estimate equal to 12.257, meaning that an increase in government debt increases GDPpc growth rate's volatility. The last two columns indicate that the effects before and after adoption are statistically very significant, confirming a structural break in the effect of government debt. These results are robust to exclusion of the financial crisis, see Table 8, and to inclusion of exchange rate as an additional control variable in the regression (9), see Table 9.

A 1 percentage point increment in government revenue reduced uncertainty by 35 percent before introduction of the euro. This effect is statistically significant at the 5% significance level. There is no structural break in its impact with exclusion of the financial crisis period and inclusion of exchange rates as an additional control variable.

Inflation and the growth rate of gross national savings and employment are statistically insignificant both before and after adoption of the euro, and thus we see no structural break after 1999. These results are robust to the exclusion of the recent financial crisis and to controlling for the exchange rate.

Interest on borrowing shows a statistically significant structural break after adoption of the euro. After 1999 increments in the interest on previous debt led to an increase in economic uncertainty. As in the case of government debt, this result can be ascribed to the fact that lack of monetary policy in a country boosts uncertainty because of the interest burden. Robustness tests indicate the structural break in the effect of interests on borrowing is sensitive to exclusion of the financial crisis. This suggests that it is the recent European crisis that drives the effect of interest on uncertainty, and not adoption of the euro. Furthermore, when we control for exchange rates the statistical significance of this effect falls from 5% to 10%.

Finally, imports have a statistically significant effect on the GDPpc growth rate's volatility before and after the euro. This effect is positive before adoption of the euro and negative after, although the latter effect seems not economically significant (0.004). Thus, we can conclude that increases in imports exhibit an almost negligible structural break for economic uncertainty. This result is robust to exclusion of the financial crisis period and to inclusion of exchange rates.

4.3 Non-Euro Countries

We again investigate whether these results can also be seen in the non-euro European countries. We run regression (9) using data on the Czech Republic, Denmark, Hungary, Norway, Sweden, Switzerland, and the United Kingdom. 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 Table 10. We see that only interest on borrowing and imports experience a statistically significant structural break in their effects on GDPpc growth rate volatility, and the latter is significant only at the 10% significance level. Except for the effect of interest on debt, comparison of euro and non-euro European countries indicates that the results are particular to the euro zone countries.

5 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. Robustness checks that control for the historical change of countries' monetary institutions and for other macroeconomic variables indicate that the structural break in the effect of the growth rate of debt on economic growth is driven by the financial crisis. The statistically significant structural break in the effect of the debt growth rate on economic uncertainty seems robust to several robustness checks, including exclusion of the financial period. The effect of the growth rate of imports on gross domestic product growth also experienced a structural break with a positive but small effect on growth after adoption of the euro. The remaining economic fundamentals either experience no structural breaks after 1999 or any changes are not robust to exclusion of the recent financial crisis or not specific to the euro zone.

Although some of our coefficients seem to us very large, we try to not take them too lit-

erally. Rather, we hope our results will help researchers and policy makers better understand the benefits and costs of adoption of the euro, providing more information on implementing appropriate economic policies.

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. Inspired by Alesina and Spolaore (1997) and Alesina and Perotti (1999), Luque, Morelli, and Tavares (2012) 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.

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6 Appendix

6.1 The production function

Here we indicate the main steps to derive our equation (2). First, we equate the marginal productivity of the intermediate good produced in country 1 to its price μ_t^1, obtaining:

$$K_t = (A_t G_t \alpha_1 / \mu_t^1)^{1/(1-\alpha_1)} (L_t)^{(1-\alpha_1-\alpha_2)/(1-\alpha_1)} (M_t)^{\alpha_2/(1-\alpha_1)}. \tag{10}$$

The final output produced by this representative firm can be written as follows:

$$Y_t = \left((A_t G_t)^{1/\alpha_1)} M_t^{\alpha_2/\alpha_1)} (\alpha_1/\mu_t^1) \right)^{\alpha_1/(1-\alpha_1)} L_t^{(1-\alpha_1-\alpha_2)/(1-\alpha_1)}. \tag{11}$$

We next log-linearize equation (11) and take the derivative with respect to time on both sides of the result, and obtain the differential equation:

$$\frac{\dot{Y}_t}{Y_t} = \frac{1}{1-\alpha_1} \left(\frac{\dot{A}_t}{A_t} + \frac{\dot{G}_t}{G_t} \right) + \frac{\alpha_2}{1-\alpha_1} \frac{\dot{M}_t}{M_t} + \frac{\alpha_1}{\alpha_1 - 1} \frac{\dot{\mu}_t^1}{\mu_t^1} + \frac{1-\alpha_1-\alpha_2}{1-\alpha_1} \frac{\dot{L}_t}{L_t}, \tag{12}$$

where $\dot{X}_t \equiv \frac{dX_t}{dt}$, for $X_t = Y_t, A_t, G_t, M_t, \mu_t^1, L_t$, denotes the variation with respect to time of variable X_t. Equation (12) presents the variables in growth rate and shows that GDPpc growth rate depends on the growth rates of productivity, government spending, imports, inflation, and employment.

Thereafter, we disentangle the variable government expenditure G_t by writing the government's budget constraint in period t as follows:

$$G_t = \alpha_3 B_t + \alpha_4 T_t + \alpha_5 S_t + \alpha_6 R_t, \tag{13}$$

where B_t is the new government debt, T_t is the government revenue from taxes, S_t is the gross national savings (GNS), and R_t is the debt inherited from the previous period and associated interests R_t. We now take the derivative of equation (13) with respect to time, and write

$$\dot{G}_t = \alpha_3 \dot{B}_t + \alpha_4 \dot{T}_t + \alpha_5 \dot{S}_t + \alpha_6 \dot{R}_t, \tag{14}$$

After some simple algebra, we get:

$$\frac{\dot{G}_t}{G_t} = \alpha_3 \frac{B_t}{G_t} \frac{\dot{B}_t}{B_t} + \alpha_4 \frac{T_t}{G_t} \frac{\dot{T}_t}{T_t} + \alpha_5 \frac{S_t}{G_t} \frac{\dot{S}_t}{S_t} + \alpha_6 \frac{R_t}{G_t} \frac{\dot{R}_t}{R_t}. \tag{15}$$

The growth rate variables on the right-hand side of equation (15) are weighted by their respective weight with respect to government expenditure. For instance, we refer to $\frac{B_t}{G_t} \frac{\dot{B}_t}{B_t}$ as the

weighted growth rate of new government borrowing. In our empirical analysis below, each variable in (15) enters as a percentage of government expenditure. For example, $\frac{B_t}{G_t}\frac{\dot{B}_t}{B_t}$ is measured as the percentage of new debt with respect to government expenditure. This is consistent with our measure of variables B_t and G_t as a percentage of national GDPpc.

Combining equations (12) and (15) leads to the final expression:

$$\frac{\dot{Y}_t}{Y_t} = \psi_0\frac{\dot{A}_t}{A_t} + \psi_1\frac{B_t}{G_t}\frac{\dot{B}_t}{B_t} + \psi_2\frac{T_t}{G_t}\frac{\dot{T}_t}{T_t} + \psi_3\frac{S_t}{G_t}\frac{\dot{S}_t}{S_t} + \psi_4\frac{R_t}{G_t}\frac{\dot{R}_t}{R_t} + \psi_5\frac{\dot{M}_t}{M_t} + \psi_6\frac{\dot{\mu}_t^1}{\mu_t^1} + \psi_7\frac{\dot{L}_t}{L_t}, \qquad (16)$$

where $\psi_0 = \frac{1}{1-\alpha_1}$, $\psi_1 = \frac{\alpha_3}{1-\alpha_1}$, $\psi_2 = \frac{\alpha_4}{1-\alpha_1}$, $\psi_3 = \frac{\alpha_5}{1-\alpha_1}$, $\psi_4 = \frac{\alpha_6}{1-\alpha_1}$, $\psi_5 = \frac{\alpha_2}{1-\alpha_1}$, $\psi_6 = \frac{\alpha_1}{\alpha_1-1}$, and $\psi_7 = \frac{1-\alpha_1-\alpha_2}{1-\alpha_1}$.

6.2 Robustness Checks and Tables

To support the main findings in Tables 2 and 7, we conduct several robustness checks

1. *We exclude the financial crisis by focusing on the period 1980-2007.* The estimation results are presented in Table 3 for economic growth and Table 8 for economic uncertainty. These tables are comparable to Tables 2 and 7.

2. *We consider as an additional control variable the exchange rates between the U.S. dollar and each euro zone country's currency.* The estimation results using the whole period 1980-2011 are reported in Tables 4 and 9. In neither table is the growth rate of exchange rates a statistically significant variable before and after adoption of the euro.

3. *We re-run the main regressions (5) and (9) using instead non-euro European countries*: Czech Republic, Denmark, Hungary, Norway, Sweden, Switzerland, and the United Kingdom. This last exercise helps us see whether the results in Tables 2 and 7 characterize simply the countries of the euro area.

Our main results that show 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. In Tables 11 and 12 we summarize our primary findings and the robustness results.

Table 1: Impact of government debt on GDP growth level, 1980-2011

GDPpc growth rate level	Coefficient	t-Statistic	Prob.
Govnt. Debt	-0.476	-0.28	0.786
Govnt. Debt*Dummy	-3.051**	-2.93	0.015
Const.	-0.037	-0.92	0.381
R-sq overall (%)	4.46		

Note: *This table reports estimation results for the panel regression*

$$\hat{v}_{it+1} = \varpi_i + (\phi_1 + \psi_1 \mathbf{I}_{i,t})\, Debt_{i,t} + v_{i,t+1},$$

where $\hat{v}_{it+1}$ *is the residual at time* $t+1$ *defined in (4),* $Debt_{i,t}$ *is the weighted growth rate of government debt at time* t, ϖ_i *is the country-specific effect,* $I_{i,t}$ *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, and* $v_{i,t+1}$ *denotes the idiosyncratic error term. The effect of government debt on the GDPpc growth rate before adoption of the euro is* -0.476, *while its effect after adoption is* $-0.476 - 3.051 = -3.527$. *The total number of both cross-sectional and time-series observations in our sample is 384. T-statistics are computed using robust standard errors.* ** *Significant at* 5%.

Table 2: Estimation results of impact of economic fundamentals on GDP growth level, 1980-2011

GDPpc growth rate level	Coefficient	t-Statistic	Prob.
Gov. Debt	-0.701	-0.84	0.403
Gov. Debt*Dummy	-3.610***	-2.59	0.010
Gov. Revenue	-11.200	-1.51	0.132
Gov. Revenue*Dummy	2.453	1.24	0.807
Gross National Savings	0.925	0.16	0.875
Gross National Savings*Dummy	2.796	0.39	0.699
Interest on Borrowing	0.051	0.70	0.482
Interests on Borrowing*Dummy	-0.411***	-2.75	0.006
Imports	-0.104**	-2.51	0.013
Imports*Dummy	0.109***	2.59	0.010
Inflation	-0.149***	3.57	0.000
Inflation*Dummy	-0.062	-0.74	0.461
Employment	12.407	0.98	0.331
Employment*Dummy	21.683	1.22	0.222
Const.	0.583***	2.77	0.006
R-sq overall (%)	19.09		

Note: *This table reports estimation results of the impact of economic fundamentals on GDPpc growth rate level. The results correspond to regression equation (5). 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 -0.701, while its effect after the euro is $-0.701 - 3.610 = -4.311$. The total number of both cross-sectional and time-series observations in our sample is 384. T-statistics are computed using robust standard errors. *** Significant at 1%, ** significant at 5%.*

Table 3: Estimation results of impact of economic fundamentals on GDP growth level, 1980-2007

GDPpc growth rate level	Coefficient	t-Statistic	Prob.
Gov. Debt	0.916	1.32	0.187
Gov. Debt*Dummy	-0.152	0.11	0.913
Gov. Revenue	-8.810	-1.44	0.153
Gov.t Revenue*Dummy	-4.415	-0.47	0.640
Gross National Savings	-1.107	-0.23	0.821
Gross National Savings*Dummy	-1.872	-0.27	0.788
Interest on Borrowing	0.090	1.45	0.148
Interest on Borrowing*Dummy	-0.161	-0.72	0.473
Imports	-0.098***	-2.84	0.005
Imports*Dummy	0.105***	2.97	0.003
Inflation	-0.198***	-5.25	0.000
Inflation*Dummy	-0.108	1.27	0.205
Employment	13.350	1.27	0.207
Employment*Dummy	-1.776	-0.09	0.929
Const.	0.754***	3.77	0.000
R-sq overall (%)	12.06		

Note: *This table reports estimation results of the impact of economic fundamentals on GDPpc growth rate level. The results correspond to regression equation (5). 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* 0.916*, while its effect after the euro is* $0.916 - 0.152 = 0.764$*. The total number of both cross-sectional and time-series observations in our sample is 336. T-statistics are computed using robust standard errors.* *** *Significant at* 1%*.*

Table 4: Estimation results of impact of economic fundamentals on GDP growth level, controlling for foreign exchange rates, 1980-2011

GDPpc growth rate level	Coefficient	t-Statistic	Prob.
Gov. Debt	0.737	0.69	0.509
Gov. Debt*Dummy	-3.703***	-3.49	0.006
Gov. Revenue	-11.120	-0.84	0.419
Gov. Revenue*Dummy	2.507	0.26	0.803
Gross National Savings	-0.919	-0.11	0.913
Gross National Savings*Dummy	4.649	0.41	0.693
Interest on Borrowing	0.057*	2.19	0.053
Interest on Borrowing*Dummy	-0.419***	-4.02	0.002
Imports	-0.102	-1.52	0.159
Imports*Dummy	0.107	1.58	0.146
Inflation	-0.154	-2.08	0.065
Inflation*Dummy	-0.063	-0.43	0.676
Employment	14.112	1.90	0.086
Employment*Dummy	19.995	1.10	0.299
Exchange Rate	-0.907	-1.46	0.174
Exchange Rate*Dummy	0.907	1.46	0.174
Const.	3.661***	13.81	0.000
R-sq overall (%)	35.19		

Note: *This table reports estimation results of the impact of economic fundamentals on GDPpc growth level. In regression (5) we also control for exchange rates. The effect of economic fundamental j before adoption of the euro is given by the coefficient ϕ_j, and after adoption by the coefficient $\phi_j + \psi_j$. The total number of both cross-sectional and time-series observations of our sample is 384. T-statistics are computed using robust standard errors.* *** *Significant at* 1%, and * *significant at* 10%.

Table 5: Estimation results of impact of economic fundamentals on GDP growth level, non-Euro countries, 1980-2011

GDPpc growth rate level	Coefficient	t-Statistic	Prob.
Gov. Debt	3.817	1.36	0.180
Gov. Debt*Dummy	-1.371	-0.46	0.644
Gov.t Revenue	10.106	1.03	0.307
Gov. Revenue*Dummy	-7.533	-0.55	0.581
Gross National Savings	-8.530	-0.97	0.337
Gross National Savings*Dummy	8.775	0.88	0.383
Interest on Borrowing	-0.209	-0.76	0.452
Interest on Borrowing*Dummy	0.274	0.71	0.479
Imports	-0.002	-0.21	0.832
Imports*Dummy	-0.024	-1.01	0.317
Inflation	0.096	0.89	0.374
Inflation*Dummy	-0.459***	-3.44	0.001
Employment	21.34	0.82	0.418
Employment*Dummy	-32.490	-0.90	0.371
Const.	0.429***	1.17	0.245
R-sq overall (%)	19.89		

Note: *This table reports estimation results of the impact of economic fundamentals on GDPpc growth level, using a different sample of countries (Czech Republic, Denmark, Hungary, Norway, Sweden, Switzerland, and the United Kingdom). The results correspond to regression (5). The effect of economic fundamental j before adoption of the euro is given by the coefficient ϕ_j, and after adoption by coefficient $\phi_j + \psi_j$. The total number of both cross-sectional and time-series observations of our sample is 256. T-statistics are computed using robust standard errors.* *** *Significant at* 1%.

Table 6: Impact of government debt on GDP growth volatility, 1980-2011

GDPpc growth rate volatility	Coefficient	t-Statistic	Prob.
Gov. Debt	-9.314***	-3.15	0.002
Gov. Debt*Dummy	24.131***	4.76	0.000
Const.	2.965***	7.13	0.000
R-sq overall (%)	8.07		

Note: *This table reports estimation results for the panel regression:*

$$\hat{v}_{it+1}^2 = \kappa_i + (\beta_1 + \gamma_1 \mathbf{I}_{i,t})\, Debt_{i,t} + e_{i,t+1},$$

where $\hat{v}_{it+1}$ *is the residual at time* $t+1$ *defined in (4),* $Debt_{i,t}$ *is the weighted growth rate of government debt at time* t, κ_i *is the country-specific effect,* $I_{i,t}$ *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, and* $e_{i,t+1}$ *denotes the idiosyncratic error term. The effect of government debt on the GDPpc growth rate volatility before adoption of the euro is* -9.314, *while its effect after adoption is* $-9.314 + 24.131 = 14.817$. *The total number of both cross-sectional and time-series observations in our sample is 384. T-statistics are computed using robust standard errors.* *** *Significant at* 1%.

Table 7: Estimation results of impact of economic fundamentals on GDP growth rate volatility, 1980-2011

GDPpc growth rate volatility	Coefficient	t-Statistic	Prob.
Gov. Debt	-10.526***	-5.15	0.000
Gov. Debt*Dummy	22.873**	2.64	0.025
Gov. Revenue	-35.379**	-2.52	0.031
Gov. Revenue*Dummy	37.495	1.80	0.102
Gross National Savings	-20.066	-0.46	0.654
Gross National Savings*Dummy	-24.503	-0.44	0.669
Interest on Borrowing	0.147	0.46	0.655
Interest on Borrowing*Dummy	0.951**	2.80	0.019
Imports	1.049**	2.27	0.047
Imports*Dummy	-1.045**	-2.25	0.048
Inflation	0.298	1.50	0.165
Inflation*Dummy	0.181	0.87	0.406
Employment	71.958	1.14	0.281
Employment*Dummy	-94.331	-0.92	0.381
Const.	1.691**	2.96	0.014
R-sq overall (%)	31.39		

Note: *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 square* of *the residual v_{it} in (3). The results correspond to regression equation (9). 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 -10.526, while its effect after adoption is $-10.526 + 22.873 = 12.257$. The total number of both cross-sectional and time-series observations in our sample is 384. T-statistics are computed using robust standard errors.* *** *Significant at* 1% *and* ** *significant at* 5%.

Table 8: Estimation results of impact of economic fundamentals on GDP growth volatility, 1980-2007 (without financial crisis period)

GDPpc growth rate volatility	Coefficient	t-Statistic	Prob.
Gov. Debt	-11.190***	-3.62	0.000
Gov. Debt*Dummy	14.993**	2.54	0.012
Gov. Revenue	-45.407*	-1.68	0.095
Gov. Revenue*Dummy	41.379	1.01	0.316
Gross National Savings	-2.730	-0.14	0.888
Gross National Savings*Dummy	-12.085	-0.42	0.674
Interest on Borrowing	-0.893***	-3.50	0.001
Interest on Borrowing*Dummy	-0.228	-0.23	0.817
Imports	1.061***	7.37	0.000
Imports*Dummy	-1.054***	-7.17	0.000
Inflation	0.729***	3.80	0.000
Inflation*Dummy	0.079	0.21	0.832
Employment	45.362	1.01	0.315
Employment*Dummy	-15.088	-0.17	0.862
Const.	-0.532	-0.58	0.564
R-sq overall (%)	38.87		

Note: *This table reports estimation results of the impact of economic fundamentals on GDPpc growth rate volatility. The dependent variable (proxy of GDPpc growth volatility) is given by the square* of *the residual v_{it} in (3). The results correspond to regression equation (9). 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 -11.190, while its effect after adoption is $-11.190 + 14.993 = 3.803$. The total number of both cross-sectional and time-series observations of our sample is 336. T-statistics are computed using robust standard errors.* *** *Significant at* 1%, ** *significant at* 5%, and * *significant at* 10%.

Table 9: Estimation results of impact of economic fundamentals on GDP growth volatility, controling for foreign exchange rates, 1980-2011

GDPpc growth rate volatility	Coefficient	t-Statistic	Prob.
Gov. Debt	-10.430***	-3.27	0.403
Gov. Debt*Dummy	22.597***	4.25	0.000
Gov. Revenue	-36.937	-1.31	0.193
Gov. Revenue*Dummy	38.108	0.99	0.321
Gross National Savings	-20.495	-0.91	0.362
Gross National Savings*Dummy	-24.490	-0.89	0.375
Interest on Borrowing	0.095	0.34	0.736
Interest on Borrowing*Dummy	1.029*	1.79	0.075
Imports	1.037***	6.55	0.000
Imports*Dummy	-1.033***	-6.42	0.000
Inflation	0.275	1.72	0.087
Inflation*Dummy	0.210	0.65	0.514
Employment	56.43	1.14	0.254
Employment*Dummy	-78.506	-1.15	0.251
Exchange Rate	-6.378*	-1.79	0.075
Exchange Rate*Dummy	6.379*	1.79	0.075
Const.	1.675**	2.08	0.039
R-sq overall (%)	32.95		

Note: *This table reports estimation results of the impact of economic fundamentals on GDPpc growth volatility. The dependent variable (proxy of GDPpc growth volatility) is given by the square of the residual v_{it} in (3). In regression (9) we also control for exchange rates. Recall that the effect of economic fundamental j before adoption of the euro is given by the coefficient β_j, and after adoption by the coefficient $\beta_j + \gamma_j$. The total number of both cross-sectional and time-series observations of our sample is 384. T-statistics are computed using robust standard errors.* *** *Significant at* 1%, ** *significant at* 5%, and * *significant at* 10%.

Table 10: Estimation results of impact of economic fundamentals on GDP growth volatility, non-Euro countries, 1980-2011

GDPpc growth rate volatility	Coefficient	t-Statistic	Prob.
Gov. Debt	0.013	0.00	0.998
Gov. Debt*Dummy	1.684	0.38	0.730
Gov. Revenue	10.169	0.19	0.862
Gov. Revenue*Dummy	-7.863	-0.14	0.898
Gross National Savings	-21.240	-0.85	0.457
Gross National Savings*Dummy	6.117	0.19	0.858
Interest on Borrowing	-0.577***	-12.93	0.001
Interest on Borrowing*Dummy	0.951***	10.99	0.002
Imports	0.011	1.39	0.258
Imports*Dummy	0.024*	2.82	0.067
Inflation	0.260	0.91	0.432
Inflation*Dummy	-0.047	-0.12	0.912
Employment	42.719	0.86	0.454
Employment*Dummy	-64.762	-0.72	0.523
Const.	1.179*	2.03	0.135
R-sq overall (%)	5.42		

Note: *This table reports the estimation results of the impact of economic fundamentals on GDPpc growth volatility, using a different sample of countries (Czech Republic, Denmark, Hungary, Norway, Sweden, Switzerland, and the United Kingdom). The dependent variable (proxy of GDPpc growth volatility) is given by the square of the residual* v_{it} *in (3). The results correspond to regression (9). Recall that the effect of economic fundamental* j *before adoption of the euro is given by the coefficient* β_j*, and after adoption by coefficient* $\beta_j + \gamma_j$*. The total number of both cross-sectional and time-series observations of our sample is 256. T-statistics are computed using robust standard errors.* *** *Significant at* 1%*,* and * *significant at* 10%*.*

Table 11: Effect of fundamentals on economic growth

Fundamental	Stat. significant structural break	Robust to exclusion of financial crisis	Robust to exchange rate	Break for non-euro countries
Gov. Debt	YES*** (-)	NO	YES	NO
Gov. Revenue	NO	YES	YES	NO
GNS	NO	YES	YES	NO
Interest on debt	YES*** (-)	NO	YES	NO
Imports	YES*** (+)	YES	NO	NO
Inflation	NO	YES	YES	YES***
Employment	NO	YES	YES	NO

Note: *This table summarizes the findings in the main Table 2. "YES" indicates there is an effect, and "NO" that there is no effect.* *** *Significant effect at* 1%.

Table 12: Effect of fundamentals on uncertainty

Fundamental	Stat. significant structural break	Robust to exclusion of financial crisis	Robust to exchange rate	Break for non-euro countries
Gov. Debt	YES*** (+)	YES	YES	NO
Gov. Revenue	NO	YES	YES	NO
GNS	NO	YES	YES	NO
Interest on debt	YES** (+)	NO	YES	YES***
Imports	YES, but small (γ_{imp}= 0.004)	YES	YES	YES*
Inflation	NO	YES	YES	NO
Employment	NO	YES	YES	NO

Note: *This table summarizes the findings in Table 7. "YES" indicates there is an effect, and "NO" that there is no effect.* *** *Significant effect at* 1%, ** *significant effect at* 5%, and * *significant effect at* 10%.