Cost of borrowing shocks and fiscal adjustment*

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July 21, 2015

Abstract

Do capital markets impose fiscal discipline? To answer this question, we estimate the fiscal response to a change in the interest rate paid by 14 European governments over four decades in a panel VAR, using sign restrictions to identify structural shocks. A jump in the cost of borrowing leads to an improvement in the primary balance although insufficient to prevent a rise in the debt-to-GDP ratio. Adjustment mainly takes place via rising revenues rather than falling primary expenditures. For EMU countries, the primary balance response was stronger after 1992, when the Maastricht Treaty was signed, suggesting an important interaction between market discipline and fiscal rules.

Keywords: Fiscal policy, Interest rates, Market discipline, Europe, Maastricht Treaty

JEL classifications: E43, E62, H60

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Abstract

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... *The [Irish] Government has today decided that an overall [fiscal] adjustment of €15 billion over the next four years is warranted ... The key reasons for the significant increase from the figure announced in Budget 2010 are lower growth prospects ... and higher debt interest costs.* (Statement by the Irish Government, 26 October 2010).[1]

1 Introduction

During the European sovereign debt crisis, sharp rises in yields on government bonds have been met with promises from governments to accelerate and expand their fiscal consolidation plans. To the extent the promises are acted upon, this behavior can be interpreted as a form of market-imposed fiscal discipline. Against this background, we examine empirically, over a long time series and across several European Union (EU) countries, the proposition that governments systematically respond to increases in their cost of borrowing by improving their fiscal positions.

In doing so, the paper addresses an issue that, to date, has received little attention in academic research. As pointed out by Bayoumi et al. (1995), analyses of whether fiscal authorities are subject to market discipline should address two questions. First, do markets adjust the terms at which they lend to governments when fiscal positions change? Second, do governments adjust their fiscal positions when their cost of borrowing changes? A great deal of research has investigated the first question in isolation.[2] However, the hypothesis of market-induced fiscal discipline implies simultaneous responses of government bond market prices and fiscal policies, thus suggesting that the price and quantity of public debt are jointly determined. Yet, the causation from the cost of public debt service to fiscal policy decisions has, until recently, received little attention in the empirical literature, although a few recent papers have contributed to reducing this gap.[3] This paper aims to bring some balance to the joint determination of fiscal

[1] http://www.finance.gov.ie/viewdoc.asp?DocID=6552&CatID=1&StartDate=01+January+2010

[2] Since the work of Evans (1985), there has been a large empirical literature on the effect of fiscal policy on long-term interest rates. Some more recent studies include Faini (2006), Ardagna et al. (2007), Attinasi et al. (2009), Laubach (2009), Schuknecht et al. (2009) and Afonso and Rault (2011).

[3] For instance, Theofilakou and Stournaras (2012) estimate a fiscal rule for a panel of European countries and find evidence in favour of including government bond yields in governments' reaction functions. Their methodological approach is different to that used here, as they estimate a single equation model. In a recent contribution to this literature, Dell'Erba et al. (2015) study whether market pressure has acted as a trigger for fiscal consolidation in a sample of OECD countries over a 30 year horizon. In contrast to our approach, which uses changes in the primary balance as a summary metric of the fiscal response and treats fiscal contractions and expansions symmetrically, Dell'Erba et al. (2015) focus on specific multi-year fiscal adjustment episodes. Mauro et al. (2013) assess the interaction between the sovereign cost of borrowing and the level of public debt in a panel of 55 countries over up to two centuries and find that the primary balance response to changes in

variables and the cost of government borrowing by empirically assessing the budgetary response to exogenous interest rate changes in a dynamic context.

To motivate our empirical analysis, we present simulations of a simple model, in which the government of a small open economy optimally commits to a state-contingent path of government spending, distortive taxes, and debt. The government is able to issue debt on capital markets, paying the world interest rate plus a risk premium. In this set up, an exogenous rise in the risk premium demanded by investors for holding this debt generates a tightening of the budgetary path.[4] The optimal speed and composition for budget tightening is dependent on several structural features of the economy, including the initial debt ratio, the cost of adjusting fiscal instruments, and the presence of fiscal rules.

The model based simulations are then confronted with empirical estimates of the response of fiscal variables to exogenous changes in the government's cost of borrowing. We use a vector autoregressive (VAR) model for a panel of 14 European countries and annual data from 1970 to 2011. The empirical analysis faces two important methodological challenges. First, fiscal policy and the cost of borrowing are jointly determined, making it difficult to isolate exogenous movements in the cost of borrowing for governments. To overcome this challenge, we use the sign-restriction methodology of Mountford and Uhlig (2009) to identify several fundamental shocks that have been well documented in the macroeconometric literature. Having thus identified business cycle and policy shocks, we treat any additional unexpected movements in interest rates, orthogonal to the business cycle and fiscal policy shocks, as exogenous shocks to the cost of borrowing.

The second methodological challenge relates to the fact that empirical estimates must respect the government's intertemporal budget constraint. We impose this restriction by keeping track of the nonlinear debt dynamics using the methodology of Favero and Giavazzi (2007). On this basis, it is possible to assess whether the fiscal response is sufficient to offset the dynamics of

government debt slightly increases when sovereign bond yields are higher. Similar to our paper, Debrun and Kinda (2013) model the trade-off between primary balance adjustment and higher debt service in response to a cost of borrowing shock; on this basis, they estimate the primary balance response to higher interest expenditures in a single-equation, dynamic panel setting for advanced and emerging countries.

[4] Cost of borrowing shocks might originate from various sources, including for instance a change in global risk aversion, shifts in the supply and demand of foreign sovereign debt securities on account of additional countries gaining access to global financial markets, or idiosyncratic vulnerabilities that lower the perceived creditworthiness of certain issuers. The exact source of the cost of borrowing shock is immaterial for the budgetary response of the fiscal authorities, as predicted by the model. In any case, the cost of borrowing shock raises the interest payments and, via this channel, introduces a trade-off between fiscal tightening and debt sustainability concerns. The key challenge in the empirical part is then to separate such shocks from other disturbances (for instance to real activity and inflation) that endogenously affect both, the budgetary position and sovereign borrowing costs.

rising debt generated by an increase in the cost of borrowing.[5]

We find a significant fiscal policy response to exogenous changes in the cost of borrowing. In our baseline estimations, a 1 percentage point rise in the cost of borrowing leads to a cumulative increase in the primary balance-to-GDP ratio of 1.75 percentage points after 10 years. However, the debt-to-GDP ratio is 1.3 percentage points higher 10 years after the shock, i.e. the budgetary response is insufficient to compensate for the automatic debt-increasing effect of higher borrowing costs. The impulse responses reveal that the fiscal response is not immediate, with a significant consolidation appearing only two years after the shock. Almost all the adjustment takes place on the revenue side while primary expenditure remains broadly unchanged. Building on these baseline results, we then assess features that, according to the model, may influence the fiscal response to cost of borrowing shocks. In line with the theoretical predictions, we find that countries subject to tighter constraints (deriving from formal fiscal rules or the domestic political setup) tend to display a stronger response to cost of borrowing shocks.

Given the wide-ranging changes in the European fiscal framework over recent decades, the effect of such rules on budgetary adjustment is particularly relevant in EU member states. Separating our panel into EMU and non-EMU countries and the periods pre- and post-1992 (which marks the signing of the Maastricht Treaty), we find, consistent with the literature (see for example Camba-Mendez and Lamo (2004) and Gali and Perotti (2003)), that there was a systematic change in the behavior of fiscal policy following the introduction of the Maastricht Treaty. Our estimates reveal that the sub-sample including the post-1992 EMU countries show a significantly stronger fiscal consolidation response following a rise in the cost of borrowing than the pre-1992 EMU sample. A possible interpretation of this pattern is that those countries that eventually joined monetary union and its rules-based fiscal governance framework had an additional incentive to compensate for higher interest payments (which count against the Maastricht budget deficit criterion) by tightening their stance with respect to other budget items.

The rest of the paper proceeds as follows. Section 2 presents a simple model to clarify the responses predicted by standard macro theory. Section 3 outlines the empirical methodology. Section 4 presents the results and Section 5 discusses the policy implications and concludes.

[5] The non-linearity induced by the budget constraint implies that impulse responses in our setup will be sensitive to economic conditions at the time of the shock, in particular the debt-to-GDP ratio. There is a rapidly growing literature on the role of non-linearities in fiscal VARs following Auerbach and Gorodnichenko (2012).

2 Theoretical motivation

The model describes a small open economy populated by a continuum of identical households and a government. Households have preferences over private and public consumption goods and hours worked and have access to incomplete international capital markets. The government can also borrow on international capital markets, has two fiscal instruments, distortionary labor income taxes and public consumption expenditure, and sets policy optimally under commitment.

2.1 The model

The objective of a representative household is to

$$\max_{c_t, n_t, b_t^h} \mathbf{E}_0 \sum\nolimits_{t=0}^{\infty} \beta^t \left(u\left(c_t, n_t\right) + v\left(g_t \xi_t^g\right)\right), \tag{1}$$

subject to the intertemporal budget constraint

$$c_t = b_t^h - r_{t-1}^h b_{t-1}^h + \left(1 - \tau_t \xi_t^{\tau}\right) w_t n_t, \tag{2}$$

where $\beta \in (0,1)$ is the subjective discount factor, c_t is private consumption, n_t is hours worked, and $g_t \xi_t^g$ is public consumption (g_t is a policy instrument while ξ_t^g is exogenous and stochastic).[6] The functional form for preferences over c_t and n_t follows Greenwood et al. (1988), thus eliminating wealth effects on labor supply.[7] The real wage is w_t and $\tau_t \xi_t^{\tau}$ is the tax rate on labor income (τ_t is the policy instrument while ξ_t^{τ} is an exogenous component). Households issue debt, b_t^h, on international capital markets. The interest rate households face, $r_t^h \equiv r^h \left(\widetilde{b}_t^h, y_t\right)$, is assumed to be an increasing and convex function of the *aggregate* debt-to-output ratio of the private sector, $\widetilde{b}_t^h / y_t$. Production in the economy follows a linear technology, $y_t = \xi_t^a n_t$, which implies that the real wage (before taxes) is equal to productivity, ξ_t^a. The first-order conditions of the household problem are

$$c_t: \quad u_{c,t} = \beta \mathbf{E}_t u_{c,t+1} r_t^h, \tag{3}$$

and

$$n_t: \quad \left(1 - \tau_t \xi_t^{\tau}\right) \xi_t^a = -\frac{u_{n,t}}{u_{c,t}}, \tag{4}$$

where $u_{c,t}$, for example, denotes the marginal utility of consumption.

[6] All shocks, ξ_t^x, take the form $\xi_t^x \equiv \exp\left(\varepsilon_t^x\right)$ where $\varepsilon_t^x = \rho^x \varepsilon_{t-1}^x + \sigma^x u_t^x$ and $u_t^x \sim iid\,(0,1)$.

[7] Appendix A.1 gives the functional form for preferences and debt elastic interest rates.

The government can levy labor income taxes and issue debt in international capital markets to finance public consumption. The government's intertemporal budget constraint is:

$$g_t \xi_t^g = b_t^g - r_{t-1}^g b_{t-1}^g + \tau_t \xi_t^\tau \xi_t^a n_t - \varphi^g \left(g_t, g_{t-1}\right) - \varphi^\tau \left(\tau_t, \tau_{t-1}\right) \tag{5}$$

where $\varphi_t^g \equiv \frac{\psi_g}{2}\left(g_t - g_{t-1}\right)^2$ and $\varphi_t^\tau \equiv \frac{\psi_\tau}{2}\left(\tau_t - \tau_{t-1}\right)^2$ are convex costs of adjusting government expenditure and tax rates, respectively. These reduced-form costs play an important role in shaping the responses to a cost of borrowing shock.[8]

Following the literature, these costs can be interpreted in different ways. First, they could be administrative costs of changing the tax code or devising well-targeted government spending programmes.[9] Second, the adjustment costs might capture, in reduced form, the dynamics of distributional conflict between different fiscal agents (or political parties) that have different preferences over the mix of fiscal instruments. Tabellini (1986) showed that in this setting, the non-cooperative equilibrium exhibits slower fiscal adjustment. Third, the adjustment costs can be interpreted in analogy to the literature on optimal monetary-policy inertia. Aoki (2006) and Woodford (1999) show that adjusting the monetary policy interest rate gradually is optimal without imposing any penalty on interest rate variations. As long as there is some friction due to which the policymaker cannot achieve its stabilization objectives independently in each period, optimal policy is history dependent.

The interest rate on government borrowing, $r_t^g \equiv r^g\left(b_t^g, y_t\right)\xi_t^r$, like that of the households, is assumed to be an increasing and convex function of the government debt-to-GDP ratio, b_t^g/y_t, where ξ_t^r is the exogenous cost of borrowing shock of interest.

To close the model, we assume that the government is benevolent and is able to commit to a time invariant (i.e. from the timeless perspective) optimal policy.[10] The government solves the following Lagrangian, which maximizes household utility subject to resource constraints and

[8] In the macro-fiscal literature, fiscal policy is often specified as a set of highly autocorrelated fiscal instrument rules to capture the gradual adjustment of fiscal policy. Instead, we assume the government faces adjustment costs.

[9] Papers such as Browning (1976) and Mayshar (1991) estimate these administrative and compliance costs to be of the order of one percent of tax revenues.

[10] An alternative would be to specify fiscal rules in which the tax and spending instruments respond to endogenous macro variables, such as the output gap and government debt, as in Leeper et al. (2010). However, the specific conjecture of this paper is that fiscal policy also reacts independently to interest rates. It is therefore preferable to solve for optimal policy rather than specifying a set of ad hoc rules.

the household's first-order equilibrium conditions

$$\max_{\substack{c_t, n_t, \\ b_t^g, b_t^h, g_t, \boldsymbol{\mu}_t}} \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t \begin{bmatrix} u(c_t, n_t) + v(g_t \xi_t^g) - \frac{\psi^{td}}{2} (\max\{td_t, 0\})^2 \\ +\mu_{1,t} \left\{ b_t^h - r^h \left(b_{t-1}^h, n_{t-1}\right) b_{t-1}^h + (1 - \tau(c_t, n_t) \xi_t^\tau) \xi_t^a n_t - c_t \right\} \\ +\mu_{2,t} \left\{ \begin{array}{c} b_t^g - r^g \left(b_{t-1}^g, n_{t-1}\right) b_{t-1}^g + \tau(c_t, n_t) \xi_t^\tau \xi_t^a n_t - g_t \xi_t^g \\ -\varphi^g(g_t, g_{t-1}) - \varphi^\tau(\tau_t, \tau_{t-1}) \end{array} \right\} \\ +\mu_{3,t} \left\{ \beta u_c(c_{t+1}, n_{t+1}) r^h \left(b_t^h, n_t\right) - u_c(c_t, n_t) \right\} \end{bmatrix}, \quad (6)$$

where $\boldsymbol{\mu}_t = \left\{\mu_{1,t}, \mu_{2,t}, \mu_{3,t}\right\}$ are the Lagrange multipliers on the household and government budget constraints (with equation 4 substituted in), and the household Euler equation, respectively. We assume that the government has the same subjective discount factor, β, as the private sector. The first-order conditions are given in Appendix A.1.

The objective of the government (in equation 6) also includes the term $-\frac{\psi^{td}}{2}(\max\{td_t, 0\})^2$, where td_t is the budget deficit-to-GDP ratio (primary expenditures *plus* debt interest payments minus total revenues). This additional term captures the penalty of violating the deficit criterion of the Maastricht Treaty, in spirit of Beetsma and Debrun (2007).[11]

2.2 Calibration

Table 1 summarizes the calibration of the model and summarizes the steady state around which a linear approximation of the model is taken. The calibration replicates several long-run averages in our European data set. We hit a 50% debt-to-GDP ratio for both the private sector and the government, broadly in line with the sample average of 51.3% for the government debt-to-GDP ratio.[12] We set $\phi^g = \phi^h = 0.05$, which implies that a 1 percentage point increase in the debt-to-GDP ratio increases the cost of borrowing by 5 basis points, thus matching the findings in Laubach (2009).[13] The steady-state government interest rate is set below the household's subjective discount rate in order to induce a positive government debt-to-GDP ratio. Given ϕ^g, achieving the 50% debt-to-GDP ratio required setting α^g at .025.

[11] The Maastricht deficit criterion is violated when the budget deficit-to-GDP ratio is greater than 3 percent. Since we work with a linear approximation, the feasible implementation of a penalty associated with large deviations of the budget deficit is to have quadratic costs away from the steady state, so we take the max of td_t and 0, not 0.03.

[12] Unlike small open economy models featuring a non-optimizing fiscal agent, the steady state government debt-to-GDP ratio is uniquely pinned down by the parameters ϕ^g and α^g, where ϕ^g is the response of the government interest rate to a marginal change in the debt-to-GDP ratio, and α^g is the wedge between the steady state interest rate and the discount rate, β^{-1}.

[13] While the estimates in Laubach (2009) are based on US data, the available studies for EU countries tend to include both the debt ratio and (primary) budget deficit as explanatory variables (see Ardagna et al. (2007)), which makes it more difficult to apply the results to the calibration of our model.

Table 1: Calibration and steady state

Symbol	Description	Value
Calibrated parameters		
β	Subjective discount factor	0.95
σ	Preference parameter	2
θ	Preference parameter	1.8333
ϑ	Preference parameter	1.0138
α^g	Steady state interest rate discount	0.025
ϕ^g, ϕ^h	Interest rate sensitivity parameter	0.05
ρ^r	Cost of borrowing shock persistence parameter	0.8
Steady state moments		
b^g/y	Government debt-to-GDP ratio	50%
b^h/y	Private sector debt-to-GDP ratio	50%
n	Proportion of hours worked	25%
g/y	Government primary spending-to-GDP ratio	40%
τ	Tax rate	41.4%
r^g, r^h	Government and private sector cost of borrowing	2.76%, 5.26%

The preference parameters are standard with ϑ calibrated such that households work 25% of their time endowment. The weight on public consumption in the utility function is chosen to achieve a government primary spending-to-GDP ratio of 40%, consistent with the long-run average in our data set. The adjustment cost parameters, ψ^g and ψ^τ, as well as the penalty for violating the fiscal rule, ψ^{td}, do not feature in the steady state. The model is calibrated for annual data, so $\beta = 0.95$ and $\rho^r = 0.8$, with the latter being approximately equal to 0.95 at a quarterly frequency.

2.3 Impulse responses

When the government faces a higher path of borrowing costs, it must, at some point, generate a higher primary balance path to preserve solvency. The government, however, faces two important trade-offs in choosing the optimal path of its two fiscal policy instruments. The first concerns the timing of adjustment. A sharp adjustment in the short-run can be costly due to the convexity of the fiscal adjustment costs and the curvature of household preferences. However, a longer-term, more gradual adjustment implies higher future interest payments. The second trade-off concerns the composition of adjustment. Cutting primary expenditures entails adjustment costs and a reduction in welfare due to the fall in public consumption, which directly enters households' utility. Raising taxes also entails adjustment costs and increases labor market distortions. However, the tax increase allows the social planner to shift part of the economy's debt burden from the government (which, after the shock, is facing a relatively higher cost of borrowing) to the private sector.

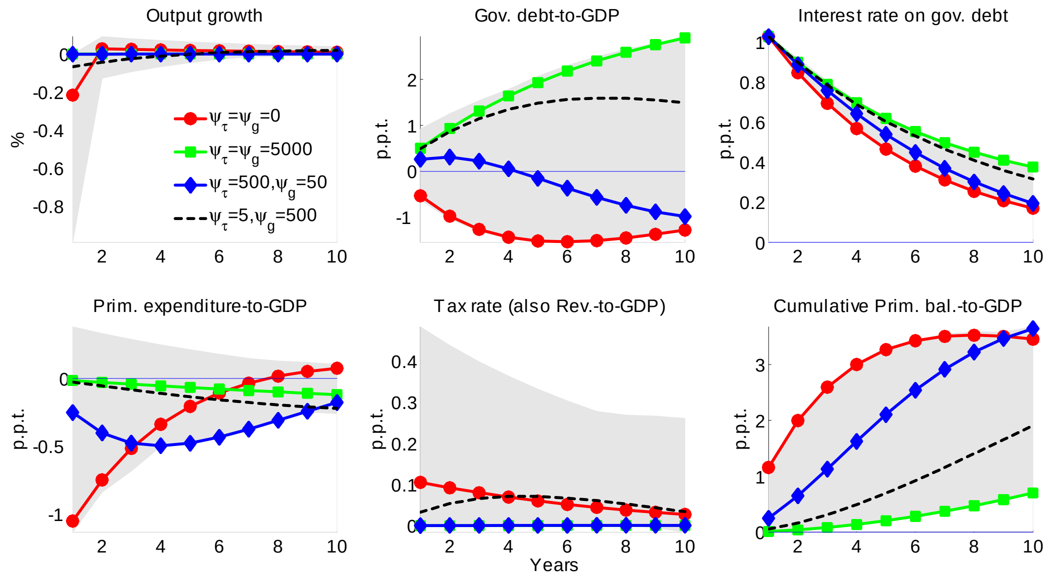
Figure 1 shows the impulse responses to an exogenous, unexpected one percentage point rise in the government cost of borrowing. The grey shaded area shows the dispersion of responses that the model generates within a given parameter space. The figure also highlights four calibrations. The green squares and the red circles compare two extremes: responses with extremely high and no adjustment costs, respectively. The most striking difference between the two calibrations is in the response of the government debt-to-GDP ratio. In the calibration without adjustment costs, the debt-to-GDP ratio drops by 1 percentage point, while in the calibration with extremely high adjustment costs, it rises by 2.5 percentage points (from its steady state level of 50 percent) by the end of the 10 year horizon. As the government makes only very gradual adjustments to its fiscal instruments in the second scenario, it needs to issue additional debt to cover interest payments, which is reflected in a rise in the debt-to-GDP ratio. Without adjustment costs, the government cuts primary expenditure by 2 percentage points on impact, after which the level of primary expenditure is slowly rebuilt. This cut in primary expenditures translates into a fall in the primary expenditure-to-GDP ratio of almost 1 percentage point. The government also raises the tax rate on labor income by just over 0.1 percentage point. Since the real pre-tax wage in this model is equal to the level of productivity, the labor tax rate is always equal to the total government revenue-to-GDP ratio. The rise in the tax rates induces a reduction in labor supply and a consequent fall in output. Households smooth consumption through increased borrowing.

The blue diamonds and the black-dash lines isolate the effect of the two fiscal instruments by varying the relative weight given to the two adjustment costs. With the blue diamonds it is relatively more costly to adjust taxes, while with the black-dashes it is more costly to adjust primary expenditure.[14] With the intermediate calibration of the adjustment cost parameters, the model generates hump-shaped responses of the fiscal instruments to cost of borrowing shocks, which is what we observe in our empirical analysis (see Section 4).

In summary, this stylized model – while allowing for an array of different patterns depending

[14] Greenwood et al. (1988) preferences imply no government spending multiplier in this model. Had we used King et al. (1988) preferences instead, the model would generate a positive multiplier. However, we would also get a rise in output growth following a cost of borrowing shock. This is because a cost of borrowing shock acts like a wealth shock, lowering the present value of future disposable income. Households react by supplying more labor which generates a counterintuitive rise in output.

Figure 1: Impulse responses to a cost of borrowing shock



Note: Shaded area shows the dispersion of responses for parameters $(\psi_\tau, \psi_g) \in [0, 5000]$.

Table 2: Model predictions

Variable: Shock:	g_t/y_t	τ_t	y_t/y_{t-1}	Inflation	r_t^g	b_t^g/y_t	Comment
ε_t^r	$(-)$	$(+)$	$(-)$	$\cdot$	$(+)$	?	g/y may be $(+)$ if all the adjustment comes from τ_t

Note: $(+)$, $(-)$, or ? indicates the response of variable z to shock ε^x on year of impact is positive, negative, or ambiguous, respectively; $\cdot$ indicates the model is agnostic.

on the calibration of (partly unobserved) parameters – yields important qualitative predictions for the fiscal response to cost of borrowing shocks (Table 2): τ_t is expected to rise and g_t/y_t is expected to fall in response to a cost of borrowing shock (except in the unusual scenario where the fall in y_t as a result of the increase in τ_t dominates the fall in g_t). Output growth is expected to fall. The sign of the debt-to-GDP ratio response, however, is highly uncertain and hence of key interest in our empirical analysis.

As the model abstracts from many features, including nominal rigidities (which would inform the response of inflation), Table 2 does not provide sufficient information for imposing restrictions in order to recover the structural shocks in the empirical VAR estimation in Sections 3-4. The model does, however, allow for several other standard macroeconomic shocks, namely, a technology, government spending, and income tax shock. There is one key feature that distinguishes these three shocks from the cost of borrowing shock (see impulse responses in Online Appendix B.2). In the case of a positive primary expenditure shock, the social planner's optimal response is to increase taxes; in the case of a positive income tax shock, the planner's optimal response is to increase government spending; and in the case of a positive technology shock, the denominator (GDP) dominates, causing both the primary expenditure-to-GDP and revenue-to-GDP ratio to fall. This positive comovement is in contrast to the cost of borrowing shock where, for reasonable calibrations, the primary expenditure-to-GDP and revenue-to-GDP ratios move in opposite directions. While we do not use this information in the formal identification procedure we employ in the empirical section, it serves as a useful cross check of our results.

In the empirical analysis, we also test for heterogeneity in the responses to cost of borrowing shocks depending on certain structural and institutional features of the economy. To motivate these tests, we use the model to make three more sets of predictions (see Figure 2) about how these features can effect fiscal adjustment.

In each experiment, the benchmark response (with $\psi^g = 500, \psi^\tau = 5, \psi^{td} = 0$) is shown in red. In panel A, we consider the effect of imposing a Maastricht-style budget deficit criterion. As shown by the blue circles (where $\psi^{td} = 50$), the government responds more aggressively to the cost of borrowing shock in the presence of fiscal rules that penalize large budget deficits. As a consequence the debt-to-GDP ratio does not rise.[15]

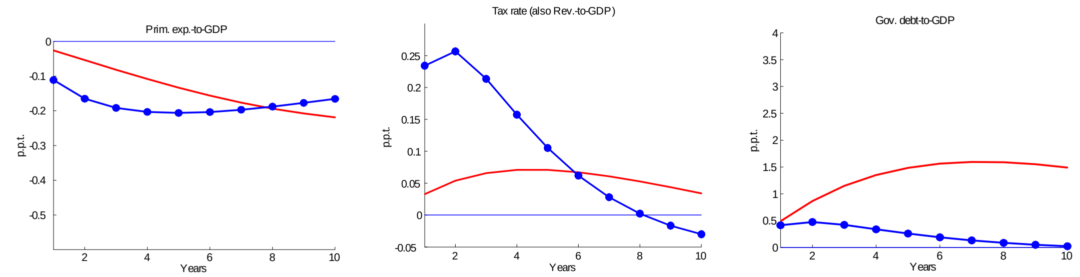
In panel B we trace out the effect of different initial (or steady state) debt-to-GDP ratios (the empirical counterpart is Figure 6). A higher initial debt-to-GDP ratio results in larger interest payments for a given cost of borrowing shock. Thus, all else equal, the debt-to-GDP ratio rises more quickly. In the model, the social planner cuts government spending by more when the initial debt-to-GDP ratio is larger. The increase in tax rates, however, is not monotonic in the initial debt-to-GDP ratio. This is because the government is trading off the counterproductive effects of higher tax rates on a shrinking tax base. As a consequence, a higher initial debt-to-GDP ratio leads to a longer period for the debt-to-GDP ratio to return to its initial value.

In Figure 8(C) in Section 4, we split our sample of countries into historically low and high debt-to-GDP countries. To motivate the existence of historically low and high debt-to-GDP ratio countries in the theoretical model we set up the following experiment: Suppose that the

[15] This finding motivates the analysis in Section 4, Figure 8(A) where we estimate subsamples pre- and post-the signing of the Maastricht Treaty (that subjected member states to a common rules-based fiscal framework).

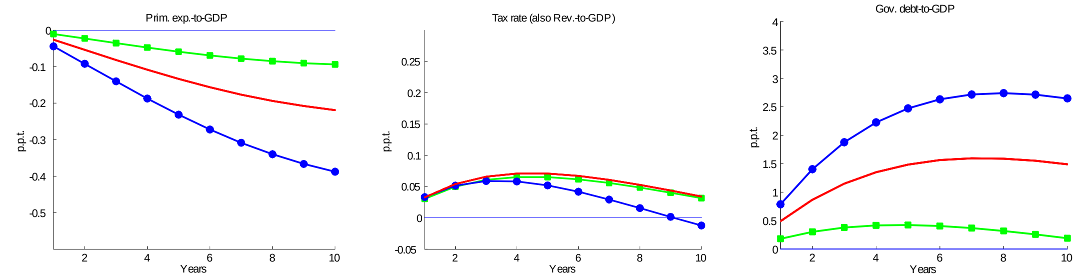
Figure 2: Cost of borrowing shocks: Three further experiments

A. Maastricht-style budget deficit criterion



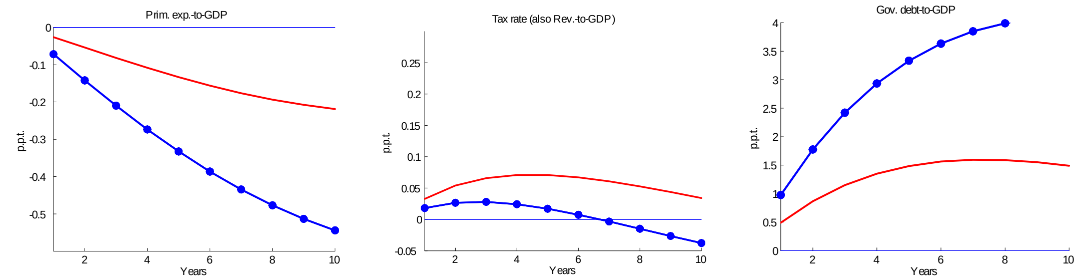
Legend: ● ψ^{td}= 50, — Benchmark calibration (ψ^{td}= 0)

B. Different initial (steady state) government debt-to-GDP ratios



Legend: ● $b^g/y = .8$, — Benchmark calibration ($b^g/y = .5$), ■ $b^g/y = .2$

C. A government that does not fully internalize the effect of debt on interest rates



Legend: ● Gov. perceives ϕ^g= .025 (true ϕ^g= .05), — Benchmark calibration (perceived and true ϕ^g= .05) social planner is imperfect in that it does not fully internalize the effect of government debt on interest rates — implemented in the model by assuming the government underestimates the debt-elastic interest rate parameter, ϕ^g, by half. As a result of not fully internalizing the effect of debt on interest rates, the government's steady state debt-to-GDP ratio is twice as high at 100% (shown with the blue circles). When the cost of borrowing shock arrives, the government's perceived marginal cost of allowing the debt-to-GDP ratio to rise is lower. As a result, the government raises tax rates by less and the debt-to-GDP ratio rises by more than 4 percentage points in the space of 10 years.

Overall, the theoretical model highlights the trade-offs created by a cost of borrowing shock, generates predictions on the likely response other variables that serve as a cross-check for the structural cost of borrowing shock we identify in the data, and produces several predictions about the relative fiscal adjustment for economies with different institutional structures.

3 Empirical methodology

This section describes the data, estimation technique, and identification strategy used to test empirically the response of fiscal policy to cost of borrowing shocks.

3.1 Data

Our baseline empirical model is a VAR in seven variables:[16] The government primary expenditure-to-GDP ratio, pe_t, government revenue-to-GDP ratio, rev_t, GDP growth rate, g_t, inflation rate, π_t, government nominal implicit interest rate, i_t^{imp}, a nominal 3 month interest rate, i_t^{3m}, and a nominal 10 year bond yield, i_t^{10y}. The data covers an unbalanced panel of 14 European countries (Austria, Belgium, Germany, France, Finland, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Denmark, UK and Sweden) at an annual frequency from 1970 to 2011.[17]

In addition to the seven endogenous variables, we include the government debt-to-GDP ratio, b_{t-1}, as a lagged explanatory variable following the method of Favero and Giavazzi (2007). The rationale for its inclusion is that it imposes the government's intertemporal budget constraint on fiscal responses to shocks. The government debt-to-GDP ratio evolves as follows

$$b_t = \frac{1 + i_t^{imp}}{(1 + g_t)(1 + \pi_t)} b_{t-1} + pe_t - rev_t + s_t, \tag{7}$$

[16] Later, we use a more parsimonious VAR in five variables for the purposes of subsample analysis after checking that the baseline results are robust to the more parsimonious set up.

[17] A full description of the sources and construction of the data series can be found in Appendix A.3.

where

$$i_t^{imp} = \frac{total\ interest\ payments_t}{b_{t-1}}. \tag{8}$$

One of the advantages of the Favero and Giavazzi (2007) method is that the evolution of the debt-to-GDP ratio in equation (7) is calculated recursively using the VAR's endogenous variables.[18] And hence, equation (7) motivates the form of the first five variables in our VAR.

Equation (7) also highlights that it is the implicit interest rate that directly determines debt-to-GDP dynamics. At the same time, prevailing market yields, as an alternative measure for the government cost of borrowing, may contain further information on the market perception of a country's fiscal and economic fundamentals which governments may internalize in their fiscal decision-making – even if changes in market yields usually do not trigger pronounced immediate changes in the implicit interest rate due to the inherent inertia in this measure. To reflect these considerations we complement the i_t^{imp} variable in our VAR with the 10 year government bond yield (which is the only maturity for which there is a long span of historical data across many countries) as a measure of the current market interest rates.[19] Appendix A.2 provides a simple model, complementary in notation to the model in Section 2, which further illustrates the conceptual link between the 10 year bond yield and the implicit interest rate in our VAR and explains how to interpret the shocks that we identify. The short-term interest rate in the VAR serves two purposes. The first is to help isolate cost of borrowing shocks from monetary policy shocks. The second is that a 10 year bond yield may on its own be a poor proxy for the prevailing interest rate environment. This is because governments finance themselves with many different types and maturities of debt instruments, and endogenously adjust the maturity at which they issue in order to minimize financing costs. Thus, having both a short and a long rate helps to better reflect the term structure from which a government may choose to borrow.[20]

[18] In fiscal accounts, there is a statistical discrepancy between the total borrowing requirement of the government (the flow) and the change in the debt (the stock). The stock-flow adjustment that ensures equality in equation (7) is denoted by s_t.

[19] Intuitively, this approach combines the following perspectives: the implicit interest rate determines the amount of resources that governments have to set aside to service their debts and hence cannot devote to other purposes, such as expanding primary spending or lowering taxes without jeopardizing solvency. As such, it captures the key trade-off that arises from a change in r_t^g in the model in Section 2. However, anecdotal evidence suggests that prevailing sovereign bond yields may contain additional information on the degree of perceived market discipline that governments are facing. For instance, during the sovereign debt crisis in several euro area countries, press and market commentary focused on certain thresholds for the 10-year sovereign bond yields beyond which they suspected debt sustainability concerns to arise – without considering that the average cost of borrowing recorded much more modest increases and substantially varied across countries over this period (for example, the Wall Street Journal published an article on November 9, 2011 entitled " Italian Bond Yields Pass Key 7% Level"). Market yields typically give a more pronounced reflection of changes in the (perceived) creditworthiness of a sovereign than the implicit interest rate measure, which is inherently inertial.

[20] Unfortunately, these two interest rates are the only ones available for which we have comparable, high-quality data for the entire sample period (see Appendix A.3 for more details). There is some, albeit limited data,

Appendix B.1 provides details on the time series properties of the data set. In particular, it is worth noting that the debt-to-GDP ratio is found to exhibit a unit root for many of the countries over our sample period, and that even using a panel based unit root test, we are not able to reject the null hypothesis of nonstationarity in the data. The nonstationarity may appear to be inconsistent with fiscal sustainability, but as stressed by Giannitsarou and Scott (2006) and Bohn (2007), that is not necessarily the case. A sufficient condition for sustainability is the existence of a feedback from the level of debt to the current primary surplus. In the VAR that we estimate, we will pay particular attention to this feedback from the debt-to-GDP ratio on our two fiscal variables.

3.2 Estimation

The panel VAR we estimate takes the form:

$$Y_{i,t} = A(\ell)\, Y_{i,t-1} + F(\ell)\, W_{i,t-1} + u_{i,t} \quad u_{i,t} \sim iid\,(0, \Sigma_u) \tag{9}$$

where $Y_{i,t}$ is a $G \times 1$ vector of endogenous variables, $W_{i,t}$ is an $H \times 1$ vector of predetermined variables, $A(\ell)$ and $F(\ell)$ are polynomials in the lag operator and *iid* means identically and independently distributed. Time is denoted by the subscript $t = 1, ..., T$ and the country unit is denoted by the subscript $i = 1, ..., N$. We estimate a *homogenous* panel VAR in the sense that the coefficient matrices A_j and F_j (where j denotes the lag) are independent of the country unit subscript i. The relatively small size of our data set prevents us from exploring potential time variation and cross-sectional heterogeneity in the VAR coefficients in a very systematic way. However, we revisit this restrictive assumption by conducting subsample analysis in Section 4.

In our baseline estimation, $G = 7$ and $Y = \left[pe, rev, g, \pi, i^{imp}, i^{3m}, i^{10y}\right]$. We have one predetermined variable: $H = 1$ and $W = b$. As long as the estimated coefficient vector, $\widehat{F}_1$, is non-zero, all endogenous variables are able to respond to movements in the government debt-to-GDP ratio. All the variables are country- and time-demeaned to account for both country and time fixed effects. The panel VAR is estimated with two lags of the endogenous variables and one lag of the predetermined variable.[21]

available on the maturity structure of government debt that we used to construct our own proxy for the marginal cost of borrowing. However, the limited available sample size meant we could not use it as our our variable of choice. Results using this measure are, however, available on request.

[21] The choice of lag length is important due to the serial correlation in the maturity structure of government debt. As of 2010, the UK has the longest average maturity of debt of 13.7 years followed by Denmark with 7.9 years. Finland has the shortest average maturity with 4.3 years. The average maturity of debt across all

The inclusion of the debt-to-GDP ratio following Favero and Giavazzi (2007) gives rise to two difficulties. First, the intertemporal budget constraint is a nonlinear function of the endogenous variables. Thus, when we generate impulse responses to shocks, the results will be sensitive to the initial debt-to-GDP ratio and the size of the shock.

Second, in the fiscal accounts data the stocks and flows do not exactly tally and the residual is captured in the stock-flow adjustment variable, s_t (see equation 7). The inclusion of s_t in the endogenous vector, Y, would ensure that the debt-to-GDP ratio holds as an identity but would also increase the number of coefficients we would need to estimate.[22]

To draw inferences about $\Phi = (A(\ell), F(\ell))$ and Σ_u, we use a Bayesian approach, which combines information from sample and priors. We employ commonly used diffuse priors which allows us to benefit from Bayesian analysis without the difficulty of obtaining an informative prior. In particular, we employ a constant prior for Φ and the Jeffreys prior for Σ, $P_J(\Sigma) \propto |\Sigma|^{-(G+1)/2}$, which means that $P_{CJ}(\Phi, \Sigma) \propto P_J(\Sigma)$. The Bayes estimators are obtained via Monte Carlo (MC) simulations. By sampling (Φ, Σ) from the joint posterior distribution, we generate the Bayes estimates numerically. Let the OLS estimates of (Φ, Σ) be (B, S). Under these assumptions, the posteriors are:

$$\begin{aligned} \Sigma &\sim IW\left[(NTS)^{-1}, NT - GL_Y - HL_W\right] \\ vec(\Phi) &\sim N\left[vec(B), \Sigma \otimes (X'X)^{-1}\right] \end{aligned}$$

where the posteriors of Σ are drawn from an inverse Wishart distribution, which takes as its arguments $(NTS)^{-1}$ and degrees of freedom, $NT - GL_Y - HL_W$ where L_Y and L_W are the number of lags Y and W respectively. The posteriors of Φ are drawn from a normal distribution,

the countries in our sample was 7 years (the data is from Faraglia et al. (2011) who source the OECD and The Economist).

Our choice of a VAR with 2 lags came from the use of standard lag length selection criteria. We considered VAR specifications with lag lengths from 1 to 7. The Schwarz Bayesian Criterion indicated a single lag, the Hannan-Quinn Criterion indicated two lags while the Akaike Information Criterion indicated 7 lags.

[22] The stock-flow adjustment captures, among other things, changes in the size of foreign-currency denominated debt associated with a change in the exchange rate, financial transactions in relation to government support to financial institutions, privatization receipts, the purchase of assets, and statistical recording discrepancies.

As pointed out by an anonymous referee, the estimated fiscal adjustment may be affected if we do not account for all important factors that generate movements in the debt-to-GDP ratio. For, instance, when a government purchases an asset by issuing government debt that does not appear as an expenditure in the fiscal accounts, but investors adjust the rate at which they are willing to lend, this may be identified as a cost of borrowing shock rather than a fiscal policy shock in our model. And, if these shocks were economically sizeable, they could therefore distort the true response of fiscal policy to cost of borrowing shocks in our results.

However, in an earlier working paper version (see de Groot et al. (2012)), we included the stock-flow adjustment term as an additional endogenous variable in our model as a robustness check and found our main results to be little affected. Hence, we retain the more parsimonious set up used in the following analysis.

where X is the matrix containing the right-hand side variables. To generate the error bands around our impulse responses, we ran 5000 MC iterations.[23]

3.3 Identification

The estimated model, in its reduced form (equation (9)), lacks economic structure. This is because the errors, u, that result from a one-step ahead forecast of the corresponding component of Y are unlikely to be orthogonal innovations since Σ_u is unlikely to be diagonal. To give the model, and the shocks, economic structure, we must place some restrictions on the model that allow us to decompose the non-orthogonal innovations into orthogonal and economically interpretable shocks. We can do this by choosing a matrix B such that $B\Sigma_u B' = I$ since the new *shocks*, $\varepsilon = Bu$ will satisfy $E(\varepsilon\varepsilon') = I$. These orthogonalized innovations have the convenient property that they are uncorrelated across equations. There are many such factorizations of Σ_u, so the choice of method of orthogonalizing is not innocuous. The aim is to choose B such that the estimated model has a clear structural form with shocks, ε, that have a convincing economic interpretation.

There are several commonly used methods to recover the structural form (i.e. to identify shocks) in the literature. We identify cost of borrowing shocks by making use of a methodology which imposes sign restrictions (see Faust (1998), Uhlig (2005), and Canova and Nicoló (2002)) upon impulse responses.[24]

The idea behind our identification strategy is that a cost-of-borrowing shock is a surprise change in the government's nominal cost of borrowing that is orthogonal to all other macroeconomic shocks. We do not want to impose any prior restrictions on the behavior of the endogenous variables to a cost-of-borrowing shock. Instead, our identification strategy imposes sign restrictions that lead to the identification of a set of shocks that have been commonly studied in the macroeconomic literature. Any unexplained variation in our cost-of-borrowing variable that is orthogonal to these other macroeconomic shocks is then judged to be a cost-of-borrowing shock.

[23] Increasing the number of runs to 10,000 does not significantly alter inference.

[24] Fry and Pagan (2011), in their critical review of the sign restriction literature, identify two problems with this methodology; the multiple models problem and the multiple shocks problem. The multiple models problem refers to the fact that there can be many sets of impulse responses, i.e. many models that fit the sign restrictions. To overcome this problem, we use an additional criterion - a penalty function - to identify one unique model. The multiple shocks problem arises if there is a failure to specify enough information to discriminate between shocks. We partly overcome this problem by identifying as many shocks as there are left-hand side variables. However, there still remains the possibility that the shocks we identify are really linear combinations of other structural shocks that we do not consider. See also Arias et al. (2014).

The theoretical model we presented in Section 2 is not rich enough to provide a robust set of sign restrictions to identify all the macroeconomic shocks we are interested in. The sign restrictions are therefore chosen from a wide reading of the macroeconomic literature to complement the findings from our theoretical model and arrive at a set of sign restrictions that are as uncontroversial as possible. For two reasons, we also only impose sign restrictions on the responses of variables on impact. First, using impact sign restrictions in a model with annual data is analogous to the existing literature which usually imposes sign restrictions for four quarters in a model with quarterly data. Second, the nonlinearity from the debt-to-GDP feedback severely complicates the identification strategy if sign restrictions are imposed at further horizons.

Rather than simultaneously identifying all the shocks, subject to the orthogonality restrictions, we identify the shocks sequentially via a penalty function following the method of Mountford and Uhlig (2009). Conceptually, for the first shock to be identified, the penalty function method finds the set of parameter restrictions which minimize the sum of

$$pf\left(x_j\right) = \begin{cases} -x_j & \text{if} \quad x_j > 0 \\ -100x_j & \text{if} \quad x_j \leq 0 \end{cases}, \tag{10}$$

across the sign restricted variables $j = 1, ..., J$, where $J \leq G$ and where x_j is the impact response of variable j (rescaled by the standard error of variable j). The function $pf\left(.\right)$ rewards large impulse responses with the right sign (we assume in equation (10) that we are looking for a positive response) more than small responses and punishes responses that go in the wrong direction. The second shock is then identified in the same way, with the additional restriction that it be orthogonal to the first shock. The rest of the shocks are identified similarly. The consequence of this sequential identification is that the penalty function ascribes as much movement as possible to the first shock, then the second shock and so on.

An overview of our identifying sign restrictions on the impulse responses is provided in Table 3. First, we identify an aggregate demand shock (row 1). The (+) symbols in the first row indicate that an aggregate demand shock is anything that generates, on impact, a positive comovement between the growth rate of GDP, the inflation rate and the short-term interest rate. The blank spaces in the first row indicates that we are agnostic about how, for example, the government primary expenditure-to-GDP ratio responds, on impact, to an aggregate demand shock. Since we associate aggregate demand shocks with the predominant cause of business

Table 3: 8-variable VAR sign restrictions

Variables: / Shocks:	Primary expenditure -to-GDP	Revenue -to-GDP	GDP growth rate	Inflation rate	Implicit interest rate	Short interest rate	Long interest rate
Aggregate demand	·	·	(+)	(+)	·	(+)	·
Cost-push	·	·	(−)	(+)	·	(+)	·
Monetary policy	·	·	(−)	(−)	·	(+)	·
Primary expenditure	(+)	·	(+)	·	·	·	·
Revenue	·	(+)	(−)	·	·	·	·
Cost of borrowing	·	·	·	·	(+)	(+)	(+)

Note: (+) or (−) mean that the response of variable x to shock y on year of impact is restricted to be positive or negative, respectively. A blank space means no restriction has been imposed.

cycle fluctuations, we identify this shock first.

Second and third, we identify a cost-push shock and a monetary policy shock. The sign restrictions that we impose are uncontroversial — they are the predictions of the canonical new-Keynesian model. Fourth and fifth, we identify two fiscal policy shocks, a primary expenditure shock and a revenue shock. Both are identified by restricting the sign of the GDP growth rate response: A government expenditure shock is assumed to boost output (i.e. the government spending multiplier is greater than 0) while the revenue shock depresses output. Again, without placing any prior restrictions on the responses of endogenous variables to a cost of borrowing shock, we force ourselves to identify five common macroeconomic shocks in order to recover a cost of borrowing shock that is truly orthogonal to other fluctuations in the macroeconomy. A cost of borrowing shock, in our scheme, is one in which the 10 year government bond yield, short term interest rate and implicit interest rate all rise on impact, yet is orthogonal to the response that the other five macroeconomic shocks generate.

A natural concern may arise regarding the ordering in which shocks are identified. How does the choice of ordering allow us to distinguish between shocks that are assumed to have the same effect on the same variables, such as the aggregate demand and primary expenditure shocks?[25] The nature of the penalty function means that the shocks identified earlier are likely to account for a larger share of total fluctuations. It seems reasonable therefore to order the business cycle shocks ahead of the fiscal policy shocks. More importantly, however, while switching the order is important for the identification of these two shocks, we find that the ordering of the first five shocks has almost no effect on the identification and impulse responses of the shock of interest,

[25] We are grateful to an anonymous referee for alerting us to this issue.

namely the cost of borrowing shock.

4 Results

4.1 Baseline results

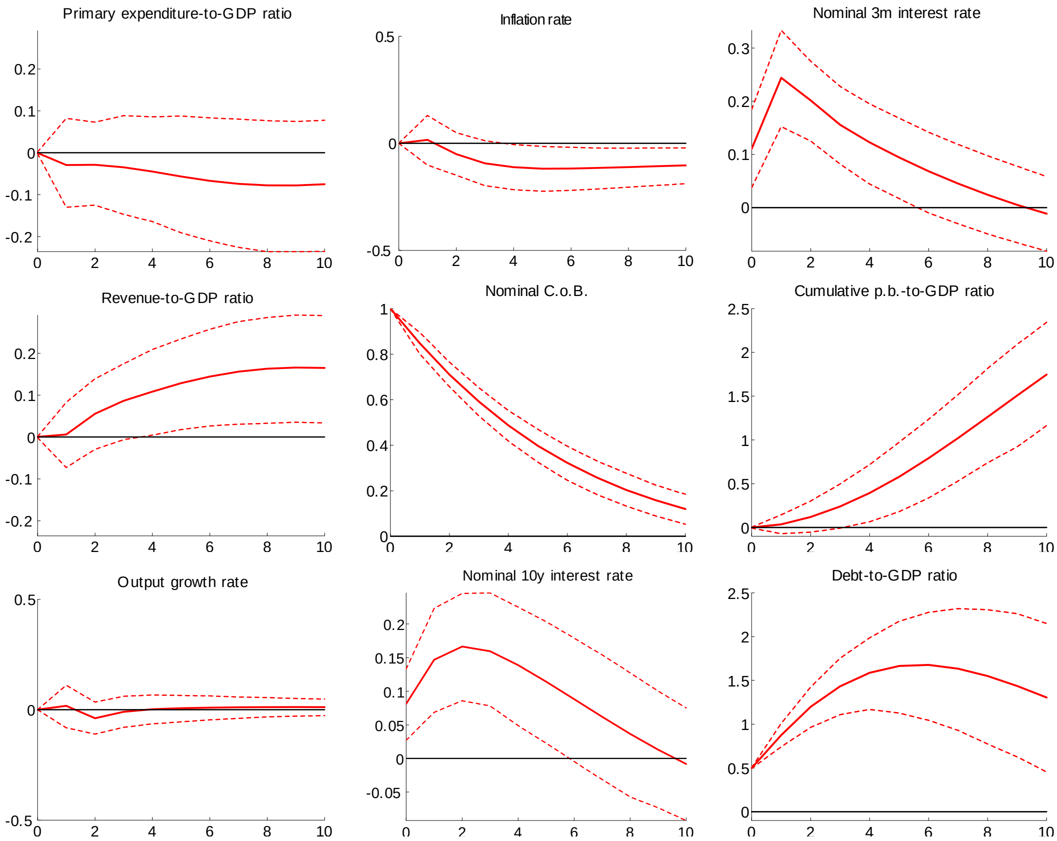
Figure 3 displays the impulse responses to a temporary cost of borrowing shock over a 10-year horizon. The responses have been normalized so that the implicit interest rate (denoted *nominal C.o.B.*) always rises by 1 percentage point. The initial level of the debt-to-GDP ratio will impact the impulse responses. In Figure 3, we initialize the debt-to-GDP ratio to 50% which is close to the sample mean. In Figure 6 below, we report sensitivity results to this choice of initial value. All the fiscal variables are measured in percentage points of GDP, while the interest rate and growth variables are measured in percent.

The impulse responses reveal four key results. First, the cost of borrowing shock generates a relatively persistent effect on the nominal implicit interest rate, which takes 4 years to halve. Second, it is revenues rather than primary expenditures that react to the cost of borrowing shock, with the revenue-to-GDP ratio 0.2 percentage points higher at the end of the 10 year horizon and the response of the primary expenditure-to-GDP remaining insignificant throughout the 10 year horizon. Third, the fiscal policy adjustment is not immediate. The primary balance is unchanged on impact but still does not turn significantly positive until the second year following the shock. Fiscal adjustment between years 3 and 5 is fairly rapid before reaching peak adjustment in year 7. The cumulative change in the primary balance-to-GDP ratio reaches 0.04, 0.40 and 1.75 percentage points in years 2, 5 and 10 following the shock. Fourth, the fiscal adjustment is insufficient to counteract the debt-increasing effect from the cost-of-borrowing shock over this time horizon. The debt-to-GDP ratio rises by 1.7 percentage points in year 6 and falls slightly to 1.3 percentage points above baseline in year 10.

The inflation and growth adjusted cost of borrowing response follows closely that of the nominal cost of borrowing response. This is because the responses of output growth and inflation are both either economically or statically insignificant. It also suggests, as we might expect, that the cost of borrowing shock is not an important driver of the business cycle. In other words, the model attributes only a small proportion of the variance of inflation and output growth to the cost of borrowing shock.

It is useful in what follows to work with a more parsimonious version of the VAR, where we

Figure 3: Responses to 1 p.p.t. increase in cost of borrowing



Note: The cost of borrowing shock is ordered sixth and orthogonal to the business cycle, monetary and fiscal policy shocks. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. Responses have been normalized to a 1 percentage point rise in the implicit interest rate (nominal C.o.B.). The debt-to-GDP ratio is initially 50%.

only include the endogenous variables that enter the debt accumulation equation. In principle, as explained in Appendix A.2, the two market rates that we have available — the 3 month rate and 10 year bond yield — are important to extract variations in the nominal cost of borrowing measure that are not a sum of moving average terms. However, in practice, the inclusion of these market interest rates does not greatly alter inference about the fiscal adjustment in response to a cost of borrowing shock.

Figure 4 compares the identified impulse response to a cost of borrowing shock in the more parsimonious 5-variable VAR relative to the initial 7-variable VAR we estimated. The key difference in terms of identification is that we do not identify a monetary policy shock.

In terms of the quantitative differences in responses, the 5-variable VAR produces a marginally stronger primary balance response to a 1 percentage point rise in the government's cost of borrowing. As a consequence the median debt to GDP ratio only peaks at 1.3 percentage points above baseline relative to 1.7 percentage points before.

Since the responses are very similar, we work with the more parsimonious 5 variable set up for the rest of the paper. In particular, this is convenient when we conduct sub-sample analysis in Section 4.4.

4.2 Identified cost of borrowing shocks

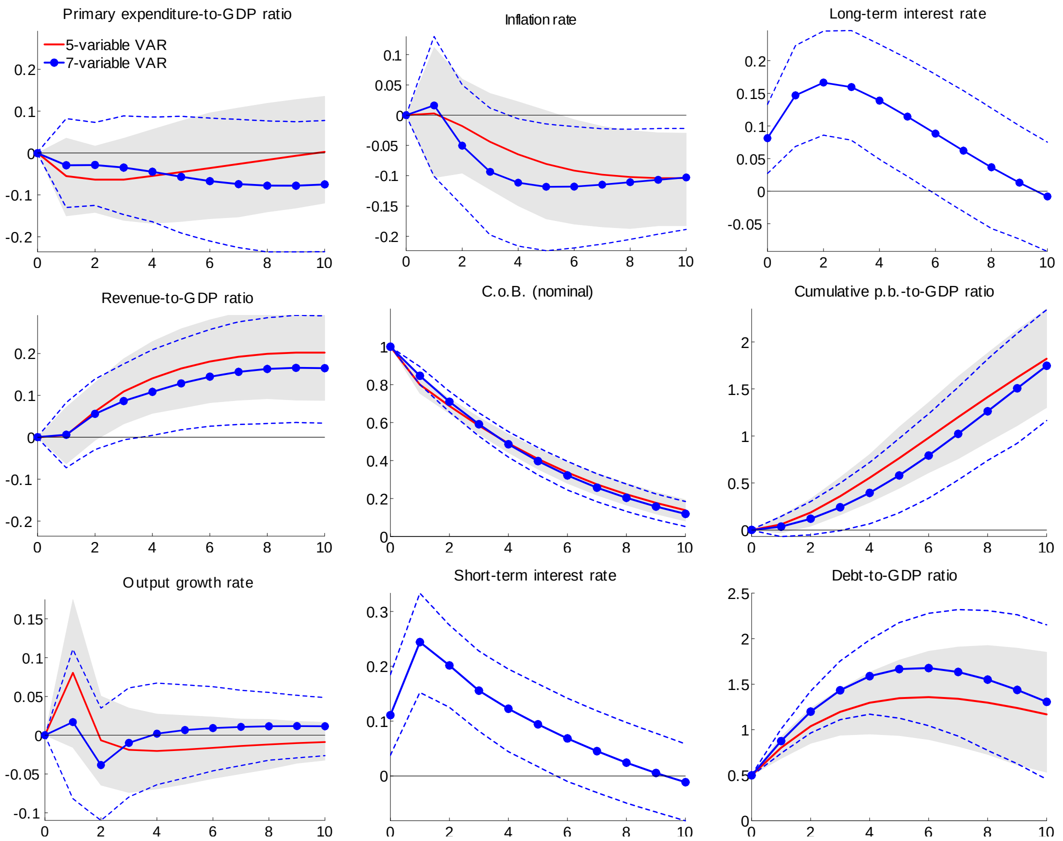
Figure 5 presents the identified cost of borrowing shocks, which are, by construction, orthogonal to the preceding macro and policy shocks we identify.[26] It suggests that the variance of cost-of-borrowing shocks was significantly higher in the 1980s and early 1990s than the late 1990s and early 2000s, across Europe.[27]

It is useful to graphically inspect if the identified shocks actually coincide or precede periods that have been identified as entailing strong fiscal efforts by certain governments. To this end, the shaded areas in Figure 5 denote periods of fiscal consolidation as identified by the narrative approach developed in Devries et al. (2011). The two measures appear to be weakly correlated.

[26] We have relegated the identified macro and policy shocks, as well as their corresponding impulse responses to Appendix B.3. Replication files for all the figures in this section, written in RATS code, are available from the corresponding author's homepage, http://sites.google.com/site/oliverdegroot/research

[27] In fact, the time series of identified cost-of-borrowing shocks in Figure 5 might not appear as one might expect, as we identify no large positive shocks for the countries struggling with the current sovereign debt crisis. In part, this relates to our discussion (in Section 3) of the marginal versus average cost of borrowing concepts. While the marginal cost of borrowing (proxied by 10 year government bond yields) for Greece, Ireland and Portugal etc. has increased sharply in recent years, their average cost of borrowing, which we use in this estimation, has moved by much less. The second explanation is that a considerable portion of the rise in governments' cost of borrowing in recent years may have been driven by changes in governments' primary deficits and debt, and have not been the consequence of unanticipated cost of borrowing shocks.

Figure 4: Responses to a 1 p.p.t. cost of borrowing shock
5 variable VAR



Note: The cost of borrowing shock is ordered fifth and orthogonal to the business cycle and fiscal policy shocks. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. Responses have been normalized to a 1 percentage point rise in the implicit interest rate (nominal C.o.B.). The debt-to-GDP ratio is initially 50%.

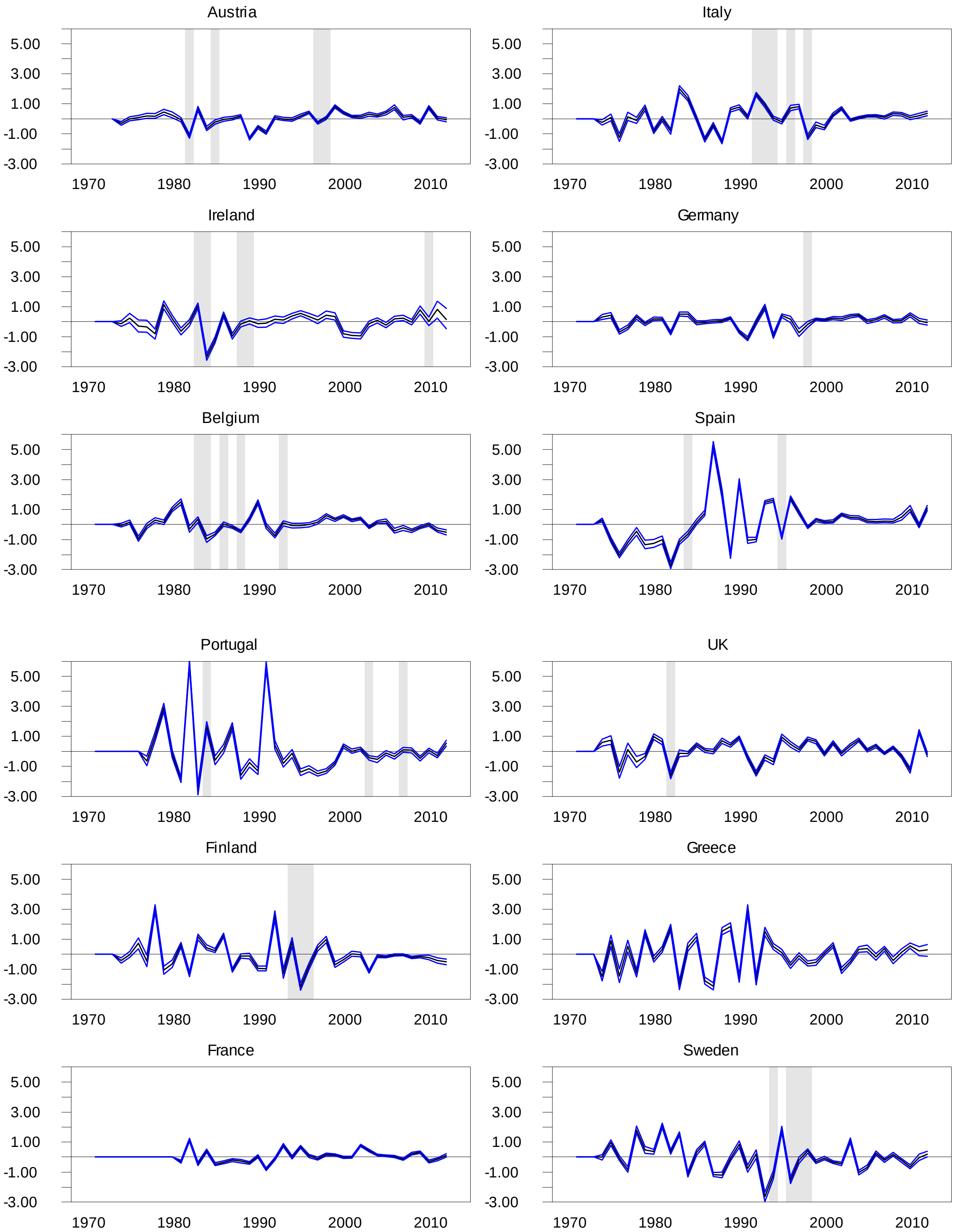
Positive cost-of-borrowing shocks preceded the fiscal adjustment in Italy in the mid-1990s, Portugal in 1981, Finland in 1992 and Sweden in the end-1990s. The most striking omission is the apparent lack of fiscal adjustment following the cost of borrowing shocks in Portugal in 1990 and Spain in 1986. However, using an alternative measure of fiscal consolidations, Alesina and Perotti (1995) [Table 5. pp.218] record strong fiscal adjustments for Portugal in 1989 and Spain in 1986-87.

4.3 Initial conditions and debt feedback

The addition of the governments' budget constraint, in the form of the lagged debt-to-GDP ratio, generates a feedback mechanism in the vector autoregression model and potentially strong nonlinearities in the responses to shocks. In particular, as shown in Section 2, we expect the fiscal adjustment to a cost of borrowing shock to be sensitive to the level of the debt-to-GDP ratio at the time of the shock. Figure 6 illustrates this non-linearity by plotting the median impulse responses of the primary expenditure-, revenue-, primary balance- and debt-to-GDP ratios to a cost of borrowing shock with two different initial debt-to-GDP ratios, 20% and 140% respectively (and the baseline impulse responses plot in the background). This experiment considers how the response of the same "representative" country to a cost of borrowing shock differs if its current debt-to-GDP ratio is either high or low (relative to a given historical average). Not until Figure 8 do we distinguish between the fiscal responses of countries with historically high and historically low average debt-to-GDP ratios.

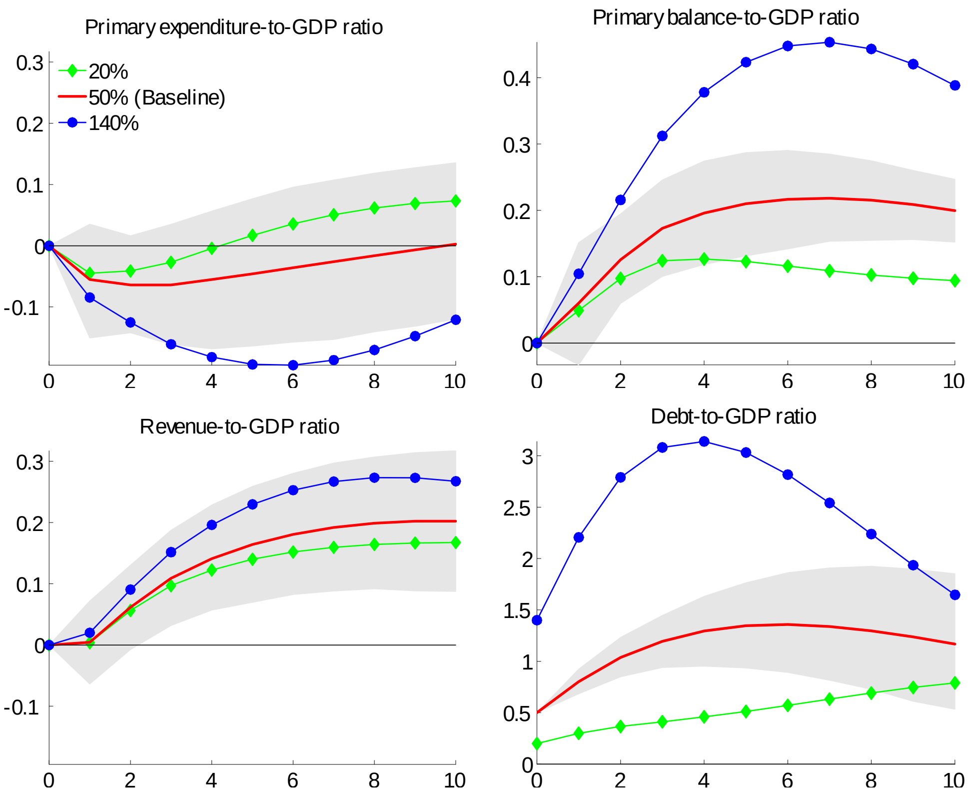
This scenario analysis shows two interesting patterns in the mechanics of fiscal adjustment, depending on initial conditions. First, when a country's debt-to-GDP ratio is high at the onset of a cost of borrowing shock, it makes substantially larger primary balance adjustments. The cumulative primary balance adjustment over 10 years is 3.6% of GDP when the initial debt-to-GDP ratio is 140%, relative to an adjustment of 1.9% when the initial debt-to-GDP ratio is 50%. Moreover, the median debt-to-GDP response peaks earlier in the 140% initial debt-to-GDP ratio scenario than in the 50% initial debt-to-GDP ratio scenario. However, the peak change in the debt-to-GDP ratio is larger when the initial debt-to-GDP ratio is higher. Second, with a high initial debt-to-GDP ratio the fiscal adjustment comes both via primary expenditure cuts and revenue increases. Using the median responses, for the 50% initial debt-to-GDP scenario, 12% of the fiscal adjustment is via cuts in primary expenditure. For the 140% initial debt-to-GDP ratio scenario, primary expenditure cuts account for 43% of the fiscal adjustment.

Figure 5: Identified Cost of Borrowing Shocks



Note: The y-axis measures the identified cost of borrowing shock with a unit standard deviation, the x-axis measures time in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. The shaded areas are periods of fiscal consolidation identified by the narrative approach in Devries et al. (2011).

Figure 6: Sensitivity to initial Debt-to-GDP ratio



Note: Impulse responses to a cost of borrowing shock which raises the implicit interest rate by 1 percentage point. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles.

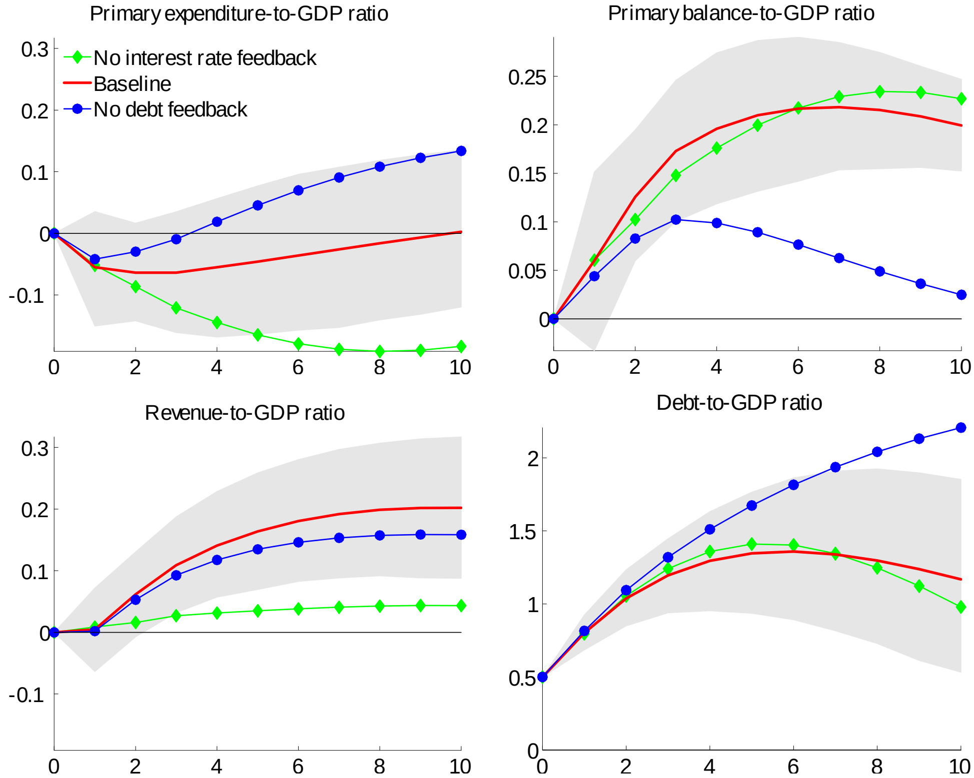
The estimates presented till now all refer to the *combined* impact of the cost of borrowing shock on budgetary variables, comprising a direct effect (as a rise in interest rates might induce governments to adjust their budgets) and indirect effects (as the interest rate shocks also transmit via other variables in the system – notably the government debt ratio). At the same time, a large body of literature, at least since Bohn (1998), has described the behavior of fiscal policy in terms of fiscal reaction functions as a way to estimate the "partial" primary balance response to changes in government debt (while controlling for other important macroeconomic variables). To disentangle the direct effect of a cost of borrowing increase from its indirect effect transmitted via the debt ratio, we consider two experiments, which are presented in Figure 7. The first is to re-estimate the model, excluding the debt-to-GDP ratio as a lagged explanatory variable (thus isolating the direct cost of borrowing effect). The second is to restrict the coefficients on the cost of borrowing for the primary expenditure and revenue variables to zero (thus isolating the indirect effect coming through the debt ratio). The impulse responses are presented in Figure 7.

They reveal two interesting results. First, the response of the primary balance to a cost of borrowing shock is still significantly positive, even in the absence of debt feedback. This suggests that budgetary policies do not only respond to the current debt-to-GDP ratio, but also financial markets' expectations of future debt dynamics, as proxied by the cost of borrowing. However, the budgetary response is insufficient to counteract the increase in the debt ratio, at least in the medium term. Second, in the absence of interest rate feedback, the adjustment of the primary balance is more sluggish than in the baseline case but then overshoots it. This pattern may reflect that fiscal policy-makers, by construction, ignore the contemporaneous cost of borrowing effect in this scenario and only respond to it once it materializes via rising debt ratios; vice versa, once they detect the cost of borrowing shock through the debt increase, they need a stronger adjustment to reverse the upward drift in this stock variable over time.

4.4 Heterogeneity across sub-samples

Thus far, we have considered the 14 countries as a homogenous block, restricting the responses to a cost of borrowing shock to be the same across the sample. While we lack sufficient degrees of freedom to estimate the model for each individual country, we can attempt to explain potential heterogeneity by sub-dividing our sample along several dimensions. Indeed, the model presented in Section 2 has identified several important factors that may shape the response to

Figure 7: No debt and no interest rate feedback



Note: Impulse responses to a cost of borrowing shock. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles.

cost of borrowing shocks, including the presence of fiscal rules and the costs associated with fiscal adjustments – for instance, related to the process of political consensus building. The key results are reported in Figure 8. The countries which comprise each sub-group are reported in Table 4. It is important to emphasize that these results are based on somewhat ad hoc sorting of countries into sub-samples, which may reduce their robustness. However, we think they are interesting to warrant future research.

The first row of Figure 8 reports responses to a cost-of-borrowing shock for the 11 EMU countries, pre- and post-1992. We are interested in whether the signing of the Maastricht Treaty (in 1992) — which binds countries to adhere to the Maastricht criteria, restricting government deficits and debts — affected the fiscal response to cost of borrowing shocks. In the pre-Maastricht period, there is a relatively small positive primary balance response to a cost-of-borrowing shock. By contrast, in the post-Maastricht period, the response of the primary balance is significantly larger. In fact, the rise in the primary balance is sufficiently strong to generate a fall of the debt-to-GDP ratio to 46.5%, below its initial value of 50%, at the end of the 10 year horizon.

The second row of Figure 8 sub-divides the 14 countries based on a measure of political

Table 4: Country Groupings

		A. Maastricht Treaty	B. Political constraints[c]		C. Government indebtedness[d]	
1	Austria	Yes	Most	0.78	Most	51%
2	Belgium	Yes	Most	0.87	Most	98%
3	Germany	Yes	Most	0.83	Least	45%
4	France	Yes	Most	0.79	Least	39%
5	Finland	Yes	Most	0.78	Least	28%
6	Greece	Yes[a]	Least	0.36	Least	46%
7	Ireland	Yes	Least	0.75	Most	68%
8	Italy	Yes	Least	0.76	Most	67%
9	Netherlands	Yes	Most	0.83	Most	89%
10	Portugal	Yes	Least	0.62	Most	60%
11	Spain	Yes	Least	0.77	Least	50%
12	Denmark	No[b]	Most	0.78	Least	48%
13	UK	No	Least	0.74	Most	51%
14	Sweden	No	Least	0.76	Least	49%

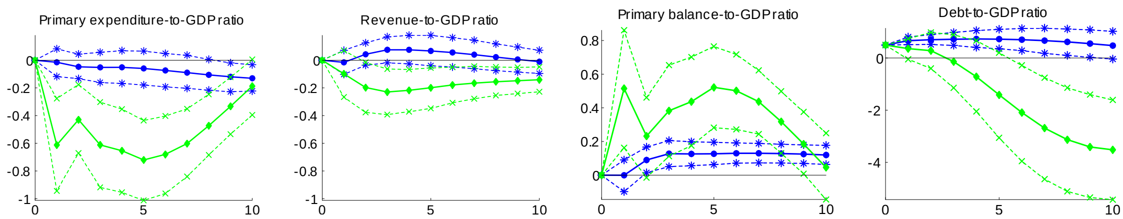
Note: [a] Greece adopted the Euro in 2001. [b] Denmark opted out of the Maastricht Treaty but remains in ERM II. [c] Average value of the POLCON index, Henisz (2000), for the period 1970-94. [d] Average government debt-to-GDP ratio for the period 1970-2011.

risk - the Political Constraint Index (POLCON) - developed by Henisz (2000). It attempts to measure "the ability of a government to craft a credible commitment to an existing policy regime" and prevent the "potential for arbitrary or capricious" policymaking, with a low score being more hazardous and a high score being more constrained. We take an average of the POLCON measure over the period 1970-1994 and split the sample of countries into a high and low grouping, using the median value in the sample as the threshold. The responses are robust to a 8-6 or 6-8 split of countries. The responses in Figure 8 for the two groups are supportive of the view that politically more constrained countries, which presumably face fewer obstacles in agreeing and implementing a certain policy path, demonstrate a more responsive fiscal stance. For example, the primary balance response of the *low* group is not significantly different from zero, while the response of the *high* group is significant and positive. Interestingly, the rise in the primary balance for the high group countries is the result of a fall in primary expenditure following a cost-of-borrowing shock.

Finally, the third row of Figure 8 sub-divides the 14 countries based on their historical indebtedness. Inference drawn from these impulse responses should be made with caution since there is a potential endogeneity problem, from the impulse responses, back to the groupings. The responses reveal that the primary balances of countries that on average have high debt do

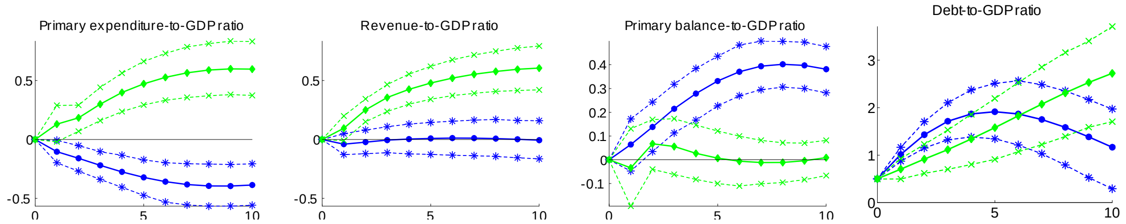
Figure 8: Heterogeneity across sub-samples

A. Maastricht Treaty



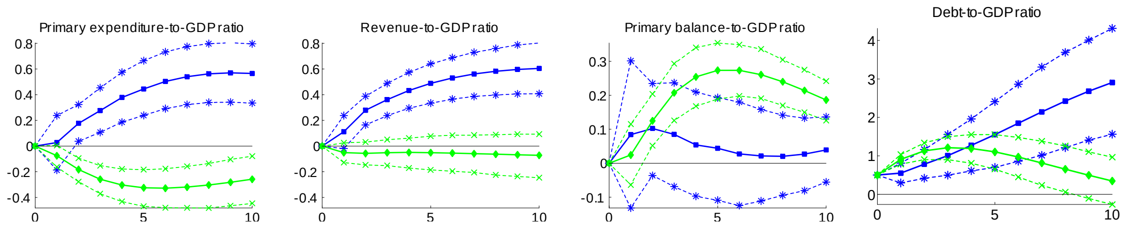
Legend: ♦ post-1992 period, ■ pre-1992 period

B. Political constraints



Legend: ♦ 7 least politically constrained countries, ■ 7 most politically constrained countries

C. Government indebtedness



Legend: ♦ 7 countries with least indebted governments, ■ 7 countries with most indebted governments

Note: Impulse responses to a cost of borrowing shock. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles.

not respond to cost of borrowing shocks, while those for countries which on average have less debt do respond positively. The median debt-to-GDP ratio of a highly indebted country rises by 2.7 percentage points, while the debt-to-GDP ratio of a less indebted country is insignificantly different from its initial level, at the 10 year horizon.

Note that this result is not in contradiction to the finding reported in Figure 6, which suggest that when a country experiences a cost of borrowing shock at a time when its debt-to-GDP ratio is high relative to what is normal for that country, the fiscal response to that cost of borrowing shock is also stronger relative to its normal response.

5 Conclusions

This paper examines the response of fiscal variables to exogenous changes in sovereign borrowing costs using a panel of European countries over four decades. To motivate the empirical analysis, we develop a simple model of fiscal behavior. This model shows that governments tend to react to increases in the cost of borrowing by improving their primary balances, but the scale and composition of the budgetary response depends on initial fiscal conditions and several structural features of the economy. In particular, the primary budget response is strong if the initial debt-to-GDP ratio is high, costs of adjusting fiscal instruments (e.g. related to administrative implementation and/or political consensus building) are low, and fiscal rules pose a binding constraint on budgetary decision-making. These parameters also determine the implications for sovereign debt dynamics subsequent to a cost of borrowing shock: for calibrations generating a relatively weak fiscal response, the improvement in the primary budget balance is insufficient to compensate for the debt-increasing effect of higher borrowing costs.

The empirical analysis confirms a positive response in the primary budget balance ratio to sovereign cost of borrowing shocks. At the sample average, however, this response is not sufficiently strong to return the debt-to-GDP ratio to baseline over a 10-year horizon. The adjustment is found to only become statistically significant two years after the shock and to be generated mainly via the revenue side. At the same time, there is some tentative evidence that the magnitude of adjustment in response to a cost of borrowing shock is larger when the debt-to-GDP ratio is high relative to a country's average. Also, the larger the adjustment, the more emphasis is placed on expenditure cuts relative to tax increases.

When subdividing our sample, we find that EMU countries in the period after the signing of the Maastricht Treaty show a significantly stronger budgetary response to cost-of-borrowing shocks than the same countries in the pre-Maastricht period. A possible interpretation of this pattern is that those countries that eventually joined monetary union had an additional incentive to compensate for higher interest payments (which count against the Maastricht deficit criterion) by tightening their stance with respect to other budget items.

Our results have important policy implications. The estimated average fiscal response suggests that market discipline can improve budgetary outcomes. Provided that financial market participants systematically and consistently sanction deteriorating fiscal positions through higher interest rates, they may deter governments from building up imbalances. At the same time, experience since the start of EMU shows that the relationship between the fiscal "health" of a country and its borrowing rates can be subject to abrupt shifts, which renders financial markets less reliable as an incentive mechanism for governments. Moreover, our estimates show that the budgetary response to market pressure tends to be delayed and alone is not sufficient to fully counteract its direct unfavourable effect on debt dynamics via rising interest payments. This in turn, suggests that further incentive mechanisms are needed to ensure that countries follow a fiscal reaction function aimed at restoring fiscal sustainability in a timely manner. Judging from our results, fiscal rules are an important complement to markets in this regard.

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A Appendix

A.1 The model: social planner first order conditions, the steady state and functional forms

The first-order conditions of the government's problem in equation (6) are:

$$c_t : 0 = \begin{bmatrix} u_{c,t} - \mu_{1,t}\left(\tau_{c,t}\xi_t^{\tau}\xi_t^{a}n_t + 1\right) + \mu_{2,t}\left(\xi_t^{\tau}\xi_t^{a}n_t - \phi_{1,t}^{\tau}\right)\tau_{c,t} - \mu_{3,t}u_{cc,t} \\ -\beta\mathbf{E}_t\mu_{2,t+1}\phi_{2,t+1}^{\tau}\tau_{c,t} + \mu_{3,t-1}u_{cc,t}r_{t-1}^{h} \end{bmatrix}, \tag{11}$$

$$n_t : 0 = \begin{bmatrix} u_{n,t} + \mu_{1,t}\left(-\tau_{n,t}\xi_t^{\tau}\xi_t^{a}n_t + \left(1 - \tau_t\xi_t^{\tau}\right)\xi_t^{a}\right) \\ +\mu_{2,t}\left(\left(\tau_{n,t}n_t + \tau_t\right)\xi_t^{\tau}\xi_t^{a} - \phi_{1,t}^{\tau}\tau_{n,t}\right) + \mu_{3,t}\mathbf{E}_t\left(\beta u_{c,t+1}r_{n,t}^{h} - u_{cn,t}\right) \\ -\beta\mathbf{E}_t\left(\mu_{1,t+1}r_{n,t}^{h}b_t^{h} + \mu_{2,t+1}\left(r_{n,t}^{g}b_t^{g} + \phi_{2,t+1}^{\tau}\tau_{n,t}\right)\right) \\ +\mu_{3,t-1}u_{cn,t}r_{t-1}^{h} \end{bmatrix}, \tag{12}$$

$$g_t : 0 = v_{g,t}\xi_t^{g} - \mu_{2,t}\left(\xi_t^{g} + \phi_{1,t}^{g}\right) - \beta\mathbf{E}_t\phi_{2,t+1}^{g}, \tag{13}$$

$$b_t^{g} : 0 = \mu_{2,t}\left(1 - \phi_{1,t}^{b}\right) - \beta\mathbf{E}_t\mu_{2,t+1}\left(r_{b^g,t}^{g}b_t^{g} + r_t^{g} + \phi_{2,t+1}^{b}\right), \tag{14}$$

$$b_t^{h} : 0 = \mu_{1,t} + \mu_{3,t}\beta\mathbf{E}_t u_{c,t+1}r_{b^h,t}^{h} - \beta\mathbf{E}_t\mu_{1,t+1}\left(r_{b^h,t}^{h}b_t^{h} + r_t^{h}\right). \tag{15}$$

When we assume that the government does not fully internalize it's choices on the interest rate (see the discussion related to Figure 2), we scale $r_{b^g,t}^{g}$ and $r_{n,t}^{g}$ by a factor of $\frac{1}{2}$.

The steady state conditions of the model are:

$$c : 0 = u_c - \mu_1\left(\tau_c n + 1\right) + \mu_2 n\tau_c - \mu_3 u_{cc} - \beta\mu_2\phi_2^{\tau}\tau_c + \mu_3 u_{cc}r_t^{h}, \tag{16}$$

$$n : 0 = \begin{bmatrix} u_n + \mu_1\left(-\tau_n n + (1-\tau)\right) + \mu_2\left(\tau_n n + \tau\right) \\ +\mu_3\left(\beta u_c r_n^{h} - u_{cn}\right) - \beta\left(\mu_1 r_n^{h}b^{h} + \mu_2 r_n^{g}b^{g}\right) + \mu_3 u_{cn}r^{h} \end{bmatrix}, \tag{17}$$

$$g : 0 = v_g - \mu_2, \tag{18}$$

$$b^{g} : 0 = 1 - \beta\left(r_{b^g}^{g}b^{g} + r^{g}\right), \tag{19}$$

$$b^{h} : 0 = \mu_1 + \mu_3\beta u_c r_{b^h}^{h} - \beta\mu_1\left(r_{b^h}^{h}b^{h} + r^{h}\right), \tag{20}$$

$$0 = \left(1 - r^{h}\right)b^{h} + (1-\tau)n - c, \tag{21}$$

$$0 = \left(1 - r^{g}\right)b^{g} + \tau n - g. \tag{22}$$

From the household Euler equation, $r^h = \beta^{-1}$ and b^h is a free parameter. This is not true of b^g. Equation (19) can be rearranged as

$$\frac{b^g}{n} = \frac{\alpha^g}{\phi^g}.$$

This says that the more debt-elastic the interest rate (i.e. the higher ϕ^g), the larger the steady state interest discount, α^g, must be in order to induce the government to maintain a certain steady state debt-to-GDP ratio.

Finally, the functional form for the utility function and the two interest rate equations are as follows:

$$u_t \equiv u\left(c_t, n_t\right) + v\left(g_t \xi_t^g\right) = \frac{\left(c_t - \vartheta n_t^\theta\right)^{1-\sigma} - 1}{1-\sigma} + \chi \log\left(g_t \xi_t^g\right) \tag{23}$$

$$r_t^g \equiv \left[1/\beta + \phi^g \left(e^{\left(\frac{b_t^g}{\xi_t^a n_t} - \frac{b^g}{n}\right)} - 1\right) - \alpha^g\right] \xi_t^r \tag{24}$$

$$r_t^h \equiv 1/\beta + \phi^h \left(e^{\left(\frac{b_t^h}{\xi_t^a n_t} - \frac{b^h}{n}\right)} - 1\right) \tag{25}$$

A.2 Marginal and average cost of borrowing

The model presented in Section 2 does not distinguish between the average and marginal cost of borrowing (the implicit government interest rate and the current market bond yield, to use the language of Section 3) because all debt has one-period maturity. To see the relationship between the average and marginal cost of borrowing, consider the following simple model.

We approximate the maturity structure of government debt using a continuum of callable perpetuity bonds with stochastic call date. With probability p a bond is called (matures) and with probability $1-p$ it survives until the next period. The stock of debt, b_t^g, evolves as

$$b_t^g = (1-p)\, b_{t-1}^g + b_{n,t}^g,$$

where $b_{n,t}^g$ is newly issued debt. The average cost of borrowing, $i_{a,t}^g$, evolves as

$$i_{a,t}^g = (1-p)\, i_{a,t-1}^g \frac{b_{t-1}^g}{b_t^g} + i_t^g \exp\left(\varepsilon_t^{cob}\right) \frac{b_{n,t}^g}{b_t^g}, \tag{26}$$

where i_t^g is the marginal cost of borrowing (i.e. the interest rate of new debt). i_t^g is the net interest rate (Section 2 used gross interest rate notation, $r_t^g \equiv 1 + i_t^g$). Think of i_t^g as the market rate that the government observes when making fiscal policy decisions. After setting its fiscal policy instruments, the debt management office is responsible for issuing debt as and when financing needs arise during the year. As a result, the true cost of borrowing on new debt is not i_t^g but $i_t^g \exp\left(\varepsilon_t^{cob}\right)$.[28]

The average maturity of the government's debt portfolio is p^{-1}. The government's flow budget constraint becomes

$$g_t = b_{n,t}^g - \left(p + i_{a,t-1}^g\right) b_{t-1}^g + \tau_t n_t.$$

When $p = 1$, then $b_t^g = b_{n,t}^g, i_{a,t}^g = i_t^g \exp\left(\varepsilon_t^{cob}\right)$, and $g_t = b_{n,t}^g - \left(1 + i_{t-1}^g \exp\left(\varepsilon_{t-1}^{cob}\right)\right) b_{t-1}^g + \tau_t n_t$ returns the model back to the flow budget constraint in equation (5) (ignoring quadratic adjustment cost terms and other fiscal policy shocks). Suppose we log-linearize the model around the steady state. At the steady state, $b^g = \frac{b_n^g}{p}$ and $i_a^g = i^g$. Therefore:

$$\widetilde{i}_{a,t}^g = (1-p)\,\widetilde{i}_{a,t-1}^g + p\widetilde{i}_t^g + p\varepsilon_t^{cob}.$$

Notice that the evolution of the average cost of borrowing is independent of the amount of new debt that is issued. Suppose next that $\widetilde{i}_t^g$ follows the following process

$$\widetilde{i}_t^g = \phi\widetilde{i}_{t-1}^g + \sigma\varepsilon_t^{ig}.$$

If we simply estimate a VAR with $\widetilde{i}_{a,t}^g$ and not $\widetilde{i}_t^g$, then we will recover the following process:

$$\widetilde{i}_{a,t}^g = (1-p)\,\widetilde{i}_{a,t-1}^g + \underbrace{p\sigma\varepsilon_t^{ig} + p\sigma\phi\varepsilon_{t-1}^{ig} + p\sigma\phi^2\varepsilon_{t-2}^{ig} + \cdots + p\varepsilon_t^{cob}}_{\text{Estimated cob shock}},$$

where the estimated shock is a function of an MA process in ε_t^{ig} and the shock ε_t^{cob}. Thus, we

[28] To place this model within an institutional context, consider the UK. The UK government is responsible for making tax and spending decisions for the coming year, given current macroeconomic, fiscal, and financial market conditions. Then there is the UK Debt Management Office (DMO), who's remit is to "carry out the Government's debt management policy of minimizing financing costs over the long term, taking account of risk, and to minimize the cost of offsetting the Government's net cash flows over time" (see About the DMO at http://www.dmo.gov.uk). Since the cost of debt management is much more complex than simply observing the current 10 year market yield on UK Gilts, the ex post calculation of total interest payments can alter the fiscal conditions in which the UK government makes its next set of tax and spending decision.

would like to estimate a VAR including both $\widetilde{i}_t^g$ and $\widetilde{i}_{a,t}^g$ as follows:

$$\begin{bmatrix} 1 & -p \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \widetilde{i}_{a,t}^g \\ \widetilde{i}_t^g \end{bmatrix} = \begin{bmatrix} (1-p) & 0 \\ 0 & \phi \end{bmatrix} + \begin{bmatrix} \varepsilon_t^{cob} \\ \sigma \varepsilon_t^{ig} \end{bmatrix}.$$

The key identifying information we get from this is that there is a zero restriction on the contemporaneous response of the marginal cost of borrowing to the cost of borrowing shock, ε_t^{cob}.

A.3 Data sources

All the data we use is publicly available. The majority of the data is taken from AMECO, which is the annual macro-economic database of the European Commission's Directorate General for Economic and Financial Affairs (DG ECFIN). Some of the interest rate series have been supplemented using data from the *International Financial Statistics* (IFS) database of the IMF. All variables used in the PVAR were year and country demeaned to account for country specific and time specific fixed effects (and the degrees of freedom in the estimated model appropriately adjusted). All AMECO codes are provided in brackets.

- *GDP growth rate* is the growth rate of Gross Domestic Product at constant prices (OVGD).
- *Inflation rate* is the growth rate of the GDP Deflator (PVGD).
- *Nominal short-term interest rate* (ISN). This is usually a 3 month interbank rate. See the AMECO website for further details of the country specific interest rates used for this measure. For several countries, data from the IFS IMF Country Tables, row 60c (Treasury Bill Rate) has been used to supplement series for missing values in AMECO.
- *Implicit interest rate* (AYIGD), which is calculated as the ratio of total interest payments in year t to the debt stock in period $t-1$.
- *Nominal long-term interest rate* (ILN). This is usually a 10 year government bond yield. See the AMECO website for further details of the country specific interest rates used for this measure. For several countries, data from the IFS IMF Country Tables, row 61 (Government Bond Yield) has been used to supplement series for missing values in AMECO.

- *Debt* is General Government Consolidated Gross Debt (UDGG) as a ratio of GDP.
- *Revenue* is the sum of Revenue from Indirect Taxes (UTVG), Revenue from Direct Taxes (UTYG) and Social Contributions Received (UTSG) as a ratio of GDP.
- *Primary expenditure* is the sum of Expenditure on Benefits (UYTGH), Expenditure on Wages (UWCG) and Expenditure on Other (which is Total Current Expenditure excluding Interest (UUCGI) minus Expenditure on Benefits and Wages) as a ratio of GDP.

B Online appendix (not for publication)

B.1 Data description

Figure 9 plots the individual time series from 1970 to 2011 of fiscal variables and interest rate series of all 14 European countries in our sample. The top two panels give the impression of an upward drift in both primary expenditure and tax ratios for many of the countries in our sample. However, the primary balance-to-GDP ratio, in the middle-left panel, at a glance appears stationary.[29] The noticeable outlier in this panel is the Irish bailout of the banking system in 2010, which accounted for almost 20% of GDP. The debt-to-GDP ratio, in the middle-right panel, follows a similar pattern for many of the countries in our sample, with low levels of debt in the 1970s, rising sharply in the 1980s before falling back in the late 1990s and early 2000s. The crisis on 2008 has caused the debt-to-GDP ratios of several countries to rise sharply again, with several countries displaying a debt-to-GDP ratio of more than 100%. The bottom two panels plot the nominal implicit interest rate (defined as the ratio of interest payments to outstanding debt) and the nominal long-term interest rate (in most cases the 10 year government bond yield), respectively. The majority of the low frequency movement in these series is the result of the inflation, which was, broadly speaking, high during the 1970s and early 1980s and has fallen steadily since. A noticeable difference between the two series is the spike in bond yields in the period 2009-2011 which is absent from the implicit interest rate measure. This is because, despite bond yields rising in financial markets, few of these governments actually borrowed in financial markets at these elevated interest rates.

Table 5 and 6 report several key statistics from the time series that were plotted in Figure 9. In particular, Table 6 highlights some of the heterogeneity, both across time and across

[29] Formal tests of stationarity are conducted below.

Figure 9: Time series of fiscal variables

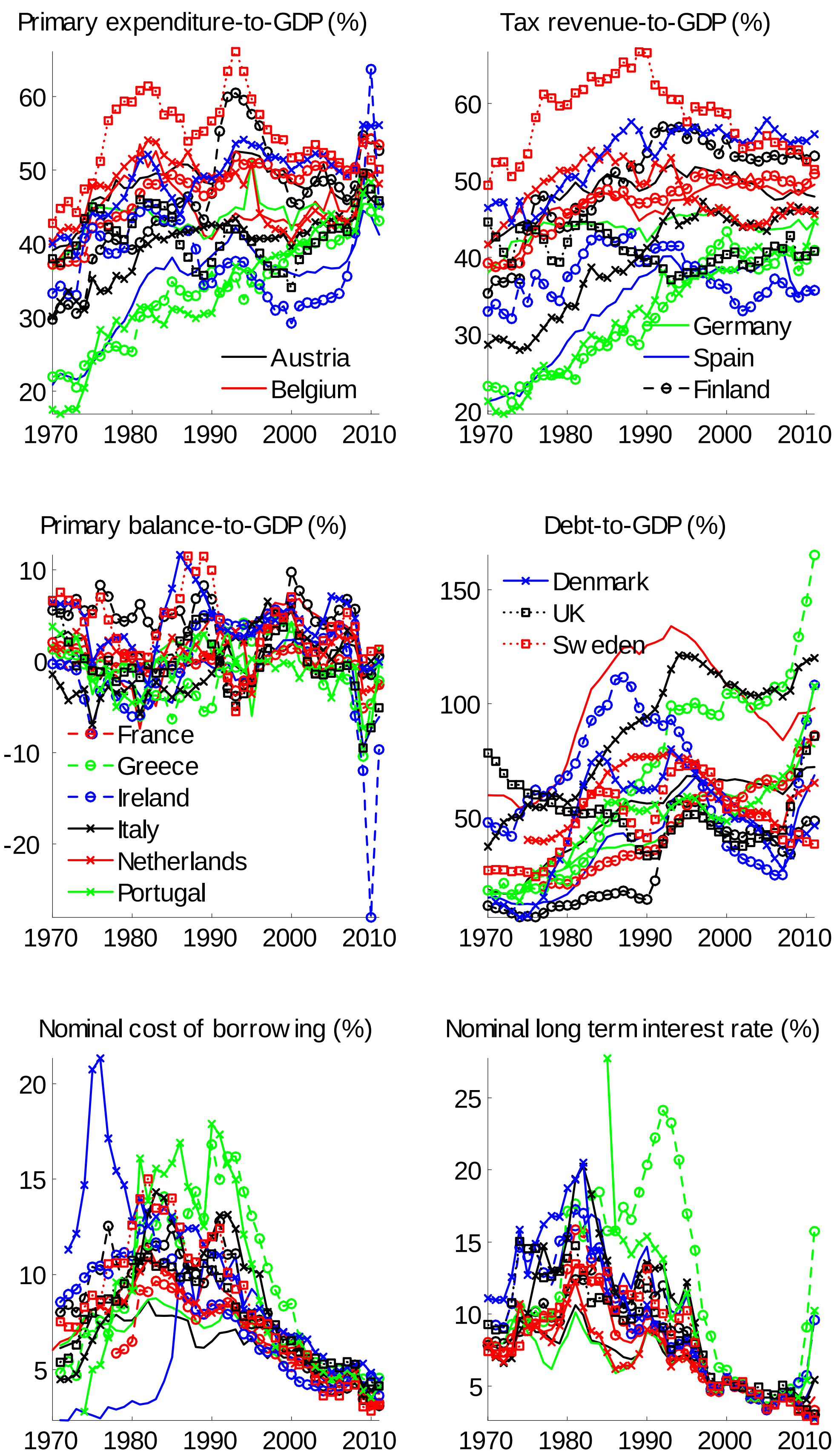


Table 5: Fiscal variables: Stylized facts I

Variable	Mean	St. dev.	Min	Max
Primary expenditure-to-GDP	42.9%	8.13%	16.9%	66.0%
			(PRT,71)	(SWE,93)
Revenue-to-GDP	43.7%	9.00%	19.6%	66.7%
			(PRT,72)	(SWE,89)
Primary balance-to-GDP	0.8%	3.69%	-28.0%	11.6%
			(IRL,10)	(DNK,86)
Debt-to-GDP	56.6%	28.6%	6.20%	165.3%
			(DNK,74)	(GRC,11)
Implied nominal interest rate	7.80%	3.25%	2.35%	21.33%
			(SPA,72)	(DNK,76)
Longer term bond yield	8.43%	4.07%	2.61%	27.74%
			(GER,11)	(PRT,85)

Note: Statistics for the entire panel. The brackets denote the country and year.

countries. The debt-to-GDP shows a large volatility, with a standard deviation ranging from 12.8% in the UK to 41.0% in Greece.

Table 7 presents several unit root tests. The two panel based unit root tests come to the same verdict that the primary balance-to-GDP ratio series are stationary while the debt-to-GDP ratio series display a unit root. The country specific tests suggest some heterogeneity with some displaying stationary dynamics while others display nonstationary dynamics. However, a smaller share of the countries display stationarity in their debt-to-GDP ratios than in their primary balance-to-GDP ratios.

B.2 Impulse responses from the theoretical model

In addition to the cost of borrowing shock, the model in Section 2 contains additional exogenous stochastic processes (for technology, government spending and income taxes). Figure 10 presents typical impulse responses behaviour of the model to these disturbances.

B.3 Identified shocks

This appendix contains the identified shocks and impulse responses of the 4 shocks of the 5 variable PVAR that we identify *before* the cost of borrowing shock. Due to space constraints, we plot the identified shocks only for a sub-set of the countries in our sample. Further details are available from the authors on request. The error bands around the identified shocks and impulse responses are generated by Monte Carlo integration, and we plot the 16th, 50th and

Table 6: Fiscal variables: Stylized facts II

Variable	Mean by country		Mean by year		St. dev. by country		St. dev. by year	
	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
Primary expenditure-to-GDP	33.5%	54.4%	33.1%	50.2%	2.54%	8.20%	3.50%	9.40%
	(PRT)	(SWE)	(70)	(10)	(GER)	(PRT)	(08)	(79)
Revenue-to-GDP	32.4%	58.2%	35.8%	46.8%	1.74%	7.34%	5.70%	10.75%
	(GRC)	(SWE)	(70)	(93)	(GER)	(PRT)	(07)	(78)
Primary balance-to-GDP	-1.21%	4.11%	-4.82%	4.74%	1.46%	6.27%	1.95%	7.24%
	(GRC)	(DNK)	(10)	(00)	(AUS)	(IRL)	(99)	(10)
Debt-to-GDP	28.5%	97.2%	27.8%	85.1%	12.8%	41.0%	18.0%	33.7%
	(FIN)	(BEL)	(73)	(11)	(UK)	(GRC)	(78)	(11)
Implied nominal interest rate	5.59%	10.24%	3.76%	11.00%	1.30%	4.85%	0.38%	4.38%
	(SPA)	(DNK)	(11)	(82)	(AUS)	(PRT)	(07)	(75)
Longer term bond yield	6.44%	11.63%	3.49%	14.79%	2.05%	5.96%	0.12%	5.06%
	(GER)	(GRC)	(05)	(81)	(AUS)	(GRC)	(01)	(85)

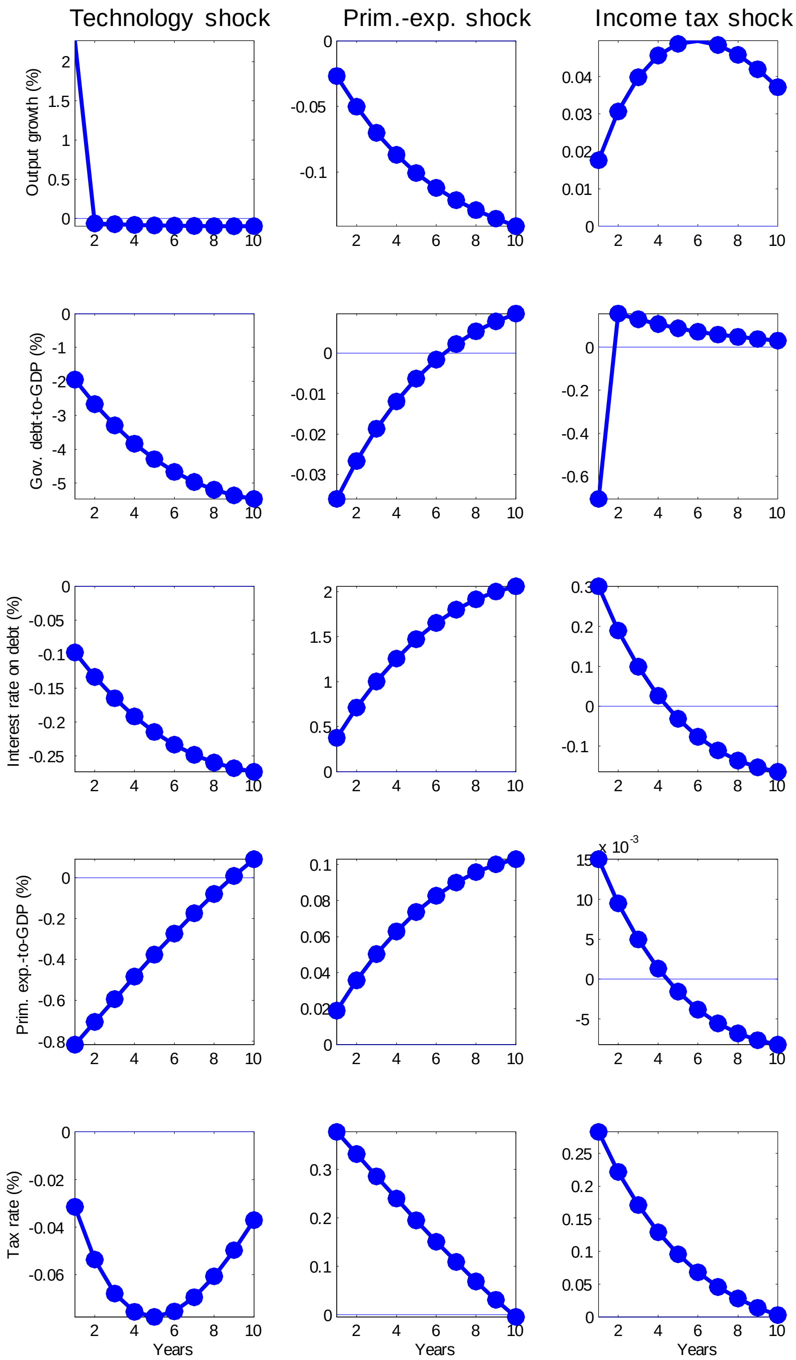
Note: The brackets denote either the country or the year.

Table 7: Unit root tests

Variable	Country specific tests				Full panel tests	
	ADF (C)	ADF(C+T)	KPSS (C)	KPSS (C+T)	IPS	LL
Primary balance -to-GDP	Stationary: AUS, GER FIN, FRA NLD, DNK UK, SWE	AUS, GER SWE	AUT, GER, SPA, FIN FRA, IRL NLD,PRT DNK, UK SWE	AUS, GER SPA, FIN FRA, DNK UK, SWE	Verdict: stationary	stationary
Debt -to-GDP	Stationary: NLD	GER, NLD	IRL, NLD, DNK, GBR	GER, FIN, FRA, GRC	Verdict: unit root	unit root

Note: ADF is the Augmented Dickey-Fuller test, KPSS is the Kwiatowski, Phillips, Schmidt, and Shin test, IPS is the Im, Pesaran and Shin test and LL is the Levin-Lin test. C denotes a constant also included in the test and T a deterministic linear trend. ADF, IPS and LL test the null hypothesis of the existence of a unit root. KSPP tests a null of stationarity. A 5% critical value is used to determine whether a test is deemed to suggest stationarity or the existence of a unit root. The ADF, IPS and LL tests use the Akaike Information Criterion to determine the appropriate lag length. The lag length in the KPSS test is fixed at 2.

Figure 10: Impulse responses to macro and policy shocks
in a stylized small open economy model



Note: Impulse responses to business cycle and policy shocks from the theoretical model. Benchmark calibration with $\psi^g = 500$ and $\psi^\tau = 5$.

84th percentiles. The identified shocks have, by construction a standard deviation of 1. We have included shaded areas to identify periods of recession. The impulse responses have been normalized so that a variable of interest (see notes on each graph) rises by 1% on impact of the shock, and have been drawn using an initial value of the debt-to-GDP ratio of 50%.

B.3.1 Aggregate demand shock

The aggregate demand shock is identified first, requiring GDP growth, inflation and the government revenue-to-GDP ratio to rise on impact. The identified aggregate demand shocks are plotted in Figure 11. Due to the use of both time- and country-fixed effects, the aggregate demand shocks correspond well with recessions which have been country specific, and corresponds less well with synchronized periods of recession. For example, if we look at the 2008-2011 period, countries that experienced relatively mild recessions appear to have experienced positive aggregate demand shocks.

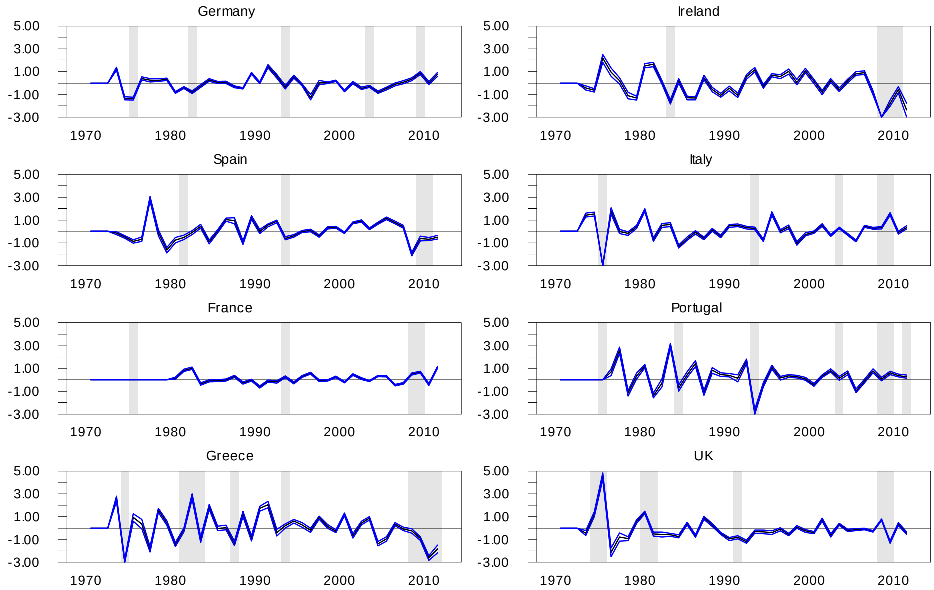
The impulse responses to an aggregate demand shock are plotted in Figure 12. A one percentage point increase in GDP growth increases the government revenue-to-GDP ratio by approximately 0.7 percentage points. With an average revenue-to-GDP ratio of 0.45, this means a 1% rise in the GDP growth rate leads to an approximate 2.6% increase in revenues.[30] This elasticity is above the estimate used by the European Commission. However, Mertens and Ravn (2013) formulate an argument why the methodology used by the European Commission might generate a downwardly biased estimate (although they use US data in their example). While the effect on output growth is relatively short-lived, the rise in the government revenue-to-GDP ratio is more persistent. The aggregate demand shock leads to a strong decline in the debt-to-GDP ratio, because the primary balance improves, and because the shock generates a large fall in the growth and inflation adjusted cost of borrowing for the government. Two years following the shock, primary expenditure begins to rise, generating a reversal of the primary balance.

B.3.2 Cost-push shock

The (negative) cost-push shock is identified second, requiring inflation to fall on impact and GDP growth and revenues to rise, while also being orthogonal to the first shock. The identified

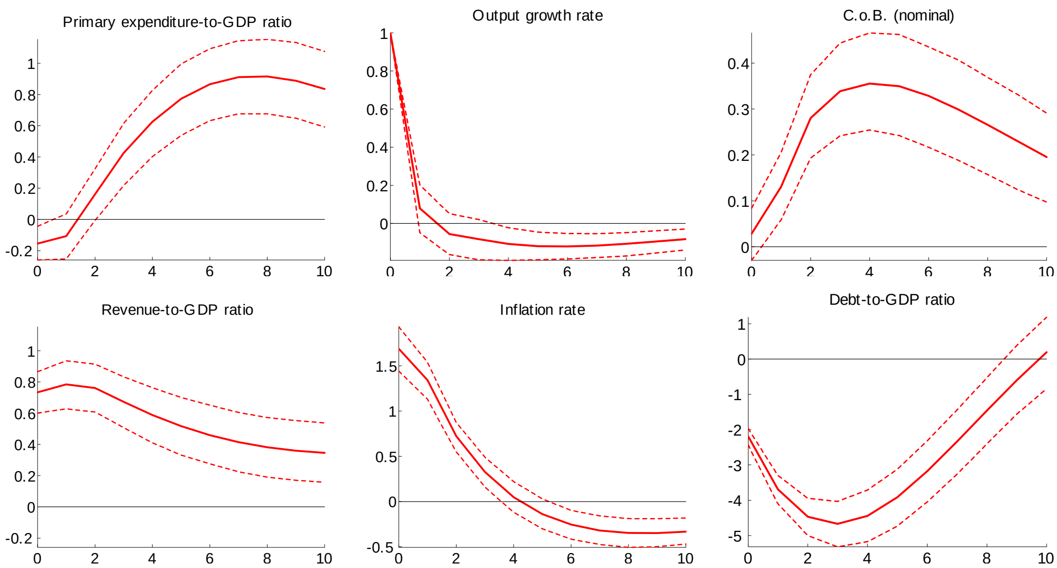
[30] The elasticity of revenues with respect to output is $\xi = \frac{\Delta R/R}{\Delta Y/Y}$. The model provides the following information: $\Delta Y/Y = 0.01$, $\Delta\left(R/Y\right) \approx 0.007$ and $R/Y \approx 0.45$. Using the approximation, $\Delta\left(R/Y\right)/\left(R/Y\right) \approx \Delta R/R - \Delta Y/Y$ we can rewrite the elasticity as $\xi \approx 1 + \frac{\Delta(R/Y)/(R/Y)}{\Delta Y/Y} = 1 + \frac{0.007/0.45}{0.01} = 2.6$.

Figure 11: Identified Aggregate Demand Shocks



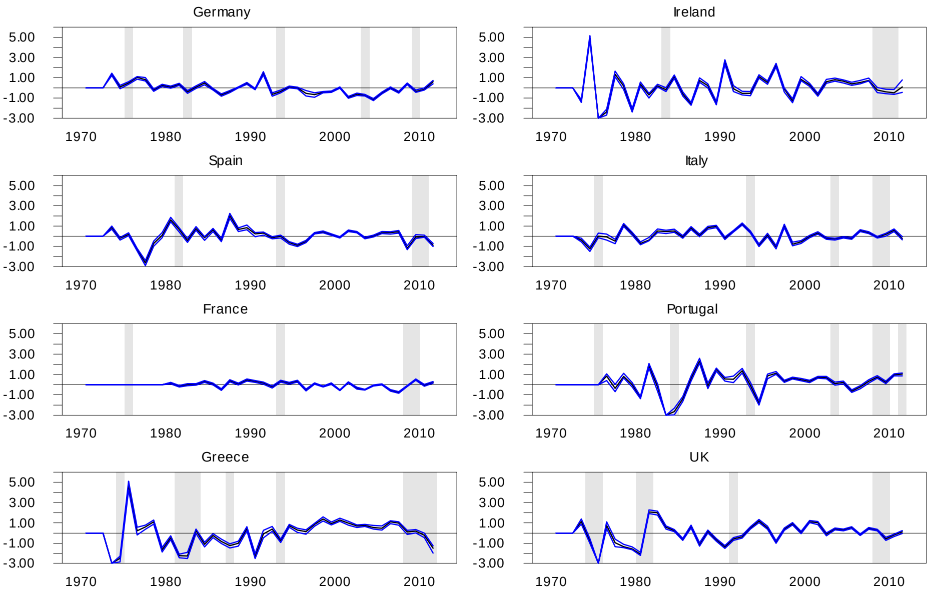
Note: The y-axis measures the identified aggregate demand shock with a unit standard deviation, the x-axis measures time in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. The shaded areas are periods of recession.

Figure 12: Impulse Responses to an Aggregate Demand Shock



Note: The aggregate demand is ordered first. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. Responses have been normalized to a 1 percentage point rise in the GDP growth rate. The debt-to-GDP ratio is initially 0.5.

Figure 13: Identified Cost-Push Shocks



Note: The y-axis measures the identified cost-push shock with a unit standard deviation, the x-axis measures time in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. The shaded areas are periods of recession.

cost-push shocks are plotted in Figure 13. These identified shocks correspond well with the existing literature, being more volatile for most countries in the pre-1990s part of the sample.

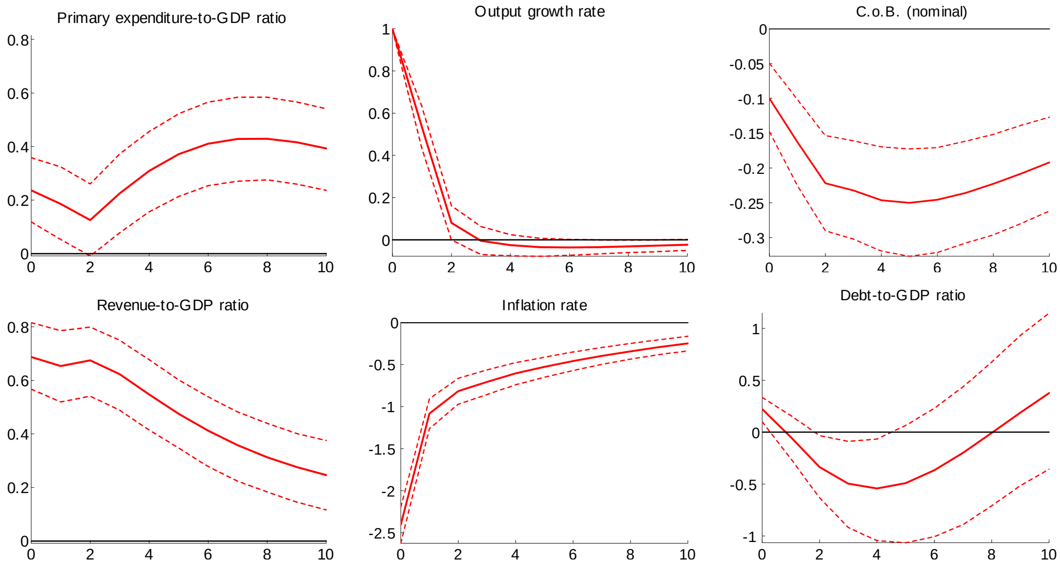
The impulse responses to a cost-push shock are plotted in Figure 14. We get a similar rise in the government revenue-to-GDP ratio on impact from a 1% rise in the GDP growth rate, as under an aggregate demand shock. The improvement in the primary balance for debt-to-GDP dynamics is however offset by a sharp rise in the inflation and growth adjusted cost of borrowing. While the nominal implicit interest rate falls moderately, the fall in inflation is more than twice the rise in output growth.

B.3.3 Primary expenditure shock

The primary expenditure shock is identified third (jointly with the government revenue shock), requiring the primary expenditure-to-GDP ratio and the GDP growth rate to rise on impact, while also being orthogonal to the two business cycle shocks. The identified primary expenditure shocks are plotted in Figure 15. The series of identified shocks is dominated by Ireland in 2010. Due to interventions in the banking system, the Irish government recorded a primary deficit-to-GDP ratio of 28%. The results of the model are not sensitive to the inclusion of this single data point.

The impulse responses to a primary expenditure shock are plotted in Figure 16. The

Figure 14: Impulse Responses to a Cost-Push Shock



Note: The cost-push shock is ordered second and orthogonal to the aggregate demand shock. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. Responses have been normalized to a 1 percentage point rise in the GDP growth rate. The debt-to-GDP ratio is initially 0.5.

nominal implicit interest rate does not rise on impact, but does increase in the medium term, rising by a maximum of 10 basis points. This is broadly consistent with the findings of Ardagna et al. (2007). The 0.5 percentage point increase in the GDP growth rate corresponds to a government spending multiplier of 0.2, substantially below 1.[31] Assuming total revenues are unchanged, the expansion in output can explain the reduction in the revenue-to-GDP ratio on impact of the primary expenditure shock. This amplifies the deterioration of the primary balance. Expansionary government spending also generates a rise in inflation.

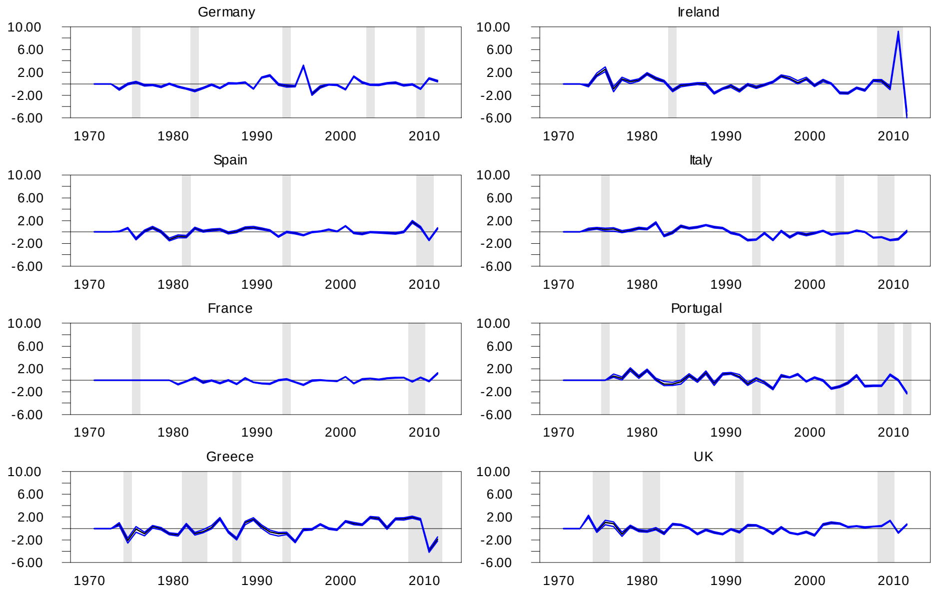
B.3.4 Government revenue shock

The government revenue shock is identified third (jointly with the primary expenditure shock), requiring the revenue-to-GDP ratio to rise and the GDP growth rate to fall on impact, while also being orthogonal to the two business cycle shocks. Note that we do not require the two fiscal policy shocks to be orthogonal, although adding this extra orthogonality restriction does not materially alter the results in Section 4. The identified government revenue shocks are plotted in Figure 17.

The impulse responses to a government revenue shock are plotted in Figure 18. A 1 per-

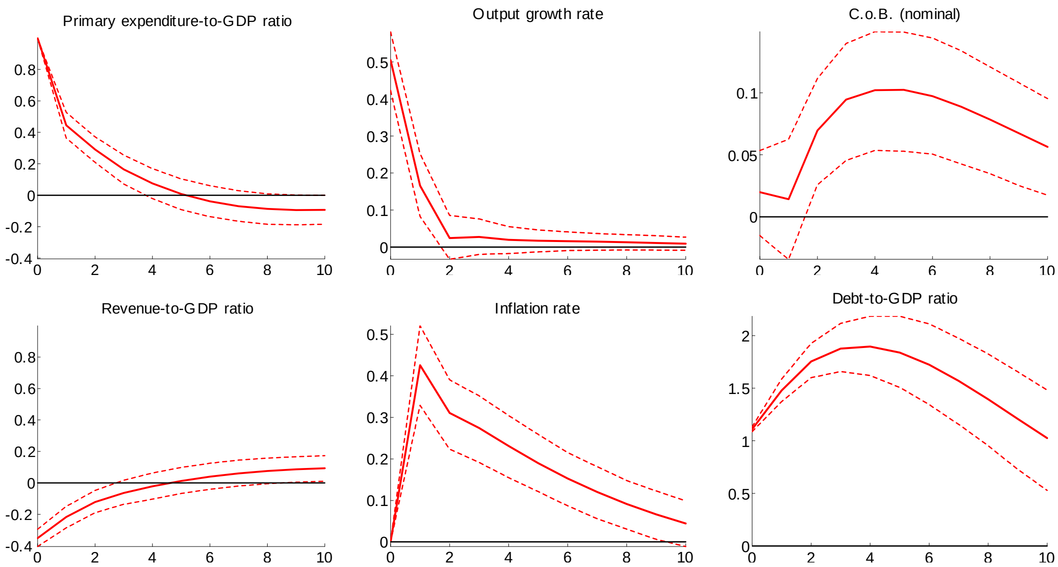
[31] The government spending multiplier is $\xi = \frac{\Delta Y/Y}{\Delta E/E}$. The model provides the following information: $\Delta(E/Y) = 0.01$, $\Delta Y/Y \approx 0.005$ and $E/Y \approx 0.45$. Using the approximation, $\Delta(E/Y)/(E/Y) \approx \Delta E/E - \Delta Y/Y$ we can rewrite the elasticity as $\xi \approx \frac{\Delta Y/Y}{\Delta Y/Y + \Delta(E/Y)/(E/Y)} = \frac{0.005}{0.005+0.01/0.45} = 0.2$.

Figure 15: Identified Primary Expenditure Shocks



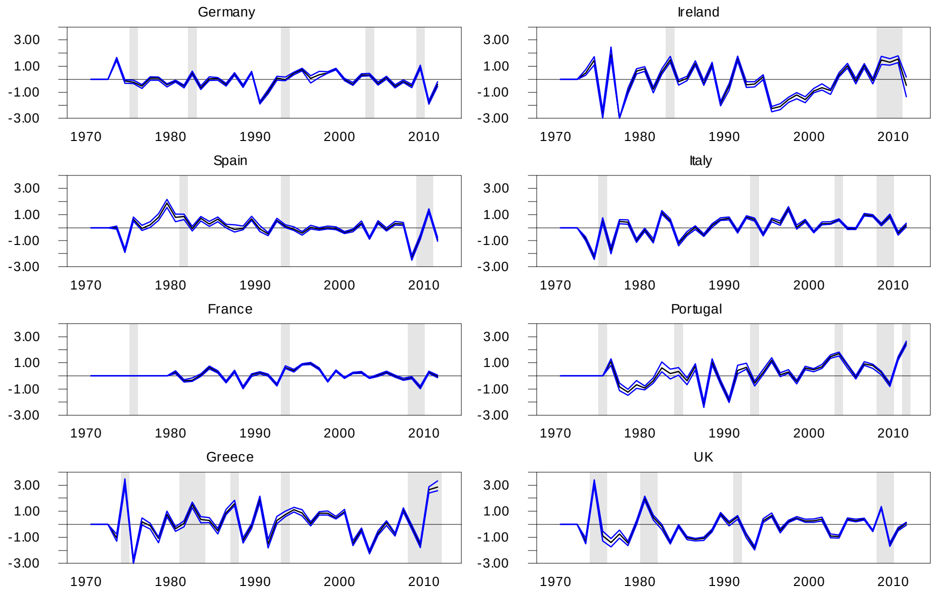
Note: The y-axis measures the identified primary expenditure shock with a unit standard deviation, the x-axis measures time in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. The shaded areas are periods of recession.

Figure 16: Impulse Responses to a Primary Expenditure Shock



Note: The primary expenditure shock is ordered (joint) third and orthogonal to the two business cycle shocks. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. Responses have been normalized to a 1 percentage point rise in the primary expenditure-to-GDP ratio. The debt-to-GDP ratio is initially 0.5.

Figure 17: Identified Government Revenue Shocks

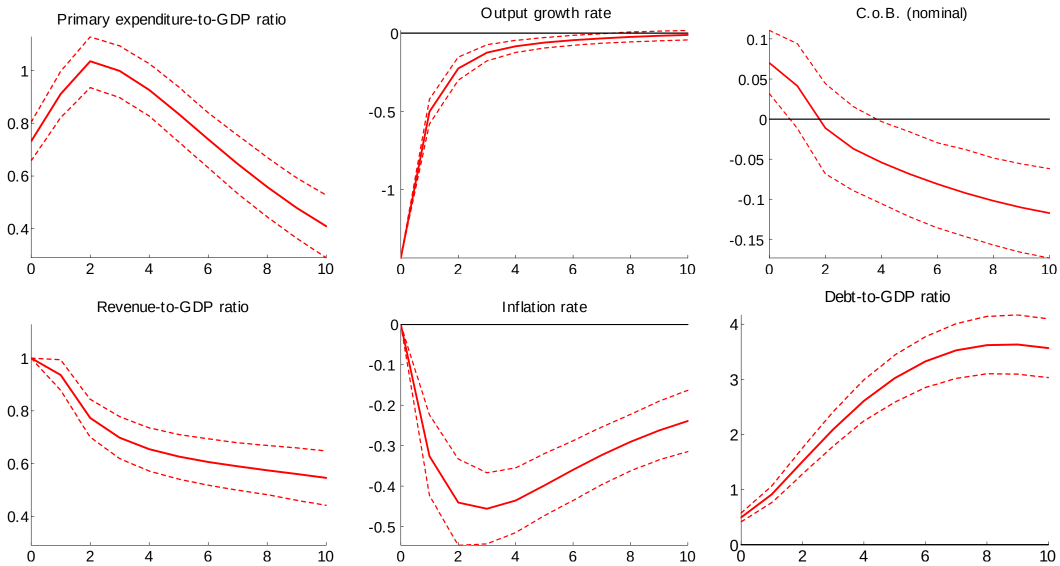


Note: The y-axis measures the identified government revenue shock with a unit standard deviation, the x-axis measures time in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. The shaded areas are periods of recession.

centage point rise in the revenue-to-GDP ratio has a bigger impact on GDP growth than a 1 percentage point fall in the primary expenditure-to-GDP ratio. GDP growth falls by 1.5 percentage points on impact, implying an impact tax revenue multiplier of -2.1, which is substantially greater than -1.[32] Again, by assuming that primary expenditure is unchanged on impact due to a government revenue shock, the fall in the denominator of the primary expenditure-to-GDP ratio can account for its rise on impact of approximately 0.7 percentage points. The size of the revenue multiplier means that the rise in the primary-balance to GDP ratio is smaller than the rise in the revenue-to-GDP ratio. In addition, the fall in GDP growth (and subsequent fall in inflation) generate a rise in the inflation and growth adjusted cost of borrowing, causing the debt-to-GDP ratio to rise in the response to a positive revenue shock.

[32] The tax revenue multiplier is $\xi = \frac{\Delta Y/Y}{\Delta R/R}$. The model provides the following information: $\Delta(R/Y) = 0.01$, $\Delta Y/Y \approx -0.015$ and $R/Y \approx 0.45$. Using the approximation, $\Delta(R/Y)/(R/Y) \approx \Delta R/R - \Delta Y/Y$ we can rewrite the elasticity as $\xi \approx \frac{\Delta Y/Y}{\Delta Y/Y + \Delta(R/Y)/(R/Y)} = \frac{-0.015}{-0.015+0.01/0.45} = -2.1$.

Figure 18: Impulse Responses to a Government Revenue Shock



Note: The government revenue shock is ordered (joint) third and orthogonal to the two business cycle shocks. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 16th, 50th and 84th percentiles. Responses have been normalized to a 1 percentage point rise in the government revenue-to-GDP ratio. The debt-to-GDP ratio is initially 0.5.