Time-varying fiscal rules in Europe – is the time different now?*

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Abstract

This paper analyses the effects of a changing institutional environment represented by the fiscal regulation in the European Union (EU) on the behaviour of national fiscal policy, in particular the implications for debt sustainability. If a government adjusts the primary balance such that its debt does not grow without any limits, its debt position is sustainable. To examine government behaviour, I extend a fiscal policy rule as in Bohn (1998) to allow for smooth adjustments and time-varying parameters, which is aligned with varying importance of fiscal policy objectives. I estimate the model for members of two groups of European countries (Euro and non-Euro) to study the effect of EU fiscal regulation on a country's debt sustainability. The results of my analysis reveals that prior to the EU debt crisis, EU regulation has been unable to influence national fiscal policy in Euro countries to ensure debt sustainability. On the contrary, fiscal policy in non-Euro countries is in line with debt sustainability. Further, the paper also finds that the introduction of new EU-wide fiscal regulation during the EU debt crisis leads to a convergence of fiscal behaviour between the Euro and non-Euro countries. My results confirms the importance of constraints' design and highlight the effect of a direct link to constrained governments.

Keywords: Sovereign debt sustainability, Time-varying parameters models, Bayesian estimation, Stochastic volatility, Fiscal rules, Euro area.

JEL Classification: C11, E62, F45.

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1 Introduction

Since the 1970s both advanced and developing countries have experienced a substantial increase in sovereign debt, often surpassing levels believed to be safe according to fiscal sustainability models.[1)] To ensure the sustainability of public debt, institutional constraints, including independent fiscal institutions and fiscal rules, have been implemented. In the aftermath of the Great Recession and the subsequent sovereign debt crisis in Europe unfolding in 2010, one of the most important objectives for policy-makers has become the introduction of new, or amendments to existing, constraints.

I analyse how changes to the institutional framework influence fiscal policy and the sustainability of public debt. In line with literature, I define debt sustainability as an equilibrium consistent with the long-run financial stability. In this concept, fiscal policy does not have to pursue the balanced budget in every period if short-run deviations from the sustainable balance are compensated accordingly. That implies that fiscal policy follows some rule(s) to ensure it. I analyse one example where fiscal institutions are an explicit component (constraint) of a country's policy, the case of the European Union (EU):[2)] the Eurozone membership of some EU countries (EA-10/12) serves to identify the effects of institutional changes relative to stand-alone EU countries (EU-3).[3)] Five fiscal treaties in the EU represent fiscal institutions: the Maastricht Treaty, the Stability and Growth Pact (Pact), its first amendment, its second amendment (the Six-Pack) and the Fiscal Treaty. The purpose of these fiscal institutions is to constrain the size of the government budget deficit.[4)] I compare the effect on an individual country's debt sustainability for each of the listed rules. The first three treaties can be viewed as the 'old fiscal regime' and the last two treaties can be classified as a 'new fiscal regime'. While the old regime aims to centralise fiscal discipline (Wyplosz, 2016), the importance of the new regime change lies in the design. In particular, the Fiscal Treaty introduces a debt brake and independent fiscal councils, which are required to be implemented at the national level. When EU fiscal institutions follow closely suggestions for optimal fiscal rules (economic rationale), a government's behaviour can be more (easily) aligned with them. Together with other supervisory mechanisms and monitoring practices for those EU members belonging to the Euro group, they reduce the need for the *ex ante* sanction principle. I argue that the

[1)] There are several possible explanations for the increasing debt levels, with the so-called deficit or spending bias of policy-makers as front-runners, Alesina and Passalacqua (2016).

[2)] Some countries seem to follow implicit rules with autocorrection mechanisms at place, such as the US (Bohn, 2005).

[3)] The EA-10 group includes: Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal, Spain; the EA-12 group includes two fiscal 'outliers' Greece, and Luxembourg; EU-3 consists of: Denmark, Sweden and the United Kingdom.

[4)] While the Maastricht Treaty specifies the limit in terms of the total (actual or planned) deficit maximally to 3% of GDP on the national account basis, the Pact puts an additional constraint on top of that, by specifying cyclically-adjusted (structural) deficits 'close to balance or surplus' or in later modifications as 'on the target or on a path to it' under normal circumstances (see Eyraud and Wu, 2015). In addition, these EU treaties also specify a limit for the general government debt (60% of GDP).

behaviour of EU-3 countries has been different, mostly because of their own national fiscal rules, being a qualitatively different constraint of national fiscal policy.

In this paper, fiscal sustainability is assessed on a country basis since fiscal policy has remained predominantly in the competence of individual member states (Wyplosz, 2016). I develop my analysis by merging two approaches. First, I use the model-based sustainability approach (MBS, D'Erasmo et al., 2016) based on the seminal work of Bohn (1998, 2007) that links the sovereign debt-to-GDP ratio and the primary balance. Debt sustainability is associated with government behaviour. An increase in the sovereign debt-to-GDP ratio requires the primary balance to improve to ensure that the intertemporal budget constraint of the government is not violated and sustainability is ensued.[5)] My empirical model is an extension of Bohn (1998)'s fiscal rule with an autoregressive term to capture smooth adjustments. Since government behaviour changes over time as a result of varying preferences of elected representatives and domestic and foreign environment, I extend the fiscal rule to allow for time-varying parameters (TVP) and use the Bayesian TVP estimation approach following Primiceri (2005). In addition, as pointed out by Debrun et al. (2008) and Heinemann et al. (2017), a country can adopt a fiscal rule in line with voters' preferences for more/less prudent fiscal behaviour (lower deficits and debts) or as a response to difficulties of a country's public finances. Therefore, by employing the time-varying parameter model, I can be rather agnostic about the size and timing of any effect. The complementary narrative evidence, provides a more direct evidence of the effects of a fiscal constraint. This indirect way of capturing institution-related effects avoids problems with possible reverse causality (endogeneity) associated with a direct measure of fiscal rule's 'strength' in Bohn's model typically used in the literature.

There is a lack of quarterly fiscal time series for many EU countries before the introduction of the Euro (1999), putting a limit on an empirical investigation. In order to analyse the first EU-wide institutional constraints implemented already in the early 1990s, I reconstruct the fiscal series of the primary balance and sovereign debt even before back to the 1980s. As long as country-specific fiscal series are available, I follow the standard bottom-up approach to construct the fiscal variables, following recent studies (Paredes et al., 2014, De Castro et al., 2014). Then, the model-based rule can be estimated individually for each country over the same sample period 1980q1–2016q4.

To identify the effect of the EU fiscal constraints on debt sustainability, represented by the estimated coefficient on public debt in my model-based fiscal rule, I rely on two approaches. First, I identify several episodes with variation in the institutional setting from the early 1990s to 2016. For this purpose, I follow Canova et al. (2012) and define the quarter of the change

[5)] Even though more recent institutional constraints are specified in terms of the structural budget balance of the general government sector, I use the primary balance for two reasons. First, it is as a tool that encompasses all 'targeted' fiscal operations of a government (structural deficit) and the effect of automatic stabilisers as well. Their strength is, however, set by the government too. Only interest payments on debt are missing since they are a consequence of past governments' behaviour and mostly beyond the direct control of a government. Second, both the cyclically and structural budget balance are subject to repeated revisions because of the underlying estimates of output gaps.

of EU fiscal institutions becomes active as the starting point of a new constraint. I assess the effects of such changes on national fiscal rules over time (size, sign and persistence). My results for the time-varying parameter fiscal rule are mixed for the old regime. Some EA countries respond to EU constraints with mostly temporary effects, with the exception of the first amendment of the Pact. In addition, I cannot identify any clear pattern with respect to their level of indebtedness, which is in line with the literature. When my rule is estimated for the new fiscal regime, some EU countries show increased debt coefficients and a more persistent change. When examining periods for individual constraints, I also plot time-varying coefficients for the debt variable for each country in my sample. That time path can be compared with a simple test of debt sustainability: the real-growth adjusted real interest rate for the country following Collignon (2012). Most EU countries in my sample seem to have passed this test. However, there are some periods of non-compliance that is consistent with time-varying debt sustainability (sustainable policy does not have to be followed at all times). Behaviour of the stand-alone EU countries does not have to be responding to the EU fiscal constraints, with the exception of the first amendment of the Pact and then the Fiscal Treaty.

However, to confirm the existence of a change, I add another identification approach, the narrative evidence. I use the aforementioned set of identified changes in EU fiscal institutions, to estimate a time-invariant version of my model with interactions terms for each EU fiscal treaty. A set of dummy variables represents changing institutional environment (EU treaties) and interaction terms with the previous set of determinants serve to estimate additional effects compared to the base period (without any rule). I can evaluate the effects of institutional changes for the five EU fiscal treaties by testing the estimated coefficients of the national fiscal rules using a Chow-type break test with a known break date.

My results from the analysis suggest that the old fiscal regime has only limited effects on national fiscal policy in the EA countries in line with the literature. However, there is a difference between the Maastricht Treaty (1993), the Pact (1998) and the first modification of the Pact (2005). I find a significant but small positive coefficients on lagged debt for the former, indicating that governments reduce their primary deficit when indebtedness increases. Furthermore, the introduction of the Maastricht Treaty led to a significant increase in the debt sustainability coefficient in about half of the EA countries. Conversely, the latter leads to a stronger adjustment of government spending policies and an increased compliance with fiscal constraints (deficit and debt). In contrast to the relatively loose Eurozone fiscal policy, the non-Euro countries followed fiscal constraints more closely indicating a more conservative fiscal policy. Turning to the new fiscal regime, I examine the second amendment of the Pact (2012) and the Fiscal Treaty (2014). I observe significant changes of coefficients for both across EA group countries.

In case of the stand-alone EU countries, I find different effects – countries show significant responses compared to the base across both regimes. This finding can be explained by the fact that the original EU-wide fiscal institutions are complemented or completely replaced with national rules (in the UK). These national rules either extend the coverage of EU rules or follow a different approach, more aligned with the economic rationale of a fiscal rule (multi-year framework, flexible limits), in line with arguments in Wyplosz (2016). They are then similar to the new fiscal regime in the EU.

Another result of my analysis is of importance. My time-varying estimation confirms a changing role of fiscal policy in several EU countries, that is, active and passive policy regimes (in Leeper (1991)'s terminology) for several countries such as Portugal, which is in line with the literature.[6] EA groups become more heterogeneous before the introduction of the Euro (1999) and more homogeneous afterwards. A similar behaviour is observed also for the non-Euro group. However, the Great Recession and the EU sovereign debt crisis period result in a different picture (especially after 2013): while the Euro group becomes somewhat more heterogeneous, the non-Euro group shows the opposite behaviour, it becomes even more homogeneous.

Related Literature. This paper is related to the literature on debt sustainability, institutions and the effects of fiscal rules. Several strands have developed in the sustainability literature since the pioneering work of Barro (1979). This study is close to Bohn (1998)'s fiscal policy rules framework, which draws on monetary policy rules (Taylor, 1993).[7] Recently, emphasis has been put on: (*a*) optimising behaviour of fiscal agents, (*b*) the importance of a connection between fiscal policy behaviour and monetary policy actions. I follow Kirsanova et al. (2005) and estimate a fiscal rule that explicitly allows for both factors.

My paper builds upon one sub-strand of the literature on the estimation of time-varying version of fiscal rules. Because of empirical evidence,[8] the latter relaxes the time-invariant assumption and draws on the idea of time-varying policy rules using Leeper (1991)'s concept of 'fiscal regimes' in two different ways. Some authors utilize the concept of Markov-Switching models (Favero and Monacelli, 2005; Chung et al., 2007; Bianchi, 2013; Afonso and Toffano, 2013; Ricci-Risquete et al., 2016). Other papers consider 'truly' time-varying fiscal rules (Canzoneri et al., 2001; Cuerpo, 2014), which provides a motivation for this paper.[9] The former study provides only a theoretical framework, and the latter uses a simple TVP rule only for Spain. In my paper I estimate a modified fiscal rule for a larger group of European countries. In addition, my results cover both the period before the Great Recession and the

[6] A government can pursue a fiscal policy regime consistent with fiscal sustainability (passive regime), that is, the primary balance responds to debt changes to ensure it or not (active regime). This finding is not as uncommon in empirical studies as illustrated by Afonso and Toffano (2013) for four European countries.

[7] This is because of the use of: (*i*) output gap (growth rates of potential or real GDP) as a proxy for cyclical behaviour and (*ii*) a 'policy variable' such as cyclically-adjusted deficit or the structural component of a budget deficit. For a direct comparison see Taylor (2000) or Leeper (1991).

[8] Either in the form of actual fiscal series Eichengreen and Panizza (2016) or using empirical tests (Ghosh et al., 2013 or Fourier and Fall, 2017).

[9] However, there are some drawbacks of Canzoneri et al. (2001)'s concept: their definition of sustainability considers only positive responses of the primary balance, which is at odds with empirical findings, in particular for longer periods of economic instability (Afonso et al., 2011; Schoder, 2014). Second, their concept is subject to critique for unbounded debt ratios, which is particularly relevant for a country facing a fiscal limit.

EU debt crisis, but also afterwards, which has not been analysed so far.

The reason for changing government's behaviour is not only related to the nature of exogenous shocks affecting an economy (see Canova et al., 2012), but it can also be triggered by a heterogeneous group of factors broadly defined as institutions. There are studies that analyse institutional (supranational) rules in individual countries, for example in federations (Imbeau, 2004; Eyraud and Gomez Sirera, 2015) and those that analyse rules applied to members of integration groups such as the EU (Wyplosz, 2014; von Hagen and Wolff, 2006).[10] These are aimed to eliminate government's deficit bias or the so-called common pool problem (Alesina and Passalacqua, 2016).[11] Halac and Yared (2015) show that a supranational rule is suggested for less impatient governments (resulting in a lower interest rate as the rule is more binding), while a national rule works better for short-sighted governments. Similarly, Aguiar et al. (2015) show that a debt ceiling can help to overcome the deficit bias even in a monetary union facing insufficient commitment in case of fiscal policy. In this paper I allow for time-varying coefficients to capture changes in preferences for debt sustainability of policy-makers and voters. I also show that not only the existence of a fiscal rule, but also the design of that rule matters for policy-making by a comparison of strict (old regime) rules with those recently introduced in the EU being more aligned with the economic rationale (multi-annual evaluation, automatic breaks, etc.).

A number of studies have examined the design and outcomes of rule-based indicators of fiscal sustainability. This paper takes a macroeconomic view, by considering the presence of EU (supranational) fiscal institutions. My analysis is then directly related to studies providing evidence on early EU fiscal institutions (the old regime: Debrun et al., 2008; Golinelli and Momigliano, 2009; Weichenrieder and Zimmer, 2014; Baldi and Staehr, 2016).[12] Few studies analyse both national constraints and EU fiscal institutions (Frankel and Schreger, 2013; Nerlich and Reuter, 2013; Bergman et al., 2016) and recent work focuses mainly on the effects of national fiscal rules (Reuter, 2015, 2017).[13] The latter provides further evidence that the effects of EU fiscal constraints (a country being in the Eurozone) is not significantly different from a situation with only national rules. However, owning to the granular approach

[10] The main issue with early versions of the EU numerical rules (before the Great Recession) are: 'creative accounting', 'window dressing' and other practices in the pre-EMU phase as documented by Buti et al. (2006) or Irwin (2015); enforceability or perceived 'double standards' for Eurozone members (Hefeker, 2005) and the design of the rules and their modifications.

[11] A deficit bias is the tendency to run high deficits or procyclical policies as a result of short-sighted government). Those policies are viewed as time-inconsistent behaviour of governments (Calmfors and Wren-Lewis, 2011). One alternative way of keeping fiscal institutions under public scrutiny is market-based fiscal discipline (Bernoth et al., 2004; Bernoth and Wolff, 2008). However, the recent experience of EMU countries does not provide much support to this hypothesis because of financial markets behaviour (Schuknecht et al., 2010).

[12] A fiscal constraint usually enters as an exogenous shock/regime switch (a dummy variable) when conducting analyses of macroeconomic effects of fiscal institutions. These studies tend to find differentiated behaviour in the pre and post-EMU period or during the sovereign debt crisis.

[13] Frankel and Schreger (2013) analyse forecasting performance under both national and supranational rules; Bergman et al. (2016) investigate which types of rules were most efficient. Reuter (2015) studies compliance with fiscal rules and Reuter (2017) whether target and coverage of a rule matter.

many Eurozone countries are not included in previous studies since they do not have any national fiscal rule, their construction is not aligned with a common definition or due to missing data. My paper complements and expands the existing evidence by adding the period after 2012 that includes the second modification of the Pact and the Fiscal Treaty. Since a less granular approach is used, my paper examines fiscal policy in a larger group of European countries. Therefore, it provides both a robustness check to previous studies, and to the best of my knowledge, it is the first one that shows empirical evidence on fiscal policy during and in the aftermath of the EU debt crisis.

Outline. The remainder of the paper is structured as follows. Section 2 reviews theoretical concepts utilized with links to the literature and describes the TVP modelling approach with illustrations of the estimation methodology. Section 3 describes the dataset and briefly reviews steps necessary for the (re)construction of fiscal variables. Section 4 presents results for Eurozone countries and stand-alone EU countries, and discusses the implications of these findings. Section 5 concludes.

2 Theoretical and empirical model

2.1 Fiscal policy rules

2.1.1 Sustainability of fiscal policy

When problems with fiscal policy re-emerged in the late 2000s, a discussion of the notion of sustainability came to the fore. This debate was related to the way debt changes over time (the so-called debt evolution equation), for details see equation (A.2) in appendix. One of the first working definitions is in (Blanchard et al., 1990, p. 6) that defines sustainability as a situation when the current course of fiscal policy can be sustained, without public debt growing without limits. This discussion led to the creation of a framework that drives the current understanding of sustainability.[14] Government debt becomes unsustainable when the present value of government assets falls below the present value of government liabilities. Formally, the notion relies on the transversality condition and the intertemporal budget constraint of the government; the government intertemporal budget constraint is violated, see the appendix (A.1).[15] The following IMF definition summarizes the current idea of fiscal sustainability (IMF, 2002, Box 1): *'[...] liability position is sustainable if it satisfies the present value budget constraint without a major correction in the balance of income and expenditure given the costs of financing [the entity] faces in the market.'* However, even this definition entails practical issues regarding the notion of a 'correction' or their repeated occurrence over time (see Lamé et al.,

[14] In economics, fiscal sustainability in the current interpretation emerged in the 1970s; alternative views for schools of economic thought summarises Burger (2005).

[15] When a sovereign does not have enough resources to meet outstanding obligations (even temporarily), it becomes illuquid, which is not analysed here. A government facing liquidity problems can still be solvent, however, the need to meet demands can lead to insolvency, well-studied in the banking/finance literature.

2014). Fiscal sustainability is a dynamic concept and implies that the government debt-to-GDP ratio is stable over time.[16)]

2.1.2 Rules based approach to sustainability

Early tests of sovereign debt sustainability (fiscal solvency) coherent with definitions à la Blanchard have been carried out since the mid-1980s (Hamilton and Flavin, 1986; Trehan and Walsh, 1988; Trehan and Walsh, 1991). These early contributions focused on tests of properties of available fiscal time series. This so-called classic debt sustainability literature is criticized because of econometric-related technical problems (Bohn, 1998, 2007; D'Erasmo et al., 2016, see appendix A.1.1 for details.) In a response to these problems, Bohn (1998) proposes a rule based approach to test fiscal sustainability. Fiscal rules or fiscal reaction functions (FRF) closely resemble the approach of Taylor rules applied in monetary policy (see Taylor, 2000).[17)]

Bohn's approach simplifies the analysis since it relies on a simple general equilibrium model with three key equations: (a) a linear fiscal reaction function (fiscal policy rule), (b) a debt transition equation and (c) the Euler equation (for formal treatment see appendix A.2). Because of its reliance on the Euler equation and a fiscal rule (see equation (2.1) below), this approach is also called Model-Based Sustainability (MBS, see D'Erasmo et al., 2016):

$$pb_t = \alpha \ d_{t-1} + \chi_t, \tag{2.1}$$

where pb_t represent the current primary balance, α is the debt response coefficient, χ_t stands for a set of determinants of primary balance, the constant term and an error term.

The MBS approach emphasises the role of (time-invariant) fiscal responses to changes in the government debt-to-GDP ratio. Bohn argues that its value must be high enough such that the No-Ponzi game condition (TVC) is satisfied. He shows that fiscal sustainability is ensured if the coefficient on government debt (α) in the fiscal rule is positive. In case of a debt stabilization goal, the sustainability condition is stricter. As a result, the long-term value of the government debt can be calculated (see appendix A.2).

2.2 Empirical model

My empirical model builds upon the MBS approach. Given recent changes in the conduct of fiscal policy responding to shocks and under close scrutiny, I argue that fiscal responses are actually more aligned with a quarterly view than those using calendar years. The reasons being: 1) EU countries typically monitor quarterly and monthly fiscal performance with a different level of details (usually compared with the data year before), however, less in real time and

[16)] Some authors then put emphasis on deficit levels that are consistent with a stable share of debt-to-GDP (Easterly and Schmidt-Hebbel, 1994) or government's dis-saving and debt dynamics (Burger, 2005).
[17)] The model does not rely on detailed micro-econometric evidence on intertemporal preferences of agents, discount rates or government bond yields.

subject to revisions compared to monthly available cash series. A government's plans for a fiscal year reflect not only quarterly, but at least implicitly monthly variation by matching of revenue and expenditure streams; 2) intra-annual fiscal information has gained importance as an early warning indicator in the system of checks by the European Commission ('European Semester', see Bénassy-Quéré, 2016); 3) more recently, the new procedure for correcting macroeconomic imbalances (MIP, 2011) requires to implement fiscal measures without lengthly delays if a government's budgetary development clearly deviate from planned paths. Because of the quarterly frequency, individual variables will contain seasonality and additional sources of noise that have to be addressed.

I derive my model from Burger and Marinkov (2012) instead of using a simple quarterly correspondence with the yearly Bohn type model.[18] In addition, I extend their specification by assuming the estimated parameters to be time-varying, as denoted by the time subscripts in equation (2.2) and allow for a richer lag structure (an AR(4) term):

$$pb_t = c_t + \sum_{r=1}^{4} \varrho_{t-r}\ pb_{t-r} + \alpha_t\ d_{t-4} + \boldsymbol{\Gamma_t}\ \boldsymbol{\Theta}_{(.)} + \xi_t', \tag{2.2}$$

where pb_t represent the primary balance, pb_{t-r} is the r-th period lagged primary balance, d_{t-4} is the four-period government debt (all variables in percent of GDP), $\boldsymbol{\Theta}_{(.)}$ is a set of stationary control variables explained below, c_t is the constant term and ξ_t is the error term. $[\varrho_{t-1}, \ldots \varrho_{t-4}, \alpha_t, \boldsymbol{\Gamma_t}] \in \mathcal{B}$ represent a set of time-varying coefficient to be estimated. The coefficients of interests are ϱ_{t-r} and α_t.

The specification (2.2) aims to explain the behaviour of the primary balance over four quarters with respect to the lagged debt ratio, business cycle fluctuations, and development of current account balance and cyclical component of government expenditures. The coefficients on lagged primary balance variables $(\varrho_t, \ldots, \varrho_{t-4})$ represent their marginal effects and measure persistence of the fiscal balance. The choice of other control variables for the fiscal rule (the base rule, FR^{Ia}, henceforth) is influenced by the macro literature on fiscal sustainability: $\boldsymbol{\Theta}_{(.)} : (gr\_gdp_{t-4}, cab_{t-4}, gcout_{t-4})$. The first control variable (gr_gdp_{t-4}) is a measure of economic activity. I use the percentage GDP growth rate over the same quarter of the previous year. The Θ_1 coefficient represents the complete dependence on business cycle. I do not distiguish between the effects of discretionary measures and automatic stabilizers since both the underlying output gaps and cyclically adjusted budget balances are usually not available at quarterly frequency. The second control variable (cab_{t-4}) is the current account balance as a share of GDP. It is included to control for the twin deficit hypothesis, that is, a link between a country's current about balance and government balance. The third control variable $(gcout_{t-4})$

[18] Only few studies have considered such differences so far (Burger and Marinkov, 2012) in spite of an increasing number of mostly for country-specific estimations for European countries (Thams, 2007; Claeys, 2008; Afonso and Toffano, 2013; Schoder, 2014; Lamé et al., 2014; Ricci-Risquete et al., 2016). The choice of country sample is constrained by still limited availability of quarterly fiscal series in emerging or developing countries.

is the temporary government spending. Following Barro (1979)'s tax smoothing hypothesis it is measured as percentage deviations of real current expenditures over their long-run trend. To construct it, I use the Baxter-King (BK) band-pass filter to estimate both the cyclical component and the trend of government non-interest expenditures.[19] Temporary government spending is included as suggested by Bohn (1998).

My primary measure of economic activity is the quarter-to-quarter real GDP growth rate. The base model choice is motivated by a lack of quarterly output gap series, and smaller effects of *ex post* data revisions on calculated growth series (even though levels change significantly). Evidence in case of yearly series confirms similar results regardless of series used (Egert, 2010). In order to have comparable results with the remaining literature and as a robustness check, I consider two measures of the output gap based on the BK and HP filter; for details on their calculation see data section below. I use additional lags of the primary balance (second to fourth), even though the associated coefficients are usually small in numerical terms from the second lag.

Alternatively, the model (2.2) can be written in a form associated more closely to the actual conduct of fiscal policy in EU countries and similar to specifications in Collignon (2012).

$$\Delta pb_t = c_t + \sum_{r=1}^{4} \varrho_{t-r}\; pb_{t-r} + (\alpha_t - 1)\; d_{t-4} + \boldsymbol{\Gamma_t}\; \boldsymbol{\Theta}_{(.)} + \xi_t', \tag{2.3}$$

where Δpb_t is the change of the primary deficit between period t and $t-4$, that is, against the same quarter one year before. The four-quarter change of the primary balance is related to its original levels over previous four quarters, GDP growth, current account balance and cyclical component of government expenditures during the same period.

Because of the dynamic nature of the model, I need to address possible sources of endogeneity. Since the model does not include an explicit fiscal rule variable, there is no problem with reverse causality (simultaneity bias) between fiscal constraints and fiscal outcomes.[20] However, GDP growth (or output gap in some specifications) can be affected by fiscal policy behaviour over the four-quarter-long period, even though in different proportions as Boussard et al. (2013) illustrate for EU countries. Therefore, I include this variable with lagged by four quarters. Similarly, there can be a link between the current account and budget balance or the cyclical component affecting the primary balance. Therefore, I include both variables with the same lag length (four quarters).

As a robustness check I consider alternative versions of the fiscal rule FR^{Ia}. First, I re-estimate the model without controlling for the current account balance, which is closer to the original definition of Leeper (1991). Second, I follow the literature on the design of optimal

[19] I utilize and the Hodrick-Prescott (HP) filter as well as a robustness check, even though it was recently criticised by Hamilton (2016) for creating spurious dynamic relations.

[20] This important problem of empirical work on effects of rules has been addressed in the literature only recently, see Bergman et al. (2016) or Heinemann et al. (2017).

fiscal rules and choose GDP growth (or output gap), lagged inflation (CPI) and temporary government spending as control variables (Kirsanova et al., 2005). In addition, I also allow for a stochastic volatility term. The main results of the base specification are not changed by the robustness checks. The corresponding results are shown in appendix (A.3).

Long-run responses

Debt response coefficients estimated in (2.2) represent short-run fiscal responses ($\alpha^{SR} \equiv \alpha$), which contain only a part of the available information. In addition, I calculate long-run fiscal responses (α^{LR}) for a particular time period t, following the logic of Chudík et al. (2015). The long-run effect can be written as:

$$\alpha_t^{LR} = \frac{\alpha_t}{(1 - \sum_{r=1}^{4} \varrho_{t-r})} \tag{2.4}$$

where ϱ_{t-r} is the sum of coefficient on the lagged primary balance variable from the model (2.2) for individual periods $t = 5, \ldots, T$.

I will take the economic environment as exogenously given (a constant interest rate GDP growth difference), and focus on the policy coefficent α. The linear relationship between primary balance and debt takes the form:

$$d_t = (1 + r - g_y)d_{t-4} - pb_t. \tag{2.5}$$

Combining (2.2) and (2.5) leads to:

$$d_t = (1 + r - g_y - \alpha_t)d_{t-4} - \sum_r \varrho_{t-r}\ pb_{t-r} - c_t - \mathbf{\Gamma_t}\ \mathbf{\Theta}_{(.)} - \epsilon_t. \tag{2.6}$$

I follow Doi et al. (2011) and re-arrange terms further, so that the equation (2.6) can be written as an AR(4) process. Then the condition for debt sustainability, that is, a constant debt-to-GDP ratio, is met when long-run responses based on the equation (2.4) surpass the real-growth adjusted real interest rate.

The debt ratio is stabilised in the long run if the primary balance responses are larger than is the value of the growth adjusted real interest rate (dynamic efficiency).[21] The condition expresses that the long-run debt ratio is equivalent to the long-run primary balance ratio, which has to be larger than the growth adjusted interest rate.[22] In addition, the equations (2.2) and (2.5) can be thought as parts of a system of linear difference equations, which can be solved to find time paths of the debt ratio and the primary balance. As long as both time

[21] Stationarity of interest rate (with a positive mean) is assumed in the literature since that allows to link the budget identity to budget constraint (Bohn, 2005, 2007). However, that is not always the case empirically.
[22] If primary balance is equal to zero, the debt ratio grows at the growth-adjusted interest rate. That determines the value of primary balance necessary to keep debt ratio stable in the long run.

paths converge to a steady state, the fiscal policy is deemed to be sustainable as it is in line with the intertemporal budget constraint.

2.2.1 Time-varying fiscal rules – estimation

I follow Primiceri (2005) and Blake and Mumtaz (2012) and assume that all coefficients follow a specific law of motion. I assume a Random Walk time-varying parameter process, without drift, for all regression coefficients in $\mathcal{B}$:

$$\mathcal{B}_t = \mathcal{B}_{t-1} + \epsilon_t, \tag{2.7}$$

where ϵ_t is assumed to be an *iid* process, homoskedastic and uncorrelated with the error term ξ_t' in (2.2) above), and with a diagonal covariance matrix Λ. Equations (2.2) and (2.7) form the state-space representation of my model. While (2.2) is the so-called measurement equation, (2.7) is the transition equation.

The parameters of the state-space model (2.2) of the fiscal rule specified above, are estimated with Bayesian methods. The advantage of the Bayesian estimation procedure is that all parameters come from a joint distribution of random variables. When one parameter is estimated, it also reflects uncertainty about the others (Kim and Nelson, 1999).[23] For my model I follow Primiceri (2005) and utilize the Gibbs sampler and Carter and Kohn (1994) algorithm. This sampler is based on Markov Chain Monte Carlo simulations. In order to use it, one has to specify priors for all unknown parameters and their posterior conditional distributions. I follow Primiceri (2005), Byrne et al. (2016) and estimate via OLS a time-invariant version of my model on a training sample period, whose results provide information to specify priors (1981q1–1985q4, that is, 20 quarters). This allows to focus on comparison of models' results since it eliminates possible differences across simulations because of differences in the priors. It also reduces the variance, increases accuracy and gives rise to more robust inference since shrinkage uses likelihood-based evidence compared to flat priors (see Giannone et al., 2015; Byrne et al., 2016). Individual parameters in the fiscal rule model are drawn from multivariate normal distribution.

Following the TVP literature, I use the inverse Gamma (IGa) distribution for the observation equation and the inverse Wishart (IW) distribution for the transition equation (variance from the training sample is rescalled using the factor of proportionality, $\nu = 3.510 \cdot 10^{-3}$). Subsequently, draws from the specified distributions can be utilized to find approximation of the marginal and joint distribution. Finally, I restrict random draws generated for the lagged dependent variables, so that their sum over four quarters lies withing the interval of ± 1.1. For results presented below, I use 20000 draws and the last 10000 are stored; for further details see the appendix (A.4).

[23] Alternatively, the Kalman filter with maximum likelihood could be employed, see Kim and Nelson (1999) for details or a quasi-Bayesian local likelihood proposed by Petrova (2016).

3 Data

3.1 Data and their treatment

My dataset covers the EA-12 and the EU-3 countries over the period 1980q1 and 2016q4. Therefore, all major steps of the European integration process in the 1990s and 2000s are included.[24)] I use end of quarter government debt in gross terms in my analysis because: it is a standardised indicator of public indebtedness compared to a more broadly defined government liabilities and it reduces a measurement error related to other indicators.[25)] In addition, gross debt series are available at a quarterly frequency for a large part of my sample period and it is possible to extend the coverage when only annual data is available. As a measure of government activity within a year, I use the primary balance. It is constructed as the difference between total general government revenues minus total general government expenditures excluding interest payments as recorded in the quarterly national accounts.

Most of the data is taken from the Eurostat: Government finance statistics and the Quarterly national accounts database. For missing data I complement my dataset with data from OECD Economic Outlook and OECD Quarterly National Accounts.[26)] Data availability of fiscal series varies by country, but the majority of series in the ESA 2010 methodology provided by Eurostat starts in the early 2000s. Since I aim to investigate changes of fiscal institutions over time, starting with those at the beginning of the monetary integration period, I need to extend the time horizon. I reconstruct missing quarterly fiscal observations back to 1980 for my sample of countries as illustrated below and in detail in the appendix (A.5).

As mentioned above, my primary measure of economic activity is the real GDP growth rate and output gaps for robustness. To construct output gap series, I employ the BK filter, as well as the HP filter. To deal with the loss of observations associated with the BK filter and the endpoint problem of the HP filter, I extend the time series of output using 12-quarter-long forecasts/backcasts to both ends of each series generated by an univariate ARIMA model.[27)] I then apply the particular filter and delete the artificial observations afterwards. This procedure is suggested by Watson (2007) and used by the European Commission (Havik et al., 2014)

[24)] This implies that EU-12 includes three members that entered in the 1980s (Greece, Portugal and Spain) and three members in mid-1990s (Austria, Finland and Sweden). None of new EA members is considered because of scarcity of data before the 1990(95). Neither do I include Norway (with a rather specific fiscal policy because of natural resources), Switzerland or other small members of the European Free Trade Association (European Economic Area, EEA) since their fiscal policy was not explicitly subject to regulation/supervision by EU institutions.

[25)] Some studies prefer net (financial) debt series as they can be consider a better match of the notion of fiscal sustainability (Schoder, 2014 or Lamé et al., 2014) or a large definition of government obligations such as general government liabilities (Aldama and Creel, 2017). Considering net debt series, it does not take into account non-financial assets and are subject to large differences among countries even for market-traded assets. Assets' composition of governments varies substantially making comparisons of net debt series more difficult. Since negative net debt series exist for some EU countries (Finland or Sweden), these would put an additional limit on the set of countries for my analysis.

[26)] See appendix for a complete list of all data sources.

[27)] I also use a $VAR(p)$ or a $AR(p)$ model, see the data appendix.

and recent studies (Aldama and Creel, 2017). I use the current account balance expressed as a share of GDP and the CPI rate of inflation based on national indices from OECD databases. All series are seasonally adjusted. Financial market series are represented by *de iure* long-term yields of 10 year government bonds, published by Eurostat, OECD and IMF IFS or *de facto* implicit rates calculated from government debt and interest rate payments to proxy for the interest burden of the government. To compute the growth adjusted real interest rates, I use the GDP deflator and the real GDP series from OECD Economic Outlook. All series are demeaned and series that are not seasonally adjusted from its original source or showed some remaining seasonal patterns, are adjusted using the TRAMO/SEATS method (Gómez and Maravall, 1996).

Fiscal variables are affected by many irregularly occurring events, which take the form of so-called one-off items. I exclude two of them the primary balance series in line with the literature: 1) UMTS licences (between 2000 and 2003), and 2) *ad-hoc* deficit increasing transactions (Germany and the Netherlands in 1995). Debt series are adjusted for these. However, there are additional country-specific one-offs mostly in the 1990s. In addition, a special type of operations related to government support to financial institutions (GAFS) during the Great Recession and Sovereign debt crisis period. It is difficult to remove GAFS from the fiscal time series as Eurostat (see Eurostat, 2017b) and national sources report GAFS only on annual basis. There are also differences in the recording of these operations. For robustness check, I follow one approach (Joumard et al., 2008) that uses HP-calculated trend of net capital transfers to adjust series (balances, expenditures) for one-off items; for further details see the data subsection in the appendix.

3.1.1 Reconstruction of quarterly series

The Eurostat quarterly fiscal database contains government variables including budget balances, which are available for most of the EU countries from 1999q1. For Germany, Ireland, and Luxembourg, the series start only in 2002q1. Longer series are available for Belgium, Spain, and Sweden (all from 1995q1), the United Kingdom (1987q1) and France (1980q1). Government debt series start from 2000q1 for a majority of countries. Longer series are available only for Belgium, and Spain (1995q1) and for Sweden (1996q1). Therefore, a sample restricting only to readily available data would not allow to study the entire integration process. In order to circumvent this problem, I reconstruct primary balance and debt series at a quarterly frequency back to 1980q1. With the extended sample I can also analyse changes in fiscal policy at the beginning of the European monetary integration process in the late 1980s and early 1990s. For some countries national sources provide longer quarterly series of fiscal variables. In case they match those provided by Eurostat, they are used to extend the time horizon. There are several other limitations of the use of fiscal series, for example the coverage of general government before 1990 in many European countries such as Spain or Sweden or the reunification of Germany. In addition, national accounts methodology has changed twice over the sample period (ESA 1979 to ESA 1995 and ESA 1995 to ESA 2010).

Debt and primary balance

In order to construct missing observations of the debt and primary balance series, I follow the bottom-up approach presented in De Castro et al. (2014) and Paredes et al. (2014). The former paper uses a mechanical decomposition to fill in missing observations of high frequency data for Spain (QESFIP dataset, from 1970q1 to 2015q4) for the period before 1986 and the latter reconstruct series for Eurozone countries (EA-15), for the period 1980q1 to 2013q4.

Because of a lack of high frequency fiscal data, either monthly indicators and/or detailed national accounts series (quarterly series), it is not possible to fully replicate their approach for all EU countries in my sample. In this case I utilize the state-space decomposition of Giannone et al. (2015) and Bañbura et al. (2015) and the main steps are described below. The Bayesian approach has several advantages of this approach compared to mechanical techniques for temporal disaggregation such as Chow-Lin, Fernandez or Litterman (see Quilis, 2004; De Castro et al., 2014). Quarterly series are thus constructed using information from other time series that are highly correlated with the to-be-reconstructed fiscal series and are available at a quarterly frequency. To avoid the use of series of macroeconomic aggregates in my analysis, which may create a bias in fiscal series (Onorante et al., 2010; De Castro et al., 2014), I use only fiscal (sub-)aggregates correlated with total government revenues and expenditures. The set of variables employed for the reconstruction consists of the following series:

1) government revenues: direct tax (households and firms), indirect tax (indirect tax revenue from household consumption), and other revenues;

2) total government expenditures (with/without interest): subsidies, transfers to private sector, government final consumption and government fixed capital formation, and other expenditures.

Since I have not been able to reconstruct social and unemployment benefits series for a larger sub-sample of my country/period sample, they are not included in the current decomposition exercise. Expenditure series for countries with these two additional expenditure items are not substantially different from series reconstructed without them. In terms of total revenues/expenditures' coverage, it varies between 60% and 70% for my set of countries.[28)]

A great emphasis during this exercise is put on the comparability of series. I follow Berti et al. (2016), which recommend using the same source (database) for country/year observations. Missing observations are primarily reconstructed using annual series (according to ESA 1995) obtained from the database of the European Commission (Annual macro-economic database, AMECO, Spring 2017) that is compatible with Eurostat. If that is not possible, I use OECD (Economic Outlook database, No. 101, June 2017) and/or a historical dataset

[28)] I thank Giovanni Ricco for sharing an earlier version of their Matlab code used in Caruso et al. (2015).

of fiscal variables prepared by the IMF (Public Finances in Modern History Database, see Mauro et al., 2013); the only country that is not covered is Luxembourg, where I used old editions of AMECO database and OECD country surveys. Fiscal series are checked and complemented with those available in Global macro data database provided by Oxford Economics (OE, 2017).

Subsequently, using actual or reconstructed yearly series, missing observations in quarterly series are obtained using the state-space model approach as explained above. Once quarterly series are generated, they are adjusted to ESA 2010 levels by applying average growth rates to levels as House et al. (2017). This solves the potential problem of different dynamics of fiscal series in both national accounts standards. Further details and illustrations of reconstructed and actual series for Spain and Italy can be found in the panels of figures (B.1) in the appendix. A visual inspection of generated fiscal series (primary balance) confirms that they match the SNA-reconstructed series very closely, validating the utilized Bayesian decomposition approach.[29)]

3.2 Institutional environment in Europe and its changes

Many empirical studies have shown limited impact of institutions on fiscal policy in Europe. The focus has been on the Maastricht Treaty that put formal limits on fiscal policy (a maximum deficit of 3% of GDP and debt of 60% of GDP) and then on the Stability and Growth Pact that specifies two forms of fiscal surveillance (preventive and corrective). The so-called dissuasive arm includes a sanction mechanism; detailed rules of the so-called excessive deficit procedure (EDP) see EC (2017). With the arrival of the Global Recession and the EU sovereign debt crisis, a series of institutional changes has been approved and subsequently implemented (see an explanation for the failure of the previous Pact in Buti and Carnot, 2012). Apart from another modification of the Pact, a new framework was agreed upon and implemented (the Fiscal Treaty, see below), that is, fiscal policy is *de facto* subject to two supranational rules. There have been several important institutional changes since the late 1980s with effects on the conduct of fiscal policy that are summarised in table (3.1).

Since there is a significant amount of uncertainty regarding the timing for the set of institutional changes, I follow Canova et al. (2012)'s approach for setting a particular cut-off time for individual events. These can be viewed as a guidance as to when to expect changes in estimated fiscal response coefficients. Leave aside possible lags in observable effects, the key dates are the following. Fiscal policy became regulated with targets for the first time formally set in the Maastricht treaty. Based on its implementation, the decisive quarter is set to the

[29)] With respect to data revisions, several studies have shown the importance of data vintages' effects on fiscal series (such as Golinelli and Momigliano, 2009), mainly government balances (in particular on cyclically adjusted fiscal series). Unfortunately, a real-time analysis cannot be carried out in the case of quarterly time series that are published by Eurostat. Even in the case of yearly series, the AMECO database that has been running since 2002, comparable series available since 2008, and the OECD Economic Outlook database, also provides yearly series only.

Table 3.1: EU supranational rules and their modifications

	institutional rule	approved / in effect	narrative cut-off	impl.	
old fiscal regime (Υ_2)	Maastricht Treaty	February 1992/November 1993	1993q1	..	D_2
	Stability and Growth Pact	July 1997/July 1998	1998q3	..	D_3
	Stability and Growth Pact (reform)	March 2005/July 2005	2005q1	−	D_4
new fiscal regime (Υ_3)	Stability and Growth Pact ('6-Pack')	March 2011/December 2011	2011q4	+	D_5
	Stability and Growth Pact ('2-Pack')	November 2011/May 2013	2013q2	+	
	Fiscal Treaty	March 2012/January 2014	2014q1	+	D_6

Notes: '..' = introduction, '−' = weakening, '+' = strengthening. The Maastricht Treaty was drafted in December 1991 during the European Council and signed in February 1992; for an early overview of important dates see Rogers (2007). These changes included, both further minor modifications of the Pact, the second major change since 1997 that was mainly implemented to enhance compliance with its principles, and additional changes of the institutional framework, comprising: (*i*) the so-called 'Six Pack', consisting of five regulations and one directive of the European Commission amending the Pact by attempting to improve compliance with the Pact, strengthened fiscal surveillance and introduce an early warning system (Macroeconomic Imbalances Procedure, MIP), and a correction mechanism in case of excessive macroeconomic imbalances; (*ii*) the so-called 'Two Pack' consisting of two regulations complementing the Six Pack, with focus on governance (complementing the Six Pack by further layers for coordination and surveillance of EA countries); and (*iii*) the Fiscal Compact (the third title of the Fiscal Treaty) that modified and extended the Pact by introducing balanced budget rule, debt brake rules (if debt is above 60% of GDP) required transposition into national law, and strengthening monitoring via national fiscal councils. For overview of individual amendments and the new rules including progress with their adoption, see Eyraud and Wu (2015); EC (2017) or Masten and Gnip (2016), for a recent critical review see Wyplosz (2016). The Fiscal Treaty is expected to modify fiscal policy behaviour as shown for example in Baldwin and Giavazzi (2016). *Source:* studies cited above, own adaptation.

first quarter of 1993. The effects associated with the Pact can be set to the third quarter of 1998, when final decisions were made (on the single monetary policy and the common currency). That was also the moment clarifying who would be subject to the rule and its sanction principles. Linking to that event, the first major amendment to the Pact that was endorsed in late March 2005. I set the cut-off to 2005q2 since the complexity and uncertainty around the final version of the Pact's text (and accompanying EU regulations) resulted in a great deal of effort to fix issues such as ameliorating problems with non-compliance. The EU sovereign debt crisis, which started unfolding in late 2009 but gained momentum in early 2010 (see Bruegel, 2015), triggered changes in the EU economic environment and as a result found their reflection in the institutional framework. The Pact was strengthened in a radical reform encompassing the so-called Six-pack and later on the so-called Two-Pack (minor changes). I set the decisive date to the fourth quarter of 2011. Despite the fact that the reform of the Pact coincides with the introduction of the Fiscal Treaty (see below) I treat both changes as separate (additional) events.[30] Finally, the last institutional 'correction', the Fiscal Treaty, represents a

[30] As highlighted in Wyplosz (2016), there are two sets of supranational rules aiming at fiscal discipline from

new approach to fiscal policy in the EU that is primarily nation-based (Wyplosz, 2016). Signatories to this Treaty were additionally granted a period of one year to carry out necessary amendments at the national level, after its ratification by a twelfth country using the Euro in late December 2012 (that is, from January 2013). As a result, it became binding for the first time for EA participating countries from January 2014. Given the requirement to implement modifications in national laws, the actual date of full implementation could be delayed. Nevertheless, its cut-off is set to 2014q1 (see table (3.1) above). Since the time-varying methodology provides coefficient estimates in any period within the sample, the narrative breakpoints can be validated by the estimates.

Differences and similarities in case of the stand-alone EU-3 countries

Two countries – Denmark and the United Kingdom – negotiated the right to opt-out in case of the Euro adoption in early 1990s. Therefore, they could have pursued their own fiscal policy, free of concerns about EU fiscal criteria. Despite the right to op-out, Denmark has followed the EA group quite closely, including a currency fix to the Euro since 1999 (the so-called ERM II mechanism). However, after a rejection of entry in September 2000 there has not been a clear plan to join in near future. Denmark has used a structural general government balance target (positive) outlined in a medium-term fiscal strategy since 2001. Early approval of the Fiscal Treaty by Danish citizens cannot be considered as unexpected (already in late May 2012). Conversely, Sweden that is still liable to adopt the single currency and in particularly the UK have been much more sceptical towards the single currency.

The UK has had their own fiscal rules and has been effectively outside the sanction mechanism of the Commission and Council regarding its fiscal policy (no sanctions if recommendations were not followed) owning to the opt-out. The fiscal constraint in the UK was represented by the Golden Rule and the so-called Sustainable Investment Rule during the period 1998–2008. Both rules were specified over a business cycle, that is, no particular target was set to a fiscal year: (i) the Golden Rule requires a balanced budget; (ii) the Sustainable Investment Rule demanded public sector net debt to be below 40% of GDP. Both worked quite well since public indebtedness was declining before the Great Recession. The financial crisis resulted in establishing a new limit in the form of temporary operating rule (in terms of the cyclically adjusted current balance, CACB). CACB was allowed to decline in the crisis and should be at least balanced in the medium run. The debt criterion is again expressed in net terms and expected to be declining (postponed from 2015/16 to 2016/17 fiscal year).[31] The last member of the EU-3, Sweden, was subject to the Maastricht convergence criteria before entering the EU (1995). Before the Euro referendum took place in September 2003, Sweden was expected to join the monetary union, which meant following EU fiscal institutions closely. The Fiscal

different angles.

[31] The CACB does not include net public sector investment. When it is added and adjustment for one-offs is carried out, it is equal to structural budget balance; for details see HM Treasury (2010) and more recent updates.

Treaty was approved in March 2013. Moreover, after a banking crisis in the mid-1990s, a new comprehensive reform of public finances was implemented. It included several elements such as a budget rule with a positive balance over a cycle and yearly updated and approved expenditure limits at least for three years ahead. As a result, Sweden has become an example of a country with well-functioning national fiscal rules and Swedish public finances have not been too negatively affected during the Great Recession; for a discussion of possible factors see Bergman (2011). All countries also have an independent fiscal council, only in the UK it was established during the Great Recession (2010).

4 Empirical analysis

In this section I present the empirical results. First, I show the country specific estimates of the fiscal response parameters to highlight the effects of institutional changes on fiscal policy. Second, I compare the effects of fiscal rules for EA-12 and EU-3 countries to identify common patterns and differences. Third, I compute cross-sectional standard deviations of country-specific fiscal response coefficients of members of both groups for individual quarters of my sample period, so that an analysis of harmonization of fiscal responses can be carried out (see Zdarek, 2017). The baseline results are presented for the fiscal rule FR^{Ia}. Finally, I present robustness checks on the specification of the fiscal rule, the sets of countries included in the sample, the sample period and the set of priors used in the simulation process. I will focus on the time-varying coefficient of the debt-to-GDP variable (country-specific response), when describing my results, unless it will be indicated otherwise.

4.1 Baseline model – has there been any institutional effect?

Differences in adjustment of the fiscal rule (in country-specific responses) are mainly driven by differences in debt levels. Therefore, EA countries are divided into three subgroups: with low ($< 50\%$), medium ($\geq 50\% \wedge < 80\%$) and high ($\geq 80\%$) debt-to-GDP ratios.

Figures (4.1) and (4.2) below show the median of the country-specific estimates of $\alpha_{i,t}^{LR}$, that is, the time-varying long-run response coefficients on the lagged debt. Credibility intervals of the posterior distribution are not shown for the sake of readability, but can be found in Figure (B.3) in the appendix. In what follows, countries that were subject to international support programs are labelled 'programme countries'. Those countries hit by the Great Recession or the EU debt crisis that have had fiscal difficulties but have not received any international support are labelled 'weaker countries'.

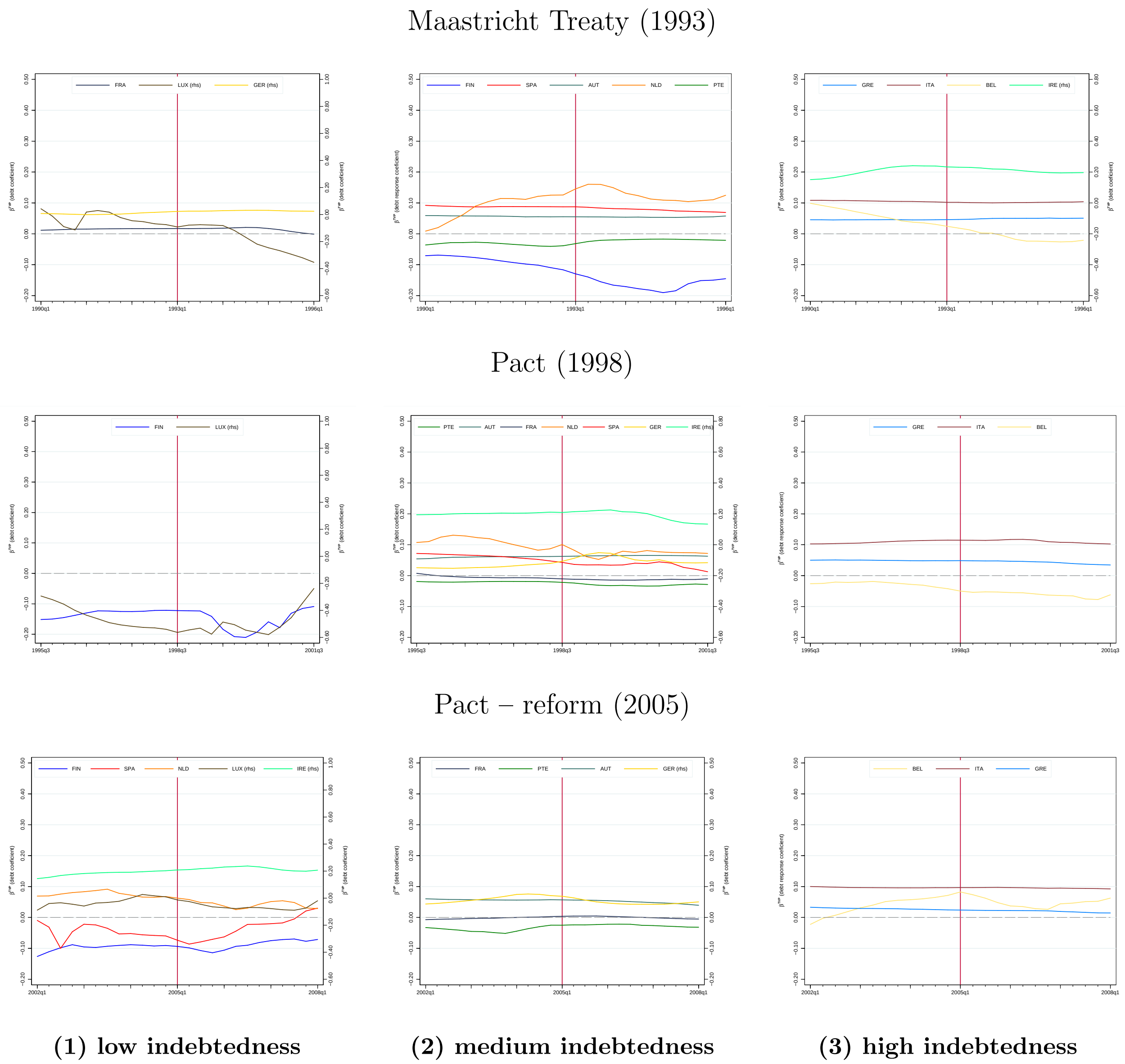
Old fiscal regime – time-varying evidence

The cut-off for the Maastricht Treaty as a first institutional change is set to 1993q1 (the vertical line in the top row of Figure (4.1) below). I focus only on countries' behaviour in case responses are significant, when describing individual panels of each row in the figure. I also add the number of the panel from the row is brackets after the last name in the group). Considering the Maastricht period (the first row), it is only Germany (#1) and the Netherlands (#2). For some countries a change of their behaviour may have occurred even before (Ireland), possibly coinciding with the Treaty ratification process or with some delay (Austria, Finland, perhaps even Greece). In the case of the Stability and Growth Pact, whose enforcement rules became binding for EA countries in 1998q3 (second row in the figure), there is a change of behaviour in the medium debt group in case of Austria and Germany (#2). Some countries seems to have responded with a delay (Ireland, Luxembourg, and the Netherlands) or before (Italy). Some authors such as Fernández and Perea (2015) suggest that there was a lack of reform efforts in this period, which can be attributed to a reduction of (long-term) interest rates immediately following the Maastricht period.

The last row in the figure shows country-specific responses for the first major reform of the Pact that was approved in early 2005 (2005q1) in an attempt to strengthen fiscal discipline and restore vanishing credibility of the rule. A change is visible in case of Belgium, Portugal (#1), with some countries lagging/leading: Germany, and the Netherlands. There were no significant responses in the cases of France, Italy or Portugal (caught misreporting fiscal accounts in 2003), despite relatively high debt levels in both countries during that period(s). That can be a result of the decision of some large countries not to respect the Commission's decisions.

For the purpose of comparison, responses for the stand-alone EU-3 countries are shown in panels of figure 4.3 below indicating all institutional changes. A brief inspection reveals that debt responses are significantly different around the period of the Pact; Denmark belongs to the medium debt group, and the United Kingdom belongs to the low debt group. Responses are significantly different for Denmark and the UK (low debt countries) also around the period of the Pact's change. Responses for Sweden are not significant for any of these three institutional changes.

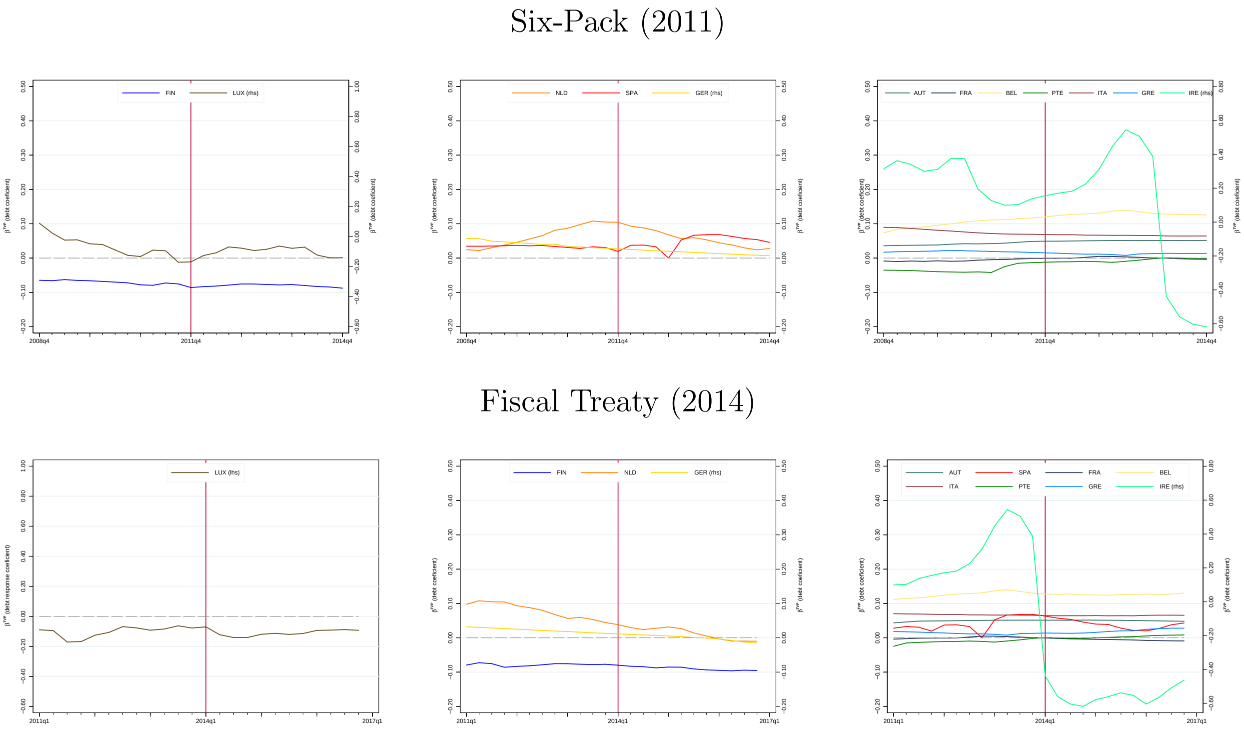
Figure 4.1: Fiscal behaviour – in the pre-sovereign debt crisis period (1986–2009)



Note: country-specific long-run responses for FR_{Ia} (median). A vertical red line represents a particular institutional change. Colours for individual countries do not vary across time periods for the sake of comparison. Left column of panels shows countries whose debt-to-GDP in the year of an institutional change was below 50% ((1) low indebtedness); the middle column shows countries whose debt-to-GDP was $\leq$ 50% and < 80% ((2) medium indebtedness), and the right column shows countries whose debt-to-GDP was $\geq$ 80% ((3) high indebtedness). The grey horizontal line is set at zero level (left axes) and it can be different from the second (right) 'y' axis. *Source:* own calculations.

Two further sets of results are shown in panels Figure 4.2 below. These are related to institutional changes during and in the aftermath of the EU debt crisis. Even though the remaining sample period before its end is rather short, some consequences of these changes are already visible, at least in the case of countries trying to restore soundness of their public finances. This can be interpreted as a first evaluation of those reform steps in the macro-fiscal rules (governance principles).

Figure 4.2: Fiscal behaviour – in the sovereign debt crisis period (2009–2016)



(1) low indebtedness **(2) medium indebtedness** **(3) high indebtedness**

Note: country-specific long-run responses for FR^{Ia} (median). A vertical red line represents a particular institutional change. Colours for individual countries do not vary across time periods for the sake of comparison. Left column of panels shows countries whose debt-to-GDP in the year of an institutional change was below 50% ((1) low indebtedness); the middle column shows countries whose debt-to-GDP was $\leq$ 50% and $<$ 80% ((2) medium indebtedness), and the right column shows countries whose debt-to-GDP was $\geq$ 80% ((3) high indebtedness). The grey horizontal line is set at zero level (left axes) and it can be different from the second (right) 'y' axis. *Source:* own calculations.

New fiscal regime – some preliminary evidence

Firstly, I investigate the so-called Six Pack in its final version approved in 2011q4 since it seems to have triggered different country-responses. Whether they were only conditional upon temporary worsened of economic conditions or a response to the changing nature of fiscal constraints is discussed below. I keep the the definition of debt groups despite increasing indebtedness and thus transition of countries towards the last group.

In case of the modification of the Pact, I identify significant responses for Austria, Ireland and Portugal (#3) and delayed in Spain. The effects of the Fiscal Treaty in case of Luxembourg

(#1), Greece, and Portugal (#3) and delayed in Belgium. Given the fact that EA participating member states were granted a period of one year to carry out necessary changes, a change in behaviour should be seen from 2013 onwards, when accounting for the existence of various lags from 2014 onwards. However, the effect can be watered down by the conduct of non-standard monetary policy by the ECB, which relaxed financial markets and provided additional fiscal space to Eurozone countries.

Comparing the evolution of responses of the stand-alone EU countries, Denmark and Sweden (low debt group) have showed improving (positive) responses since 2005 and 2008 respectively with a mild reversal in 2016. British responses has been improving since 2009, also with a reversal in 2016 (with its debt ratio belonging to the high debt group). The British responses have also been in a non-standard monetary policy environment since 2009. In addition, the UK did not sign the Fiscal Treaty compared to the other two countries. Interestingly, Denmark realised active fiscal policy between 2002 and 2008, the UK after 2010.

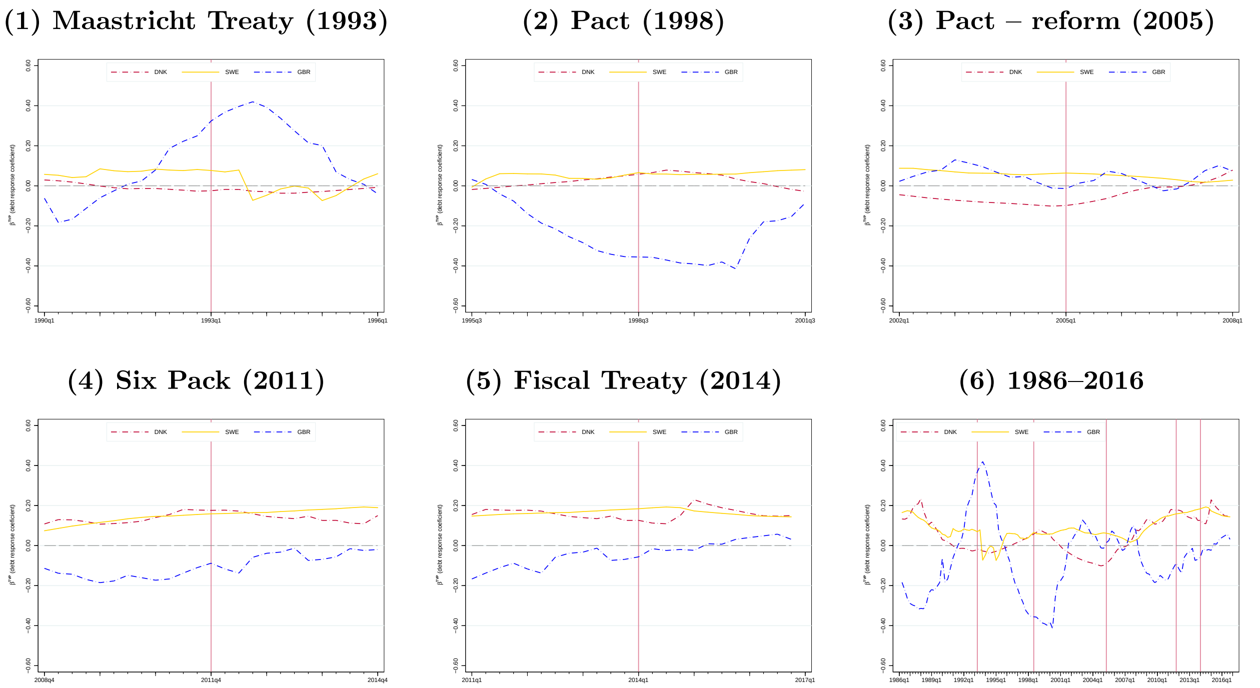
The relatively low significance of country-specific responses can be explained by a number of factors: the assumption of a random walk for parameters in the fiscal rule, the use of demeaned data, and by the choice of the primary balance in the fiscal policy rule. Since the first two are model-specific, the next subsection investigates all institutional changes using an alternative methodological concept, narrative evidence. The last factor can be explored as well, however, the availability of quarterly output series is rather low and subject to large revisions. That is also one reason for the use of primary balance series to limit the measurement error.

Existence of institutional breaks – narrative evidence

Apart from visual inspection of simulated series checked against the possible break points identified (see table (3.1) above), I apply the narrative approach to individual episodes of changes. That provides a first robustness check to my TVP model results, which can suffer from too high level of 'smoothness' because of the assumption of random walk for parameters. Identification of 'structural break' is in that case rather difficult. In addition, fiscal policy operates in a dynamic environment, that is, there are also other factors at play that may have led to a rise/decline in coefficient in a particular quarter. Therefore, to test the significance of individual episodes, I rely on the Chow break test procedure for known break dates as suggested in the econometric literature (see Davidson and MacKinnon, 2004). For that purpose my model of the fiscal rule (now time-invariant coefficients, frequentist estimation) is extended with dummy variables in two versions: (a) allowing for two different regimes (old/new) or (b) individual episodes D_k as identified above. Because of a very short time period under the six-pack and two-pack changes, I consider them jointly as one change, which is also consistent with their interpretation (character of both changes). The system takes the form:

$$pb_t^{*} = \gamma_1 + \boldsymbol{V} + \upsilon_t, \tag{4.1a}$$

Figure 4.3: Fiscal behaviour – stand-alone EU countries



Note: country-specific long-run responses for FR^{Ia} (median). A vertical red line represents a particular institutional change. Colours for individual countries do not vary across time period for the sake of comparison. The grey horizontal line is set at zero level (left axes) and it can be different from the second (right) 'y' axis. *Source:* own calculations.

$$pb_t^i = \gamma_1 + \boldsymbol{V} + \sum_k \gamma_k \times D_k + \sum_k \gimel_{(.)} \boldsymbol{V}\#D_k + \upsilon_t, \tag{4.1b}$$

where $\boldsymbol{V} = FR^{Ia\ (I/II)}$ stands for a particular set of determinants of the fiscal rule, $\boldsymbol{V}\#D_k$ represent interaction terms (all determinants of fiscal rules with the set of dummy variables, that is, for $k = \begin{cases} 2,\dots,6 & \Leftrightarrow \quad D_2,\dots,D_6 \\ 2,3 & \Leftrightarrow \quad D_{old}, D_{new} \end{cases}$ and $\gimel_{(.)}$ represents their to-be-estimated regression coefficients.

In the next step, I test jointly parameters of the interaction terms in the unrestricted model (4.1b) and the coefficient of the dummy variable (γ_k) using a standard F-test. This procedure is then similar to carrying out a Chow break test under the assumption of know break dates. Since previous results show a significant amount of heterogeneity accompanying individual institutional changes, it is likely that results of the global testing will be affected and thus less significant.

Table (4.1) summarises results of individual tests. The results show the number of countries, whose dummy or interacted terms are significant across institutional changes. There is a clearly visible patter of an improved compliance for more recent changes. The results of the last period, the Fiscal Treaty (D_6), can be affected by the non-conventional monetary policy of the ECB that changes fiscal space for EA countries. The failure of testing the dummy variable for individual periods may provide insight why simple dummy tests for fiscal constraint have

Table 4.1: Fiscal constraints – narrative evidence

	Institutional change	# of significant periods [$\alpha = 0.05$] intercept (γ_1)	slope ($\gimel \times (.)$)
old fiscal regime	Maastricht Treaty [D_2]	[3/12]	[7/12]
	Stability and Growth Pact [D_3]	[6/12]	[8/12]
	Stability and Growth Pact (modif.) [D_4]	[3/12]	[11/12]
new fiscal regime	Stability and Growth Pact ('Six-Pack'+'Two-Pack') [D_5]	[11/12]	[12/12]
	Fiscal Treaty [D_6]	[6/12]	[10/12]

Note: base is the period before the Maastricht Treaty. # number of breaks – number of countries with a significant structural break for a particular institutional change in the cut-off period. In case of EU-3 countries, the number of significant periods for intercept is: 0/1/1/2/0 and for slope: 3/3/2/3/3. *Source:* own calculations.

offered mixed picture in the literature. Interacted coefficients point out, however, a trend...

This way of testing fiscal constraints is imperfect since it compares individual periods with the period before any fiscal constraint, that is, before the Maastricht Treaty took effect. A more strict test can be carried out by comparing for the Maastricht Treaty period using a reduced sample (1993q1–2016q4) as a base against all the other periods with fiscal constraints. Results for this tests are presented in table (4.2). They are very similar to previous ones.

How to reconcile the significant results of the EU-3 countries across different institutional settings? All these countries have retained their own monetary policy and the possibility to adjust exchange rate (with the exception of Denmark) alongside fiscal policy. Therefore, they have not been forced to keep sound fiscal policy as the only available stabilization tool. Despite this, public finances in Denmark and Sweden are in much better shape then they used to be. Only the UK that has been seriously hit by the Great Recession and experienced a banking crisis after 2007 (and failed the D_4 test) has tried to restore sustainability with the help of radical austerity measures since then. The explanation proposed is that these countries combined the EU constraint with national regulation and made it thus more binding. The same was expected to happen under the new fiscal regime for the EA group.

Discussion of my findings

Generated TVP responses can be also compared with a measure of sustainability calculated as the real-growth adjusted real interest rate (IR_{LR}, ex post real 10-year yield on government bonds using GDP deflator) based on the condition: $\alpha > (r - g_y)$. My results by country for

Table 4.2: Fiscal constraints – narrative evidence robustness

	Institutional change	# of significant periods [$\alpha = 0.05$] intercept (γ_1)	slope ($\beth \times (.)$)
old fiscal regime	Stability and Growth Pact [D_3]	[3/12]	[6/12]
	Stability and Growth Pact (modif.) [D_4]	[2/12]	[10/12]
new fiscal regime	Stability and Growth Pact ('Six-Pack'+'Two-Pack') [D_5]	[9/12]	[12/12]
	Fiscal Treaty [D_6]	[2/12]	[9/12]

Note: calculated for a reduced sample period, the Maastricht period is the base. # number of breaks – number of countries with a significant structural break for a particular institutional change in the cut-off period. In case of EU-3 countries, the number of significant periods for intercept: 1/0/3/0 and for slope: 3/2/3/2. *Source:* own calculations.

the base fiscal rule (FR^{Ia}) are presented in panels of figure (B.7) in appendix.[32] However, as explained above, this condition does not have to hold every period as showed for a simple case by Canzoneri et al. (2001). A more appropriate procedure would be to compare the IR_{LR} series with the time-varying coefficients for individual countries using a test for cointegration and examine the co-integration vector. However, my sample is rather short, so I do not carry out the test. However, I can compare the time-varying coefficients with mean values of the growth adjusted real interest rate for individual fiscal rules. The after-tax real-growth adjusted real interest rate can be calculated as well, however, it only results in a level effect.[33] Alternatively, I define the measure of sustainability in terms of implicit interest rate on government debt, adjusted in the same way (IR_{irp}, ex post).

There is some evidence of both sustainable and unsustainable behaviour in both groups of countries. Even though it is only an approximative test of debt sustainability, for many countries it provides good evidence for my findings (Austria, Belgium, Germany, Portugal, Sweden or the UK). It also illustrates the presence of countries with active fiscal regime (using Leeper's expression). For example Afonso and Toffano (2013) identify several fiscal regimes in Italy or Portugal in a Markov Switching Model model using a sample period up to 2010. These findings resonate with Afonso et al. (2011) and my results that show the existence of an active fiscal regime and rather inefficient and short-lived fiscal measures in Portugal. However, there is a difference in fiscal behaviour of both countries that reflects the preferences of both policy-

32) I check that the real-growth series follow a random walk, that is, I test for the presence of a unit root allowing for structural breaks in these series (the Andrews and Zivot and the Lumsdaine and Pappel test). I could not confirm stationarity for all countries in my sample.

33) Collignon (2012) considers both versions of the growth adjusted interest rate with negligible differences for EU countries.

makers and voters.[34] Regarding Spanish responses, one can see a continuous reduction and a decline after 1999, reversed after the modification of the Pact in 2005. This offers a completely different picture compared to the quasi-Bayesian TVP estimates presented in Cuerpo (2014) or the finding on passive fiscal regime after 1992 in Ricci-Risquete et al. (2016) using MSVAR model and an older vintage of the Spanish quarterly dataset (QUESFIP, De Castro et al., 2014). A reason for differences can be also explained by their methodology (two-regime MSM specification) for highly persistent series is not able to detect changes over shorter spells. The two remaining countries in the GIIPS group show different trajectories: Irish responses were positive in the 1990s and 2000s, with an fall in responses after 2014, which seems to be related to data (a small decline using the post-1999 sample and/or support to financial institutions). Excluding observations before 2000, which may not be fully objective, Greece was losing fiscal ground (weakening responses also visible for shortened sample) until a reversal took place in 2013, most likely because of international fiscal supervision.

Turning to the remaining EA countries, three sub-groups can be identified: (*i*) Luxembourg with spells of negative responses (active regime), (*ii*) Austria, Belgium, Germany, Italy or the Netherlands with mostly positive responses, and (*iii*) Finland or France with rather insignificant responses.[35] My results for Germany accord with those in Thams (2007) – they are insignificant in the early 1990s during the reunification of Germany (and before) and an improved fiscal performance is reflected in positive, rather strong numerical terms, and significant responses after 2000, which is in line with Afonso and Toffano (2013). There is some recent evidence on sustainability in France (Aldama and Creel, 2017). This study finds sustainable policy in France between 1996 and 2008. My TVP estimates compared to IR_{LR} reveal short spells of sustainability in late 1980s and around mid-1990s (1994–1996), however, then again between 2004 and 2008, when France was mostly under the Excessive Deficit Procedure (2003–2007). A similar picture is also obtained for my second measure of the 'adjusted interest rate' (implicit rate). Turning to the results of the narrative evidence, global tests indicate sustainable policy under the old regime using extended sample, but results of the post-Maastricht sample only, indicate existence of a different regime, which is also confirmed by tests for individual sub-periods. The imperfect match can be partially explained by the use of gross financial liabilities utilized in that study (debt ratios are higher), quarterly vs. yearly series (noise) and by vintage effects. After 2011, I find country French fiscal responses in line with this sustainability measure using either of the interest rates.

In case of the stand-alone countries shown in the last row of figure (B.7) in appendix,

[34] While Italy tends to report a primary surplus since 1990s, without a significant impact on high public debt (that is, a reduction towards the 60% limit) accumulated throughout the 1970s and 1980s, Portugal has kept running primary deficits since the late 1990s following a period of primary surpluses in the 1980s, which has taken its toll on country's indebtedness (the third highest in the Euro area in 2016) and resulted in a prolonged recession during the EU debt crisis (2011–2013).

[35] This specific behaviour of Finnish fiscal policy is usually explained with large stocks of assets, that is, the net position is positive (a net *creditor*). A similar explanation holds for Luxembourg, where improved fiscal performance allowed it to achieve very low levels of public debts already in the late 1980s.

Denmark shows positive responses outside two spells, one after 1999 closed with a reversal in 2005. Responses in Sweden remained positive and mostly insignificant, the UK shows rather 'cyclical' patterns (mostly insignificant after 2000), that is, spells of passive and active policy (late 1980s and mid 1990s). The latter accords with Afonso and Toffano (2013) who also find a passive regime around 1995, however, there is no evidence for the other after 2007, which seems to be data related.

4.2 Sensitivity section

Since the use of a TVP model is associated with a number of modelling choices, this section presents robustness checks for one country (Spain) when main choice is changed. For simplicity, I consider only one at a time. Spain is selected owing to the availability of longer official series by Eurostat and a quarterly fiscal database that extends official series back to (1986q1/1970q1, see De Castro et al., 2014). Even this dataset extends series before 1986 using a state-space model; for details see *ibid.* I focus on two types of checks: (I) those that are related to the estimation of country-specific fiscal rules and (II) those related to harmonization of fiscal responses. Results are shown for the base rule, that is, FR^{Ia} if not indicated otherwise.

In case of ad (I), first a set of robustness checks aims to check the effects of a longer training period and effects of one-offs (first row of panels in figure (B.8) in appendix): figure (a) repeats the base result for FR^{Ia}. It clearly indicates a period of increased uncertainty (after 2000) and thus insignificant response coefficients, repeated around 2013 and in quarters of 2016 indicating a reduction in median responses. (b) extends the length of the training period is extended to 32 quarters (8 years), so that starting values use more information and there is no difference. (c) uses adjusted series to gauge any bias due to the extraordinary budgetary operations mainly associated with the EU debt crisis (support to financial institutions). (d) repeats estimation for Eurostat series and for the sake of comparability with other countries, the sample is reduced to the period 1999q1–2016q4, expanding the training period to 72 quarters (1980q1–1998q4). However, that excludes the possibility to analyse institutional changes in the 1990s. The period of uncertainty is visible as well, the fiscal response remains insignificant and a decline towards the end of the sample is preserved.

Another series of robustness checks presented in the middle row of panels in the figure $[(e) - (h)]$, investigate effects of changes in amount of information (variance) coming from the training sample by changing the factor of proportionality and its base value ($\nu = 3.5 \cdot 10^{-3}$). investigate the effects of alternating a very important parameter in the Bayesian TVP estimation (the scaling factor ν). I allow for a lower (higher) amount of information to be passed through from the training period, and also allowed for faster changes of parameters: $\nu^{alt_1} = 1.0 \cdot 10^{-4}$, utilized in Primiceri (2005) strand of the literature. Subsequently, it is increased to $\nu^{alt_2} = 3.5 \cdot 10^{-2}$. Both changes are analysed for adjusted series. A reduction in the factor of proportionality produces smoother path of medians of fiscal responses, however, a decline in early 2000s and towards 2016 are preserved. An increase of the factor leads to more time varying path of median responses with main patterns similar to the base model results.

The last set of results in low panels of figure $[(i) - (l)]$, illustrates median responses for the alternative rule (FR^I) that excludes the Barro's taxation/expenditure smoothing motive (variable *cgout*), while keeping other choices unchanged (training sample, factor of proportionality). Both the alternative rule and the result of adjusted series show similar patterns to the base estimation, that is, a continuous decrease in significant responses until late 1990s, negative responses and increased volatility, followed by a reversal and another decline towards the sample end. Similar patterns are shown, when the Spanish QUESFIP dataset is utilized: the last two figures use all fiscal and macroeconomic series from that source, which gives rise to some differences with main patterns are preserved, because of vintage effects (fiscal and GDP series). Similarly to my sample, there is a large amount of uncertainty between 2000–2006, which is reflected in widening of credibility intervals.

Since political parties take various views on fiscal issues and/or they put different weight on main components in their loss functions, represented by a policy rule, the speed with which measures are implemented and their size differs. The latter calls for an estimation allowing for changing volatility across regimes in addition to the time-varying specification. In addition, changes in a broadly defined institutional environment include changing monetary policy stance (monetary policy regimes) such as the onset of non-standard monetary policy by the ECB in early 2015 with implications both for refinancing costs of government debt and business cycle dynamics. Therefore, the last robustness check combines time-varying parameter estimation with stochastic volatility outlined in the main text, see figure (B.9) in appendix. Apart from the time-varying volatility, also the factor of proportionality is changed to $\nu^{alt_2} = 3.5 \cdot 10^{-2}$, which is already used in robustness checks above. Results for the base model of the fiscal rule are similar to the TVP model with constant volatility discussed above.

5 Conclusions

This paper explores how national fiscal policy responds to external constraints placed upon it. It uses a set of EU countries and analyses their reactions to changes in the institutional environment determined by the EU regulation. Studies typically include a proxy for EU fiscal constraints and analyse their effects on fiscal behaviour. They tend to show limited compliance with fiscal regulation in the 1990s and during early years of the Eurozone. However, they do not cover more recent changes in EU fiscal constraints adopted as a response to the EU debt crisis, do not allow for time-variation in fiscal behaviour and as Bergman et al. (2016) show suffer from endogeneity issues. My paper uses an indirect way of evaluating fiscal constraints and shows that the design of institutional constrains matter. In addition, it highlights the role of a link to domestic environment in a monetary union since that provides an impetus to follow such a constraint more closely.

I investigate the effects of changing institutional environment in the EU because it requires different behaviour from a group of countries using the Euro, compared to the others. I identify five main episodes, characterised by EU fiscal institutions placing constraints on the national fiscal policy. These EU fiscal constraints include the Maastricht Treaty, the Stability and Growth Pact, and the first modification of the Pact, all of them labelled as the old fiscal regime. The Six Pack and the Fiscal Treaty form another, the new fiscal regime. The key difference between them lies in the design of constraints and accompanying mechanisms.

Empirically, I employ a narrative approach and estimate country-specific fiscal rules with period-related interaction terms. I find weak effects of the 'old fiscal regime' and stronger effects for the 'new fiscal regime' in terms of debt stabilization for individual EA members. There is no significant difference across both regimes in case of the stand-alone EU countries. This paper argues that the design and thus the possible ownership of fiscal rules echoed by a proponent of the new regime (Wyplosz, 2016). While the old regime aims to steer a country's fiscal behaviour with help of exogenous constraint(s), the new regime tries to combine the exogenously given part with a domestic counterpart, putting more emphasis on the economic justification such as a multi-year evaluation period or an automatic debt brake that accords with the principles for optimal fiscal rules suggested in Kopits and Symansky (1998). A similar approach is applied in the EU-3 countries, especially well-designed in case of Sweden.

The results of narrative evidence are mostly confirmed when I re-estimate the model allowing for time-varying coefficients. That model also shows periods when countries respond to changing debt ratios, for example after the start of the EU debt crisis or when they relax, such as first years of the Euro adoption or more recently due to the conduct of non-conventional monetary policy by several central banks. This behaviour is in line with the time-varying model of debt sustainability. Countries do not have to follow a sustainable policy all the times, but they have to ensure that a reversal towards sustainability occurs after a period of temporary deviations.

Policy-makers do use debt and will continue to do so not only in line with tax, expenditure, consumption smoothing principles, but also to support their re-election, which can results in high deficits and increasing debts. However, to be able to use fiscal tools, they have to be available and functional. Therefore, debt burdens have to be managed in a way that allows to respond to financial crises, large cyclical swings and stimulate economic growth, which is the way how to deal with debts. To promote such behaviour not only in a monetary union, it is crucial to increase public awareness and so public scrutiny in case of fiscal issues. The co-existence of both types of EU fiscal regulation contributes to high complexity of the system and in some cases even creates trade-offs and challenges. As a result, some economists (Wyplosz, 2016) call for abandoning the old regime completely and focus on the new one. That accords with my findings. An environment with national-based constraints can be created, supported by independent fiscal councils, which would further reduce the need for a sanction mechanism imposed by third (supranational) EU parties. The role of the EU fiscal regulation would remain in terms of providing a unifying framework supported by supervision and regular monitoring.

However, the decision on a future development can also encompass steps towards a large amount of sharing of fiscal competencies at the EU level or a fiscal union complementing the existing monetary and still-to-be-finished banking union.

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A Appendix

A.1 Government budgeting

Effects of government policies can be analysed either on the primary balance and subsequently on a change of government debt or alternatively, as a problem of available resources and a set of actions (needs) to be funded. The former can be formalised as:

$$PB_t \; [\equiv \Delta D_t] = NT_t - (G_t^n - IRP_t), \tag{A.1}$$

where PB_t is the primary balance equivalent to the net change in debt,[36] NT_t represents net government taxation (total tax collection net of subsidies), G_t^n stands for government expenditures including interest payments associated with debt service, which is captured by $IRP_t = r_t D_{t-1}$, and thus $G_t = G_t^n - IRP_t$. The evolution of nominal (real or relative when scaled by GDP) government debt takes the form:[37]

$$D_t = (1 + R_t)D_{t-1} - PB_t, \tag{A.2}$$

where D_t is the government debt at the end of period t and R_t is the nominal (real or real-growth adjusted) interest rate.

The latter, considering resources available to a government (taxation and/or newly issued bonds) and a set of activities reflecting government priorities (objectives) that is represented by an amount of expenditures takes the form:[38]

$$B_t \cdot (1 + r_t)^{-1} = (NT_t - G_t) + B_{t-1}. \tag{A.3}$$

Considering this setting for a series of time period, it gives rise to two key constraints a government faces – *flow* (period) based (see (A.3) above) and *dynamic* (intertemporal) (see (A.4) below). Assuming that a government keeps its promise to honour its obligations (No-Ponzi game), the dynamic constraint the government faces is represented by the solvency requirement imposed upon fiscal policy deemed to be sustainable: the present value of public debt has to be smaller or at maximum

[36] For further explanation and alternative definitions (using cash or accrual definition, that is, based on the System of National Accounts, SNA) see an early study by Blejer and Cheasty (1991) or an update by Irwin (2015) providing a recent summary and definitions of indicators consistent with a new SNA standards.

[37] This debt equation (A.2) is usually written with an additional term ($\aleph_t$) on the right side of the equation that represents all other factors affecting a debt change between two periods. These cannot be attributed to previous determinants but it can contribute significantly to debt dynamics (such as debt demonetization, differences in valuation of assets (for net debt) and liabilities including exchange rate effects), for details see Irwin (2015).

[38] There is no distinction among possible sources of financing of an incurred budget deficit in the Bohn (1998)'s inspired literature, that is, in line with the Ricardian Equivalence hypothesis.

equal to the present value of all future primary surpluses. That condition can be written as:[39)]

$$D_{t-1} \leq \sum_{k=0}^{\infty} \mathbb{E}_t \left[\frac{PB_{t+k}}{(1+r_{t,k})} \right]. \tag{A.4}$$

The (A.4) is know as the intertemporal budget constraint of the government (IGBC) and has to hold with equality, when debt is expected to be fully repaid, see Bohn (2008). In addition, the terminal value of government debt in present value has to be finite (equal to zero in case of repayment), that is, the so-called transversality condition (No-Ponzi scheme) takes the form:

$$\lim_{k \to \infty} \mathbb{E}_t \left[\frac{PB_{t+k}}{(1+r_{t,k})} \right] \leq 0, \tag{A.5}$$

where the TVC must hold with equality.

A.1.1 Econometric approaches to sustainability

Early empirical tests of sovereign debt sustainability (fiscal solvency) coherent with definitions à la Blanchard and available fiscal time series have been carried out since mid-1980s: Trehan and Walsh (1988); Wilcox (1989); Trehan and Walsh (1991) summarise early work on fiscal sustainability, for a comprehensive overview see Burger (2005). These belong to the so-called **classic debt sustainability** literature (D'Erasmo et al., 2016), however, they are subject to critique mostly because of empirical (econometric-related) issues associated with them. Some of these have been identified and subsequently addressed in a series of articles (Bohn, 1995; 1998; 2007; 2008). The issues raised can be classified into several groups (*cf.* D'Erasmo et al., 2016):

i) choice of discount rate: Bohn (1995) argues that common sustainability tests using a constant safe interest rate (Hamilton and Flavin, 1986; Hansen et al., 1991; Galí, 1991) or actual (stochastic) interest rate (Wilcox, 1989) instead of a stochastic discount factor, implicitly assuming no uncertainty, risk-neutral agents or perfect foresight, which can even give rise to misleading conclusions and inference (see D'Erasmo et al., 2016).

ii) economic cycle: Bohn (1998) argues that the failure to include a control for cycles such as output gap or cyclical component of government spending invalidates results of fiscal time series properties tests (unit root).

iii) econometric restrictions: Bohn (2007) argues that early econometric approaches assume properties of fiscal time series for TVP to hold, which are not needed (for example stationarity Hamilton and Flavin, 1986 or integration of series Kremers, 1989; Trehan and Walsh, 1991; Hakkio and Rush, 1991; Quintos, 1995). Their application would imply debt responses linked to debt-to-GDP behaviour not respecting any positive threshold implied by a fiscal limit.[40)]

[39)] Sometimes is this derivation presented using a simplification, which is the assumption of a constant interest rate, that is, $r_t = r_s \equiv r > 0, t \neq s$ (similarly for expected rates). Bohn (2008) views such conditions for debt sustainability as the *ad hoc* TVP and IGBC.

[40)] Bohn (2007) then shows that the IGBC and TVC hold for debt-to-GDP of any high but finite order of integration. Moreover, he basically does not consider fiscal limits that represent a specific situation. Nevertheless, he allows for the existence of a limit for primary balance associated with a stable level of indebtedness

Nevertheless, recent empirical studies have attempted to correct for some of the previously listed issues when conducting similar econometric exercises following the sustainability literature à la Bohn. For example Uctum and Wickens (2000) work with discounted debt and deficit series (in response to the issue *i*) above), and explicitly allowing for debt and deficit ceilings; for a recent overview and classification of 'neo-classic' sustainability studies see Chen (2014).

A.2 Fiscal rule with microeconomic foundations

Our fiscal rules employed in empirical models when testing sovereign debt sustainability, primarily rely on Bohn (1995; 1998)'s contributions. The underlying model with a government subject to a fiscal rule is derived in a cash-less economy with a stochastic endowment, two agents (a representative household, consumer, and a government) and complete capital markets. The model set-up draws upon a model by Lucas (1978). The key equations of the Bohn (1998)'s model are represented by a fiscal rule, a government budget constraint and the Euler equation reflecting the household's optimal behaviour as outlined in the main text.

Household

The representative household decides upon consumption and a purchase of government bonds. They consume a share of the endowment (the other fixed share is consumed by the government) that cannot be stored (perishable) with a finite present value, X_t. The household solves a problem being an optimal consumption path for all time periods (t), states of the nature, $s_t \in \mathbb{S}(h_{t-1})$, and the history of realized states up to the present periods, $h_t \in \mathbb{H}_t$ since the original history, h_0, and $\pi(h_t)$ is the probability of the event h_t (state s_t occurs conditional upon date $t-1$ history). The consumer maximises their expected utility:

$$\sum_{t=0}^{\infty} \sum_{h_t} \beta^t \pi(h_t) \mathbb{U}(C(h_t)) = \mathbb{E}_t \left[\beta^t \mathbb{U}(C(h_t)) \right], \tag{A.6}$$

subject to the t-th period budget constraint in line with the entire realised history h_t:

$$B(h_t) + Y(h_t) - T(h_t) = C(h_t) + \sum_{s_{t+1}} Q(s_{t+1}|h_t) B(s_{t+1}|h_t), \tag{A.7}$$

where the subjective discount factor is positive ($\beta > 0$), the utility function $\mathbb{U}(.)$ is concave and strictly increasing ($\mathbb{U}'(.) > 0, \mathbb{U}''(.) < 0$). Private consumption $C(h_t)$ and lump-sum taxes $T(h_t)$ are consistent with h_t. $Q(s_{t+k}|h_t)$ is the market price of Arrow-Debreu security $B(s_{t+k})$ holding in t providing one unit of consumption good only in the state s_{t+k} for date $t+k$.

Government

Lump-sum taxes and borrowing in capital markets, allows the government to honour their debts and finance their stochastic consumption path. However, there is no actual transfer of physical good,

needed for achieving fiscal sustainability. That restriction would, however, be justified by other economic circumstances than the IGBC.

only appropriation claims by the government. That can possibly lead to debt increasing over time (no finite debt-to-GDP ratio, that is, a fiscal limit)[41] consistent with TVC as a result of unbounded primary balance and no limits on future taxation.[42] This specification also means that Lucas (1978) allows for a government, whose tax collection exceeds income of goods. The government can then lend households to finance their consumption. The government budget constraint takes the following form:

$$D(h_t) + G(h_t) - T(h_t) = \sum_{s_{t+1}} Q(s_{t+1}|h_t) D(s_{t+1}|h_t), \tag{A.8}$$

where $D(h_t) = -B(h_t)$ is the outstanding government debt, defined as the amount of goods (date $t+1$) promised by the government at date t to be delivered if the economy is in a state s_{t+1} at date $t+1$ in line with the given history h_t.

In case the representative household cannot run Ponzi scheme against the government, Bohn (1995) shows that (assuming pay-off $D(h_{t+K}|h_t)$ at the date $t+K$ for government bonds):

$$\lim_{K \to +\infty} \sum_{h_{t+K}} Q(s_{t+K}|h_t) D(h_{t+K}|h_t) = 0. \tag{A.9}$$

The combination of Eqs. (A.6) and (A.7) makes possible to solve the household optimization problem. Let's define $d_{t,k}$ as the stochastic discount factor (common pricing kernel for assets) in this economy $\left(d_{t,k} \equiv \beta^k \frac{\mathbb{U}'(C_{t+k})}{\mathbb{U}'(C_t)}\right)$. Then, by using its definition, and utilizing the first-order condition (FOC) written as $Q(s_{t+K}|h_t) = \pi(h_{t+K}|h_t) d_{t,k}$, the Eq. (A.9) can be subsequently expressed in the form:

$$\lim_{K \to +\infty} \sum_{h_{t+K}} \pi(h_{t+K}|h_t) d_{t,k} D(h_{t+K}|h_t) = 0. \tag{A.10}$$

Realising that the sum of probabilities over all states is equal to one (for the period $t+K$) and using the expectation operators ($\mathbb{E}_t[.]$) leads to the transversality condition (TVC) in the stochastic environment, see (A.9):[43]

$$\lim_{K \to +\infty} \mathbb{E}_t[d_{t,K} D(h_{t+K}|h_t)] = 0. \tag{A.11}$$

Besides the transversality condition, another condition, the intertemporal budget constraint of

[41] Leeper (2010) provides a definition: if a government has reached a point at which taxes cannot be raised or spending and transfers reduced, that point is the fiscal limit.

[42] This particular feature has been criticised in the subsequent literature, see D'Erasmo et al. (2016). Therefore, Bohn (2007) proposes restrictions on the debt accumulation process and an alternative interpretation of the response coefficient (α) that ensures a debt-to-GDP limit to be finite; for details see *ibid.*
Given ratios of taxes on GDP in most countries in our sample, these do not seem to be near a limit for taxation, regardless political economy arguments.

[43] This expression – (A.11) – neglects the other part of the formula, that is, the covariance term:
$\mathbb{E}_t[d_{t,k} \cdot D(.)] = \mathbb{E}_t[d_{t,k}] \cdot \mathbb{E}_t[D(.)] + COV_t[d_{t,k}, D(.)]$. In a general set-up of a stochastic economy and risk-averse households, the assumption of zero correlation of government bond yields and marginal utility of consumption is unlikely to hold. Therefore, the LHS and RHS of the TVC condition will not be equal, for details see for example Bohn (1995).

the government (IGBC) is needed to characterise fiscal policy behaviour in this model. Employing the expectation operator and the government debt equality $D(h_t) = -B(h_t)$ together with Eqs. (A.7) and (A.9) results in:[44)]

$$D_t = \sum_{k \geq t} \mathbb{E}_t[d_{t,k} PB(h_{t+K}|h_t)], \tag{A.12}$$

where the $PB(h_t) = T(h_t) - G(h_t)$ term represents the government primary balance (surplus: $PB > 0$ or deficit: $PB < 0$).

Defining the return on an asset in state s_{t+1} as $r(s_{t+1}|h_t)$, employing the Euler equation in the form $\sum_{s_{t+1}} Q(s_{t+1}|h_t)(1 + r(s_{t+1}|h_t)) = 1$, then the debt accumulation equation can be written in a relative way, that is, as a fraction of output (assuming balanced growth for all variables in levels):

$$d_t = \left(\tfrac{1+r_t}{1+g_t}\right) d_{t-1} - (1 + r_t)pb_t, \tag{A.13}$$

where d_t and pb_t is the sovereign debt and primary balance expressed as percentage shares of GDP respectively, g_t is the real GDP growth rate and r_t the real interest rate (between $t - 1$ and t).

Bohn's model and empirical tests

To summarise, Bohn's approach of assessing fiscal sustainability (MBS approach) emphases the role of fiscal responses It relies on a general equilibrium model with three key equations: (a) linear fiscal reaction function (fiscal policy rule), (b) debt transition equation (government budget constraint for one period) and (c) the Euler equation (for all variables are expressed as a share of GDP):

$$pb_t = \alpha d_{t-1} + \chi_t, \tag{A.14a}$$

$$d_t = \frac{1 + r_t}{1 + g_{y,t}} d_{t-1} - (1 + r_t)pb_t, \tag{A.14b}$$

$$\mathbb{E}_t \left[\frac{\mathbb{U}'(C_t)}{\mathbb{U}'(C_{t+1})} \right] = \beta(1 + r_{t+1}), \tag{A.14c}$$

where α is the debt response coefficient, χ_t stands for a set of determinants of primary balance, the constant term (c) and an error term (ζ), a well-behaved utility function U_t: $U'(.) > 0$ and $U''(.) < 0$, β is the subjective interest rate (rate of preference), C_t represents a level of consumption (in period t) and the other variables have the same interpretation as above.

Bohn argues that its value must be high enough that the No-Ponzi game condition (TVC) is not violated. He shows that is enough to have a positive coefficient on the debt variable (A.15a). In case

[44)] In a model of a stochastic economy, the covariance term does not drop out from the IGBC (similar to the TVC condition in the footnote 43) above): $D_t = \sum_{k \geq t} \mathbb{E}_t[d_{t,k}] \cdot \mathbb{E}_t[PB_{t+k}(.)] + \sum_{k \geq t} COV_t[d_{t,k}, PB_{t+k}]$. The stochastic discount factor ($\mathbb{E}_t[d_{t,k}]$) represents here the price of a safe $k-$period bond. It can be interpreted as a measure of systematic risk. Schoder (2014) presents some evidence that bonds of *non-sustainable* EMU countries (based on low debt response coefficients in MBS tests) were more risky than those issued by non-sustainable non-EMU countries in the run-up period before the EU debt crisis.

debt should stabilise at a particular long-run level, the sustainability condition is stricter (A.15b):

(A.15a) $$\alpha > 0,$$

(A.15b) $$\alpha > \widetilde{r} \; (\equiv \overline{r} - g_y),$$

where g_y is the real GDP growth and $\overline{r}$ is the interest rate on government debt (average), and the domestic growth-adjusted interest rate is $\widetilde{r}$. As a result, the long-term value of the government debt can be calculated, by taking expectation over the debt development equation (A.14b) after substituting for pb_t from (A.14a):

(A.16) $$\mathbb{E}_t[d_t] \approx \frac{-(1+r)\overline{\chi}}{(1+r)\alpha + \frac{(g_y - r)}{(1+g_y)}},$$

where $\overline{\chi} < 0$ is the mean of χ_t and the other variables have the same interpretation as above.

A.3 Alternative fiscal rules

Since the literature has not yet reached a consensus as to which are the most important (apart from the debt variable and a proxy for economic conditions), I consider two versions of the fiscal rule that differ only in the set of control variables included in the $\mathbf{\Theta}_{(.)}$ term: two versions of the fiscal rule, which are different from each other only in variables included in the $\mathbf{\Theta}_{(.)}$ term:

(*i*) **Fiscal Rule I** (FR^I) – a model that resembles a Leeper (1991)'s fiscal rule, combining the very simple idea of fiscal policy responding to debt, while controlling for business cycle related fluctuations. This rule is close to the (macro) sustainability strand of the literature: $(ogap_{t-4}, cab_{t-4}) \in \mathbf{\Theta}_{(.)}$, where the first member in the vector of determinants is either the real GDP growth rate (y-on-y), the current account balance, expressed as percent of GDP, and the third being a proxy for taxation motives in line with Barro (1979). It represents the deviations of total real current expenditures from their long-run trend over GDP (estimated using the Baxter-King (BK) band-pass filter or for a robustness check using the Hodrick-Prescott (HP) filter). Similar to the base model, for the sake of comparability with the literature, I consider the output gap (using both the BK and HP filter, in relative terms) as a measure of the business cycle; for details see data section or data appendix.

(*ii*) **Fiscal Rule II** (FR^{II}) – a specification in accordance with Kirsanova et al. (2005)'s model ('optimal fiscal policy'): $(ogap_{t-4}, \pi_{t-4}, gcout_{t-4}) \in \mathbf{\Theta}_{(.)}$, where the second variable is the lagged rate of inflation (CPI, in percent) and the last one deviations of total real current expenditures constructed as explained above.

Model of time-varying rules with stochastic volatility

Fiscal regimes reflect changes in preferences of governments (political representatives), when conducting fiscal policy or legislative changes. In my sample governments have been conducting fiscal policy under different monetary policy regimes and in a changing external environment. In particular, the onset of the Great Recession calls for another extension of the fiscal rule ($FR^{Ia\ (I/II)}$). My model is then extended to allow for time-varying volatility as in Primiceri (2005) or Fernández-Villaverde at al. (2015).

This extension of the fiscal rule model draws upon the previous specification as it assumes the same specification of the model and only adds stochastic volatility in the error term. It takes the following form:

$$\begin{aligned} pb_t &= \sum_{r=1}^{4} \varrho_{t-r}\ pb_{t-r} + \alpha_t\ d_{t-4} + \boldsymbol{\Gamma_t}\ \boldsymbol{\Theta}'_{(.)} + \xi_t \sqrt{\exp\left(\ln(v_t)\right)}, \\ \ln v_t &= \ln v_{t-1} + \iota_t, \end{aligned} \tag{A.17}$$

where the regression coefficients $[\varrho, \alpha, \boldsymbol{\Gamma}] \in \mathcal{B}$ follow a random walk, v_t is the time-varying variance. It is assumed to follow a random walk with $\iota_t \sim N[0; h]$. The set of determinants of the primary balance varying based on specification $(FR^{Ia\ (I/II)})$ and their interpretation is the same as above. However, the inclusion of the stochastic volatility makes the state space model non-linear in the measurement equation and there are two state equations; for details on the modelling procedure see appendix (A.4.3).

A.4 Time-varying parameter models and Bayesian estimation technique

The TVP regression model allowing for time-variation of coefficients in the measurement (observation) equation, (A.18a) takes the following form:

$$\boldsymbol{y_t} = \aleph \boldsymbol{b_{0,\,t}} + \mathbb{F}_t \boldsymbol{\beta_t} + \boldsymbol{\epsilon_t}, \quad t = 1, 2, \ldots, T \tag{A.18a}$$

where $\boldsymbol{y_t}$ is a $(m \times 1)$ univariate vector of observations, $\mathbb{F}_t$ is a $(m \times p)$ matrix of time-varying elements (not given as data), $\boldsymbol{\beta_t}$ is a $(p \times 1)$ vector of the time-varying coefficients (unobserved state variables). $\boldsymbol{b_{0,\,t}}$ is a $(l \times 1)$ vector of exogenous time-invariant variables and their associated coefficients $\aleph$. The error term $(\boldsymbol{\epsilon_t})$ is an $(m \times 1)$ vector of serially uncorrelated disturbances with mean zero and the time-invariant covariance matrix, $\boldsymbol{\Xi}$, that is, $\boldsymbol{\epsilon_t} \sim \mathcal{N}[\boldsymbol{0}, \boldsymbol{\Xi}]$, and $E[\boldsymbol{\epsilon_t}, \boldsymbol{\beta'_t}] = 0$ for $t \neq s$.
Furthermore, the transition equation (A.18b) defines how the state variables are generated:

$$\boldsymbol{\beta_t} = \boldsymbol{\Lambda} \boldsymbol{\beta_{t-1}} + \boldsymbol{\mathcal{Z}} \boldsymbol{\varepsilon_t}, \tag{A.18b}$$

where $\boldsymbol{\Lambda}$ and $\boldsymbol{\mathcal{Z}}$ represent $(r \times r)$ matrices of coefficients, and $\boldsymbol{\varepsilon_t}$ is an $(r \times 1)$ vector of serially uncorrelated disturbances with mean zero and the time-invariant covariance matrix, $\boldsymbol{\Theta}$, that is, $\boldsymbol{\varepsilon_t} \sim \mathcal{N}[\boldsymbol{0}, \boldsymbol{\Theta}]$. Based on my specifications in the main text, $\aleph \boldsymbol{b_{0,\,t}} = 0$ and $y_t \equiv pbal_t$. Explanatory variables are elements of the matrix $\mathbb{F}_t$ and $\boldsymbol{\Delta}$ is an identity matrix $(\sim I_k)$.

Before the Kalman filter can be initialized, the state space representation of my model has to be completed (Kim and Nelson, 1999 or Pesaran, 2015): either starting values – the initial state with a mean $\boldsymbol{\beta_{(0|0)}}$ and a covariance matrix $(\boldsymbol{V_{(0|0)}})$ or initial conditions. This is done alongside selecting initial values for the variance of the measurement (observation) equation – $\boldsymbol{\Xi}$ – and the variance-covariance matrix of the transition equation – $\boldsymbol{\Theta}$. A full derivation of the Kalman filter can be found for example in Frühwirth-Schnatter (2006) or Pesaran (2015).

Following Primiceri (2005) I obtain initial values for the KF ($\beta_{(0|0)}$, $V_{(0|0)}$), by estimating a time-invariant version of my model for a training period. Because of the four-quarter-lag length specification, the training period (T_{TP}) spans: 1981q1–1985q4, that is 20 quarters. Even though the length of this training sample period is rather short, it provides some information for the estimation. Its length and potentially limited information content is reflected in the low value of the scaling parameter ν (see below), which accords with Byrne et al. (2016) suggestion for country-specific estimations. As a result, the starting values for the Kalman filter are (the initial state and the initial variance): $\beta_{(0|0)} \equiv \beta_{OLS}$ and $V_{(0|0)} \equiv V_{OLS}$. This, however, reduces the sample period for estimation of fiscal responses to 1986q1–2016q4 (i.e. 124 quarters).

$$\beta_{OLS} = (\mathcal{B}'_{TP,t} \cdot \mathcal{B}_{TP,t})^{-1}(\mathcal{B}'_{TP,t} \cdot y_{TP,t}), \tag{A.19a}$$

$$V_{OLS} = \Omega_{TP} \otimes (\mathcal{B}'_{TP,t} \cdot \mathcal{B}_{TP,t})^{-1}, \tag{A.19b}$$

where β_{OLS} is the vector of OLS coefficients and V_{OLS} is the OLS covariance matrix with

$$\Omega_{TP} = (y_{TP,t} - \mathcal{B}_{TP,t} \cdot \beta_{OLS})'(y_{TP,t} - \mathcal{B}_{TP,t} \cdot \beta_{OLS}) \cdot (T_{TP} - r)^{-1}, \tag{A.19c}$$

where r is the number of parameters to be estimated and $\beta_{(.)}$ and $V_{(.)}$ are priors to be calculated.

The prior for the variance in the measurement (observation) equation is the inverse Gamma (IGa): $P(\Xi) \sim IGa\,[\Xi_{TP}, (T_{TP} - r)]$ with the degree of freedom from the training sample $(T_{TP} - r)$ and the scale matrix $\Xi_{TP} = \Omega_{TP}$. Following the recommendations of Blake and Mumtaz (2012), I restrict the matrix Θ_{TP} since it affects the variation of coefficients in my model (larger values lead to large dispersion), and the starting period provides rather limited information on individual variables. Therefore, the calculated variance is re-scaled via: $\Theta_{TP} = V_{OLS} \times T_{TP} \times \nu$, where ν is the factor of proportionality. I set it to a relatively small number $\nu = 3.510 \cdot 10^{-3}$ for my base fiscal rule (FR^{Ia}) following Blake and Mumtaz (2012). Byrne et al. (2016) use even a smaller value for their single equation model, however, my model is estimated upon demeaned series and it is so closer to the Primiceri's VAR model. This choice affects the speed of adjustment of parameters of TVP models.[45)]

The prior for the variance in the transition (updating) equation is the inverse Wishart distribution: $P(\Theta) \sim IW\,[\Theta_{TP}, T_{TP}]$ with the variance $V_{TP} = \Theta_{TP}$ and degrees of freedom T_{TP} coming from the training sample. Individual parameters (β's) are drawn from multivariate normal distribution, in accordance with the recommendation in the Bayesian literature (see Kim and Nelson, 1999). Since my both models include the lagged dependent variable, I restrict the generated set of random draws of coefficients for that variable to those that lie only between zero and approximatively one in absolute value, that is, for $\Psi = \{\widehat{\varrho}_t, \widehat{\varrho}'_t\}$ in the model (2.2) above so that $\Psi \in (-1.1; +1.1)$ holds to guarantee convergence for all countries in my sample.[46)]

45) On the one hand, one could argue that fiscal measures and changes in fiscal policy are not very frequently adopted because of institutional dynamics. On the other hand, there have been periods of time, when fiscal policy have responded rather quickly. Therefore, alternative values of the scaling factor ν were tried, see the robustness section below.

46) This step eliminates non-stationary processes. For some countries this condition is met without difficulties, while for others a larger number of draws is discarded as not meeting the condition to generate the stored sample (for example, Ireland, Sweden or the UK).

A.4.1 Conditional posterior distribution

Following Blake and Mumtaz (2012), I use the Carter and Kohn (1994) (C-K) algorithm. This algorithm with the Gibbs sampler enables to draw samples (for example for the state variable $\boldsymbol{\beta_T}$) from the posterior distribution. For that purpose, it is necessary to specify conditional posterior distributions. The conditional posterior distribution of Θ in the measurement equation given a draw of the state variable and other parameters takes the form:

$$F(\Theta|\beta_t, y_t, \Xi) \sim \Gamma^{-1}\left(\frac{T_{TP} - p + T_{sim}}{2}, \frac{\xi_1}{2}\right) \tag{A.20}$$

where $\xi_1 = \Theta_0 + (y_t - \beta_t \mathcal{F})'(y_t - \beta_t \mathcal{F})$.

Similarly, for the transition equation, the conditional posterior distribution of Ξ given a draw of the state variable and other variables reads:

$$V(\Xi|\beta_t, y_t, \Theta) \sim IW\left(\overline{\Xi}, T_{sim} + T_{TP}\right) \tag{A.21}$$

where $\overline{\Xi} = \Xi_0 + (\beta_t - \beta_{t-1})'(\beta_t - \beta_{t-1})$.

Lastly, the $(T \times 1)$ state variable $\boldsymbol{\beta_T}$ has conditional posterior distribution given the other parameters:

$$\mathcal{F}\left(\boldsymbol{\beta_T}|\boldsymbol{y_T}, \Theta, \Xi\right) = \mathcal{F}\left(\beta_T|\boldsymbol{y_T}\right) \Pi_{t=1}^{T-1}\left(\beta_t|\beta_{t-1}, \boldsymbol{y_t}\right). \tag{A.22}$$

A.4.2 Carter and Kohn algorithm

The Gibbs sampling routine requires starting values for both transition and measurement equation. They are set using values from the pre-sample estimation: $\Xi_0 = V_{OLS}$ and $\Theta_0 = V_{OLS} \times T_{TR} \times \nu$. The routine then proceeds following these steps:

- β_t is drawn from its posterior distribution (A.22) conditional upon Θ and Ξ employing the Carter and Kohn algorithm and the Kalman filter;
- Θ is sampled from its conditional posterior distribution (conditional upon β_t) – (A.20);
- Ξ is sampled from its conditional posterior distribution (conditional upon β_t) – (A.21);
- Previous three steps are repeated K to achieve convergence. The last M draws of β_t, Θ, Ξ are stored and provide an approximation to the marginal posterior distribution.

To verify that the C-K algorithm meets the necessary conditions for convergence in my empirical work, I calculate two statistics suggested by Geweke (1992): (i) the relative numerical efficiency (RNE) and (ii) convergence diagnostic (CD) at 20% and 50% of the retained Gibbs draws (the former level is increased from 10% following Byrne et al. (2016). The tests are complemented with visual inspection of retained Gibbs draws – serial autocorrelation and recursive means – as recommended in Blake and Mumtaz (2012). Using the calculation suggested by Raftery and Lewis (1992), I arrive at the minimum number of draws (~ 5000) for both models, I discard the first 10000 draws and store the last 10000 draws. The stored draws are used for further inference.

A.4.3 Model with stochastic volatility

An extension of my fiscal rule's model mentioned in the main text (see equation (A.17) above), I consider the possibility of changing variability over time (stochastic volatility), when estimating the fiscal rule. Because of time-varying variance, the state variable – v_t – (the observation equation is non-linear) and a different sampling algorithm has to be used. Following Blake and Mumtaz, 2012, I employ an independence Metropolis-Hastings (M-H) algorithm for the volatility term and then the C-K algorithm.

$$\begin{aligned} &\xi_t \sqrt{\exp\left(\ln(v_t)\right)}, \\ \ln v_t = \ln v_{t-1} + \iota_t, &\quad \iota_t \sim N[0; h] \end{aligned} \tag{A.23}$$

where v_t is the time-varying variance, the prior for $h, p(h)$ follows an Inverse Gamma distribution: $h \sim IGa[h_0; V_0]$. Starting values for the M-H algorithm are again obtained from the training sample as in the previous case. Acceptance probability for draws is set to $0.2 - 0.4$. This approach draws a single units of the stochastic volatility at a time. Alternatively, it an entire time-series of the stochastic volatility can be drawn. For details and a detail description on individual steps of the algorithm see Blake and Mumtaz (2012).

The routine follows these six steps (for a detailed overview, see Blake and Mumtaz, 2012):

- an IW prior for Ξ is set (based on the OLS training period estimation $\Xi_0 = V_{OLS} \times T_{TR} \times \nu$); starting value v_t is generated (squared residuals also from the OLS estimation), set IGa prior for h, obtain starting values for h and IW;

- a $(T \times 1)$ vector $\boldsymbol{v_T}$ is generated in three individual steps (due to approximation of the first and last value):
  (1) initial value v_0 is generated (conditional on h and time-varying coefficient stacked in $\mathcal{B}_t$) using the log-normal density (with mean and variance set upon initial values obtained from the OLS estimation, rescaled with a possibly big number ($\daleth$) to reflect uncertainty for these values, similar to the variance adjustment above);
  (2) $v_s, s = 1, \ldots, T-1$ are sequentially generated (conditional on $h, \mathcal{B}_t$) from the density (with mean $(\ln v_{t+1} - \ln v_{t-1})/2$ and variance $h/2$); each draw is tested before it is retained as a new unit in the $\boldsymbol{v_T}$ using the acceptance probability p larger than a threshold value $u_{pass}, u_{pass} \sim U[0,1]$;
  (3) the last value, v_T, is also generated from the candidate density (mean equal to the penultimate value of v and variance h) and retained if passes the threshold test;

- residuals for the transition equation are computed (ι_t) given a draw v_t. Then IGa is used to obtain a draw h;

- $\mathcal{B}_t$ is drawn conditional upon Θ and Ξ employing the Carter and Kohn algorithm. This and the next steps are as in the Carter-Kohn algorithm above with a difference: the variance of the transition equation error varies over time ($t = 1, \ldots, T$);

- Ξ is sampled from its conditional posterior distribution (conditional upon $\mathcal{B}_t$);

– Previous five steps are repeated K times to achieve convergence. The last M draws of $\mathcal{B}_t, v_t, h, \Xi$ are stored and provide an approximation to the marginal posterior distribution.

A.5 Data treatment

A complication for users of long time-series is associated with a recent change of statistical/methodological concept. European countries have adopted the European System of Accounts (ESA) 2010, replacing its previous version, ESA 1995, triggered by a similar update of the world-wide system by the UN (SNA 1993 → SNA 2008). Series based on the ESA 1995 ceased to be updated in late 2013 or latest in early 2014. Series based on the new standard are typically not available before 1995 or even 1999/2002 in case of truly fiscal series such as public debt. The exception represent some linked/recalculated series provided by OECD (mainly as a part of their *Economic Outlook* series published biannually) and the database of annual (only) series – AMECO – of the European Commission. (Both providers actually link series of main economic indicators back to 1960s based on both ESA 1995, ESA 1979 and/or older and alternative methodological concepts for some non-EU countries.) However, Eurostat and its databases that are the primary source for my dataset, are organised by methodological concept only. Therefore, I backcast some time series myself, using a method based on growth rates recently utilized in House et al. (2017) for a similar purpose. A series of an indicator z_t that is linked (extrapolated backwards for $t < T$) utilizing another series w_t, is constructed as:

$$z_t = w_t \frac{1}{4} \sum_{m=0}^{3} \frac{z_{T+m}}{w_{T+m}}, \tag{A.24}$$

where the additional term under the summation serves to correct for any level differences using four additional observations of both series.

A.5.1 Data sources

This section describes main sources of data utilized in the paper and some transformation needed. Further details on the reconstruction of fiscal series and series of output gaps are below. Main sources of individual series are the following:

a) Fiscal variables – the primary balance series calculated as the difference between total general government revenue minus total government expenditures without interests payments and general government debt are in levels in the ESA 2010 methodology (millions of units of national currency, not seasonally adjusted) provided by Eurostat (Eurostat, 2017; Eurostat, 2017a;c) and the European Commission (DG ECFIN, Annual macro-economic database, AMECO henceforth, see EC, 2017). Because of a lack of quarterly observations before 1995 (public debt) and 1999 (primary balance) for most of the Euro and non-Euro countries (for exact dates see the main text), both series are reconstructed using the Historical Public Finance Database (HPFD, henceforth, see Mauro et al., 2013) or the AMECO database, by applying growth rates calculated from level series (see below);
Germany was treated as West Germany before 1990 and growth rates applied to the first observation for the re-united country in 1991 using the HPFD database in line with Berti et al.

(2016); separate calculations for West Germany up to 1991 and for Germany 1990–2016 in comparison with the previous approach has only negligible effect, so the previous method is preferred.
To remove one-off items from primary balance series, I follow the standard OECD approach described in Joumard et al. (2008) applied to government expenditures (see below). Subsequently, I recalculate primary balance series consistent with these adjustments.

b) Total current expenditures without interest payments are calculated from underlying series of the National account aggregate using series from Eurostat database (quarterly, mil. of national currency, not seasonally adjusted). I apply the definition provided in the methodological notes to the AMECO database, and then complement these series with AMECO database and/or the HPFD database depending on the availability of other series. Since these series are at yearly frequency, quarters are created using the same decomposition method as for other fiscal series. Consequently, three years (twelve quarters) of observations are backcasted/forecasted via *ARIMA* model, where its lag length p is chosen optimally for each country in the sample (the AIC criterion). Subsequently, the BK and HP filter are applied to calculate trend deviations of current expenditures. Stored series without the extended observations are then expressed in relative terms dividing cyclical series with trend series, to create the temporary government spending variable ($cgout_t$) used in the fiscal rule.
To remove one-off items from expenditure series, I follow the standard OECD approach described in Joumard et al. (2008). I calculate seasonally adjusted series of net capital transfers, extend them using the same forecasting/backcasting procedure and apply the HP filter with increased ($4\times$) the standard value of the smoothing parameter λ for quarterly series: $\lambda' = 6400$ $[1600 \times 4]$. After elimination of extended parts of the series, I use the trend component to adjust the original non-interest total government expenditure series.

c) Quarterly GDP series and series of its main components (General government final consumption expenditures, Private final consumption expenditures and Investments – Gross Fixed Capital Formation), either in real terms (2010 constant prices) or in nominal terms and in levels; all series and GDP deflator series are seasonally adjusted. When series are annualised, I divide them by four to create quarterly series. The source is OECD Quarterly National Accounts database (QNA henceforth, OECD, 2017a) and OECD Economic outlook (EO No. 101, OECD, 2017).

d) Price index series (consumer prices, seasonally adjusted, national definition) are obtained from the OECD EO No. 101 database;

e) Interest rates, both short term (3M interbank rates) and long term (10Y bonds), are primarily obtained from Eurostat databases (Eurostat, 2017a) and complemented with OECD EO No. 101, OECD Main Economic Indicators database (MEI henceforth, OECD, 2017b) and Datastream/Haver or Oxford Economics (OE, 2017) country databases.

f) Unemployment rates (Labour force survey, harmonized series – ILO definition, seasonally adjusted) are taken from OECD MEI database and from IMF IFS database (IMF, 2017);

g) Current account balances (according to the IMF's 6^{th} Balance of Payments manual – IMF BMP6) are primarily taken from OECD EO No. 101 database, complemented with OECD MEI database, IMF IFS database and Oxford Economics database. Series for Greece, Ireland and Luxembourg are complemented with IMF Balance of Payments Statistics (IMF, 2017a). All series are seasonally adjusted (TRAMO/SEATS).

A.5.2 Database construction

This section describe main steps used for reconstruction of fiscal series and series of output gaps necessary for creating the quarterly database employed in the paper. Following recent studies such as Mauro et al. (2013) or Berti et al. (2016), emphasis is put on ensuring that the reconstructed time series are consistent over the utilized sample period. In general, the main steps applied are the following:

– As described in the data source section above, Eurostat databases (see data sources above) are the primary source of fiscal quarterly series (total deficit, gross debt, interest payments, and non-interest expenditures, in the ESA 2010 standard often available only from the mid-1990s to 2015).

– In case those series are not available, yearly series are taken from a database published by the DG ECFIN (AMECO see above). If they are available only partially (usually public debt series but not primary balance series), the Historical Public Finance Database (HPFD, see above) providing both series is preferred as the main source for both primary balances and public debt series.
The HPFD series are linked to AMECO series by utilizing growth rates of HPFD series to the first data point (observation) available in the AMECO database if necessary.

– Once yearly series for the time period are completed (1980–2015), they are imputed into a mixed frequency database (quarterly series alongside yearly ones) to check consistency of yearly and quarterly country-period observations. There are only minimal differences between the yearly values provided by the AMECO database and sums of reconstructed series (since quarterly series reflect seasonal adjustment, minor differences ($< 0.5\%$) are to be expected because of rounding, etc.).

– The main challenge is the recalculation of the primary balance for Luxembourg due to missing yearly observations at the end of the 1980s (1988 and 1989). I collect information on central government operations from OECD Economic Survey of Luxembourg (OECD, 1986; 1988; 1989; 1990; 1992; 1994) and calculate growth rates for budgetary out-turn and preliminary values for 1989 (no other values are available even after consultations with staff working with fiscal data in the Banque de Luxembourg) of net lending/net borrowing items. These rates are applied to the AMECO database's ESA 1995 series available for other years in this period. Since estimates of interest payments are unavailable for the general government in the national accounts either, I use the trend of interest payments for central and general governments provided by the IMF GFS (Government Finance Statistics, cash data, see IMF, 2014). The resulting series are similar to those available in Oxford Economics database (OE, 2017).

- Missing observations of quarterly series are constructed using information from other fiscal time series available at a quarterly frequency. To avoid the use of series of macroeconomic aggregates in my analysis, which may lead to a bias (Onorante et al., 2010; De Castro et al., 2014), I use only fiscal (sub-)aggregates that are components of the to-be-reconstructed series – total government revenue and expenditures. The set of variables employed for the reconstruction consists of the following series (with some variation by country, see details in data appendix):
  1) government revenues: direct tax (households and firms), indirect tax (indirect tax revenue from household consumption), and other revenues;
  2) total government expenditures (with/without interest): subsidies, transfers to private sector, government final consumption and government fixed capital formation, and other expenditures. Alternative series are used for Portugal (Social Security and Domestic Transfers from the sector of households) and Luxembourg (including financial series, interest rates).
  Since I cannot reconstruct social and unemployment benefits series for a larger share of my country/period sample, they are not included in the current decomposition exercise. If these two additional expenditure items are added to the set of series for reconstruction, the reconstructed series (total expenditures) are not significantly different from those without them. In terms of total revenues/expenditures' coverage, it varies between 60% and 70% for my set of countries. For the reconstruction, I use a state-space model setting similar to (Giannone et al., 2015 and Bańbura et al., 2015).

- Series of quarterly output gaps are not readily available (only yearly series) and they have to be calculated on basis of yearly series using the Baxter-King band-pass filter (Baxter and King, 1999) and the Hodrick-Prescott filter (Hodrick and Prescott, 1997). I do not use industrial production because of weak correlation of GDP for European countries with large service sectors. To mitigate the issue with the beginning and end of quarterly GDP series (as a robustness check year-on-year growth rates in a particular quarter are utilized), the main steps are the following:
  first, I forecast and backcast up to four years (16 quarters) of GDP using an unconditional bivariate $VAR(p)$ model for log differences of GDP and differences of inflation. The lag length p is selected via the Akaike information criterion following Watson (2007).[47] Since the original Watson (2007)'s approach works with time series, including house permits that are not available for this sample (all countries and years), quarterly series of industrial production and inflation (and interest rates spreads) are used instead as a robustness check for output gaps generated using quarterly GDP and inflation (and interest rates). OECD series of industrial production are already seasonally adjusted.
  Both filtering techniques are applied on the extended GDP series, carefully selecting the filter specifications: the BK filter ($BK_{12}(6,32)$) covers $1^1/_2 - 8$ years, that is, business cycle frequencies, in line with Market and Ravn (2007).[48] Alternatively, I repeat all previous steps following

[47] The optimal lag selection starts with the 'rule-of-thumb' recommendation for the maximum number of lags as suggested by Schwert (1989) and commonly applied for lag selections.

[48] Since the optimal lag length of the BK filter was larger than 12 for several countries, 16 quarters of GDP were forecasted and backcasted, and not just 12 (three years) as recommends by Watson (2007). That allows to keep the sample period at the same length for all EA and stand-alone countries.

(Watson, 2007) – an $AR(p)$ model for GDP without any covariates and Marcellino and Musso (2010) that uses GDP growth rates in an $AR(4)$ model, and also with country-specific $AR(p)$ models to allow for differences across countries in the sample (some catching-up, other developed countries).

An evaluation of forecasted/backcasted observations is carried out by comparing all results against the OECD forecast and OECD QNA database. All methods perform well in terms of relative errors of predictions for the period 2017q1–2018q4. As a consequence, I keep the $VAR(p)$ predictions and store the others for robustness.[49)]

Secondly, output trends are calculated using the Baxter-King band pass filter that is applied to individual GDP series in order to find the best fit; the standard specifications for most of the EA/EU countries (MA component with 12 lags and the length of cycles between 6 and 32 months) provide smooth series (checked by periodogram). The optimal number is higher only for a few countries (16 lags: Greece, Ireland and Sweden). In order not to lose observations from the sample, four years of actual (backcasted) data are used with this filter. The differences between both specifications of output gaps are negligible.

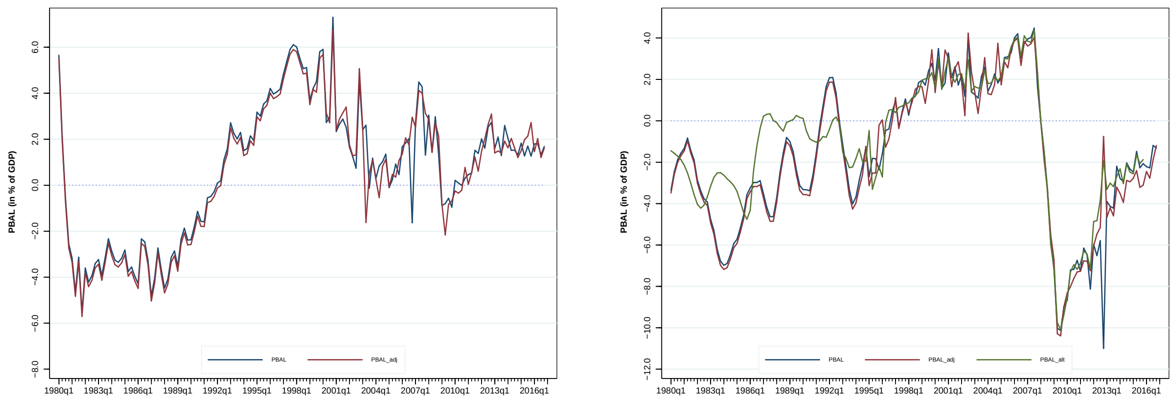
Thirdly, the HP filter is used with $\lambda = 1600$ recommended in the literature (Ravn and Uhlig, 2002), checked against alternatives: $\lambda = 6400$ and $\lambda = 25200$. I experiment with large values of λ, following Coibion et al. (2017): $\lambda = 2.10^6$ or Perron and Wada (2009): $8 \cdot 10^5$ (500 times the standard value) to capture changes in the slope of the trend, and thus eliminate bias coming from attributing too little variation to the cyclical component in comparison with the trend component. However, they cannot be used fully utilized given the sample length. Next, all observations outside the sample period are excluded from steps. The HP filtered series are used only for robustness checks in this paper because of the objectives explained in Hamilton (2016).

[49)] Since the variables (GDP and CPI) are non-stationary, the transformations mentioned in the text are applied to both series. I also experiment with a larger bivariate VAR (with differences of unemployment rate and interest rate spread following Watson (2007). Since results are similar in terms of prediction errors to the simpler model, it is preferred (transformations reduce correlations among variables).

B Figures and tables

Figure B.1: Examples of primary balances – reconstructed, officially published and adjusted series, 1980q1–2016q4 (% GDP)

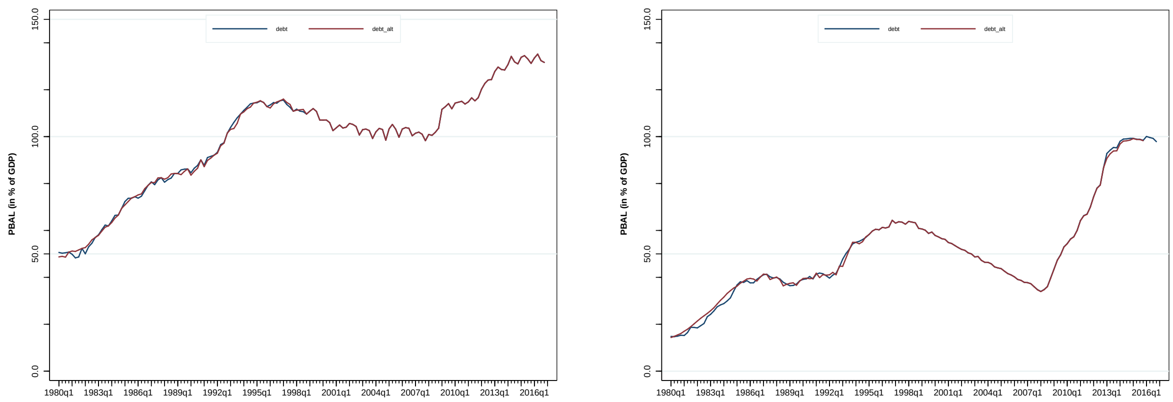
(a) Italy **(b) Spain**



Note: GAFS series are non-zero for Spain since 2008, and since 2009 for Italy. *PBAL* – officially published series (Eurostat, QNA), *PBAL_adj* – officially published series with adjustments for GAFS in local currency unit (ESP and Euro 1999 onwards). *PBAL_alt* is Euro-based series for Spain up to 2015q4 without GAFS items only between 2011 and 2015, and thus not fully comparable since Eurostat provides non-zero GAFS observations from 2008; the plotted series is based on a 2016 update of the QESFIP dataset (De Castro et al., 2014). Vertical axes are different for some countries. Source: own calculation and Eurostat (2017); Eurostat (2017c).

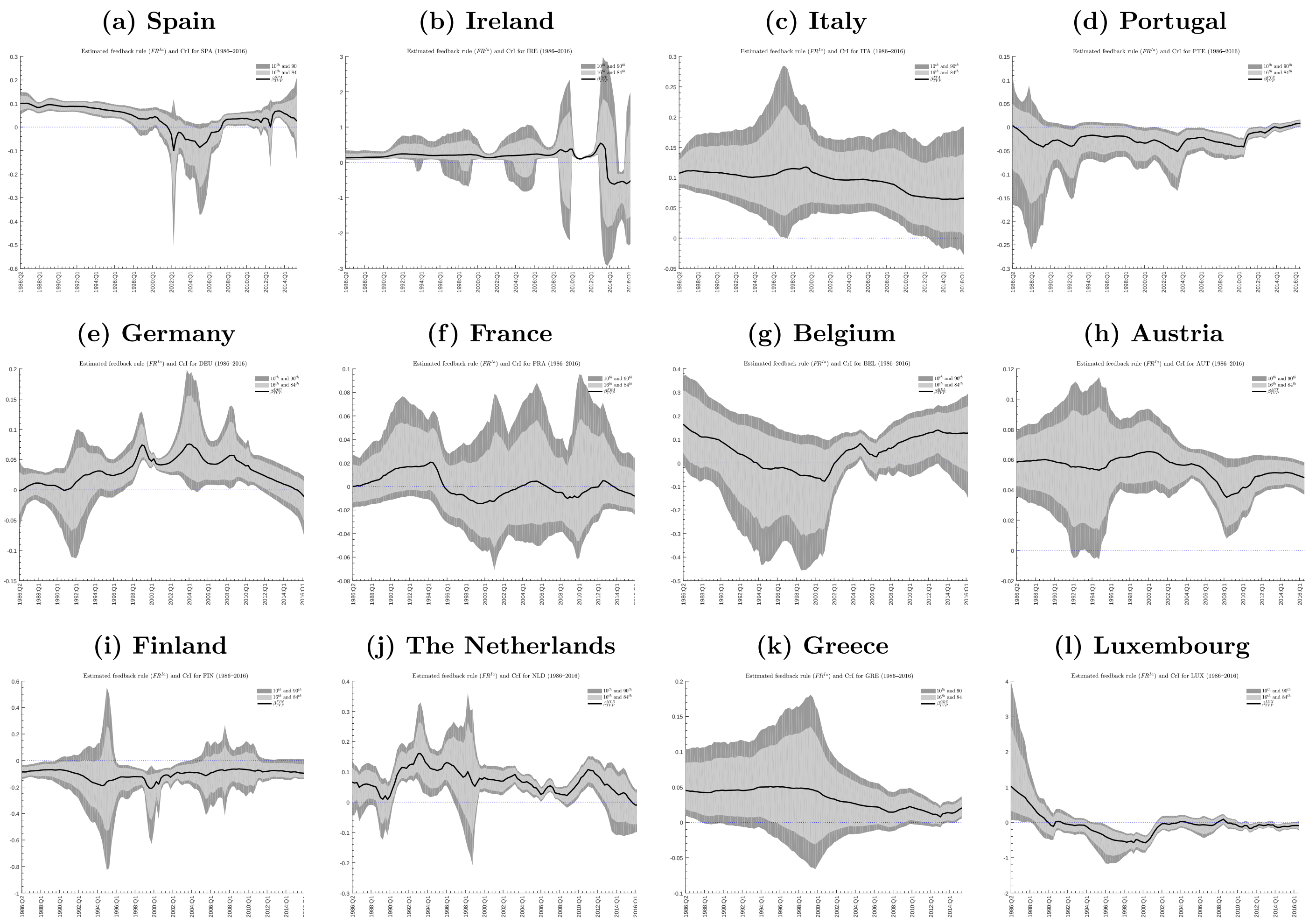
Figure B.2: Examples of debt – reconstructed, and officially published series, 1980q1–2016q4 (% GDP)

(a) Italy **(b) Spain**



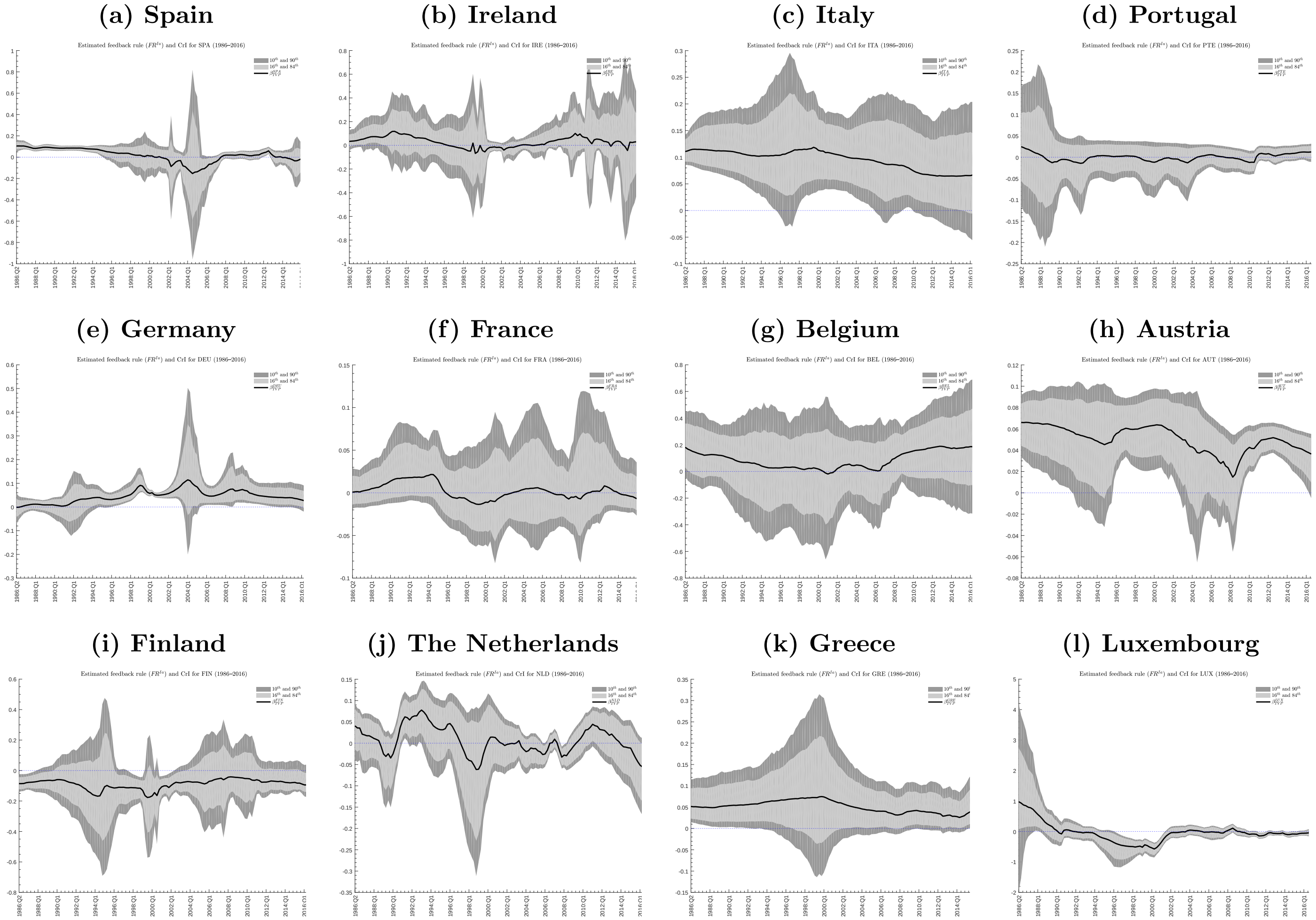
Note: GAFS series are non-zero for Spain since 2008 and since 2009 for Italy. *debt* – officially published series (Eurostat, QNA), *PBAL_alt* for Spain up to 2015q4 is based on a 2016 update of the QESFIP dataset (De Castro et al., 2014), and officially published series for Italy. Vertical axes are different for some countries. Source: own calculation and Eurostat (2017); Eurostat (2017c), Banca d'Italia (2017).

Figure B.3: Long run country-specific fiscal responses – FR^{Ia}, EA-12



Note: country-specific debt responses for FR^{Ia} (median). Darkness of grey areas represents credible intervals (16^{th} and 84^{th} and 10^{th} and 90^{th} percentile of the posterior distribution). Blue dashed line represents zero response. Vertical axes vary from country to country. *Source:* own calculations.

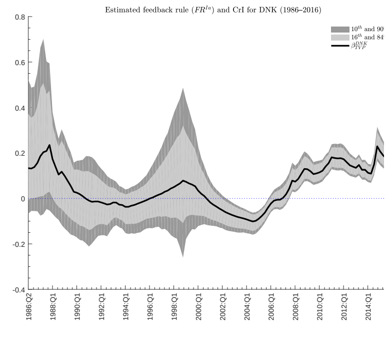
Figure B.4: Long run country-specific fiscal responses – FR^{Ia}, EA-12, adjusted series



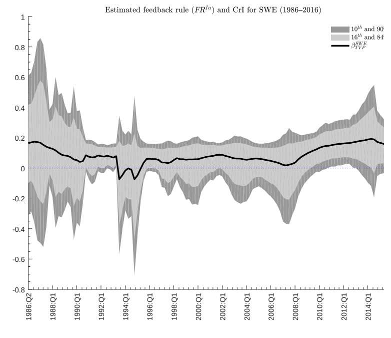
Note: country-specific debt responses for FR^{Ia} (median). Underlying series adjusted for large capital transfers. Darkness of grey areas represents credible intervals (16^{th} and 84^{th} and 10^{th} and 90^{th} percentile of the posterior distribution). Blue dashed line represents zero response. Vertical axes vary from country to country. *Source:* own calculations.

Figure B.5: Long run country-specific fiscal responses – FR^{Ia}, EU-3

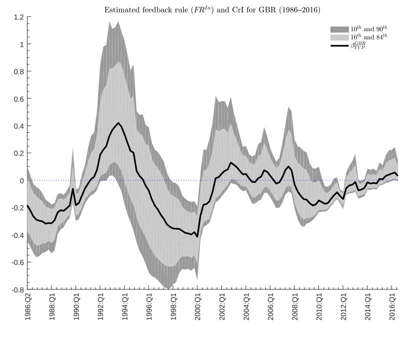
(a) Denmark



(b) Sweden



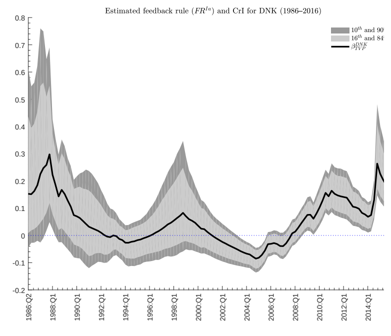
(c) United Kingdom



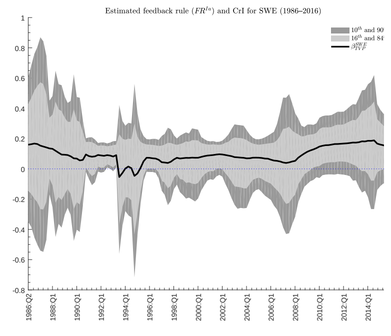
Note: country-specific debt responses for FR^{Ia} (median). Darkness of grey areas represents credible intervals (16^{th} and 84^{th} and 10^{th} and 90^{th} percentile of the posterior distribution). Blue dashed line represents zero response. Vertical axes vary from country to country. *Source:* own calculations.

Figure B.6: Long run country-specific fiscal responses – FR^{Ia}, EU-3, adjusted series

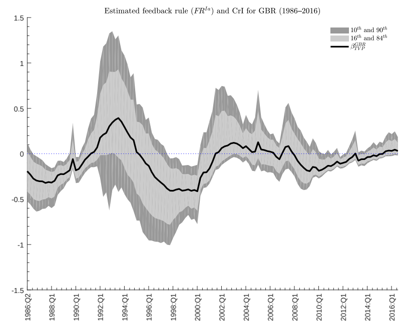
(a) Denmark



(b) Sweden

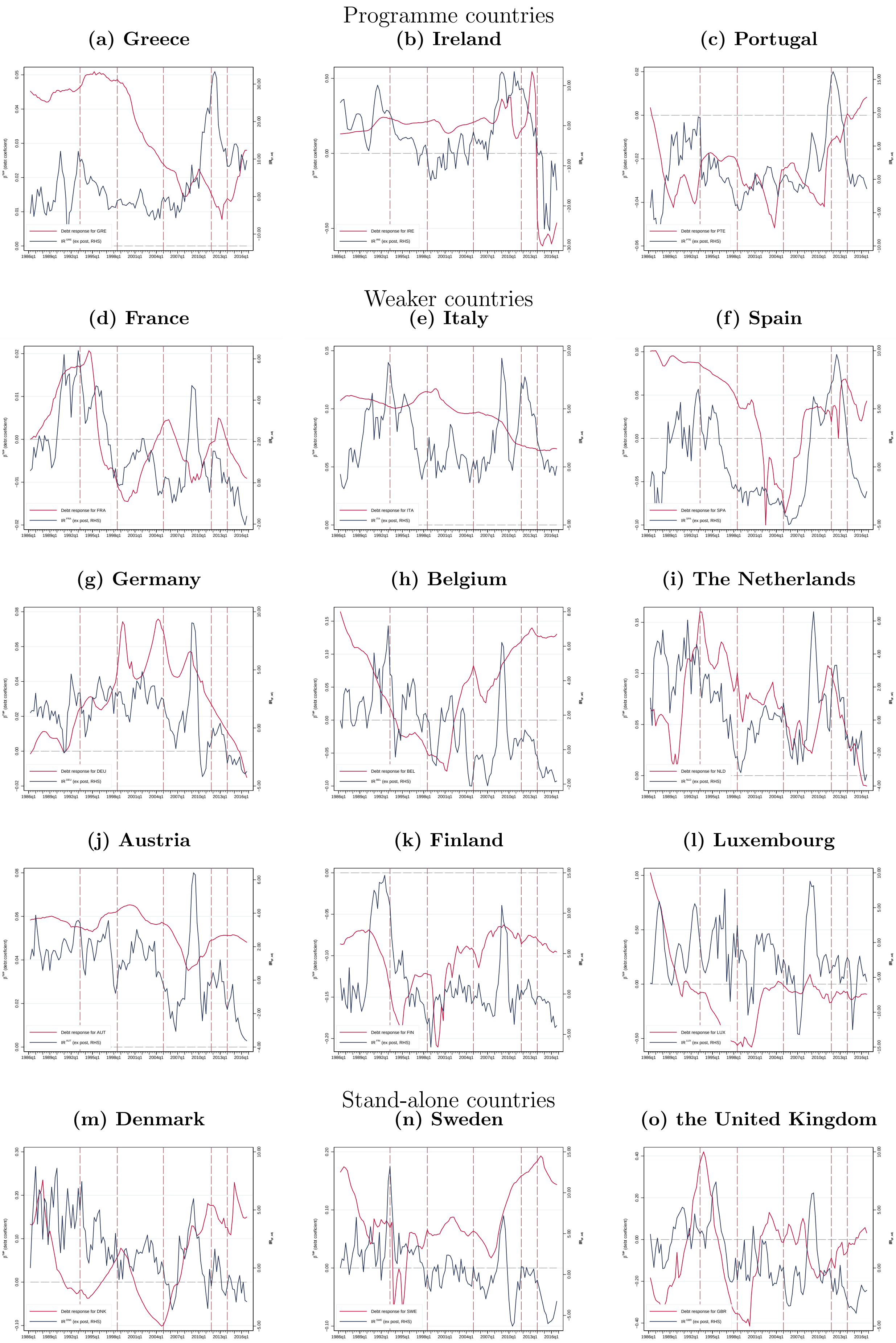


(c) United Kingdom



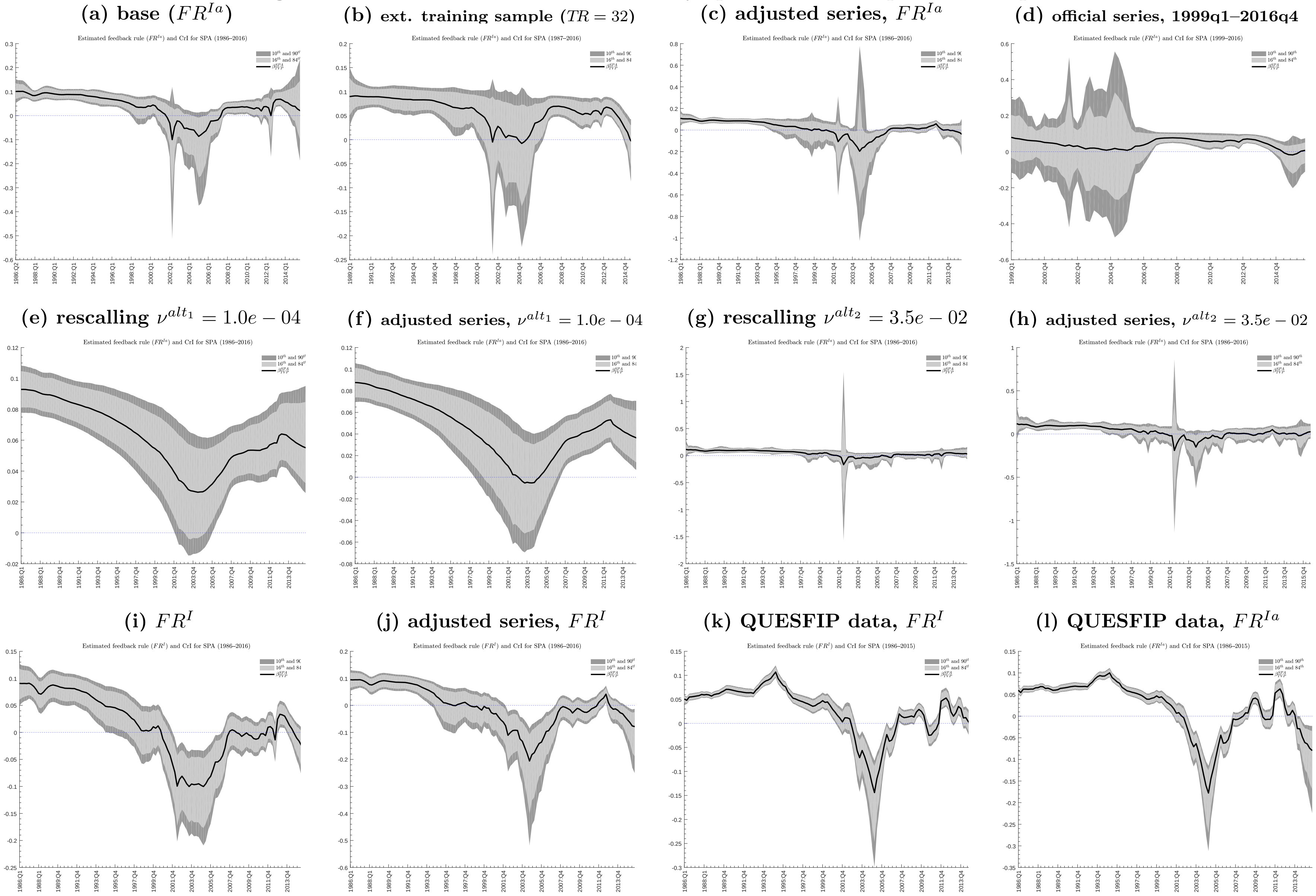
Note: country-specific debt responses for FR^{Ia} (median). Underlying series adjusted for large capital transfers. Darkness of grey areas represents credible intervals (16^{th} and 84^{th} and 10^{th} and 90^{th} percentile of the posterior distribution). Blue dashed line represents zero response. Vertical axes vary from country to country. *Source:* own calculations.

Figure B.7: Fiscal responses and growth adjusted interest rate



Note: country-specific debt responses for FR^{Ia} (median) vs. real-growth adjusted real interest rate (*ex post*, GDP deflator based).
Source: own calculations.

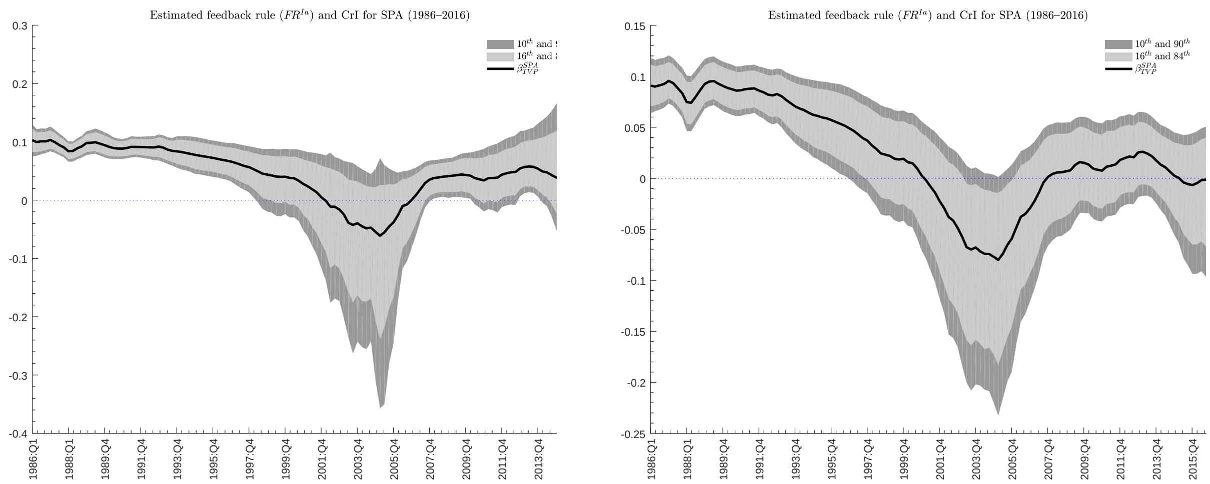
Figure B.8: Robustness checks – country-specific fiscal responses for Spain



Note: country-specific debt responses (median) for FR^{I} and FR^{Ia} model. QUESFIP data – Banco de España dataset only up to 2015q4 (De Castro et al., 2014). Official series – series published by Eurostat. Adjusted series – fiscal series adjusted for large net capital transfers (one-offs). Vertical scales are different for individual panels. Grey areas represent the credible intervals (16^{th} and 84^{th}, 10^{th} and 90^{th} percentile of the posterior distribution). Blue dash-dot line represents zero response. *Source:* own calculations.

Figure B.9: Country-specific fiscal responses with stochastic volatility for Spain

(a) base (FR^{Ia}) (b) FR^{I}



Note: country-specific debt responses (median) for FR^{Ia} and FR^{I} model (factor of proportionality set to $\nu^{alt_2} = 3.5 \cdot 10^{-2}$ for all models). Vertical scales are different for individual panels. Grey areas represent the credible intervals (16^{th} and 84^{th}, 10^{th} and 90^{th} percentile of the posterior distribution). Blue dash-dot line represents zero response. *Source:* own calculations.