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COST OF BORROWING SHOCKS AND FISCAL ADJUSTMENT

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In 2012 all ECB publications feature a motif taken from the €50 banknote.

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Abstract

Do capital markets impose fiscal discipline on governments? We investigate the responses of fiscal variables to a change in the interest rate paid by governments on their debt in a panel of 14 European countries over four decades. This is done in the context of a panel vector autoregressive (PVAR) model, using sign restrictions via the penalty function method of Mountford and Uhlig (2009) to identify structural cost of borrowing shocks. Our baseline estimation shows that a one percentage point rise in the cost of borrowing leads to a cumulative improvement of the primary balance-to-GDP ratio of approximately 1.9 percentage points over 10 years, with the fiscal response becoming significantly evident only two years after the shock. We also find that the bulk of fiscal adjustment takes place via a rise in government revenue rather than a cut in primary expenditure. The size of the total fiscal adjustment, however, is insufficient to avoid the gross government debt-to-GDP ratio from rising as a consequence of the shock. Sub-dividing our sample, we also find that for countries participating in Economic and Monetary Union (EMU) the primary balance response to a cost of borrowing shock was stronger in the period after 1992 (the year in which the Maastricht Treaty was signed) than prior to 1992.

Keywords: Fiscal policy, Long-term interest rates, Vector-autoregressive models, Sign restrictions

JEL classifications: C33, E43, E62, H60

Non-technical summary

During the ongoing 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 these promises are acted upon, this behaviour can be interpreted as a form of market imposed fiscal discipline. Against this background, this paper examines empirically the proposition that governments systematically respond to adverse shocks in their market borrowing rates by improving their fiscal positions.

Based on a vector autoregressive (VAR) model with a panel of 14 European countries and annual data from 1970 to 2011, it finds a statistically significant fiscal policy response to exogenous changes in the cost of borrowing. A one percentage point rise in the cost of borrowing leads to a cumulative increase in the primary balance-to-GDP ratio of 1.9 percentage points after 10 years. However, the debt-to-GDP ratio is 1.0 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. A decomposition of the primary budget balance into its revenue and expenditure components shows that almost all the adjustment takes place via the revenue side while public expenditure remains broadly unchanged.

We further separate our panel into EMU and non-EMU countries and pre- and post-1992, which marks the signing of the Maastricht Treaty, to account for the wide ranging changes in the European fiscal framework over recent decades and their potential effect on economic policy in EU member states. The estimates reveal that 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. This finding possibly reflects that countries that eventually joined monetary union had an additional incentive to compensate for higher interest payments by tightening their fiscal stance.

Our results have important policy implications. The estimated average fiscal response suggests that market discipline can enhance budgetary prudence. 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.

... 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 ongoing European sovereign debt crisis, sharp rises in yields on government bonds (see Figure 1) have been met with promises from governments to accelerate and expand their fiscal consolidation plans. This behaviour (to the extent the promises are acted upon) 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 adverse shocks in their market borrowing rates by improving their fiscal positions.

This question is relevant for two reasons. First, governments typically do not formulate fully binding and clearly defined long-term budgetary plans that would allow private sector agents to precisely anticipate future tax and spending behavior. By exposing past patterns in the response of EU governments to changes in their cost of borrowing, the current analysis allows observers to form more informed expectations on how the medium-term fiscal stance is likely to evolve in view of the re-pricing of sovereign risk that has taken place since the start of the current crisis. Second, the paper provides a new perspective to the ongoing policy debate that is currently shaping economic governance in Europe. The common perception that, apart from a failure of the EU governance framework, financial markets have failed in inducing prudent budgetary policies has been a central motive for the recent initiatives to strengthen fiscal rules in the European Union in general and the euro area in particular.[2] The empirical analysis presented here may contribute to this debate by allowing for a systematic assessment on whether and to what extent this perception is warranted.

In doing so, the paper addresses an issue that, to date, has received little attention in academic research. As pointed out by Bayoumi, Goldstein, and Woglom (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.[3] 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 is jointly determined. Yet, the causation, from the cost of public debt service to fiscal policy decisions has received little attention in the empirical literature.[4] This paper aims to bring some balance to the joint determination of fiscal variables and long-term interest rates by empirically testing the response of fiscal policy to exogenous interest rate changes in a dynamic context.

To motivate our empirical analysis, we present a simple model, in which the government chooses a primary balance path that minimizes deviations from its preferred fiscal stance while

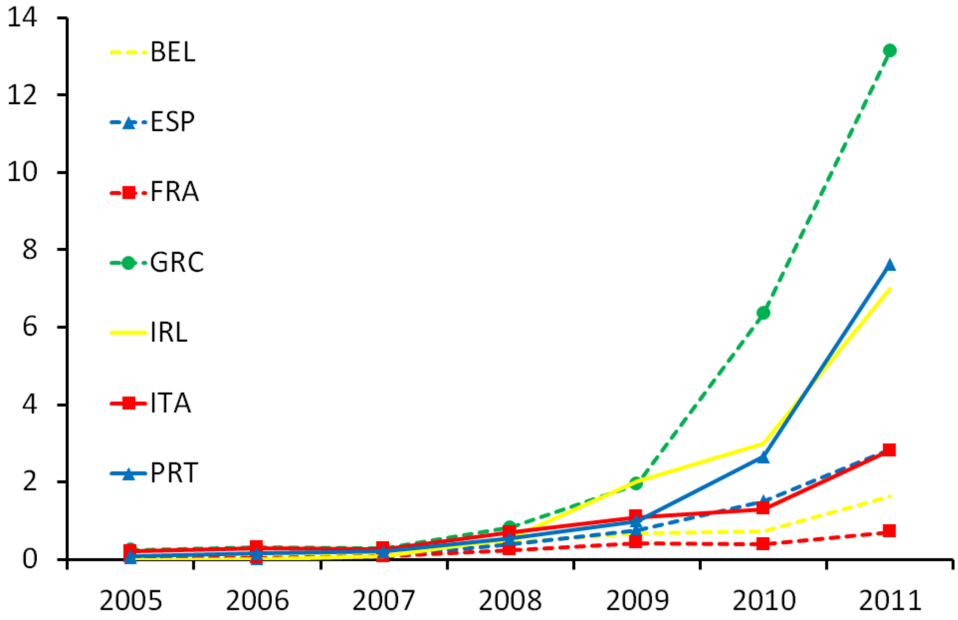
[1] http://www.finance.gov.ie/viewdoc.asp?DocID=6552&CatID=1&StartDate=01+January+2010

[2] For a discussion see, for example, Schuknecht, Moutot, Rother, and Stark (2011).

[3] 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 of the more recent studies include Faini (2006), Ardagna, Caselli, and Lane (2007), Attinasi, Checherita, and Nickel (2009), Laubach (2009), Schuknecht, Von Hagen, and Wolswijk (2009) and Afonso and Rault (2011).

[4] The exception is Theofilakou and Stournaras (2012). They 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 quite different to that used here, as they estimate a single equation model.

Figure 1: Nominal long term interest rates (spread over German)



Note: Government benchmark 10 year bond yields. See AMECO code ILN for details.

maintaining a sustainable fiscal position over time. The government can issue debt, paying the world interest rate plus some risk premium. In this set up, an exogenous rise in the risk premium demanded by international investors for holding this debt would generate a tightening of the budgetary path unless the government's supply of debt securities is perfectly inelastic.

This hypothesis is then confronted with empirical estimates of the response of fiscal variables to changes in long-term interest rates. To this end, 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, since fiscal policy and the cost of borrowing are jointly determined, it is 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 fiscal policy shocks, we treat any additional unexpected movements in long-term interest rates, orthogonal to the business cycle and fiscal policy shocks, as truly exogenous shocks to the cost of borrowing.

Second, empirical estimates must respect the government's intertemporal budget constraint. This is achieved by keeping track of the non-linear 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 rising debt dynamics generated by an increase in the cost of borrowing.

We find a statistically significant fiscal policy response to exogenous changes in the cost of borrowing. A one percentage point rise in the cost of borrowing leads to a cumulative increase in the primary balance-to-GDP ratio of 1.9 percentage points after 10 years. However, the debt-to-GDP ratio is 1.0 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. A decomposition of the primary balance into its revenue and expenditure components shows that almost all the adjustment takes place via the revenue side while primary expenditure remains broadly unchanged. We subject the data to a battery of sensitivity tests to check the robustness of our results.

Given the wide ranging changes in the European fiscal framework over recent decades and their potential effect on economic policy in EU member states, we separate our panel into EMU and non-EMU countries and pre- and post-1992 (which marks the signing 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 which eventually joined monetary union had an additional incentive to compensate for higher interest payments (which count against the Maastricht balance criterion) by tightening their stance with respect to other budget items.

The rest of the paper proceeds as follows. Section 2 provides a simple theoretical framework to clarify the responses predicted by standard macroeconomic theory. Section 3 outlines the empirical methodology, in particular the identification strategy. Section 4 presents the results while Section 5 discusses policy implications and concludes.

2 Theoretical motivation

In this section we provide a stylized framework to analyze the expected response of governments to an exogenous rise in the cost of borrowing. The law of motion of public debt is given by the government budget constraint:

$$d_t = (1 + r_t)\, d_{t-1} - b_t \tag{1}$$

where d is the government debt-to-GDP ratio, b is the primary balance-to-GDP ratio, and r is the nominal interest rate on debt, relative to inflation and the growth rate of real GDP.[5] We assume that r follows an exogenous process, $r_t = r^W + \sigma_t$, where r^W is the world risk-free rate and σ_t is a risk premium demanded by investors for holding the government's debt. This implies that the economy considered here is small and faces perfect international markets while governments are subject to idiosyncratic shocks in their perceived credit worthiness. Appendix A extends the model to allow r to include an endogenous component as a function of d and b.[6] The qualitative results however, are unchanged.

The government chooses the time path of $\{b_t, d_t\}$ to minimize a loss function that is quadratic in the state variable d and the policy instrument, b:

$$\min_{\{b_t,d_t\}} \mathcal{L} = \sum_{t=0}^{\infty} \frac{1}{2}\beta^t \left[(b_t - b^*)^2 + \lambda_1 (b_t - b_{t-1})^2 + \lambda_2 \left\{ \begin{array}{cc} (d_t - d^*)^2 & \text{if } d_t > d^* \\ 0 & \text{else} \end{array} \right. \right], \quad \lambda_{1,2} > 0 \tag{2}$$

subject to the government budget constraint, equation (1). This formulation of a governments loss function is similar to the one used by Tabellini (1986). Equation (2) states that the government seeks to minimize deviations of the primary balance from a given target, b^*, the speed of adjustment of the primary balance, $b_t - b_{t-1}$ from 0, and deviations of the stock of outstanding government debt from d^*. The asymmetric preference on debt implies that the government is indifferent between different levels of debt below d^*. The parameters $\lambda_{1,2}$ indicate the relative weight assigned to the three objectives. Finally, β is the discount factor.

While this set up does not explicitly model allocation, redistribution and stabilization objectives of the fiscal authorities, these are implicit in the desired targets for b and d. The primary balance and debt targets could reflect, for example, the preferred intergenerational distribution of a given amount of public service provision while aiming to avoid debt sustainability concerns.[7]

[5] Specifically, $(1 + r) = \frac{(1+i)}{(1+g)(1+\pi)}$ where i is the nominal interest rate, g is the growth rate of real GDP and π is the inflation rate.

[6] The reduced form relationship between r and d would however suffers from the Lucas critique since the parameters of this relationship are unlikely to be structural and invariant to policy changes.

[7] Crucially though, the preferences (b^*, d^*) need not be consistent with a steady state outcome (b^{SS}, d^{SS}).

The "habit" term, $\lambda_1 (b_t - b_{t-1})^2$, captures political constraints to quickly adjusting status quo policies. Appendix A shows a simple extension of the model to introduce government primary expenditure and government revenue objectives explicitly, and the potential for non-cooperative behaviour between different fiscal agents with different preferences regarding the expenditure and revenue composition of fiscal adjustment.

Next we characterize the solution to the optimal control problem under the assumptions of an infinite horizon, complete information and $d_t > d^*$. The first order condition is:

$$\begin{aligned} 0 = &-(b_t - b^*) - \lambda_1 (b_t - b_{t-1}) + \lambda_2 (d_t - d^*) \\ &+\beta \left[(1+r)(b_{t+1} - b^*) + (2+r)\lambda_1 (b_{t+1} - b_t)\right] \\ &-\beta^2 (1+r)\lambda_1 (b_{t+2} - b_{t+1}) \end{aligned} \tag{3}$$

Equations (1) and (3), the initial stock of outstanding debt, d_0 and the transversality condition:

$$\lim_{T\to\infty} \left(\frac{1}{1+r}\right)^{T+1} d_{T+1} = 0$$

fully characterize the equilibrium. The system of differential equations can be written in matrix form as:

$$\begin{aligned} 0 \;=\; &\begin{bmatrix} \left\{ \begin{array}{c} \beta\left((1+r)+(2+r)\lambda_1\right) \\ +\beta^2(1+r)\lambda_1 \end{array} \right\} & 0 & -\beta^2(1+r)\lambda_1 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} b_{t+1} \\ d_{t+1} \\ b_{t+2} \\ b_t \end{bmatrix} \\ &+ \begin{bmatrix} \left\{ \begin{array}{c} -\beta(2+r)\lambda_1 \\ -(1+\lambda_1) \end{array} \right\} & \lambda_2 & 0 & \lambda_1 \\ 0 & -(1+r) & 0 & 0 \\ 0 & 0 & -1 & 0 \\ -1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} b_t \\ d_t \\ b_{t+1} \\ b_{t-1} \end{bmatrix} + \begin{bmatrix} \left\{ \begin{array}{c} -(1-\beta(1+r))b^* \\ -\lambda_2 d^* \end{array} \right\} \\ 0 \\ 0 \\ 0 \end{bmatrix} \end{aligned}$$

2.1 Steady state comparative statics

We ignore for now the transitory dynamics and conduct steady state comparative statics. The first order equilibrium condition reduces to:

$$(\beta(1+r) - 1)\left(b^{SS} - b^*\right) + \lambda_2 \left(d^{SS} - d^*\right) = 0 \quad \text{if} \quad d^{SS} \geq d^* \tag{4}$$

where the SS superscript denotes a variable's steady state value. For the propositions that follow we assume that $\beta = 1$.[8] We also restrict attention to non-negative values of government debt. Using the steady state budget constraint, $b^{SS} = rd^{SS}$, we can rewrite equation (4) as:

$$b^{SS}\left(b^{SS} - b^*\right) + \lambda_2 d^{SS}\left(d^{SS} - d^*\right) = 0 \quad \text{if} \quad d^{SS} \geq d^* \tag{5}$$

When $d^{SS} < d^*$ and if $b^* < 0$, $r < 0$ we have $b^{SS} = b^*$ and $d^{SS} = b^*/r$, while if $b^* < 0$ and $r > 0$ then $b^{SS} = d^{SS} = 0$. In words, if the steady state debt-to-GDP ratio is below d^* (so that the government is indifferent as to the exact value of d^{SS}), and if the inflation and growth adjusted cost of borrowing is negative, then the government is able to run its target deficit. If however, the inflation and growth adjusted cost of borrowing is positive, the government will choose to run a balanced budget and reduce its debt stock to zero. When $b^* > 0$ the (government targets a positive primary balance), the results flip such that $b^{SS} = b^*$ when $r > 0$ and $b^{SS} = 0$ when $r < 0$. The following proposition describes the effect of a change in r on steady state outcomes.

[8] Discounting the future "twists" the government's iso-loss curves, thus complicating the comparative static analysis. But, for values of β close to 1, the comparative static results are qualitatively unaffected.

Proposition 1 *a) when* $d^{SS} \geq d^*$ *then:*

$$\frac{\partial d^{SS}}{\partial r} \gtreqqless 0 \text{ if } b^{SS} \lesseqqgtr \frac{b^*}{2}$$
$$\frac{\partial b^{SS}}{\partial r} > 0$$

b) when $d^{SS} < d^*$ *then:*

$$\frac{\partial d^{SS}}{\partial r} \geqq 0 \text{ if } r \lesseqgtr 0 \text{ and } b^* < 0$$
$$\frac{\partial d^{SS}}{\partial r} \leqq 0 \text{ if } r \gtreqless 0 \text{ and } b^* > 0$$
$$\frac{\partial b^{SS}}{\partial r} = 0$$

Proof. *We begin with a proof of a). Implicit differentiation of equation (5) gives:*

$$\frac{\partial d^{SS}}{\partial b^{SS}} = -\frac{\left(2b^{SS} - b^*\right)}{\lambda\left(2d^{SS} - d^*\right)} \text{ and } \frac{\partial^2 d^{SS}}{\partial\left(b^{SS}\right)^2} = -2\frac{\left(1 + \left(\frac{\partial d^{SS}}{\partial b^{SS}}\right)^2\right)}{\lambda\left(2d^{SS} - d^*\right)}$$

First, we note that $\frac{\partial d^{SS}}{\partial b^{SS}} = 0$ *at* $b^{SS} = \frac{b^*}{2}$ *and since* $\frac{\partial^2 d^{SS}}{\partial(b^{SS})^2} < 0$ *(since* $d^{SS} > d^*$ *by assumption), then the* d^{SS} *consistent with* $b^{SS} = \frac{b^*}{2}$ *is a local maximum,* $d^{SS}_{\max}$*. Next, implicit differentiation of equation (5) with respect to r gives:*

$$\frac{\partial b^{SS}}{\partial r} = -\lambda\frac{\partial d^{SS}}{\partial r}\left(\frac{2d^{SS} - d^*}{2b^{SS} - b^*}\right)$$

This equation makes clear that $\frac{\partial b^{SS}}{\partial r}$ *is monotonic, since if, for example,* $\frac{\partial d^{SS}}{\partial r}$ *is positive for* $b^{SS} < \frac{b^*}{2}$ *then* $\frac{\partial d^{SS}}{\partial r}$ *must be negative for* $b^{SS} > \frac{b^*}{2}$ *and visa versa. We finally need to check whether* $\frac{\partial b^{SS}}{\partial r}$ *is monotonically increasing or decreasing. We show by contradiction that* $\frac{\partial b^{SS}}{\partial r}$ *must be monotonically increasing in r. Take the constraint evaluated at the steady state,* $rd^{SS}(r) = b^{SS}(r)$*. Implicit differentiation with respect to r gives:*

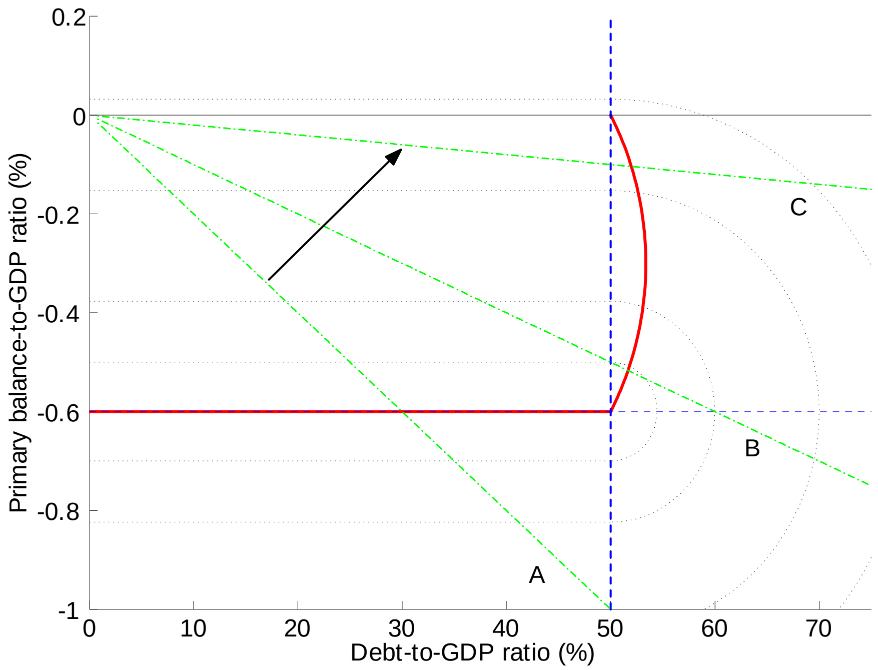
$$0 = d^{SS} + r\frac{\partial d^{SS}}{\partial r} - \frac{\partial b^{SS}}{\partial r} \tag{6}$$

Suppose that $\frac{\partial b^{SS}}{\partial r} < 0$*. The we must have that* $\frac{\partial d^{SS}}{\partial r} < 0$ *to satisfy equation (6). However, there is a value of* b^{SS} *for which* $\frac{\partial d^{SS}}{\partial r} > 0$*, leading to a contradiction. Thus, we must have that* $\frac{\partial b^{SS}}{\partial r} > 0$*.*

The proof of part b) follows by inspection. When $d^{SS} < d^*$ *and* $b^* > 0$*, we know that the government can always achieve* b^* *if* $r < 0$ *or at worst* $b^{SS} = 0$ *if* $r > 0$*. Thus,* $\frac{\partial b^{SS}}{\partial r} = 0$*. This means that equation (6) becomes* $\frac{\partial d^{SS}}{\partial r} = -\frac{1}{r}d^{SS}$*. When* $r < 0$ *therefore,* $\frac{\partial b^{SS}}{\partial r} > 0$*. The remaining scenarios follow similarly.* ■

Figure 2 provides a graphical representation of the results in Proposition 1. In this example, we fix the government's preferences $(d^*, b^*, \lambda_1, \lambda_2)$ and adjust the steady state cost of borrowing, r. In particular, we set $b^* = -0.006$ (target 0.6% primary deficit-to-GDP ratio) and $d^* = 0.5$, marked on with the dash blue lines. The dot black lines are iso-loss lines, showing the loci of (d, b) combinations for which the government is indifferent. The feasible set of combinations (d, b) for any given r (derived from the government budget constraint) is given by the dash-dot green line, which passes through $(0, 0)$ and has a slope of r. A rise in r is denoted by an

Figure 2: Steady State Comparative Statics



anti-clockwise rotation of the dash-dot green line around $(0,0)$. The solid red line sketches out the loci of equilibrium steady state outcomes for different possible values of r.

Suppose r is initially low, with the feasible set of (b,d) shown by line A. In this case, $d^{SS} < d^*$ and $b^{SS} = b^*$. A small rise in r will be met with unchanged policies (b^{SS} remains at b^*), causing the steady state debt-to-GDP ratio to rise. If, however, the inflation and growth adjusted cost of borrowing r is at a higher steady state with feasible set B then a small rise in r will cause the government to begin consolidating, increasing the primary balance-to-GDP ratio, although not by enough to prevent a rise in the debt-to-GDP ratio. Only if r is such that the feasible set is given by the line C, does a small rise in r cause the government to consolidate sufficiently in order to reduce the steady state debt-to-GDP ratio. When r, however, turns positive, the government will aim for a steady state in which both the primary balance and debt-to-GDP ratio are zero.

2.2 Dynamic adjustment

It is clear that this model is quite flexible in its ability to generate various fiscal behavior. To make these ideas more concrete, we use the back of the envelope parameterization shown in Table 1. Values have been chosen to match the long-run averages for the debt and primary balance-to-GDP ratios and the inflation and growth adjusted cost of borrowing for Portugal in our sample. Thus, the experiment involves fixing the initial steady state $\left(d^{SS}, b^{SS}\right)$ and adjusting the parameters of the loss function $(d^*, b^*, \lambda_1, \lambda_2)$. Intuitively, the parameters of the loss function $(b^*, d^*, \lambda_1, \lambda_2)$ can be interpreted as reflecting country-specific characteristics that determine the time lag associated with changes in the fiscal stance, such as the legal status of key budget items, such as public sector wages and pensions,[9] the social and political landscape

[9] For example, if these spending items are protected by the constitution, they are more difficult to be cut than if they are governed by administrative law.

Table 1: Back-of-the-envelope parameterization based on Portugal

	No response	Mild response	Strong response	Extra strong response
Calibrated parameters				
β			$\mathbf{0.98}^{\sharp}$	
d^*	3		**0.4**	
b^*	$0.0062^{\ddagger}$	0.015	**0.03**	
λ_1			**5**	0.5
λ_2		$0.0026^{\dagger}$	$\mathbf{0.0071}^{\dagger}$	
Steady state values (Portugal 1977-2007)				
d^{SS}			**0.5067**	
b^{SS}			**−0.0062**	
$1+r^{SS}$			**0.9878**	

Note: Where spaces have been left, the numbers are the same as those reported in the Strong Response column. $^{\sharp}$ since periods are one year. † chosen to match steady state values. ‡ $b^* = b^{SS}$.

of a country,[10] and the fiscal constitution of the country.[11] By varying these parameters, we are able to generate responses ranging from *no response* at one extreme, where the primary balance is not adjusted, to an *extra strong response* at the other extreme where the fiscal response is swift enough to cause the debt-to-GDP ratio to fall almost immediately.

The model is calibrated for annual data to match the annual frequency of our data set. We therefore use a discount rate of $\beta = 0.98$ following Faraglia, Marcet, and Scott (2011). The Portuguese debt-to-GDP ratio has averaged approximately 50% over the period 1977-2007 and it has sustained a primary deficit-to-GDP ratio of 0.6%. This has been achieved because the growth and inflation adjusted cost of borrowing has been negative. This is not an unusual finding in our data sample.

To generate a *no response* outcome (column 1 in Table 1), we set d^* extremely (and quite unrealistically) high at 3 times GDP. This ensures that the government is able to sustain its current stance of fiscal policy without the rise in its debt-to-GDP ratio generated by the increased cost of borrowing being of concern (i.e. incurring any losses in its loss function). As discussed in the previous section on steady state comparative statics, it is possible to achieve an outcome where the debt-to-GDP ratio converges to either a higher or lower steady state in response to a rise in the cost of borrowing. For a given level of r, this can be achieved by adjusting the weight given to the debt stabilization objective, λ_2. This distinguishes the *mild* from the *strong* response in columns 2 and 3 of Table 1. Column 4 in Table 1, generates an *extra strong* response of the primary balance. This is achieved by reducing the weight placed on the habit term in the loss function. This parameter adjustment leaves the steady state unaffected but alters the optimal pace of fiscal adjustment, and can therefore determine whether the debt-to-GDP dynamics present overshooting, or not.

In Figure 3 we plot the transition (solid blue line) of the primary balance- and debt-to-GDP ratios from the initial steady state (dash red line) to the new steady state (dash-dot green line) in the event of a permanent increase in the cost of borrowing by 1 percentage point. The four panels $A - D$ correspond to the four columns in Table 1. Panel A shows the *extra strong* response

[10] Countries with strong social and political coherence are likely to garner consensus regarding corrective fiscal measures than countries that are highly fragmented along these dimensions.

[11] A country with strong budget autonomy at sub-national level might find it more difficult to transmit a planned change in the fiscal stance to the entire public sector.

with a quick adjustment of the primary balance, leading to an almost immediate downward trajectory for the debt-to-GDP ratio. Panel B presents the *strong* response. The primary balance adjustment is slower, leading to an initial rise in the debt-to-GDP ratio before falling to its new, lower steady state level. Panel C presents the *mild* response. The government still increases its primary balance-to-GDP ratio, but the adjustment is insufficient to prevent a permanent rise in the debt-to-GDP ratio. Finally, the *no response* outcome in Panel D is a very extreme result in which the primary deficit is left unchanged at 0.6% of GDP and debt is allowed to rise to 277% of GDP.

This simple conceptual framework yields a set of empirical hypotheses on the patterns of fiscal adjustment to cost of borrowing shocks. Based on this model, we test our main hypothesis empirically in the next section. Although the model section has been concerned only with fiscal adjustments following a permanent cost of borrowing shock, the empirical section considers both temporary and permanent shocks. Note also, that we do not use the predictions of our model to derive identifying restrictions, but instead constrain ourselves by choosing identifying restrictions commonly found in the macroeconomic literature.

3 Empirical methodology

Our baseline estimation is a panel vector autoregressive (PVAR) model in 5 variables: the government primary expenditure-to-GDP ratio, government revenue-to-GDP ratio, GDP growth rate, inflation rate and nominal interest rate on debt. The government's intertemporal budget constraint (involving these five variables) is adhered to by keeping track of the debt-to-GDP ratio, which enters as a lagged explanatory variable in the PVAR. 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.[12] All the endogenous variables we use are stationary. We have used the GDP ratio measure for primary expenditure and revenue so the implied primary balance is easily computed. In log levels, the calculation would have required the additional complication of estimating steady state ratios.

There are two alternative measures of the cost of public debt finance. The first is to calculate an implicit interest rate using the government's total debt interest payments in any given period divided by the previous period's debt stock:

$$i_t^{IMP} = 100 \times \frac{interest\ payments_t}{debt\ stock_{t-1}} \tag{7}$$

This is the measure we use in our estimation. The drawback of this measure is that it represents the *average* cost of borrowing rather than the *marginal* cost of borrowing. The average and marginal cost of borrowing would only coincide if the entire debt stock needed to be refinanced every year. Since governments generally fund themselves at a longer average maturity than one-year, a 1% rise in the marginal cost of borrowing will lead to a less than one for one rise in the average cost of borrowing.[13] Yet, a temporary shock to the marginal cost of borrowing (assuming debt issuance patterns in terms of instruments, maturity etc. remain unchanged)

[12] The complete dataset is available from the corresponding author's homepage, http://sites.google.com/site/oliverdegroot/research

[13] Suppose we model the maturity structure of debt as a continuum of callable perpetuity bonds with stochastic call date, which arrives with probability p. Then the stock of outstanding debt evolves as:

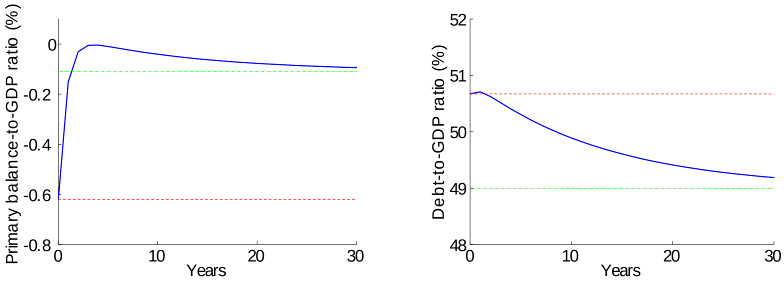
$$D_t^{stock} = (1-p)\, D_{t-1}^{stock} + D_t^{new}$$

and the average interest rate is:

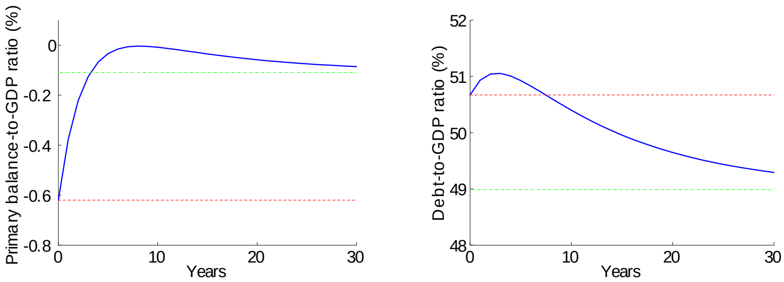
$$i_t^{average} D_t^{stock} = (1-p)\, i_{t-1}^{average} D_{t-1}^{stock} + i_t^{marginal} D_t^{new}$$

The average maturity of the government's debt portfolio is $\frac{1}{p}$ and the effect on the average cost of borrowing for

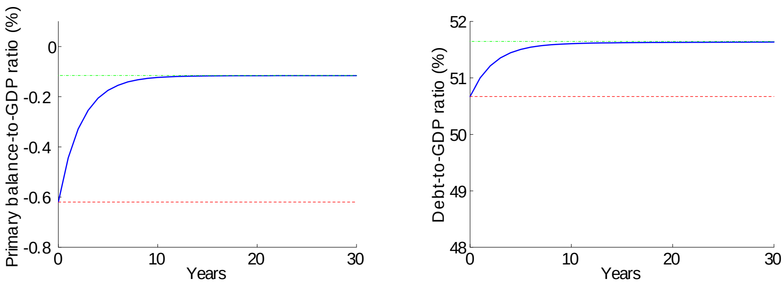
Figure 3: Responses to a 1 Percentage Point Interest Rate Rise



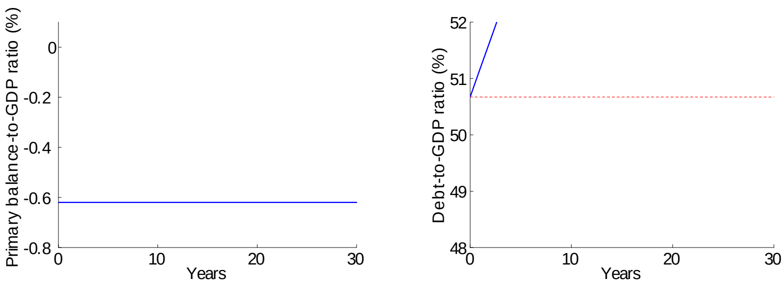
Panel A: Extra strong response



Panel B: Strong response



Panel C: Mild response



Panel D: No response*

Note: * The debt-to-GDP ratio settles at 277%.

has the same effect on the total cost of borrowing, independent of the maturity structure of the debt.[14]

Collecting accurate data on the marginal cost of borrowing is problematic since governments borrow using a large set of debt instruments, making any single bond yield a poor proxy. We do, however, test for robustness along this dimension by including the yield on 10 year government bonds in our PVAR in Section 4.

The VAR is estimated with two lags of the endogenous variables, with no intercept.[15] The variables are all stationary and have been country and time demeaned to account for both country and time fixed effects. In the benchmark estimation, we have assumed homogeneity across countries in terms of the coefficient matrix on the lagged endogenous variables. We revisit this restrictive assumption in Section 4.

The inclusion of the government's (non-linear) intertemporal budget constraint follows the method of Favero and Giavazzi (2007). The VAR we estimate (ignoring, for sake of exposition, the added complexity of the panel structure in the notation) is as follows:

$$\begin{aligned} y_t' &= \sum_{j=1}^{L} y_{t-j}' B_j + \gamma d_{t-1} + \epsilon_t' \\ d_t &= \frac{1+i_t}{(1+g_t)(1+\pi_t)} d_{t-1} + pe_t - v_t + s_t \end{aligned}$$

where $y_t = [pe_t, v_t, g_t, \pi_t, i_t]$ is the vector of non-predetermined endogenous variables, d_t is the debt-to-GDP ratio, pe_t is the primary expenditure-to-GDP ratio, v_t is the revenue-to-GDP ratio, g_t is the GDP growth rate, π_t is the inflation rate and i_t is the nominal implicit interest rate. In fiscal accounts, the stocks and flows don't exactly tally and the residual is captured in the stock-flow adjustment, s_t. The inclusion of s_t in the endogenous vector, y_t, would ensure that the debt-to-GDP ratio held as an identity. However, we omit this variable from the system we estimate. In part, this means that there is an additional source of uncertainty in the debt equation. Nevertheless, since it is not necessary to identify all the shocks in our system, we treat s_t as i.i.d.. We return to this assumption in the next section. The inclusion of the debt-to-GDP ratio means that as long as the estimated coefficient vector, $\widehat{\gamma}$, is non-zero, all the endogenous variables are allowed to respond to the debt-to-GDP ratio. Its inclusion in this way means that

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a change in the marginal cost of borrowing, evaluated at the steady state is:

$$\left.\frac{di_t^{average}}{di_t^{m\arg inal}}\right|_{D_t^{stock}=D^{stock}} = p$$

Thus, when $p = 1$, the marginal and average cost of borrowing coincide, but as the average maturity of the debt stock increases to infinity, the effect on the marginal cost of borrowing falls to 0.

[14] Using the model in the footnote above and setting $D_t^{stock} = D^{stock}$ and $D_t^{new} = pD^{stock}$ for $\forall t$ then:

$$i_t^{average} = (1-p)\, i_{t-1}^{average} + p i_t^{m\arg inal}$$

Let $i_t^{m\arg inal} = \begin{cases} i^{m\arg inal} + \sigma \text{ for } t=0 \\ i^{m\arg inal} \text{ for } t>0 \end{cases}$. Then it is straight forward to show that:

$$\sum\nolimits_{t=0}^{\infty} (i_t^{average} - i^{average}) = \sigma$$

which is independent of p, the maturity structure of the debt portfolio.

[15] At annual frequency, the lag length is important to pick up the serial correlation due to the maturity structure of government debt. As of 2010 [the data is taken from Faraglia, Marcet, and Scott (2011) who in turn source the OECD and The Economist], 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 countries in our sample was 7 years.

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.

the debt-to-GDP ratio also evolves endogenously in response to changes in y_t. We will see that the effect of a cost of borrowing shock on debt dynamics is an important channel through which fiscal policy reacts to the cost of borrowing shock.

3.1 Inference

Given the panel structure of our data set, we estimate the following model:

$$\widetilde{y}'_{it} = \sum_{j=1}^{L} \widetilde{y}'_{it-j} B_j + \gamma \widetilde{d}_{it-1} + \widetilde{\epsilon}'_{i,t} \tag{8}$$

where we use $L = 2$; $\widetilde{y}'_{it} = y'_{it} - \overline{y}'_i - \overline{y}'_t + \overline{y}'$, $\widetilde{d}_{it} = d_{it} - \overline{d}_i - \overline{d}_t + \overline{d}$and $\widetilde{\epsilon}'_{i,t} = \epsilon'_{it} - \overline{\epsilon}'_i - \overline{\epsilon}'_t + \overline{\epsilon}'$ for $i = 1, ..., N$ and $t = 1, ..., T$ are time and country demeaned endogenous variables and the associated reduced form errors, respectively, and $(B_1, ..., B_L) = \Phi'$ is the VAR regression coefficient matrix. The covariance matrix of the error term is Σ. To draw inferences about Φ and Σ we employ the Bayesian approach, which combines information from sample and priors. This is a useful approach since the size of our sample relative to the size of the VAR is not sufficiently large to justify the use of classical asymptotic theory. We make use of a non-informative prior that allows us to benefit from Bayesian analysis without the difficulty of obtaining an informative prior. In particular, we employ the commonly used diffuse prior which is a constant prior for Φ and the Jeffreys prior for Σ, which is proportional to the square root of the determinant of the Fisher information matrix:

$$f(\Phi, \Sigma) \propto \frac{1}{|\Sigma|^{(p+1)/2}}$$

where $p = 5$ is the number of endogenous variables in y_{it}.

The Bayes estimators are obtained via Monte Carlo (MC) simulations. By sampling (Φ, Σ) from the joint posterior distribution we can generate the Bayes estimates numerically. Let the OLS estimates of (Φ, Σ) be (B, S). With the standard diffuse (Jeffreys) prior, the posterior is:

$$\Sigma \sim IW\left[(NTS)^{-1}, NT - pL\right]$$

where Σ has an inverse Wishart distribution, which takes as its arguments $(NTS)^{-1}$, where NT is the number of observations and the degrees of freedom, $NT - pL$. And, given Σ:

$$vec(\Phi) \sim N\left[vec(B), \Sigma \otimes (X'X)^{-1}\right]$$

we obtain draws of Φ. To generate the error bands around our impulse responses, we ran 5000 MC iterations.[16]

3.2 Identification

The estimated model, in its reduced form [equation (8)], lacks economic structure. This is because the errors, $\widetilde{\epsilon}'$, that result from a one-step ahead forecast of the corresponding component of $\widetilde{y}'$ are likely to be non-orthogonal innovations as Σ is unlikely to be diagonal. To give the model, and the shocks, some economic structure, we must place some restrictions on the model, that turn the non-orthogonal innovations into orthogonal and economically interpretable shocks. We can do this by choosing a matrix G such that $G\Sigma G' = I$ since the new innovations, $v' = G\widetilde{\epsilon}'$ will satisfy $E(vv') = I$. These orthogonalized innovations have the convenient property that they are uncorrelated across equations. There are many such factorizations of Σ, so the choice of one particular method of orthogonalizing is not innocuous. The aim of the factorization is to impose an economic structural interpretation on these shocks.

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

There are several commonly used methods for recovering the structural equation parameters (identifying the shocks) present in the literature.[17] Most of these methods explicitly utilize parametric restrictions. In each case the restrictions free up enough instruments for the contemporaneous endogenous variables in the structural equations to enable the parameters of the structural equations to be estimated. The method employed here is that of sign restrictions (see Faust (1998), Uhlig (2005), and Canova and Nicoló (2002)) upon the impulse responses as a way of identifying shocks.

A cost of borrowing shock is a surprise change in the interest rate on government debt. We identify a cost of borrowing shock by imposing a positive reaction of the impulse response of the cost of borrowing for the year in which the shock occurs, and by requiring the shock to be orthogonal to two business cycle shocks and two fiscal policy shocks, which in turn are also identified using sign restrictions. If we were not to control for fiscal policy, for example, it would be easy to end up confusing changes in the cost of borrowing due to supply shocks (surprise changes in the supply of government bonds) with changes in the level of government borrowing due to demand shocks (surprise changes in the demand for government bonds).

Rather than simultaneously identifying all the shocks, subject to the orthogonality restrictions, we identify the business cycle and fiscal policy shocks first via a penalty function based on sign restrictions, thus ascribing as much movement as possible to these shocks. The cost of borrowing shock is then identified via sign restrictions as well as the orthogonality restrictions. The penalty function rewards large impulse responses with the right sign more than small responses and punishes responses that go in the wrong direction. Specifically, the penalty function follows Mountford and Uhlig (2009), which is the sum across the constrained responses:

$$f(x_h) = \begin{cases} -x_h & \text{if} \quad x > 0 \\ -100x_h & \text{if} \quad x \leq 0 \end{cases}$$

where, for a given sign restriction, x_h is the response of variable X at horizon h.[18] The penalty function therefore weakly rewards those that have the correct sign (first line) and strongly penalizes those responses that have the wrong sign (second line).

An overview of our identifying sign restrictions on the impulse responses is provided in Table 2. An aggregate demand shock is defined as a shock which jointly moves output, inflation and government revenue in the same direction for the year of the shock.[19] This restriction on the movement of government revenue is crucial for identifying the government revenue shock later. While there is debate in the literature on the numerical estimate of the income elasticity of tax revenue, the procyclicality is uncontroversial. Since we associate aggregate demand shocks with the predominant cause of business cycle fluctuations, we identify this shock first.

Second, we identify a cost-push shock which moves output and inflation in opposite directions. We also require the cost-push shock to be orthogonal to the aggregate demand shock. Shocks three and four are the primary expenditure and revenue shocks, respectively. Both are identified by assuming there is an impact multiplier (output moves positively to a primary expenditure shock and negatively to a revenue shock). These are orthogonal to shocks one and two but we do not require the two fiscal policy shocks to be orthogonal to each other. Again, we need to identify these shocks to ensure movements in the cost of borrowing that we identify as exogenous are not in fact an endogenous response to another type of shock. Thus, we

[17] For early contributions to this literature, see Sims (1980), Blanchard and Watson (1986) and Sims (1986). More recently, the literature has followed either the use of short-run identifying restrictions, see Christiano, Eichenbaum, and Evans (1999), or long-run identifying restrictions, see Blanchard and Quah (1993). An alternative approach to the structural VAR literature has been the narrative (or natural experiment) approach of Romer and Romer (1989).

[18] To be precise, a response, x is rescaled to adjust for the scale of the variable relative to the other variables in the VAR, and the sign of the response is flipped if a negative response is required.

[19] We try and impose the minimum amount of restrictions necessary. We therefore leave unrestricted the sign on responses in year 1 and beyond following the shock. Imposing restrictions in year 1 following the shock, however, does not materially affect our results.

Table 2: Contemporaneous Identifying Sign Restrictions

	Primary exp.-to-GDP	Revenue -to-GDP	GDP growth rate	Inflation rate	Cost of borrowing
Aggregate demand shock	·	(+)	(+)	(+)	·
Cost-push shock	·	·	(−)	(+)	·
Primary expenditure shock	(+)	·	(+)	·	·
Revenue shock	·	(+)	(−)	·	·
Cost of borrowing shock	·	·	·	·	(+)

Note: This table shows the sign restrictions on the impulse responses for each identified shock. (+) and (−) means that the impulse response of the variable in question is restricted to be positive and negative for the year of impact, respectively. · means no restriction has been imposed.

choose a set of sign restriction that is well established in the literature and does not place any restriction on the cost of borrowing. We want to leave the signs of the fiscal variables to a cost of borrowing shock unrestricted because this will protect us from imposing a restriction which mechanically forces the response of the fiscal variables to respond in a certain direction. The cost of borrowing shock is then identified only through restricting the impulse responses of the cost of borrowing variable and through the requirement that it be orthogonal to the aggregate demand, cost-push and two fiscal policy shocks. The main purpose of identifying these shocks prior to identifying the cost of borrowing shock is to filter out the effects of these shocks on the level of government debt and the price at which governments can borrow.

A natural concern may arise regarding the ordering in which shocks are identified under this scheme. How does the choice of ordering allow us, for example, to distinguish between shocks that are assumed to have the same effect on the same variables, such as the aggregate demand and primary expenditure shock?[20] 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 though, while switching the order is important for the identification of these two shocks, we found that the ordering of the first four shocks has almost no effect on the identification and impulse responses of the shock of interest, namely the cost of borrowing shock.

4 Results

This section presents the results from the 5 variable, 14 country panel VAR model. We have relegated the identified aggregate demand, cost-push and fiscal policy shocks, as well as their corresponding impulse responses to Appendix C. Figure 4 presents the identified cost of borrowing shocks, which are, by construction, orthogonal to the preceding four shocks.[21]

Figure 4 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. In fact, the time series of identified cost of borrowing shocks in Figure 4 might not appear as one might expect, since 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 the average cost of borrowing. While the marginal cost of borrowing (proxied by 10 year government bond yields, and shown in Figure 1) 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 much of the rise in governments' cost of borrowing

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

[21] Replication files for all the figures in this section, written in RATS code, is available from the corresponding authors homepage, http://sites.google.com/site/oliverdegroot/research

in recent years may have been driven by changes in governments' primary deficits and debt liabilities, and have not been the consequence of unanticipated cost of borrowing shocks.

Before commencing the formal analysis, 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 4 denote periods of fiscal consolidation as identified by the narrative approach developed in Devries, Guajardo, Leigh, and Pescatori (2011). The two measures appear to be weakly correlated. 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.

4.1 Baseline results

Figure 5 displays the impulse responses to a temporary cost of borrowing shock over a 10 year horizon. The responses have been normalized so that the cost of borrowing always rises by 1 percentage point. The initial level of the debt-to-GDP ratio will impact the impulse responses. In Figure 5 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. Finally, all the fiscal variables are measured in percentage points of GDP, while the interest rate and growth variables are measured in percent.

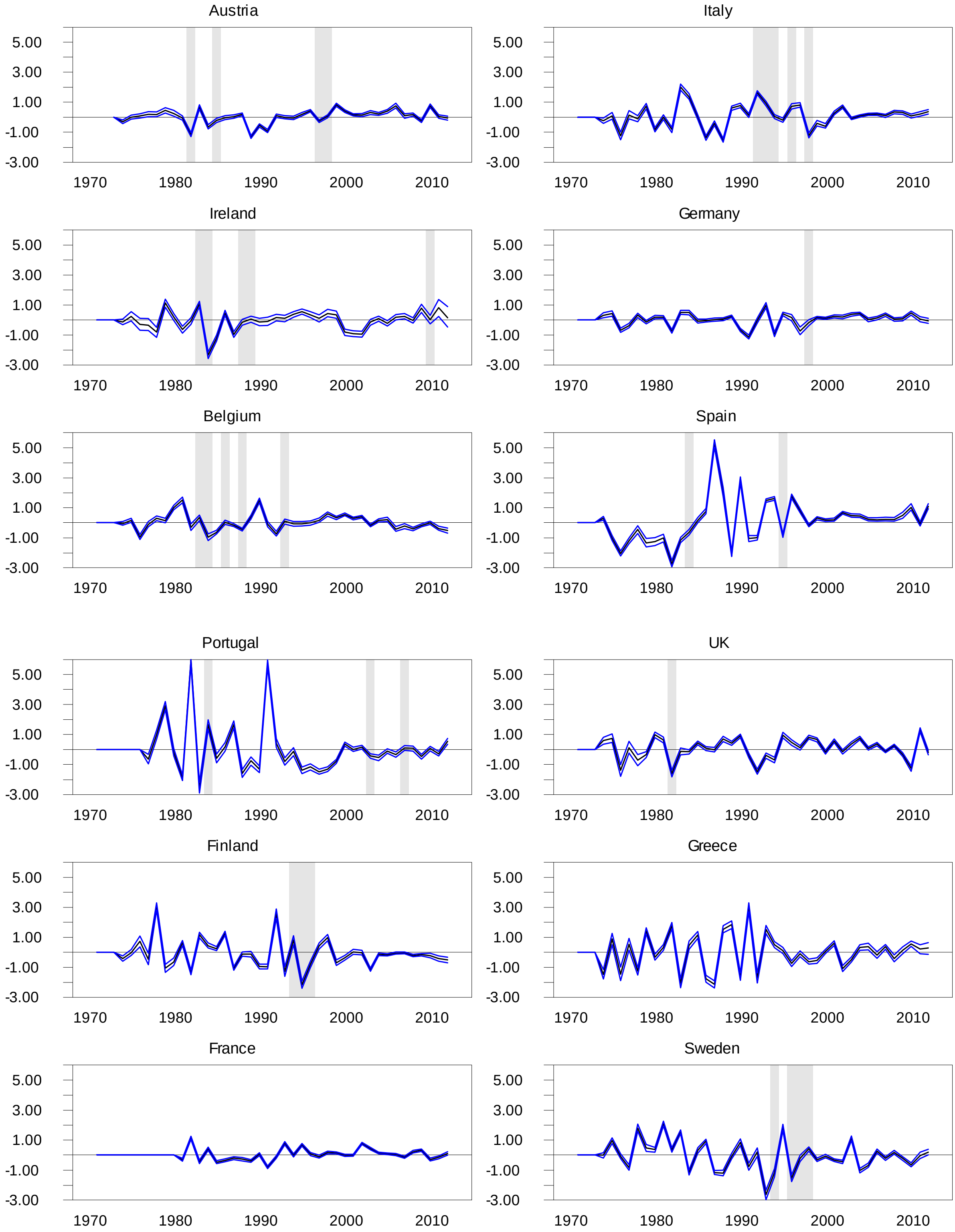
The impulse responses reveal four key results. First, the shock generates a relatively persistent effect on the nominal cost of borrowing, which takes 4 years to halve. Second, it is revenues rather than primary expenditures that react to the cost of borrowing shock, with the revenue-to-GDP ratio 0.2 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 0.19, 0.79 and 1.88 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 to 51.34% in year 6 and falls slightly to 51.13% by 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. The insignificant response of output growth suggests that shocks to the governments' cost of borrowing do not systematically affect private sector borrowing costs. The lack of a meaningful inflation response also suggests that we can be confident that we are not conflating a cost of borrowing shock with a movement in the yield curve due to a monetary policy shock (see below).

The addition of the governments' period budget constraint, in the form of the lagged debt-to-GDP ratio, generates a feedback mechanism in the vector autoregression model and potentially strong non-linearities in the responses to shocks. In particular, we find that the fiscal adjustment to a cost of borrowing shock is sensitive to the level of the debt-to-GDP ratio at the time of the shock. Figure 6 plots the impulse responses of the primary expenditure-, revenue-, primary balance- and debt-to-GDP ratios to a cost of borrowing shock with three different initial debt-to-GDP ratios, 20%, 80% and 140% respectively.

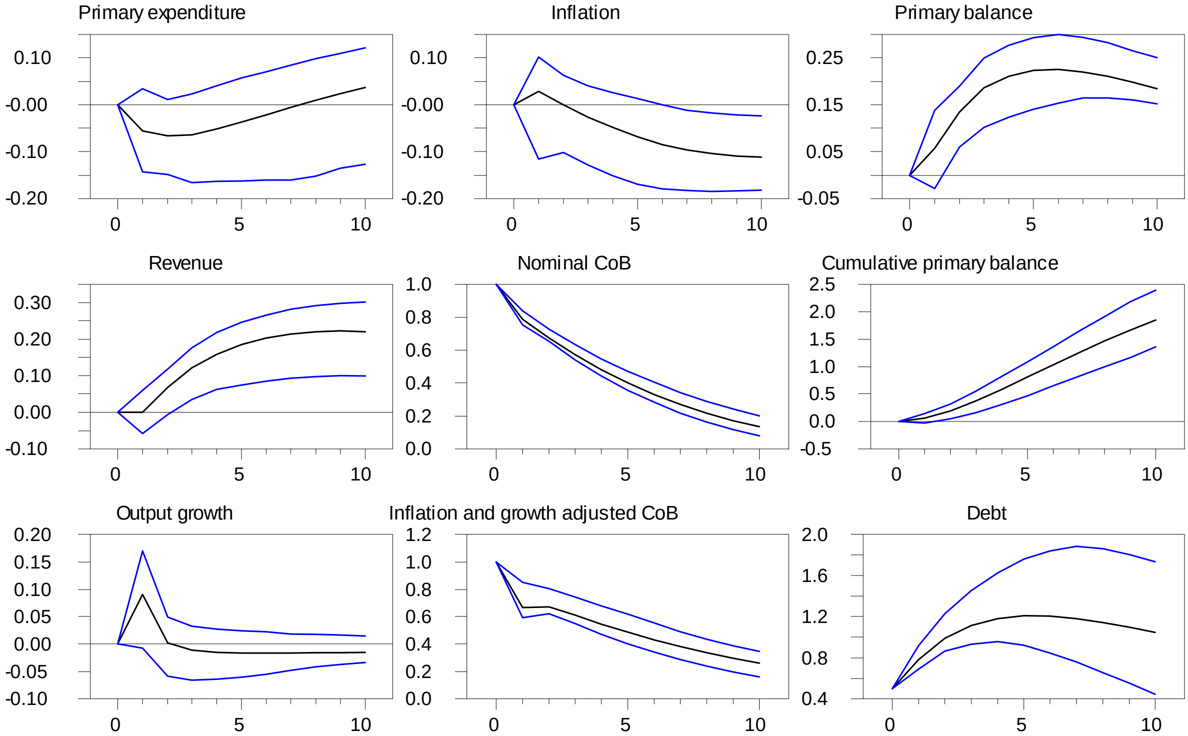
This scenario analysis shows two interesting patterns. First, countries with higher initial debt-to-GDP ratios make larger primary balance adjustments. The cumulative primary balance adjustment over 10 years is 3.58% of GDP for a country with a 140% debt-to-GDP ratio, relative to an adjustment of 1.79% for a country with a 50% debt-to-GDP ratio. Moreover, the median

Figure 4: Identified Cost of Borrowing Shocks



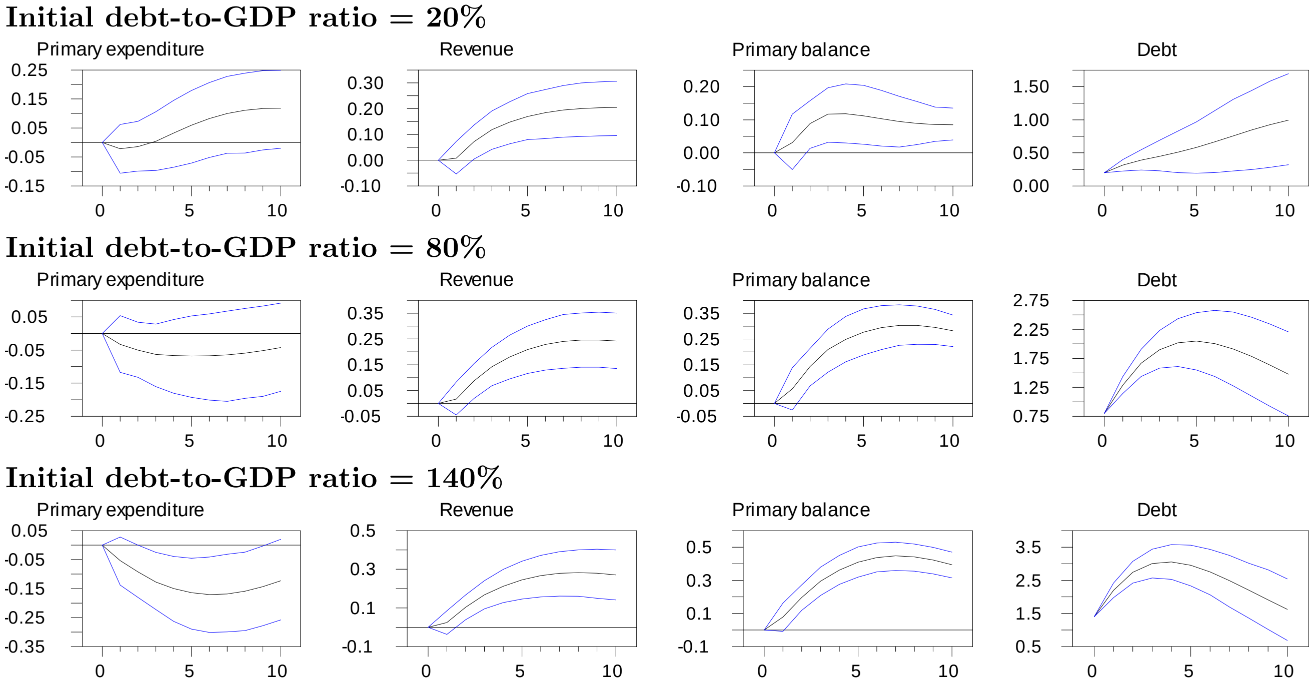
Note: The y-axis measures the identified cost of borrowing shock with a unit standard deviation, the x-axis measures time in years. The error bands are generated by Monte Carlo integration, showing the 14th, 50th and 86th percentiles. The shaded areas are periods of fiscal consolidation identified by the narrative approach in Devries, Guajardo, Leigh, and Pescatori (2011).

Figure 5: Impulse Responses to a Cost of Borrowing Shock



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 14th, 50th and 86th percentiles. Responses have been normalized to a 1 percentage point rise in the cost of borrowing. The debt-to-GDP ratio is initially 0.5.

Figure 6: Impulse Responses to a Cost of Borrowing Shock
Sensitivity to the Initial Debt-GDP Ratio



Note: Impulse responses to a cost of borrowing shock which raises the cost of borrowing 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 14th, 50th and 86th percentiles.

debt-to-GDP response leaves the debt-to-GDP ratio closer to its initial level after 10 years in the 140% initial debt-to-GDP ratio scenario than in the 80% 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, countries with high initial debt-to-GDP ratios generate fiscal adjustment 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.

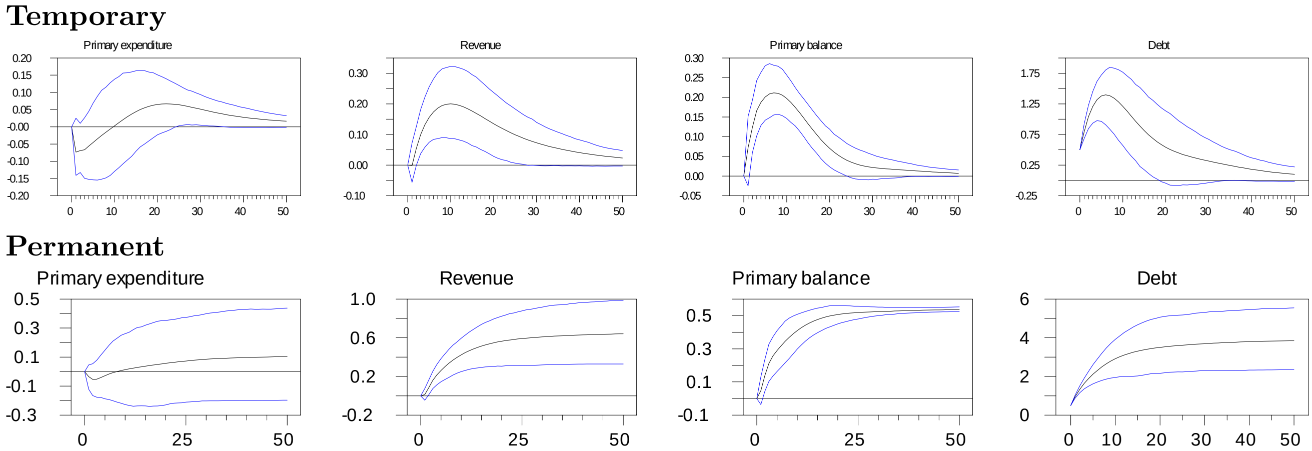
4.2 Temporary versus permanent shocks

The impulse responses to a cost of borrowing shock, presented above, cannot directly be compared with the theoretical model in Section 2. This is because the theoretical model considers a permanent shift up in the inflation and growth adjusted cost of borrowing, while Figures 5 and 6 plot the responses to a temporary (nominal) cost of borrowing shock. To draw a more direct comparison with our theoretical motivation, we plot the impulse responses to a temporary and permanent cost of borrowing shock in Figure 7 (setting the initial debt-to-GDP ratio at 50%). The temporary shock is the same as Figure 5, only that it has been plotted over a 50 year horizon. The permanent shock impulse responses are generated by hitting the model with a sequence of cost of borrowing shocks that ensure that the inflation and growth adjusted cost of borrowing rises by 1% in period 0 and remains at that level over the 50 year horizon.

Under this scenario of a permanent increase in the inflation and growth adjusted cost of borrowing, the primary balance rises to a new permanent level, 0.54 percentage points of GDP higher, while the debt to GDP ratio rises to 53.8%. These qualitative responses are in line with the *mild response* scenario presented in Section 2.

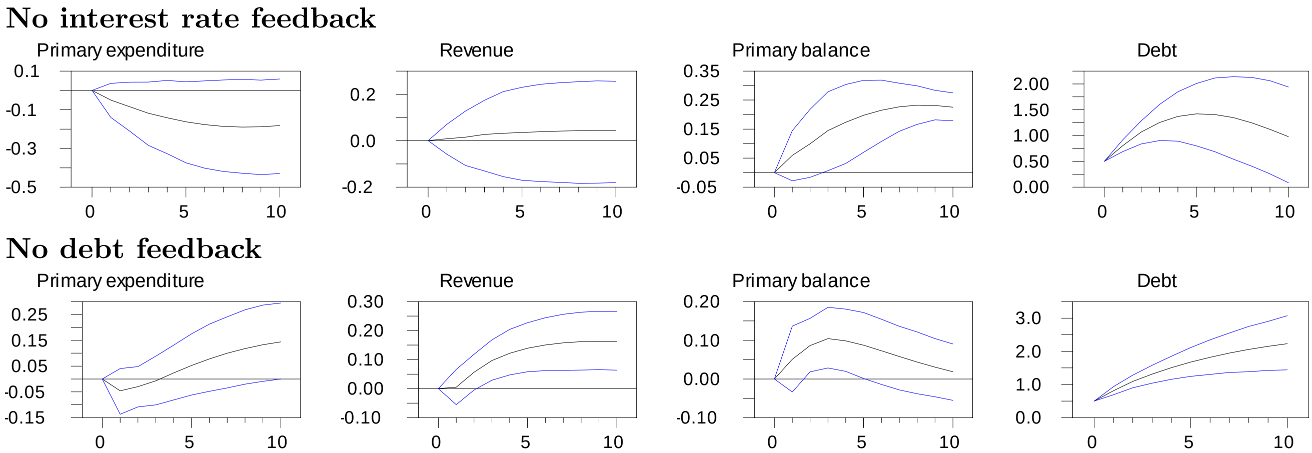
Since Bohn (1998), it has been common practice to describe the behavior of fiscal policy in

Figure 7: Impulse Responses to a Cost of Borrowing Shock
Temporary vs. Permanent shocks



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 14th, 50th and 86th percentiles.

Figure 8: Impulse Responses to a Cost of Borrowing Shock
No Debt 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 14th, 50th and 86th percentiles.

terms of a fiscal reaction function, with the primary balance reacting to fluctuations in output and debt. How much of the response of the primary balance to a cost of borrowing shock is a direct response to a change in the debt-to-GDP ratio, and how much is a reaction to a change in the cost of borrowing? To investigate this, we restrict the coefficients on the cost of borrowing and then the coefficients on the lagged debt-to-GDP ratio for the primary expenditure and revenue variables to zero. The impulse responses are presented in Figure 8.

The impulse response functions 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. Second, in the absence of interest rate feedback, the adjustment of the primary balance to a cost of borrowing shock becomes significantly positive with a longer lag. This suggests a fiscal reaction function does 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.

Table 3: Country Groupings

		EMU country	Average POLCON††† (1970-1994)	Average debt -to-GDP ratio (1970-2011)
1	Austria	Yes	High (0.78)	High (51%)
2	Belgium	Yes	High (0.87)	High (98%)
3	Germany	Yes	High (0.83)	Low (45%)
4	France	Yes	High (0.79)	Low (39%)
5	Finland	Yes	High (0.78)	Low (28%)
6	Greece	Yes†	Low (0.36)	Low (46%)
7	Ireland	Yes	Low (0.75)	High (68%)
8	Italy	Yes	Low (0.76)	High (67%)
9	Netherlands	Yes	High (0.83)	High (89%)
10	Portugal	Yes	Low (0.62)	High (60%)
11	Spain	Yes	Low (0.77)	Low (50%)
12	Denmark	No††	High (0.78)	Low (48%)
13	UK	No	Low (0.74)	High (51%)
14	Sweden	No	Low (0.76)	Low (49%)

Note: † Greece adopted the Euro in 2001. †† Denmark opted out of the Maastricht Treaty but remains in ERM II. ††† See Henisz (2000) for details.

4.3 Sample splits

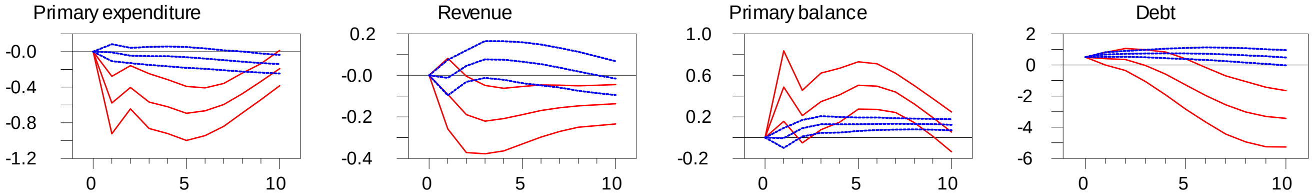
Thus far, we have considered the 14 countries as an homogenous block, restricting each country variable's responses to a cost of borrowing shock to be the same. While we lack sufficient degrees of freedom to estimate the model for each individual country, we can attempt to explain potential heterogeneity by sub-dividing our sample along several dimensions. The key results are reported in Figure 9. The countries which comprise each sub-group are reported in Table 3. Before discussing the findings, it is important to emphasize that these results may lack robustness and that we do not place too much weight on them. However, we think they are sufficiently interesting to warrant future research.

The first row of Figure 9 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 fiscal convergence 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 9 sub-divides the 14 countries based on a measure of political 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 9 for the two groups are supportive of the view that politically more constrained countries demonstrate more fiscal prudence. For

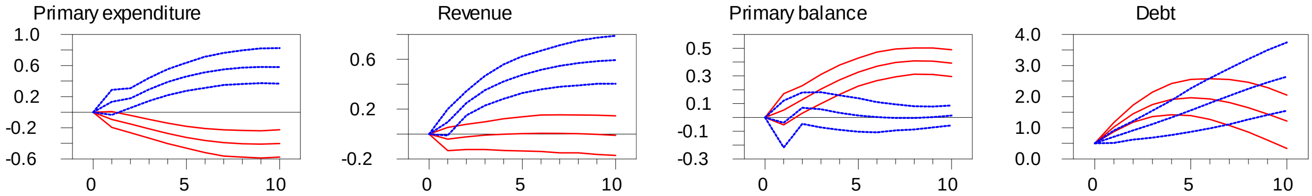
Figure 9: Impulse Responses to a Cost of Borrowing Shock
Heterogeneity across Sub-samples

Maastricht Treaty



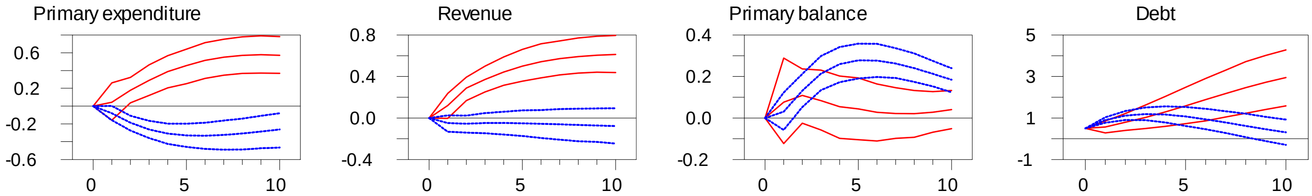
11 EMU countries only. Dotted blue = pre-1992 period, solid red = post-1992 period

Political constraints



Dotted blue = 7 least politically constrained countries, solid red = 7 most politically constrained countries

Government indebtedness



Dotted blue = 7 countries with least indebted governments, solid red = 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 14th, 50th and 86th percentiles.

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 9 sub-divides the 14 countries based on the historical indebtedness of the governments. Inference drawn from these impulse responses should be made with caution since there exists a potential endogeneity problem, from the impulse responses, back to the groupings. The responses reveal that the primary balance of highly indebted countries do not respond to cost of borrowing shocks, while those for the less indebted countries do respond positively. The median debt-to-GDP ratio of a highly indebted country rises by 2.7 percentage points rises, 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. The subsample estimation reveals that countries that have, on average, high debt-GDP ratios also display weak responses to cost of borrowing shock. The results from Figure 6, in contrast, 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 what is normal.

Table 4: Contemporaneous Identifying Sign Restrictions
8 equation VAR

	Primary exp.-to-GDP	Revenue -to-GDP	Stock-flow adj.	GDP growth rate	Inflation rate	Cost of borrowing	Short rate	Long rate
Aggregate demand shock	·	(+)	·	(+)	(+)	·	·	·
Cost-push shock	·	·	·	(−)	(+)	·	·	·
Primary expenditure shock	(+)	·	·	(+)	·	·	·	·
Revenue shock	·	(+)	·	(−)	·	·	·	·
Monetary policy shock	·	·	·	·	(−)	·	(+)	(+)
Stock-flow adj. shock	·	·	(+)	·	·	·	·	·
Cost of borrowing shock	·	·	·	·	·	(+)	·	(+)

Note: This table shows the sign restrictions on the impulse responses for each identified shock. (+) and (−) means that the impulse response of the variable in question is restricted to be positive and negative for the year of impact, respectively. · means no restriction has been imposed.

4.4 Expanding the model

The results presented thus far are the product of a 5 variable VAR. We next expand the model to include an additional 3 endogenous variables, the stock-flow adjustment in fiscal accounts, a short-term nominal interest rate and a long-term nominal interest rate. The impulse responses following a cost of borrowing shock are presented in Figure 10.

The net lending figure in fiscal accounts does not necessarily equal the change in the stock of debt.[22] In the above analysis, we treated the stock-flow adjustment as an exogenous i.i.d. shock process. Here we include it as an additional endogenous variable.

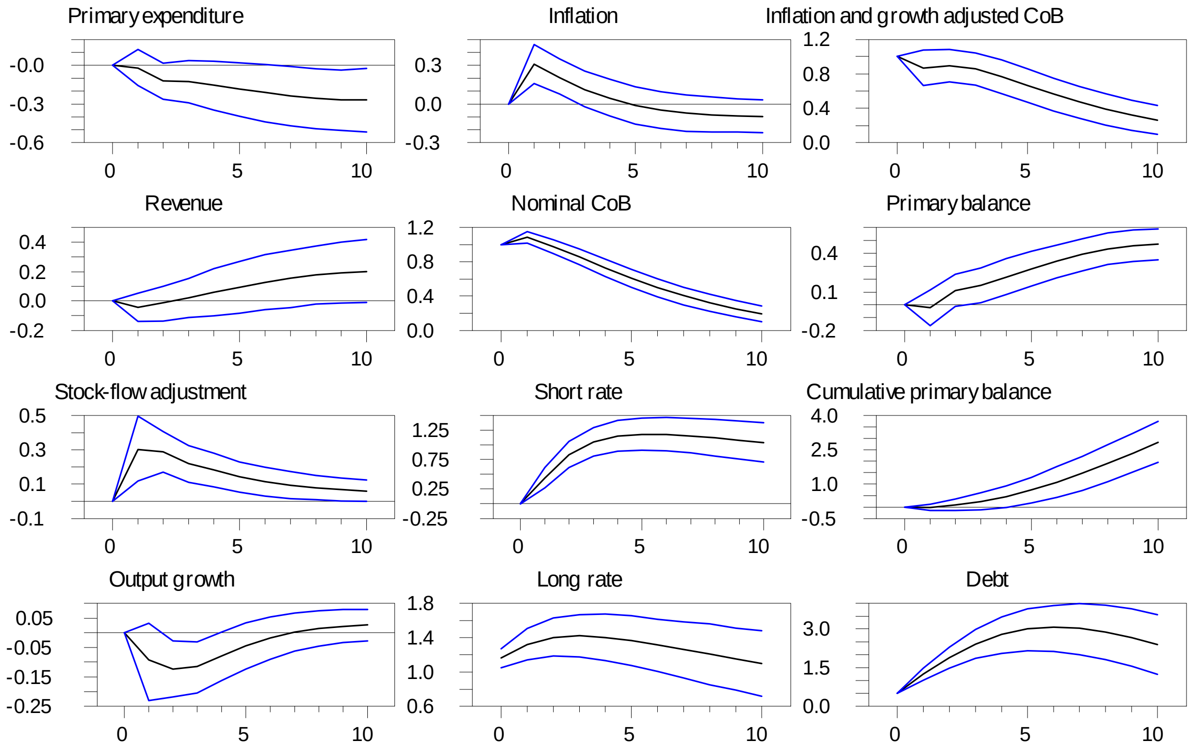
One of the notable omissions from the 5 variable VAR was any discussion of monetary policy. Unanticipated monetary policy shocks effect interest rates at both the short and the long end of the yield curve, Kuttner (2001). Including the short-term interest rate (3 month interbank rate) and a long-term interest rate (10 year government bond yield) allows us to identify a monetary policy shock, and ensure that the cost of borrowing shock we identify is orthogonal to the monetary policy shock. The identifying assumption are shown in Table 4. The first four shocks we identify are as before. The fifth shock we identify is the monetary policy shock. A monetary policy shock is identified by a contemporaneous increase in the short and long rates and a fall in the inflation rate, as well as being orthogonal to the preceding four shocks. Almost by construction though (due to the orthogonality restriction), the inflation rate is unchanged on impact. The sixth shock is the stock-flow adjustment, and the seventh is the cost of borrowing shock. While before, we identified the cost of borrowing shock simply by the orthogonality requirements to the preceding shocks, and the cost of borrowing rising, in this VAR, we identify the cost of borrowing shock as simultaneously increasing both the long rate and the nominal cost of borrowing.

Qualitatively, the responses in this expanded VAR are relatively similar to the 5 variable VAR. The response of the primary balance is greater rising to 0.49% of GDP at the end of the 10 year horizon. However, the rise in the debt-to-GDP ratio is also greater, with the median response reaching a maximum of 52.8% of GDP in year 6 following the shock. This is, in part, because the rise in the inflation and growth adjusted cost of borrowing is more persistent.

As one final experiment, we also test the robustness of our measure for the cost of borrowing. As discussed in Section 3, fiscal adjustment is likely to be a factor both of the marginal cost of

[22] This 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 istitutions, privatization receipts and the purchase of assets. During financial crises, it can thus become an important determinant of government debt developments.

Figure 10: Impulse Responses to a Cost of Borrowing Shock
8 variable VAR



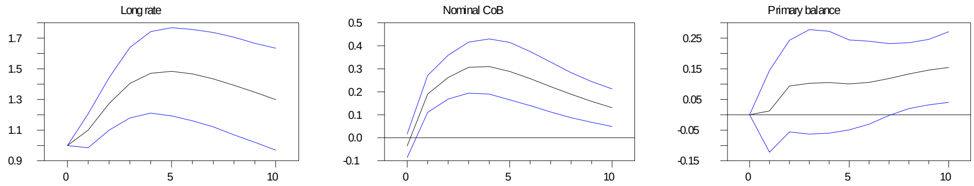
Note: The cost of borrowing shock is ordered seventh and orthogonal to the business cycle, fiscal and monetary policy shocks. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 14th, 50th and 86th percentiles. Responses have been normalized to a 1 percentage point rise in the cost of borrowing. The debt-to-GDP ratio is initially 0.5.

borrowing and the average cost of borrowing, and we conjectured a relationship between these two measures. In practice, the 10 year bond yield measure is only a proxy for the marginal cost of borrowing as governments can borrow using various bonds of different maturities. Thus, an increase in the 10 year bond yield is likely to over state the rise in the marginal cost of borrowing, unless there is a level shift in the entire yield curve. In any case, in Figure 11 we report the impulse responses to a cost of borrowing shock where we identify the cost of borrowing shock only as a rise in the long-term bond yield. It is clear that the true nominal cost of borrowing only increases with a lag, and that it increases by less than the increase in the long-term bond yield.[23] The result is a more modest fiscal response, with the primary balance not turning significantly positive until 7 years following the shock. This has been clear in the current debt crisis, that although bond yields have risen sharply for some countries, governments have delayed going to the market to refinance debt, or received financial support so that there true cost of borrowing has not risen very steeply.

We have applied several additional robustness checks to our estimates. These have included altering the identifying sign restrictions for various shocks, altering the order in which some of the shocks are identified, and altering the definition of some of the variables used. These additional robustness checks are available from the authors on request.

[23] If we use the response of the cost of borrowing in year 1 as our estimate of $di^{average}/di^{marginal}$ the we get an estimate of the average maturity of debt of $1/0.18 \approx 5.6$ years.

Figure 11: Impulse Responses to a 10yr Bond Yield Shock



Note: The cost of borrowing shock is ordered seventh and orthogonal to the business cycle, fiscal and monetary 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 14th, 50th and 86th percentiles. Responses have been normalized to a 1 percentage point rise in the 10 year bond yield. The debt-to-GDP ratio is initially 0.5.

5 Conclusions

This paper examines the response of fiscal policies to exogenous changes in the cost of public borrowing using a panel of European countries over four decades. Consistent with a simple theoretical model of fiscal behaviour, our results suggest that governments react to increases in the cost of borrowing by increasing their primary balances over several years. At the sample average, however, this response is not sufficiently strong to reduce the gross debt-to-GDP ratio 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 revenues side. At the same time, there is some tentative evidence that the magnitude of adjustment in response to a cost of borrowing shock increases with the size of the debt-to-GDP ratio. The larger the adjustment, the more recurrence to cutting expenditure is made.

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 of our sample. 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 enhance budgetary prudence. 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 Model appendix

A.1 Endogenizing the cost of borrowing

Assume that $r(t) = r(d(t-1); \sigma(t))$ where $r_1(.) > 0$. For simplicity, set the adjustment cost parameter, λ_1 in the loss function, equation (2) to zero. The first order condition is altered from:

$$-(b_t - b^*) + \lambda_2 (d_t - d^*) + \beta (1+r)(b_{t+1} - b^*) = 0$$

with r exogenous to:

$$-(b_t - b^*) + \lambda_2 (d_t - d^*) + \beta \left(1 + r + r' d_t\right)(b_{t+1} - b^*) = 0$$

with r endogenously dependent on the debt-to-GDP ratio. The first order condition is clearly non-linear, requiring an approximation of the models' dynamics around the steady state. The distance from the steady state and the curvature of the "supply curve", r_1 are important for determining the size of responses, but do not effect the qualitative results in the main text. All else equal, an increase in r_1 (the sensitivity of the cost of borrowing to the debt stock), the lower will be the steady state debt-to-GDP ratio. Further details are available on request.

A.2 A non-cooperative equilibrium

Suppose instead that there are two fiscal agents, who both care about the dynamics of the debt-to-GDP ratio, but have different preferences over the mix of fiscal instruments (government primary expenditures and revenues). For simplicity, again set $\lambda_1 = 0$.[24] The two fiscal agents' loss functions are:

$$\begin{aligned}
\mathcal{L}_t^G &= \sum_{t=0}^{\infty} \frac{1}{2}\beta^t \left[(g_t - g^*)^2 + \lambda_{2,G}(d_t - d^*)^2\right], \quad \lambda_{2,G} > 0, \quad \text{and} \\
\mathcal{L}_t^V &= \sum_{t=0}^{\infty} \frac{1}{2}\beta^t \left[(v_t - v^*)^2 + \lambda_{2,V}(d_t - d^*)^2\right], \quad \lambda_{2,V} > 0
\end{aligned}$$

respectively. Since the model is linear-quadratic, we can postulate the solutions are of the form $g_t = a + a_g g_{t-1} + a_v v_{t-1} + a_d d_{t-1}$ and $v_t = b + b_g g_{t-1} + b_v v_{t-1} + b_d d_{t-1}$, where $\underline{a}$ and $\underline{b}$ are two vectors of coefficients to be determined in equilibrium. Each fiscal agent then solves the usual Lagrangian, but adding the conjectured solution of the other fiscal agent as a constraint. The equilibrium solution is then computed by using the method of undetermined coefficients. Compared to the cooperative outcome, it can be shown that the speed of adjustment is always lower under non-cooperation and the steady state level of the debt-to-GDP ratio is always higher. Further details are available from the authors on request.

[24] The recent conflicts between the Republican and Democratic parties in the U.S. over raising the debt ceiling, and whether fiscal adjustment should be via raising taxes or cutting expenditures is a clear example of the non-cooperative game.

B Data appendix

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.
- *Cost of borrowing* in the benchmark estimation is the Implicit Interest Rate (AYIGD), which is calculated as the ratio of total interest payments in year t to the debt stock in period $t-1$. Alternatively we use the *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.
- *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.

C Preliminary results

This appendix contains the identified shocks and impulses responses of the 4 shocks of the 5 variable PVAR that we identify *before* the shock of interest - 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 14th, 50th and 86th 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 0.5.

C.1 Aggregate demand shock

The aggregate demand shock is identified first, requiring GDP growth, inflation and government revenue-to-GDP ratio to rise on impact. The identified aggregate demand shocks are plotted in Figure 12. 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 13. 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.[25] This elasticity is above the estimate used by the European Commission. However, Mertens and Ravn (2011) 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 temporary, 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.

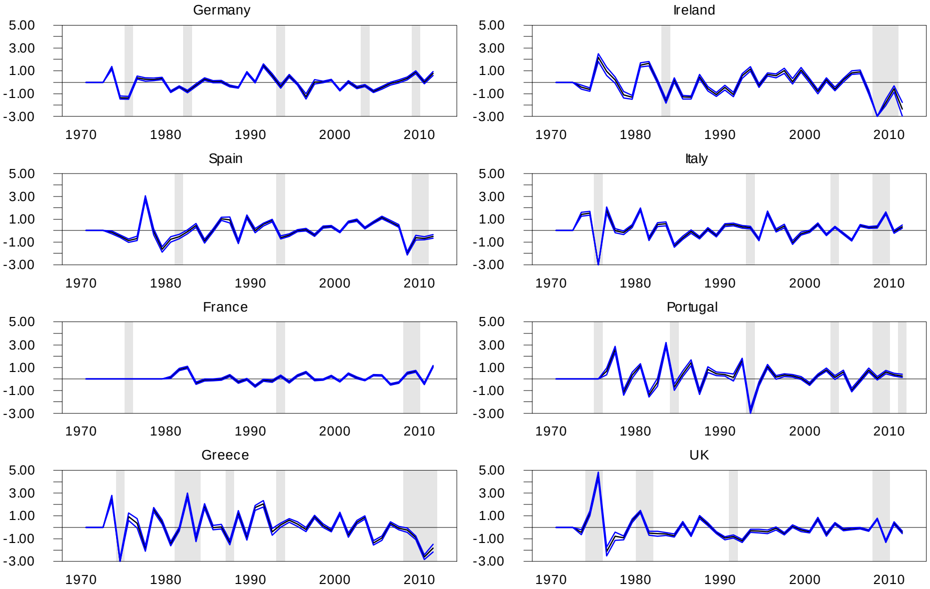
C.2 Cost-push shock

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 cost-push shocks are plotted in Figure 14. 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 an cost-push shock are plotted in Figure 15. 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 from 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 cost of borrowing falls moderately, the fall in inflation is more than twice the rise in output growth.

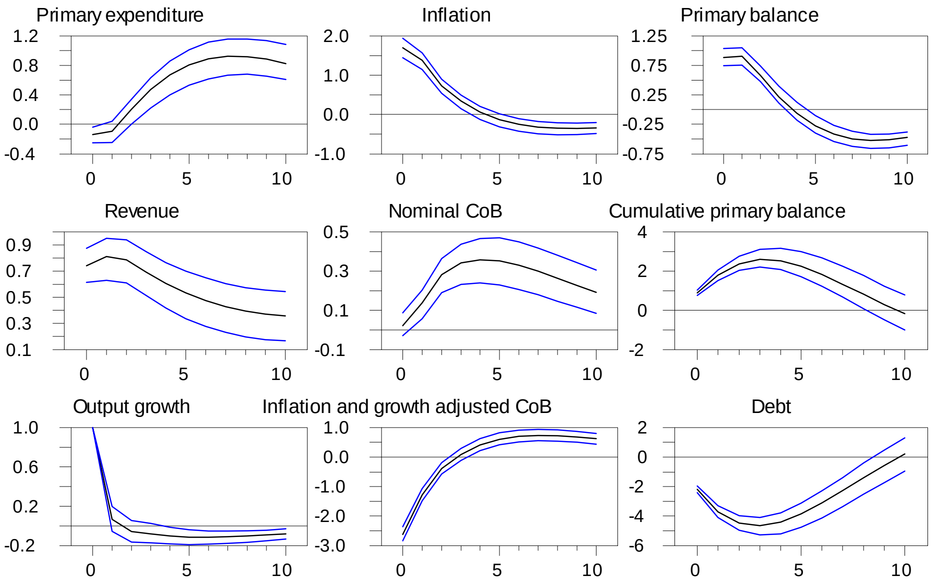
[25] The elasticity of revenues with respect to output is $\xi = \frac{\Delta R/R}{\Delta Y/Y}$. The model provides the following information: $\Delta Y/Y = 0.01$, $\Delta\left(R/Y\right) \approx 0.007$ and $R/Y \approx 0.45$. Using the approximation, $\Delta\left(R/Y\right)/\left(R/Y\right) \approx \Delta R/R - \Delta Y/Y$ 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 12: Identified Aggregate Demand Shocks



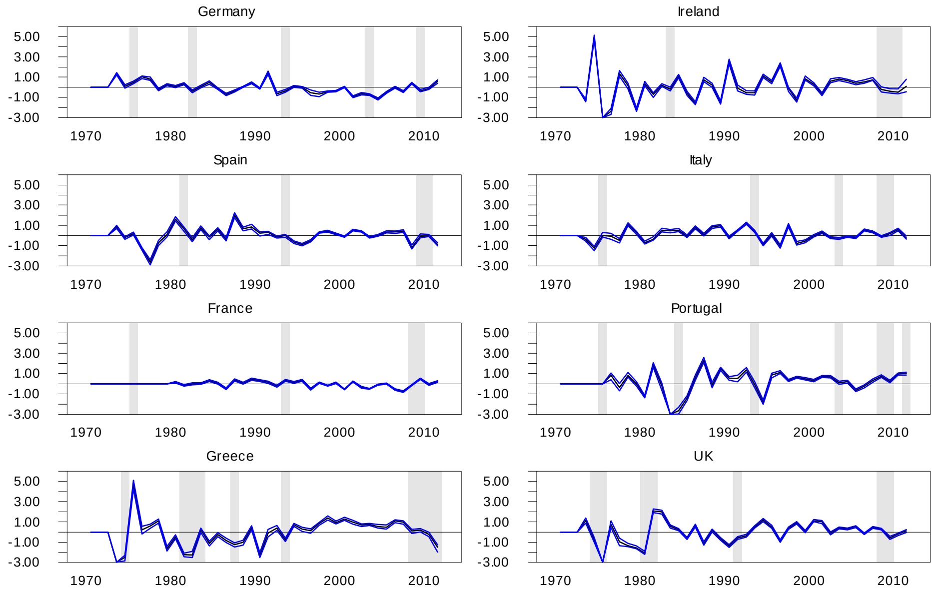
Note: The y-axis measures the identified aggregate demand shock with a unit standard deviation, the x-axis measures time in years. The error bands are generated by Monte Carlo integration, showing the 14th, 50th and 86th percentiles. The shaded areas are periods of recession.

Figure 13: Impulse Responses to an Aggregate Demand Shock



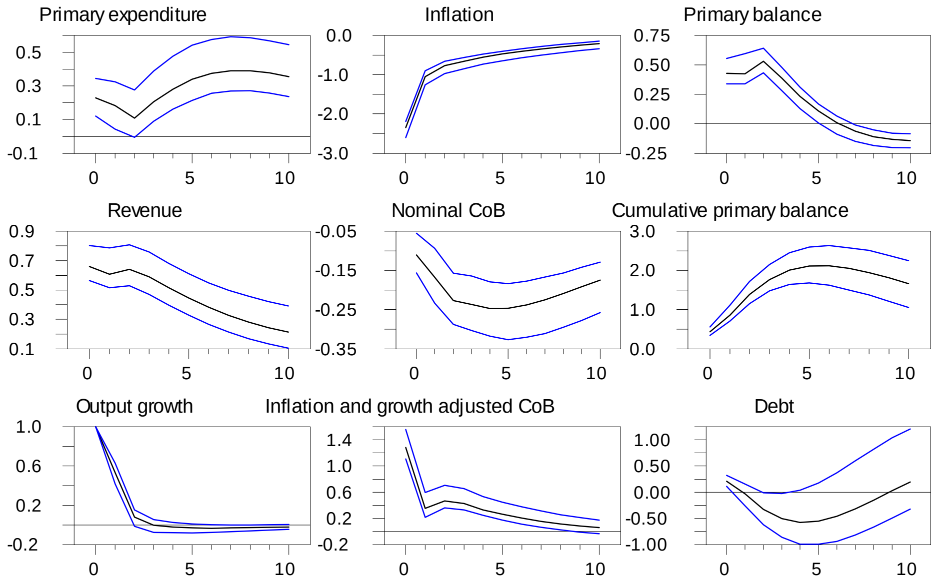
Note: The aggregate demand is ordered first. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 14th, 50th and 86th percentiles. Responses have been normalized to a 1 percentage point rise in the GDP growth rate. The debt-to-GDP ratio is initially 0.5.

Figure 14: Identified Cost-Push Shocks



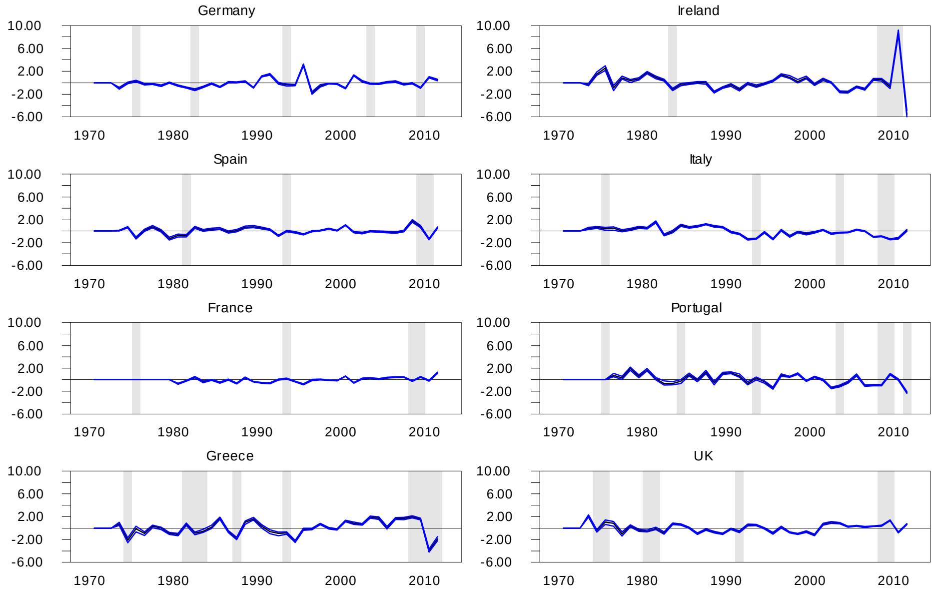
Note: The y-axis measures the identified cost-push shock with a unit standard deviation, the x-axis measures time in years. The error bands are generated by Monte Carlo integration, showing the 14th, 50th and 86th percentiles. The shaded areas are periods of recession.

Figure 15: 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 14th, 50th and 86th 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 16: 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 14th, 50th and 86th percentiles. The shaded areas are periods of recession.

C.3 Primary expenditure shock

The primary expenditure shock is identified (joint) third, 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 16. 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 an primary expenditure shock are plotted in Figure 17. The nominal cost of borrowing 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, Caselli, and Lane (2007). The 0.5 percentage point increase in the GDP growth rate corresponds to a government spending multiplier of 0.2, substantially below 1.[26] 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.

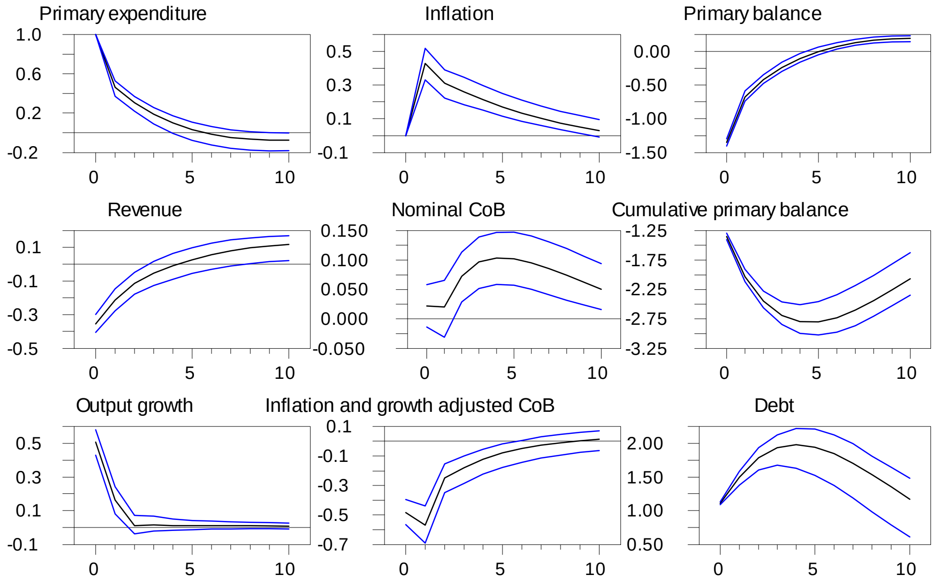
C.4 Government revenue shock

The government revenue shock is identified (joint) third, 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 the Section 4. The identified government revenue shocks are plotted in Figure 18.

The impulse responses to an government revenue shock are plotted in Figure 19. A 1 percentage point rise in the revenue-to-GDP ratio has a bigger impact on GDP growth than

[26] The government spending multiplier is $\xi = \frac{\Delta Y/Y}{\Delta E/E}$. The model provides the following information: $\Delta\left(E/Y\right) = 0.01$, $\Delta Y/Y \approx 0.005$ and $E/Y \approx 0.45$. Using the approximation, $\Delta\left(E/Y\right)/\left(E/Y\right) \approx \Delta E/E - \Delta Y/Y$ 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 17: Impulse Responses to a Primary Expenditure Shock

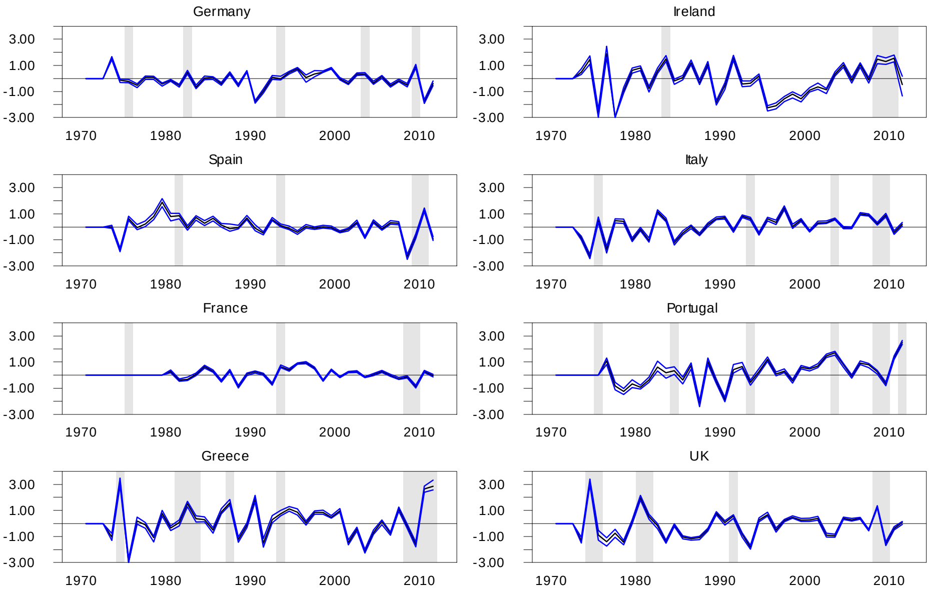


Note: The primary expenditure shock is ordered (joint) third and orthogonal to the two business cycle shocks. The y-axis is in percentage points, the x-axis is in years. The error bands are generated by Monte Carlo integration, showing the 14th, 50th and 86th percentiles. Responses have been normalized to a 1 percentage point rise in the primary expenditure-to-GDP ratio. The debt-to-GDP ratio is initially 0.5.

a 1 percentage point fall in the primary expenditure-to-GDP ratio. GDP growth falls by 1.5 percentage points on impact, implying a impact tax revenue multiplier of -2.1, which is substantially greater than -1.[27] 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.

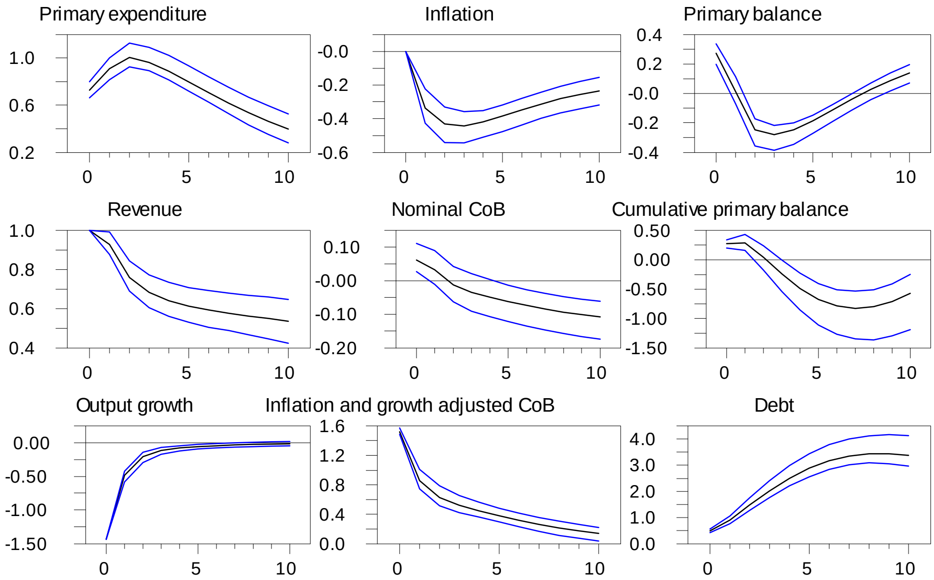
[27] The tax revenue multiplier is $\xi = \frac{\Delta Y/Y}{\Delta R/R}$. The model provides the following information: $\Delta\left(R/Y\right) = 0.01$, $\Delta Y/Y \approx -0.015$ and $R/Y \approx 0.45$. Using the approximation, $\Delta\left(R/Y\right)/\left(R/Y\right) \approx \Delta R/R - \Delta Y/Y$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

Figure 18: 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 14th, 50th and 86th percentiles. The shaded areas are periods of recession.

Figure 19: 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 14th, 50th and 86th 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.