



Level, slope, curvature of the sovereign yield curve, and fiscal behaviour

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ABSTRACT

We study fiscal behaviour and the sovereign yield curve in the US and Germany. We obtain the latent factors, level, slope and curvature, with the Kalman filter, and use them in a VAR with macro, fiscal and financial stress variables. In the US, fiscal shocks generate an immediate response of the short-end of the yield curve, associated with monetary policy, lasting 6–8 quarters, followed by a response of the whole yield curve lasting 3 years, with an implied elasticity of long-term yields of 80% for the government debt shock and 48% for the budget balance shock. In Germany, fiscal shocks have entailed no significant reactions of the yield curve shape and no response of the monetary policy interest rate, notably after 1999; only in the case of debt shocks there is a short-lived decrease in the medium-end of the yield curve in the following 2nd and 3rd quarters.

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1. Introduction

A relevant question, notably for policy makers, is to understand the dynamic relations between fiscal developments and the shape of the sovereign yield curve. A few studies have assessed the issue at specific time horizons. Nevertheless, an attempt at thoroughly uncovering the dynamic relations between fiscal policy developments and the whole shape of the yield curve seems to be lacking. It is well known from the finance literature that this shape may be parsimoniously represented by estimates of the level, slope and curvature of the yield curve. Such approach has been followed by a recent macro-finance literature mainly focused on non-fiscal macro variables, namely real output, inflation and the monetary policy rate.

In this paper, we use the macro-finance analytical framework and enrich the empirical model of the economy with variables representing fiscal policy as well as an additional variable related to financial factors, meant to control for the financial stress conditions faced by the economy. Our set of variables allows both for

a reasonable identification of the main policy shocks, and also for a study of the economy in the low-yield environment and the ensuing financial and economic crisis of 2008–2009.

More specifically, the paper contributes to the literature by empirically studying the dynamic relation between fiscal developments – government debt and the budget deficit – and the shape of the sovereign yield curves for the US and Germany. The shape of the yield curve is measured by estimates of the level, slope and curvature in the [Nelson and Siegel \(1987\)](#) tradition, following the state-space specification and maximum-likelihood estimation with the Kalman filter suggested by [Diebold and Li \(2006\)](#) and [Diebold et al. \(2006\)](#).

The yield curve latent factors and the fiscal variables are related in country-specific VAR macro-finance models that further comprise real output, inflation, the monetary policy interest rate and a financial conditions index. The evidence is based on impulse response function analysis, and forecast error variance decomposition.

Our contribution to the literature is threefold. First, we enhance the empirical framework of [Diebold et al. \(2006\)](#) including fiscal variables and a control for financial conditions, as well as estimating VAR models that are not *ex-ante* restricted in their lag length. Second, we add to the standard analyses of the relation between fiscal behaviour and sovereign yields accounting for the dynamic effects of fiscal policy on the full shape of the yield curve, rather than estimating the elasticity of a specific interest rate at a specific

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time-horizon. Third, our analysis allows for a direct comparison between the cases of the US and the biggest euro area economy.

The samples begin in the early 1980s and end in the last quarter of 2009, thus including at least two recessions (1992–1993, 2001) and the recent economic and financial crisis (2008–2009). Our choice of the sample period and control variables also allows us to take into account potential regime shifts such as the Volcker chairmanship of the FED (1979–1987) in the US, and for the case of Germany, the reunification, the approval of the Maastricht Treaty (in 1992), and the creation of the euro (in 1999).

Our results show that for the US fiscal shocks have generated an immediate response of the short-end of the yield curve, associated with the monetary policy reaction, lasting 6–8 quarters, and, subsequently, a response of the long-end of the yield curve, lasting 3 years. In Germany, overall budget balance shocks created no response from the yield curve shape; the only notable reaction – to shocks in the debt ratio – is some decrease in the medium-end and, albeit less, the long-end of the yield curve in the following 2nd and 3rd quarters. For Germany fiscal shocks have had significant impacts over the yield curve shape only before 1999.

The paper is organised as follows. Section two gives an overview of the literature. Section three explains the methodology to obtain the yield curve latent factors and the VAR specifications. Section four conducts the empirical analysis and section five concludes.

2. Literature overview

The literature on the relation between fiscal policy and interest rates has largely focused on long-term interest rates, under the *rationale* that changes in budget deficits and/or in government debt cause an adjustment in expected future short-term rates and, if the expectations hypothesis holds, an immediate change in long-term rates (following the *consensus* that long-term sovereign yields are mostly determined by expectations of inflation, (trend) growth and the budget deficit and government debt sustainability – see e.g. Canzoneri et al., 2002). While there are multiple theoretical channels motivating such *rationale* (beyond the scope of this paper), the empirical evidence remains somewhat mixed (see e.g. the surveys by Barth et al., 1991; Gale and Orszag, 2003; European Commission, 2004; and Terzi, 2007).

First, there seems to be a significant impact of budget deficits and government debt on long-term interest rates, especially in studies that use budget deficits and debt projections, rather than current fiscal data (see e.g. Canzoneri et al., 2002; Gale and Orszag, 2004; Laubach, 2009; Afonso, 2010; Hauner and Kumar, 2011). More recently, after the recent crisis actual fiscal developments may have reinforced their impact – Schuknecht et al. (2010) report that the interest rate effects of budget deficits and government debt were higher after the Lehmann default.

Second, the sensitivity of interest rates to fiscal variables seems to be smaller in Europe than in the US (see e.g. Codogno et al., 2003; Bernoth et al., 2006; Faini, 2006; Paesani et al., 2006; and, for event studies, Afonso and Strauch, 2007; and Ardagna, 2009). Third, the relation differs across different initial government debt ratios (see e.g. Faini, 2006; Ardagna, 2009; Ardagna et al., 2007). Fourth, the elasticity of interest rates to government debt seems to be significantly smaller than the elasticity to the budget deficit (see e.g. Laubach, 2009; Engen and Hubbard, 2005; Kinoshita, 2006; Chalk and Tanzi, 2002).

A recent subset of this literature has studied the convergence (divergence) of government bond yields in Europe, especially among the Euro Area countries, attributing a possible role to fiscal factors in such convergence (divergence). These studies have typically looked at 10-year government bonds (see e.g. Attinasi et al., 2009; Haugh et al., 2009; Sgherri and Zoli, 2009; Manganelli and

Wolswijk, 2009; Barrios et al., 2009, and Afonso and Rault, 2010), even when focusing on the relevance of fiscal events (see e.g. Codogno et al., 2003; and Afonso and Strauch, 2007). Another part of this research has focused on the determinants – including fiscal ones – of the long-term yield spreads between new European Union countries and other European states and benchmarks such as the US or the German bonds (see Nickel et al., 2009; Alexopoulou et al., 2009).

Some papers analysed other segments of the yield curve. Elmendorf and Reifschneider (2002), have compared the effect of several fiscal policy actions on the 10-year treasury yield and the monetary policy rate (Fed Funds rate), in order to disentangle the financial feed-backs from fiscal policy. Canzoneri et al. (2002) have studied the effect of projections of cumulative budget deficits on the spread between 5-year (or 10-year) and 3-month Treasury yields. Geyer et al. (2004) considered the spreads, relative to the German Bunds, of the yields of two and nine years government bonds of Austria, Belgium, Italy and Spain, which they related to a number of macro, fiscal and financial variables.

In addition, Ehrmann et al. (2011) used daily yields of maturities between 2 and 10 years to study the convergence of the shape of the yield curves of Italy and Spain with those of France and Germany after the EMU, looking at the first (level) and second (slope) principal components of the yield curve. However, they have not considered the very short-end maturities and did not explicitly relate the behaviour of the yield curves to fiscal variables.

Following Litterman and Scheinkman (1991), Diebold and Li (2006) and Diebold et al. (2006), a recent literature has focused on the unobserved components of the yield curve suggested by Nelson and Siegel (1987) rather than on yields at specific maturities.

Most of the analyses in this approach have focused on the relation between the yield-curve latent factors and monetary policy, inflation and real activity (see, for example, Carriero et al., 2006; Dewachter and Lyrio, 2006; Hordahl et al., 2006; Rudebusch and Wu, 2008; Hoffmaister et al., 2010). Such approach relates closely with the vast literature on the power of the yield curve slope (and possibly the curvature) to predict fluctuations in real economic activity and inflation – with the transmission mechanism largely involving monetary policy – as well as on the relation of the level with inflation expectations (see, for example, Ang et al., 2006; Rudebusch and Williams, 2008, and references therein).

While several studies such as Diebold et al. (2006) and Carriero et al. (2006) have used the Nelson–Siegel decomposition of the yield curve, a sub-class of the macro-finance literature has used affine arbitrage-free models of the yield curve. These models essentially enhance the Nelson–Siegel parsimonious approach with no-arbitrage restrictions (see e.g. Ang and Piazzesi, 2003; Diebold et al., 2005; Rudebusch, 2010, and the references therein).

Macro-finance analyses assessing the role of fiscal variables in the behaviour of the whole yield curve do not abound. An early example is Dai and Philippon (2006), who have developed an empirical macro-finance model for the US including, in the macro block, the monetary policy interest rate, inflation, real activity and the government budget deficit. The estimation of their over-identified no-arbitrage structural VAR allows them to conclude that government budget deficits affect long-term interest rates, albeit gradually and temporarily (with high long rates not necessarily turning into high future short-term rates). They estimate that a 1% point increase in the deficit ratio increases the 10-year rate by 35 basis points after 3 years, with fiscal policy shocks accounting for up to 13% of the variance of forecast errors in bond yields. Bikbov and Chernov (2010) have set-up a no-arbitrage affine macro-finance model of the yield curve, inflation, real activity and two latent factors. By means of a projection of the latent factors onto the macro variables, they extract the additional

information therein and interpret the projection residuals as monetary and fiscal shocks, in view of their correlation with a measure of liquidity and a measure of government debt growth. They find that real activity and inflation explain almost all (80%) of the variation in the short-term interest rate, while the exogenous monetary and fiscal shocks have a prominent impact on the short and long end of the yield curve, respectively.

Finally, a paper that is closer to ours – as it uses the Nelson–Siegel decomposition – is Favero and Giglio (2006). They studied the effects of fiscal policy on the spreads between the Italian government bond yields and the Germany yields, under a pre and a post-EMU regime of expectations about fiscal policy, for the period 1991:II–2006:I. Under unfavourable fiscal expectations, they estimate that for every 10% points of increase in the Italian debt ratio the yield curve level tends to increase by 0.43% points; and that such increase in the debt ratio would imply on average an increase of 0.25% points in the medium-term part of the yield curve.

3. Methodology

We contribute to the macro-finance literature by studying the relation between the shape of the sovereign yield curve and fiscal behaviour in a framework that is a development of the approach of Diebold et al. (2006). In addition to including a fiscal variable and a control for financial conditions, we estimate the VAR subsequently to the estimation of the yield curve factors (in the spirit of Diebold and Li (2006)), which avoids restricting its lag length. Our sample period and control variables allows us to take into account the impact of the creation of the euro area, the recent global low-yield period and the 2008–2009 financial crisis, as well as potential regime shifts such as the Volcker chairmanship of the FED (1979–1987) in the US, and in the case of Germany the reunification, the approval of the Maastricht Treaty (1992), and the creation of the euro (1999).

Regarding the computation of the yield curve three main latent factors – level, slope and curvature – we follow the parsimonious Nelson–Siegel approach to the modelling of the yield curve rather than an arbitrage-free approach. Our motivation is based on the arguments set out by Diebold and Li (2006, pp. 361–362) and Diebold et al. (2006, pp. 333), stating that it is not clear that arbitrage-free models are necessary or even desirable for macro-finance exercises; indeed, if the data abides by the no-arbitrage assumption, then the parsimonious but flexible Nelson–Siegel curve should at least approximately capture it, and, if this is not the case, then imposing it would depress the model's ability to forecast the yield curve and the macro variables.

Our methodological framework consists of two steps. First, the three yield curve latent factors are estimated by maximum likelihood using the Kalman filter, as in Diebold et al. (2006). Second, we estimate country-specific VARs with the latent yield curve factors, the traditional macroeconomic variables – output, inflation and the overnight interest rate – a financial control variable – a financial stress index (FSI) – and a fiscal variable – the budget balance ratio or the change in the debt-to-GDP ratio. Then, the analyses of the VAR dynamics, in particular of innovations to the fiscal variable, allow us to address the question that motivates the paper.

3.1. The yield curve latent factors

We model the yield curve using a variation of the three-component exponential approximation to the cross-section of yields at any moment in time proposed by Nelson and Siegel (1987),

$$y(\tau) = \beta_1 + \beta_2 \left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau} \right) + \beta_3 \left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau} \right), \quad (1)$$

where $y(\tau)$ denotes the set of (zero-coupon) yields and τ is the corresponding maturity.

The Nelson–Siegel representation is interpreted as a dynamic latent factor model where β_1 , β_2 and β_3 are time-varying parameters that capture the level (L), slope (S) and curvature (C) of the yield curve at each period t , while the terms that multiply the factors are the respective factor loadings:

$$y_t(\tau) = L_t + S_t \left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau} \right) + C_t \left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau} \right). \quad (2)$$

Clearly, L_t may be interpreted as the overall level of the yield curve, as its loadings are equal for all maturities, but is typically associated to the long-end of the curve as the other two latent factors both have a zero load at the longer maturities. The loadings of factor S_t have a maximum (equal to 1) at the shortest maturity and then monotonically decay toward zero as maturities increase, while the loadings of factor C_t are null at the shortest maturity, increase until a maximum at the middle of the maturity spectrum and then fall back to zero as maturities increase. Hence, S_t and C_t may be interpreted as the short-end and medium-term latent components of the yield curve, with the coefficient λ ruling the rate of decay of the loading of the short-term factor and the maturity where the medium-term one has maximum loading.¹

Both S_t and L_t have intuitive interpretations and explanations, that render their association to macro variables relatively straightforward: the slope has been associated with changes in the risk-free interest rate and, thus, the reaction of monetary policy to the cyclical state of the economy; the level has been typically associated with the long-run nominal anchor, namely the target (and expectations) for inflation. Conversely, C_t , the varying second derivative of the yield curve, is harder to interpret and explain. The hump at intermediate maturities of a typical concave yield curve means that the market values the risk of intermediate maturities *vis-à-vis* short maturities more than it values the risk of long maturities *vis-à-vis* intermediate maturities (the dip in a convex curve means that the spread of intermediate *vis-à-vis* short maturities is smaller than the spread of long *vis-à-vis* intermediate maturities).

Therefore, the assessment of risk and the shape and intensity of the curvature, depend on several factors. While many are hard to pin-down, the short-term interest rate is a factor known to affect the curvature: the higher the short-rate volatility, the more concave is the yield curve (although not immune to it, the slope is far less affected by short-rate volatility). The macro-finance literature has not established, so far, a clear association between the yield curvature and any specific macroeconomic or policy variable.²

As in Diebold et al. (2006), we assume that L_t , S_t and C_t follow a vector autoregressive process of first order, which allows for casting the yield curve latent factor model in state-space form and then using the Kalman filter to obtain maximum-likelihood estimates of the hyper-parameters and the implied estimates of the parameters L_t , S_t and C_t .

The state-space form of the model comprises the transition system

¹ Diebold and Li (2006) assume $\lambda = 0.0609$, which corresponds to a maximum of the curvature at 29 months, while Diebold et al. (2006) estimate $\lambda = 0.077$ for the US in the period 1970–2001, with Fama–Bliss zero-coupon yields, which corresponds to a maximum curvature at 23 months.

² For instance, for a butterfly portfolio (long in an intermediate maturity, “body”, and short in smaller and larger maturities, “wings”), a way to hedge the risk is via the Nelson and Siegel (1987) model. One computes the level, slope and curvature durations of the butterfly, and then constructs semi-hedged strategies. An investor structuring a fifty-fifty weighting butterfly (selling the body and buying the wings) can bet on a steepening move of the yield curve while being hedged against the curvature risk (see Martellini et al., 2003).

$$\begin{pmatrix} L_t - \mu_L \\ S_t - \mu_S \\ C_t - \mu_C \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mu_L \\ S_{t-1} - \mu_S \\ C_{t-1} - \mu_C \end{pmatrix} + \begin{pmatrix} \eta_t(L) \\ \eta_t(S) \\ \eta_t(C) \end{pmatrix}, \quad (3)$$

where $t = 1, \dots, T$, μ_L , μ_S and μ_C are estimates of the mean values of the three latent factors, and $\eta_t(L)$, $\eta_t(S)$ and $\eta_t(C)$ are innovations to the autoregressive processes of the latent factors.

The measurement system, in turn, relates a set of N observed zero-coupon yields of different maturities to the three latent factors, and is given by

$$\begin{pmatrix} y_t(\tau_1) \\ y_t(\tau_2) \\ \vdots \\ y_t(\tau_N) \end{pmatrix} = \begin{pmatrix} 1 & \frac{(1-e^{-\lambda\tau_1})}{\lambda\tau_1} & \frac{(1-e^{-\lambda\tau_1})}{\lambda\tau_1} - e^{-\lambda\tau_1} \\ 1 & \frac{(1-e^{-\lambda\tau_2})}{\lambda\tau_2} & \frac{(1-e^{-\lambda\tau_2})}{\lambda\tau_2} - e^{-\lambda\tau_2} \\ \vdots & \vdots & \vdots \\ 1 & \frac{(1-e^{-\lambda\tau_N})}{\lambda\tau_N} & \frac{(1-e^{-\lambda\tau_N})}{\lambda\tau_N} - e^{-\lambda\tau_N} \end{pmatrix} \begin{pmatrix} L_t \\ S_t \\ C_t \end{pmatrix} + \begin{pmatrix} \varepsilon_t(\tau_1) \\ \varepsilon_t(\tau_2) \\ \vdots \\ \varepsilon_t(\tau_N) \end{pmatrix} \quad (4)$$

where $t = 1, \dots, T$, and $\varepsilon_t(\tau_1)$, $\varepsilon_t(\tau_2)$, \dots , $\varepsilon_t(\tau_N)$ are measurement errors, i.e. deviations of the observed yields at each period t , and for each maturity τ , from the implied yields defined by the shape of the fitted yield curve. In matrix notation, the state-space form of the model may be written, using the transition and measurement matrices A and Λ as

$$(f_t - \mu) = A(f_{t-1} - \mu) + \eta_t, \quad (5)$$

$$y_t = \Lambda f_t + \varepsilon_t. \quad (6)$$

For the Kalman filter to be the optimal linear filter, it is assumed that the initial conditions set for the state vector are uncorrelated with the innovations of both systems:

$$E(f_t \eta_t') = 0 \text{ and } E(f_t \varepsilon_t') = 0$$

Furthermore, it is assumed that the innovations of the measurement and of the transition systems are white noise and mutually uncorrelated

$$\begin{pmatrix} \eta_t \\ \varepsilon_t \end{pmatrix} \sim WN \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} Q & 0 \\ 0 & H \end{pmatrix} \right] \quad (7)$$

and that while the matrix of variance–covariance of the innovations to the transition system Q is non-diagonal, the matrix of variance–covariance of the innovations to the measurement system H is diagonal – which implies the assumption, rather standard in the finance literature, that the deviations of the zero-coupon bond yields at each frequency from the fitted yield curve are not correlated with the deviations of the yields of other maturities.

Given a set of adequate starting values for the parameters (the three latent factors) and for the hyper-parameters (the coefficients that define the statistical properties of the model, such as, e.g., the variances of the innovations), the Kalman filter may be run from $t = 2$ through $t = T$ and the one-step-ahead prediction errors and the variance of the prediction errors may be used to compute the log-likelihood function. The function is then iterated on the hyper-parameters with standard numerical methods and at its maximum yields the maximum-likelihood estimates of the hyper-parameters and the implied estimates of the time-series of the time-varying parameters L_t , S_t and C_t . These latent factors are then recomputed with the Kalman smoother, which uses the whole dataset information to estimate them at each period from $t = T$ through $t = 2$ (see Harvey, 1989, for details on the implementation of the Kalman filter and smoother).

3.2. Setting up the VAR

We estimate a VAR model for the above-mentioned set of countries. The variables in the VAR are: inflation (π), GDP growth (Y), the fiscal variable (f), which can be either the government debt or the budget deficit, the monetary policy interest rate (i), an indicator for financial market conditions (fsi), and the three yield curve latent factors, level (L), slope (S), and curvature (C).

The VAR model in standard form can be written as

$$\mathbf{X}_t = \mathbf{c} + \sum_{i=1}^p \mathbf{V}_i \mathbf{X}_{t-i} + \varepsilon_t, \quad (8)$$

where \mathbf{X}_t denotes the (8×1) vector of the m endogenous variables given by $\mathbf{X}_t \equiv [\pi_t \ Y_t \ f_t \ i_t \ fsi_t \ L_t \ S_t \ C_t]'$, \mathbf{c} is a (8×1) vector of intercept terms, \mathbf{V} is the matrix of autoregressive coefficients of order (8×8) , and the vector of random disturbances ε_t . The lag length of the endogenous variables, p , will be determined by the usual information criteria.

The VAR is ordered from the most exogenous variable to the least exogenous one, and we identify the various shocks in the system relying on the simple contemporary restrictions given by the Choleski triangular factorization of the variance–covariance matrix. As it seems reasonable to assume that the financial variables may be affected instantaneously by shocks to the macroeconomic and fiscal variables but these are not affected contemporaneously by the financial variables, we place the financial stress indicator and the yield curve latent factors in the four last positions in the system. In the position immediately before the financial variables we have the monetary policy interest rate, which may react contemporaneously to shocks to inflation, output and the fiscal variable but does not impact contemporaneously any of those variables, due to the well-known monetary policy lags. Finally, we assume that macroeconomic shocks (to inflation and output) may impact instantaneously the fiscal policy variable – because of the automatic stabilizers – but that fiscal shocks do not have any immediate macroeconomic effect – again due to policy lags – and thus place the fiscal policy variable in the third position in the system.

4. Empirical analysis

4.1. Data

We develop our VAR analyses for the US and for Germany using quarterly data for the period 1981:1–2009:4. The quarterly frequency is imposed by the availability of real GDP and fiscal data, and the time span is limited by the availability of the indicator of financial stress but is also meant to avoid marked structural breaks.

Given that zero coupon rates can be collected or computed for a longer time span and are available at a monthly frequency, the computation of the latent factors of the yield curves used data for 1961:6–2010:2 and 1972:9–2010:3 respectively for the US and for Germany (all data sources are described in the Appendix). We then computed quarterly averages for the time-varying estimates of the yield curves latent factors and taken the estimates since 1981:1 for the VAR analyses.

To compute the three yield curve factors (level, slope, curvature) we used zero-coupon yields for the 17 maturities in Diebold et al. (2006). The shortest maturity is 3 months and the longest 120 months.

Interestingly, the foreign holdings of US long-term government debt seem to be preferred by Asian investors. For instance, on June 2010, China and Japan were responsible for around 37% of the value of foreign holdings of sovereign long-term US securities (44%

when Taiwan, Singapore, and Hong-Kong are added). On the other hand, foreign holdings of US long-term sovereign securities by the EU countries added to around 21%. Regarding the foreign holdings of sovereign long-term German securities the corresponding shares in 2008 were around 72% and 15% respectively for the EU and for the main Asian holders.³ In addition, German Bunds are the accepted benchmark in the EU, with the yield spreads for the EU countries usually computed vis-à-vis the German yield, as such debt is seen as safe haven in the EU notably in periods of financial stress.⁴

We use the following macroeconomic variables (all expressed in percentage points): real GDP growth, inflation rate (GDP deflator) and the market interest rate closest to the monetary policy interest rate (namely the Fed Funds Rate, for the US, and the money market overnight interest rate published by the Bundesbank, for Germany).

To control for the overall financial conditions we use the March 2010 update of the financial stress index (FSI) suggested by Bala-krishnan et al. (2009). The FSI is computed considering seven financial variables and gives a composite overview of the overall financial conditions faced by each individual country. Given its composite nature, it is not expressed in percentage points: prior to their aggregation, the seven sub-indexes are demeaned and standardised, so that one unit is equivalent to one standard deviation of the sub-index. Hence, a value of 1 for the FSI indicates a one-standard deviation from average conditions across sub-indices. Zero values imply neutral financial market conditions on average across the sub-indices, negative values correspond to loose financial conditions (*i.e.* prices are on average below means or trends), and positive values imply financial stress (a value of 1 or higher has in the past been associated with a crisis).⁵

Finally, in order to integrate fiscal developments in the VAR analysis, we use, for each country, data for government debt and also for the government budget balance (ratios to GDP, in percentage points). For the case of the US we employ the Federal debt held by the public, as well as Federal Government and expenditure. For the case of Germany we use central, state and local government debt and total general government spending and revenue (see Appendix A).

4.2. Fitting the yield curve

For the 17 maturities considered in Diebold et al. (2006), vectors y_t and ε_t have 17 rows, matrix Λ has 17 rows and H has 17 columns/rows (see Eqs. (6 and 7)). Moreover, there is a set of 19 hyper-parameters that is independent of the number of available yields and, thus, must be estimated: nine elements of the (3×3) transition matrix A , three elements of the (3×1) mean state vector

μ , 1 element (λ) in the measurement matrix Λ and six different elements in the (3×3) variance-covariance matrix of the transition system innovations Q . In addition to these 19 hyper-parameters, those in the main diagonal of the matrix of variance-covariance of the measurement innovations H must also be estimated. For example, in the case of the US, where we have collected data for the 17 benchmark maturities, there are 17 additional hyper-parameters – which imply that the numerical optimisation involves, on the whole, the estimation of 36 hyper-parameters.

As regards the latent factors model assumed for the yield curve, it could be argued that, since the zero-coupon data used in this study are overall generated with the Svensson (1994) extension to the Nelson and Siegel (1987) model – see *e.g.* Gurkaynak et al. (2007), for the US case – the model should include the fourth latent factor (and the second λ coefficient). This coefficient allows the Svensson model to capture a second hump in the yield curve at longer maturities than the one captured by the Nelson–Siegel λ and the curvature factor C_t . However, this question turns out to be irrelevant in our case, because – following the vast majority of the macro-finance models in the recent literature – we consider yields with maturities only up to 120 months, as the rather small liquidity of sovereign bonds of longer maturities precludes a reliable estimation of the respective zero-coupon bonds. When present, the second hump that the Svensson extension of the Nelson–Siegel is meant to capture occurs at maturities well above 120 months. In fact, the first three principal components of our zero-coupon yield data explain, for both countries, more than 99% of the variation in the data. Moreover, fitting a model with four principal components would result in estimating a fourth factor with a loading pattern that is quite close to that of the third one.

4.2.1. US

We now present the estimation results for the model of level, slope and curvature in the case of the US. As regards hyper-parameters, we restrict the analysis to λ and the implied loadings for the latent factors.⁶

The estimate of λ (significant at 1%) is 0.03706, which implies a maximum of the medium-term latent factor – the curvature, C_t – at the maturity of 48 months and a rather slow decay of the short-term factor – the slope, S_t . Fig. 1 shows the loadings of the three latent factors implied by our estimate of λ . The difference to the estimate in Diebold et al. (2006) and the assumption in Diebold and Li (2006) – which imply maximums of C_t at 23 and 29 months, respectively – is due to differences in the sample period and in the method of computation of the zero-coupon yields.

Fig. 2 shows the time-series of the three yield curve latent factors, L_t , S_t and C_t computed with the Kalman smoother, after convergence of the maximum-likelihood estimation. The pattern of all factors is quite similar to the one seen in the related literature. The level shows the gradual rise in all yields in the build-up of the inflationary environment of the 1960s–1970s, the peak in the yields associated to the 1979–1982 inflation reduction (contemporaneous of the Volcker chairmanship of the FED), the gradual but steady fall in overall yields since the beginning of the great moderation in 1984 and the recent increase in the yields ahead and after the 2008–2009 financial crisis.

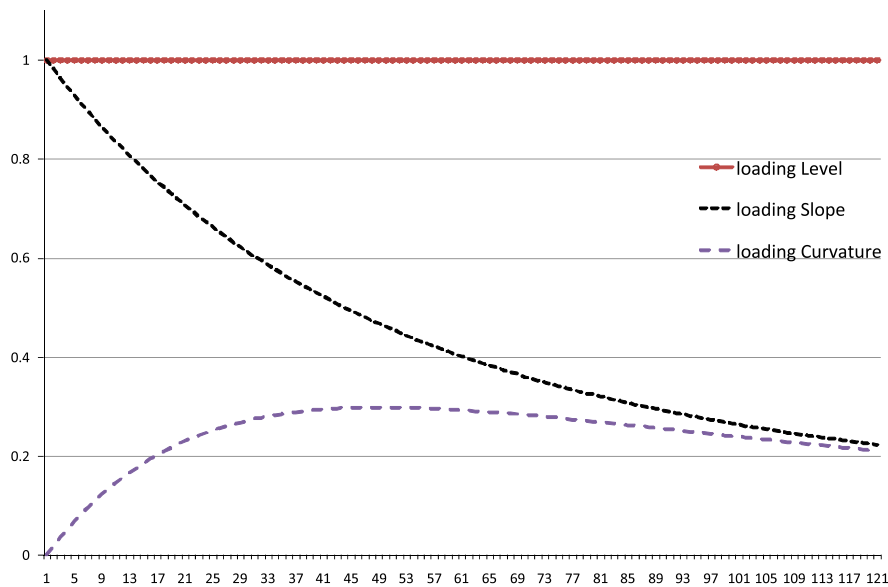
The slope shows the typical pattern of ascending yield curves (negative values of S_t) except for very brief episodes known to be associated with restrictive monetary policies, as well as for the episode of a persistently descending yield curve associated to the 1979–1982 disinflation.

⁶ Estimates and p -values of the remaining hyper-parameters are available from the authors upon request.

³ Sources: US Department of the Treasury and Bundesbank.

⁴ While considering some variable representative of shifts in the preferences (*i.e.* demand) for sovereign bonds would arguably enrich the analysis – especially if one admits that fiscal variables represent the dynamics of sovereign debt supply and the yield curve its market price – we are not aware of possible data proxies for sovereign debt preferences that could be used in the context of our framework. Our selection of macro and fiscal variables is, thus, in line with the macro-finance literature.

⁵ Specifically, the FSI is the sum of the following sub-indexes: (i) TWELVE-month rolling beta of bank stock index, (ii) Interbank TED spread, (iii) corporate bond yield spread, (iv) inverted term spread, (v) monthly stock returns (measured as declines), (vi) 6-month rolling monthly squared stock returns, and (vii) 6-month rolling monthly squared change in real effective exchange rate. It should be noted from the onset that the FSI is not really correlated with the model-based estimates of the yield curve factors that will be used in our empirical analysis. In particular, given the inclusion of a term spread in the FSI and given its leading indicator nature, we report the correlations between our slope factor and lagged values of the FSI: for the US, such correlations amount to 0.07 (1 quarter), -0.025 (2 quarters), -0.103 (3 quarters) and -0.129 (4 quarters); for Germany, the correlations are 0.32 (1 quarter), 0.24 (2 quarters), 0.18 (3 quarters) and 0.16 (4 quarters).



Note: The figure shows the loading of each latent factor at each maturity, expressed in months.

Fig. 1. Loadings of L_t , S_t and C_t , US 1961:6–2010:2.

The curvature displays, as usual, a much higher variation than the slope and the level, with an apparent positive correlation with the slope since the end of the 1980s, which does not seem to have existed in the previous period. After the 1980s, larger negative values of S_t , *i.e.* steeper ascending curves, tend to be associated with larger negative values of C_t , *i.e.* less pronounced concavity or even convex curves (lower negative values of S_t (flatter curves) tend to be associated to lower negative values of C_t , *i.e.* more pronounced concavities; and in episodes of inverted yield curves, positive values of S_t tend to be associated to less negative or even positive values of C_t , *i.e.* more pronounced concavities).

Overall, our estimates of the three yield curve latent factors describe a historical evolution of the yield curve shape that is coherent across the factors and consistent with the main known monetary and financial facts. As a sensitivity check, we computed the following empirical proxies for each of the yield curve latent factors:

$$\text{Level} = y_t(120), \quad (9)$$

$$\text{Slope} = [(y_t(3)) - (y_t(120))], \quad (10)$$

$$\text{Curvature} = [2 \times (y_t(48)) - (y_t(3)) - (y_t(120))], \quad (11)$$

where $(y_t(m))$ refers to the zero-coupon bond yield of maturity m (in months).⁷ Their correlations with the model estimates are 97%, 93% and 75%, respectively for the level, slope and curvature, which are in line with the correlations presented in analogous literature. Comparison of the time-series of latent factors and empirical proxies allow us to conclude that our estimations are in line, with an apparent advantage in some episodes, with the history described by their empirical counterparts.⁸

⁷ The proxies for the level and curvature differ from those in Diebold et al. (2006) and Diebold and Li (2006). Indeed, as pointed out by a referee, since the level should proxy for the long-end of the yield curve, we then use the 120 months yields instead of the average of a short-, medium- and long-term yield. In addition, given that our estimate for λ implies a maximum of the curvature loading at 48 months we use that maturity as proxy for the mid-point of the curvature, instead of the 24 months yield.

⁸ Detailed results are available from the authors upon request.

4.2.2. Germany

For the case of Germany, the estimate of λ (which is significant at 1%) is 0.04125, implying a maximum of loading of the curvature at the maturity of 43 months and a rather slow decay of the loading of the slope – a result fairly similar to the one obtained for the US.

Fig. 3 shows the estimated time-series of L_t , S_t and C_t (computed with the Kalman smoother) for Germany. L_t shows how Germany's yields have peaked during the first oil shock, given the well-known accommodative macroeconomic policy, but also how that peak was less marked and less persistent than the one seen in the US at the end of the 1970s, given the smaller disinflation needs. The figure further shows how yields rose after the reunification and how they have only fallen for the current standard levels in the second half of the 1990s, ahead of the creation of the EMU.

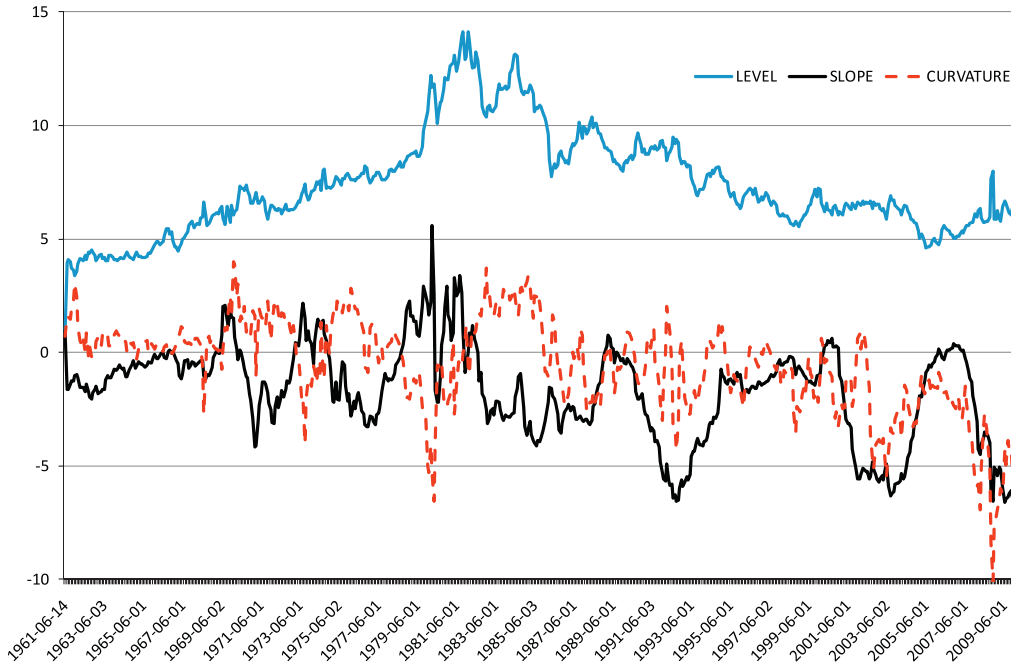
The slope, S_t , shows the typical pattern of ascending yield curves except for the episodes known to be associated with restrictive monetary policies, as well as for the episode of the German reunification (in 1991). The curvature displays, as usual, a much higher variation than the slope and the level. As in the case of the US there is an apparent positive correlation between S_t and C_t since the second half of the 1980s.

For robustness check, we have also computed empirical proxies (as in the case of the US, using Eqs. (9)–(11), replacing in the latter the 48 month maturity by the 36 month maturity as the mid-point of the curvature, in line with the estimate of λ). Disregarding the data for the 1970s – when the zero-coupon yields show an abnormal volatility – the correlations between our estimates and their empirical counterparts are 92%, 94% and 72%, respectively for the level, slope and curvature, which are close to those obtained for the US⁹

4.3. VAR analysis

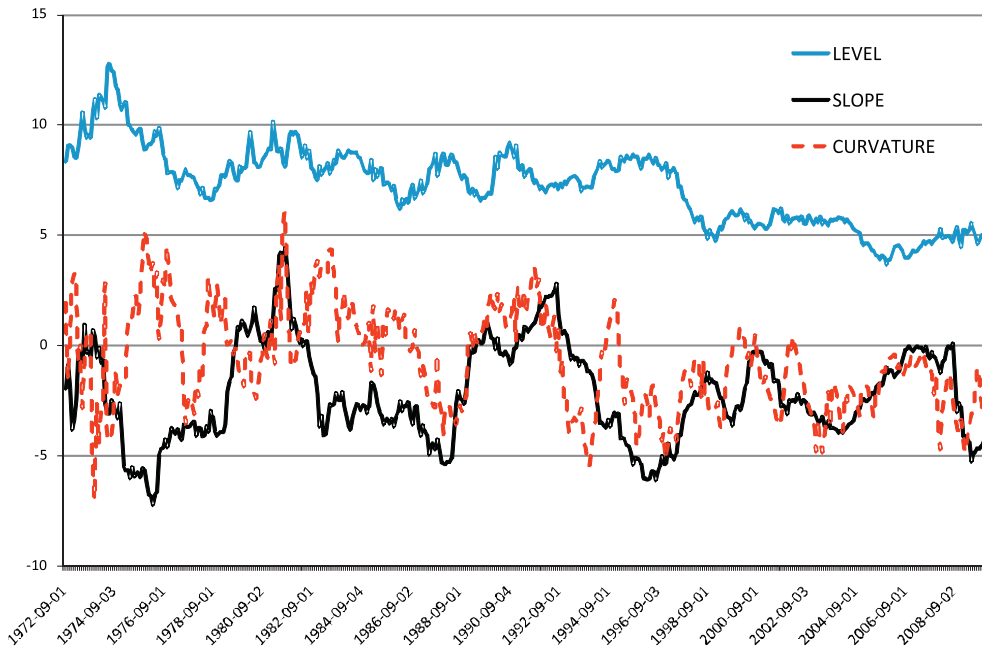
Our choice of separating the state-space modelling and estimation of the yield curve latent factors from the estimation and analysis of the macro-fiscal-finance VAR is based on two arguments.

⁹ Data are available from the authors upon request.



Note: The figure shows the values of the three latent factors at each month.

Fig. 2. Estimates of L_t , S_t and C_t , US 1961:6–2010:2.



Note: The figure shows the values of the three latent factors at each month.

Fig. 3. Estimates of L_t , S_t and C_t , Germany 1972:9–2010:3.

First, subsuming the estimation of the yield curve factors and of the VAR in a unique state-space model implies that the macro-fiscal-finance VAR is necessarily restricted to be a VAR(1), when there is no guarantee that this would be the outcome of the optimal lag length analysis. In fact, on the basis of the standard information criteria and of the analysis of the autocorrelation and normality of the residuals, we estimate a VAR(4) for the US and a VAR(2) for Germany (irrespective of the fiscal variable). Second, the encompassing state-space model would generate estimates of the yield

curve factors that would not differ markedly from those obtained in the pure finance state-space model described in Section 3.1, as only yield data are considered in its measurement system.

4.3.1. US

4.3.1.1. Impulse response functions. In this section, we report the impulse response functions (IRFs) to a positive innovation to the fiscal variable (annual change of the debt-to-GDP ratio) with magnitude of one standard deviation of the respective errors, together with

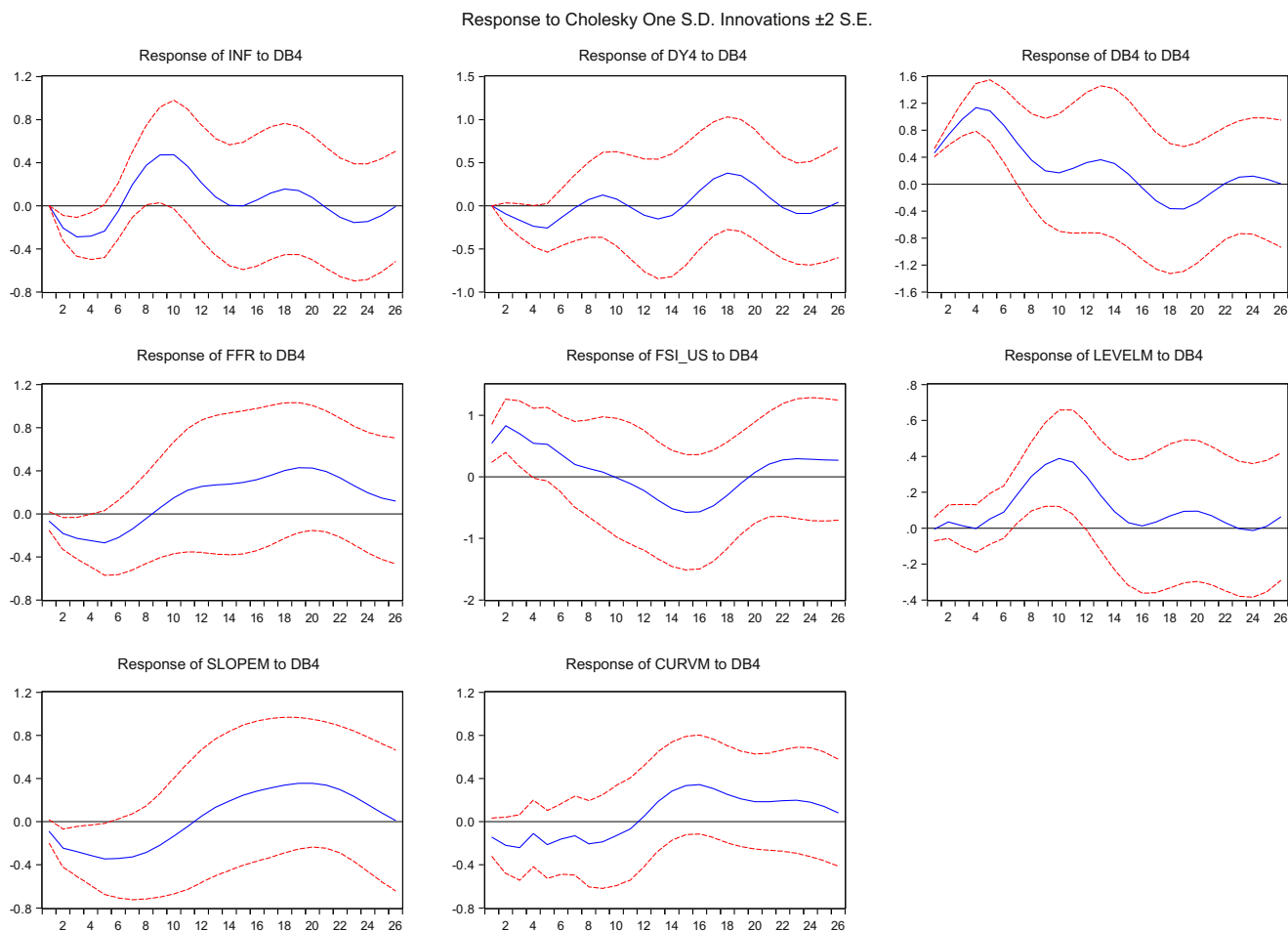


Fig. 4. Impulse response functions to shock in annual change of the Government debt-to-GDP ratio, US 1981:I–2009:IV.

the usual two-standard error (95%) confidence bands. Overall, the results confirm that the system is stationary and may be summarised as follows (see Fig. 4).¹⁰

First, output growth and inflation decrease and are significantly below their initial values during about 5 quarters. In reaction to the deterioration in real activity and deceleration of prices, the monetary policy interest rate falls for about 5 quarters. Second, the sur-

prise increase in the annual change of the debt-to-GDP ratio leads to an increase in the financial stress indicator that is significant for about 5 quarters. Third, the fiscal innovation does not lead to a statistically significant response of the yield curve curvature, but to significant, albeit transitory, reactions of its slope and level.

A positive innovation to the rate of change of the debt-to-GDP ratio initially leads to a fall in the slope factor (a steeper yield curve, with a fall in the yields especially for shorter maturities) implied by the monetary policy reaction (fall in the fed funds rate). The dynamic path of the slope essentially follows that of the fed funds rate: the correlation between their impulse response functions is 95%, and they are statistically different from zero during essentially the same period. After about 6 quarters the slope starts returning to its baseline value and the level of the yield curve increases, *i.e.* there is an increase in the whole range of yields, including the long-end maturities of the curve (which comprises, at the extreme, the usual 10 years maturity studied in most fiscal-finance analyses) and lasts about 3 years. An innovation of 0.47% points in the rate of change of the debt ratio is associated with an upward response of the yield curve longest maturities' yields that amounts to 38 basis points, at its peak in the 10th–11th quarters after the innovation, which amounts to an elasticity of about 80%. Most notably, the reaction of the long-end of the yield curve occurs after a succession of periods (1 year and a half) in which the fiscal variable has been significantly above its baseline value. The economic

¹⁰ The impulse response functions of the yield curve latent factors to fiscal shocks display, throughout the paper, lagged and persistent reactions, similar to those of the macroeconomic and policy variables. That feature of the results would hold even if the financial block of the model included no-arbitrage restrictions (see, *inter alia*, Rudebusch and Wu, 2008). The economic intuition for this lies in the dynamic properties of the macroeconomic data as well as in the inter-action of macro, policy and financial variables along time (see Chadha and Holly, 2010). Once the economy is perturbed by a shock – in our case, a fiscal policy shock – macroeconomic variables (output and inflation) react with a lag, and therefore monetary policy and financial conditions react with a lag. Moreover, as macroeconomic variables react gradually (persistently) and, also, because monetary policy-makers have a preference for interest rate smoothing, monetary policy reacts gradually (the money market interest rate reacts smoothly to changes in the macroeconomic conditions). Hence, the shape of the yield curve reacts with lags and persistence, as the main macro and policy variables. The reactions of the slope and curvature are more immediate than those of the level, because they are associated with macro and policy reactions with a smaller lag and persistence. While the former are closely associated to the short and medium-term reactions of output, inflation and the response of monetary policy, the latter is associated to low frequency changes in macro and policy variables (long-run growth, inflation expectations and target, fiscal sustainability).

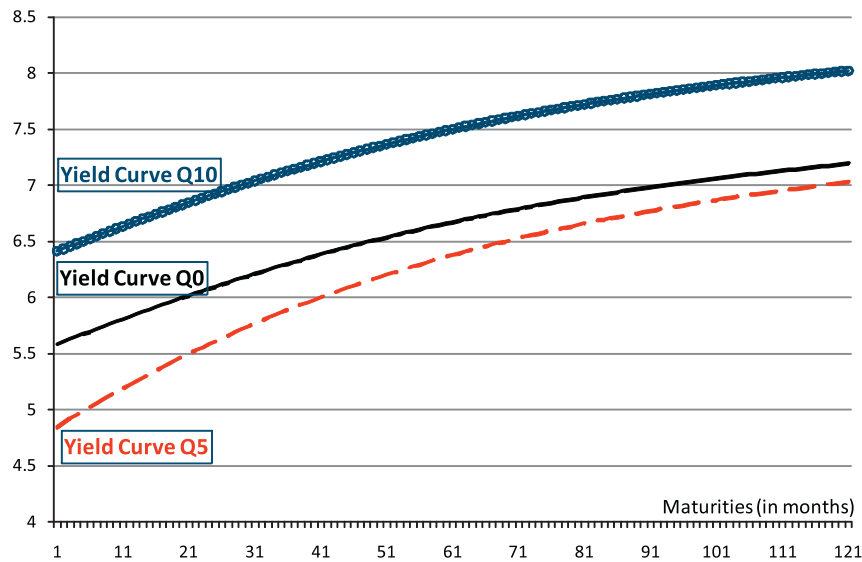


Fig. 5. Shape of yield curve at selected quarters after a 100 basis points shock to the annual change of the debt-to-GDP ratio, US 1981:I-2009:IV.

interpretation of this result, in line with theory, is that the longer yields tend to be associated with fiscal sustainability rather than with transitory fiscal developments. This is consistent with the view that the yield curve level is affected by low-frequency macro and financial developments, but adds to the traditional macro-finance literature that, due to the exclusion of fiscal variables, has associated the yield level essentially with inflation expectations or the inflation target. It should be stressed that the financial stress indicator plays a relevant role in the identification of fiscal shocks and their impact. If we excluded the indicator from the VAR, the elasticity of the level at the height of the impact would be estimated at 58%.¹¹

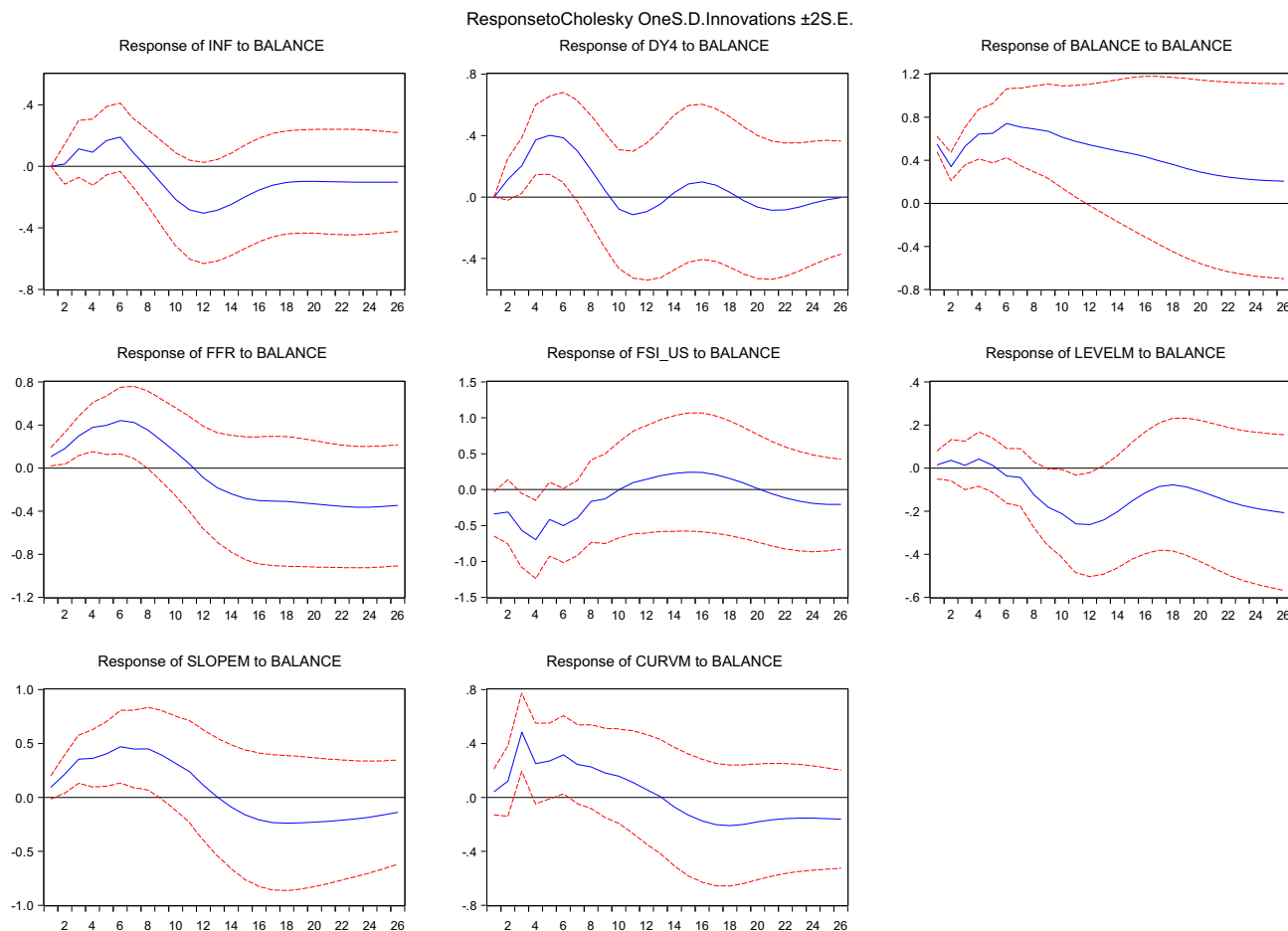
To provide a more intuitive and quantified description of the dynamic reaction of the yield curve to fiscal shocks in the US, in Fig. 5 we show the shape of the yield curve at selected quarters after a 100 basis points shock to the rate of change of the debt-to-GDP ratio. The solid black line is the baseline yield curve, *i.e.* the average shape of the yield curve in the US 1981:I-2009:IV, and has been pictured using the sample average values of the latent factors (multiplied by the respective Nelson–Siegel weights, according to (2)). The dashed red line shows the shape of the yield curve at quarter 5, following a surprise increase in the rate of change of the debt-to-GDP ratio at quarter 1. In accordance with the impulse response functions shown in Fig. 4 and with the traditional theory on the reaction to transitory monetary policy actions, the only significant change in the yield curve shape is a decrease in the slope (a steepening of the curve), meaning that most of the change in the curve occurs at the shorter maturities. As mentioned above, the impact on the slope then vanishes and the level starts increasing, until it peaks at quarters 10 and 11. The blue circled line shows the shape of the yield curve at quarter 10, in which the yield at the longest maturity (120 months) is 8.02%, *i.e.* about 80 basis points above the 7.19% recorded in the baseline yield curve (in line with the above mentioned elasticity of 80%). After the 12th quarter, the level starts decreasing and, given that no other latent factor changes, the shape of the yield curve becomes statistically undistinguishable from its baseline. We interpret these results as evidence that after a succession of quarters with higher than average debt growth, markets fear for debt sustainability

and increase long yields, but then when debt growth becomes normal long yields also return to normal.

We now move onto the impulse response functions of all the variables in the system to a positive innovation to the budget balance ratio (with a magnitude of one standard deviation of the respective errors), together with the two-standard error confidence bands (see Fig. 6). The results confirm that the system is stationary and are qualitatively identical to those obtained with innovations to the change in the debt-to-GDP ratio (as expected, with the opposite sign, as a positive shock has, here, the opposite economic meaning). Considering both the IRFs and their confidence bands, the results may be summarised as follows.

First, output growth increases between the 2nd and the 5th quarter after the innovation and inflation rises between the 4th and the 6th quarter. In reaction to the improvement in real activity and to the acceleration of prices, the monetary policy interest rate rises between the 2nd and the 6th quarter after the innovation. Second, the fiscal innovation leads to a statistically significant response of the financial stress indicator, with overall financial conditions improving, in the 3–4 quarters horizon. Third, the positive innovation to the budget balance ratio leads to an immediate increase in the slope factor (a less steep yield curve) implied by the monetary policy reaction (increase in the fed funds rate), which corresponds to a rise in the yields especially for shorter maturities. Again, the dynamic path of the slope mimics that of the fed funds rate: the correlation between their impulse response functions is 98%, and they are statistically different from zero during the same period. Three quarters after the shock the curvature increases and the yield curve becomes significantly more concave, which somehow limits the increase in the shorter rates and magnifies the increase in the medium-term yields. After about 7 quarters the slope starts returning to its baseline value and the level of the yield curve decreases, which corresponds to a decrease in the whole range of yields, including the long-end maturities of the curve, lasting about 3 years. A surprise improvement of 0.55% points in the budget balance ratio is associated with a downward response of the longest yields that amounts to 0.26% points in the 12th quarter after the innovation, which amounts to an elasticity of about 48%. Again, the reaction of the long-end of the yield curve arises only after a succession of periods (2 years) in which the fiscal variable has been significantly above its baseline value. We thus confirm that the longer yields are associated with fiscal sustainability rather than with transitory fiscal developments, reacting to fiscal

¹¹ Detailed results are not shown, but are available from the authors on request.



Notes: BALANCE – budget balance ratio, INF: inflation; DY4: annual growth rate of real GDP; FFR: federal funds rate; FSI: financial stress indicator; LEVELM, SLOPEM, and CURVM, respectively level, slope and curvature latent factors.

Fig. 6. Impulse response functions to shock in the Budget Balance, US 1981:I–2009:IV.

shocks in line with their persistence. Moreover, comparison of this result with the analogous for the macro-finance model with debt, allows one to conclude that budget balance shocks take longer to fade out and thus take longer to transmit to long yields. It is, again, noteworthy that the financial stress indicator plays a significant role in the identification of fiscal shocks and their impact. When the stress indicator is absent from the VAR, the estimated elasticity of the yield curve level at the height of impacts would be 28%.

In Fig. 7, we present the shape of the yield curve at selected quarters following a 100 basis points shock to the budget balance ratio (a positive shock that has the opposite economic meaning of the positive shock to the change in the debt-to-GDP ratio that led to Fig. 5, and hence the opposite effects on the yield curve shape). The solid black line is the baseline yield curve shape, *i.e.* the average shape of the yield curve in the US 1981:I–2009:IV. The dotted green line shows the shape of the yield curve at quarter 3, when, in accordance with the impulse response functions shown in Fig. 6, the curve has begun flattening (the slope has started to decrease) and the curvature has reached a peak (the curve has become significantly more concave). As already pointed out, the impact on the curvature is very short lived while the slope continues increasing, until it peaks at quarter 6. Again, the dashed red line shows the shape of the yield curve at that quarter, when the only significant deviation from the baseline shape is a flattening, which affects mostly the short-end of the maturities in accordance with the textbook reaction to a monetary policy transitory action (investors adjust short yields to the policy rate but predict the eventual return

to normal policy rates, and so the longer yields are only transitorily and slightly different from their baseline values). From quarter 7 onwards, the slope gradually falls and the level starts falling, and from the 9 quarter onwards the slope is not statistically different from its baseline value while the level becomes significantly lower than its baseline. The blue circled line depicts the shape of the yield curve at quarter 12, when the level reaches its minimum and the yield at the longest maturity (120 months) is 6.71%, *i.e.* about 48 basis points above the 7.19% recorded in the baseline yield curve (in line with the above mentioned elasticity of 48%). After the 12th quarter, the level starts increasing and, given that no other latent factor changes, the shape of the yield curve becomes statistically undistinguishable from its baseline.

As already mentioned, when the latent factors of the yield curve are interpreted in terms of macroeconomic variables, the level is typically associated to a perceived inflation target and the slope to a cyclical monetary policy response to the economy. This is rather clear for the US since after the fiscal shocks the change in the slope of the yield curve is essentially mirroring the response of the monetary policy rate. Our results suggest that fiscal variables also relate with the level and, as expected, an expansionary (restrictive) fiscal policy pushes upward (downward) the level of the yield curve, spanning between 6–8 quarters and 12 quarters. Our estimates that it takes a succession of quarters with fiscal policy variables deviating from their normal values to generate a change in the level (long yields), and that once the fiscal variables return to their baseline values the yield curve also returns to nor-

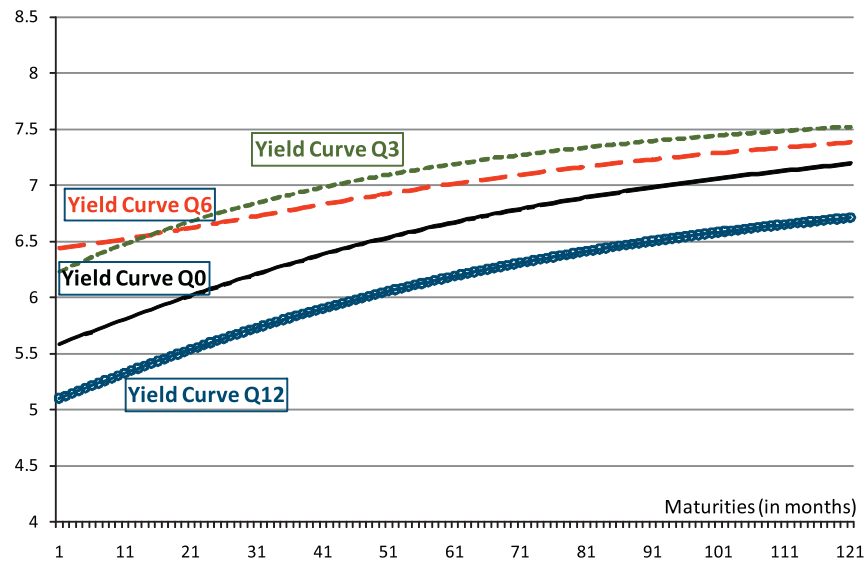


Fig. 7. Shape of yield curve at selected quarters after a 100 basis points shock to the balance-to-GDP ratio, US 1981:I–2009:IV.

mal, is consistent with the hypothesis that the yield level is associated with low-frequency macro and financial movements. Our results clearly add to those of macro-finance models that include no fiscal variables and only link the level to inflation expectations or target.

4.3.1.2. Variance decompositions. For the case of the VAR including the change of the debt-to-GDP ratio, the results may be summarised as follows (see Table 1). At a 4-quarter horizon and as expected, most of the variance of the error in forecasting the change in the debt ratio (panel 1.1) comes from fiscal innovations. However, outputs surprises and, to a lesser extent, interest rate and inflation surprises, also explain some of that forecast error variance. At the 8-quarter horizon, fiscal innovations account for about half of the forecast error variance and innovations to inflation, output and the slope of the yield curve attain a sizeable importance. For forecast horizons of 12 quarters and beyond, the importance of surprises to the slope of the yield curve stabilizes at around 10%, which corresponds to a similar explanatory power of that of output surprises (with inflation surprises remaining the main driver of the variance of the errors in forecasting the growth of the debt-to-GDP ratio in addition to fiscal surprises).

From panel 1.2 in Table 1, the variance of the errors in forecasting the level of the yield curve at a 4-quarter horizon is mostly explained by innovations to the level itself. Nevertheless, surprises to output growth and, to a lesser extent, surprises to the curvature of the yield curve explain sizeable parts of such variance. From the 8-quarter horizon onwards, innovations to the change in the debt-to-GDP ratio become the most important driver for the variance of the errors in forecasting the yield curve level (from the 12-quarter horizon onwards even above innovations to the level itself). This contribution peaks at almost 40% in the 12 quarters horizon and is still around 28% at the horizon of 6 years. From the 8th quarter onwards the shocks to the financial stress indicator also account for around 12% of the forecast error variance of the level of the yield curve and from the 16-quarter horizon monetary policy surprises account for more than 15% of the error variance. Therefore, fiscal surprises account for a much larger fraction of the forecast error variance of the yield curve level than any other macroeconomic and financial variables.

Panel 1.3 in Table 1 shows that in a 4-quarter horizon, surprises to the monetary policy interest rate explain the major part of the

Table 1

Annual change in debt-to-GDP ratio forecast error variance decomposition, US 1981:I–2009:IV.

Period	INF	DY4	DB4	FFR	FSI	L	S	C
<i>1.1. Forecasting the change of the debt-to-GDP ratio</i>								
4	3.644	13.426	75.805	2.119	3.834	0.245	0.781	0.142
8	24.466	9.944	49.373	2.229	4.070	0.097	8.145	1.673
12	22.251	9.633	43.444	6.011	6.411	0.206	10.131	1.910
16	22.899	9.222	42.587	5.985	6.706	0.374	10.013	2.209
20	22.641	8.705	42.060	6.374	8.233	0.442	9.361	2.181
24	22.793	8.591	39.994	6.354	9.059	0.426	10.410	2.369
<i>1.2. Forecasting the level of the yield curve</i>								
4	1.527	15.549	0.324	0.983	1.402	73.729	1.059	5.422
8	4.491	9.898	16.469	6.317	7.148	48.349	1.924	5.400
12	7.237	5.190	39.603	5.545	12.355	24.552	2.225	3.288
16	9.414	4.429	33.697	14.441	11.893	19.571	2.050	4.501
20	9.631	5.215	28.751	17.693	10.819	16.169	7.954	3.763
24	10.220	5.280	27.483	17.109	10.668	15.458	9.548	4.231
<i>1.3. Forecasting the slope of the yield curve</i>								
4	0.421	8.077	12.001	38.997	0.518	12.690	27.132	0.161
8	3.108	15.146	15.901	24.509	0.472	8.292	30.944	1.626
12	6.122	13.516	14.651	21.106	1.594	6.938	33.139	2.931
16	7.140	14.060	16.208	20.375	2.442	6.077	29.783	3.913
20	8.622	14.624	20.397	17.195	2.059	5.270	27.665	4.164
24	9.695	14.367	22.463	15.85	1.978	5.069	26.581	3.988
<i>1.4. Forecasting the curvature of the yield curve</i>								
4	2.959	16.937	5.614	0.521	13.713	3.906	11.182	45.164
8	4.979	20.379	7.771	0.419	11.369	6.069	13.641	35.370
12	5.222	19.769	8.659	0.544	10.640	6.797	15.529	32.837
16	5.693	17.267	15.400	0.510	12.157	5.975	14.371	28.624
20	7.845	16.014	18.484	1.258	11.065	5.342	13.179	26.810
24	7.521	15.297	20.295	2.787	10.609	5.214	12.635	25.640

Notes: INF: inflation; DY4: annual growth rate of real GDP; DB4: annual change of the debt-to-GDP ratio; FFR: federal funds rate; FSI: financial stress indicator; L: level of the yield curve; S: slope of the yield curve; C: curvature of the yield curve. Each row shows the percentage of the variance of the error in forecasting the variable mentioned in the title of the table, at each forecasting horizon (in quarters) given in the first column.

variance of the forecasting errors of the yield curve slope – a result that is consistent with the monetary policy hypothesis regarding the power of the yield curve slope to predict economic activity. Afterwards, the part explained by monetary policy innovations falls gradually, but is still 15% at a 24 quarters horizon. From the 8-quarter horizon onwards, surprises to the growth rate of real

GDP explain a sizeable part of the slope forecast error variance, as well as do surprises to inflation, albeit with a delay and smaller magnitudes. Innovations to the government debt ratio are still quite relevant for the yield curve slope, and increase their contribution gradually, from 15% at the 8-quarter horizon to 22% at the 24-quarter horizon.

Finally, panel 1.4 in Table 1 shows that at a 4-quarter horizon, surprises to the yield curve curvature itself explain the largest part of the forecast error variance of the curvature, but surprises to real output growth and the financial stress index also have important explanatory power, as well as surprises to the yield curve slope. While fiscal surprises initially do not explain a considerable part of the curvature forecast error variance, their importance increases steadily with the forecast horizon and amounts to 15 to 20% at horizons above 16 quarters. Innovations to the yield curve slope and to the overall financial conditions index have similar explanatory power.

A set of comparable variance decompositions for the budget balance ratio can be summarised as follows (Table 2). At a 4-quarter horizon, most of the variance of the error in forecasting the budget balance-to-GDP ratio arises naturally from the fiscal innovations (panel 2.1). However, surprises to the financial stress indicator, and, to a lesser extent, output surprises, also explain some of that forecast error variance. Most importantly, innovations to the yield curve slope explain around 7% of the variance of the error in forecasting the balance. At a horizon of 8 quarters, fiscal innovations still account for about two thirds of the forecast error variance, while innovations to output, financial conditions and, with increasing weight, innovations to the slope of the yield curve attain a sizeable importance. For forecast horizons of 12 quarters and beyond, surprises to the slope of the yield curve

are the larger explanation for the forecast error variance (stabilizing at around 12%).

In panel 2.2 of Table 2, the variance of the errors in forecasting the level of the yield curve at a 4-quarter horizon is mostly explained, by innovations to the level itself. Nevertheless, surprises to output growth and to the curvature of the yield curve also explain sizeable parts of such variance, similarly to the case of the debt ratio. At the 8, 12 and 16 quarters horizons, innovations to the FSI become the most important explanations for the variance of the errors in forecasting the yield curve level. The explanatory importance of the budget balance ratio increases steadily along the forecast horizon, and while it is still inferior to those of output and inflation surprises at the 8 quarters horizon, it becomes more important at the 12 quarter horizon, and almost as relevant an explanation for the errors in forecasting the level of the yield curve at the 16, 20 and 24 quarters horizon as the financial conditions index.

Regarding the variance of the forecasting errors of the yield curve slope, they are mainly explained by surprises to the monetary policy interest rate at a 4-quarter horizon (panel 2.3 of Table 2). Yet, surprises in the budget ratio and in the level of the yield curve explain a considerable proportion of the forecast error variance. Moreover, as the forecast horizon widens, surprises to the fiscal balance are the larger explaining factor for the variance of the errors in forecasting the yield curve slope (apart the slope itself). In fact, surprises to the monetary policy innovations keep on having a considerable role, but their contribution is much smaller than in the case of the model with government debt. In turn, surprises to real output growth have a similar importance. In comparison to the model with the debt ratio, in the case of the budget balance ratio, fiscal innovations explain much more of the forecast error variance of the slope than of the level.

Finally, from panel 2.4 of Table 2, at a 4-quarter horizon surprises to the yield curve curvature itself explain the largest part of the forecast error variance of the curvature, but surprises to real output growth and the financial stress index also have important explanatory power. In comparison to the case of the model with the debt-to-GDP ratio, surprises to the yield curve slope have a more limited explanatory power of the variance of the forecast errors of the curvature. Budget balance surprises explain a considerable part of the curvature forecast error variance, and their importance increases steadily with the forecast horizon and amounts to 24% at horizons above 20 quarters, more than surprises to real output growth and to the financial stress indicator.

4.3.2. Germany

4.3.2.1. Impulse response functions. Fig. 8 depicts the impulse response functions to a positive innovation to the annual change of the debt-to-GDP ratio, together with the two-standard error confidence bands. The dynamic reactions are different from those estimated for the US First, there is no significant reaction of the macroeconomic variables and the market measure of the monetary policy interest rate consistently holds to its baseline value. Second, the financial stress indicator does not react immediately and decreases in the 5th and 6th quarters after the fiscal shock – even though barely significantly. Third, there is no statistically significant response of the yield curve, except for a very brief fall in the curvature during the 2nd and 3rd quarters after the fiscal shock that is only marginally significant.

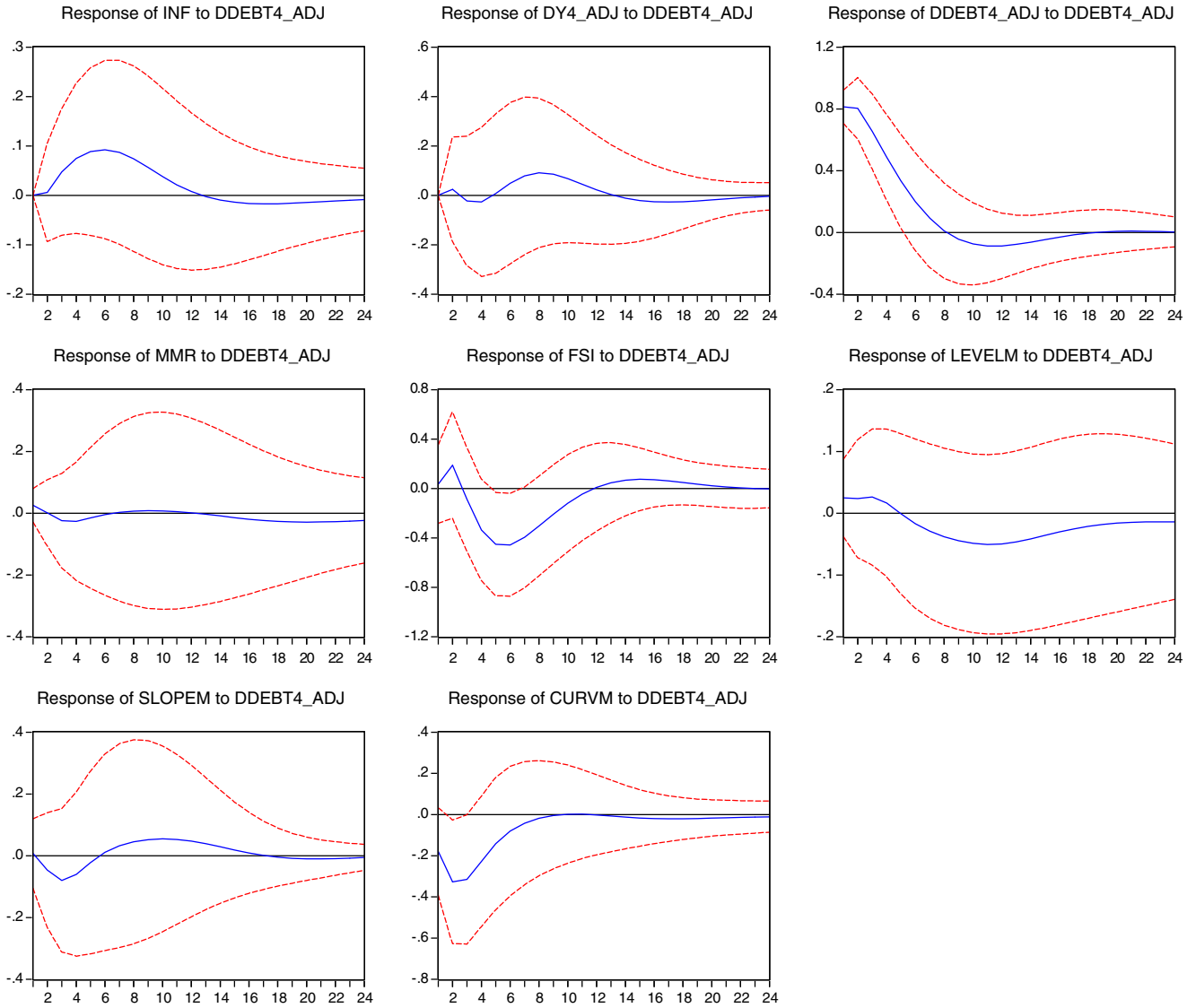
In short, the only impact of a surprise increase in the annual change in the debt ratio is a fall in the medium-term – albeit less, in the long-term – component of the yield curve within the following year, with both a delay and duration of 2 quarters. Both the level and the slope of the yield curve do not change significantly, and the decline in its concavity is barely significant. In view of the results obtained for the US it does not come as a surprise that the slope of the yield curve does not react: given no significant change

Table 2
Balance forecast error variance decomposition, US 1981:I–2009:IV.

Period	INF	DY4	Balance	FFR	FSI	L	S	C
<i>2.1. Forecasting the budget balance</i>								
4	2.018	5.984	69.998	0.470	10.578	3.433	7.091	0.429
8	3.592	7.049	65.332	0.839	7.131	3.116	12.776	0.166
12	3.327	7.286	60.621	4.909	7.282	2.226	14.238	0.110
16	3.615	6.950	58.149	7.363	9.061	1.938	12.803	0.121
20	3.749	6.853	56.329	9.417	9.184	1.898	12.106	0.462
24	3.777	6.868	55.243	10.289	9.448	1.987	11.600	0.788
<i>2.2. Forecasting the level of the yield curve</i>								
4	1.653	19.183	0.771	1.016	2.027	68.705	1.314	5.330
8	10.873	12.876	2.946	4.109	15.703	46.076	1.493	5.924
12	7.506	7.296	17.151	6.293	30.553	25.656	1.263	4.282
16	6.196	5.694	20.448	17.717	24.903	19.414	1.211	4.417
20	5.937	4.963	18.873	21.355	24.972	16.662	2.771	4.467
24	5.998	4.717	21.299	21.124	24.010	14.925	2.810	5.118
<i>2.3. Forecasting the slope of the yield curve</i>								
4	1.548	6.634	15.905	34.293	0.038	15.055	26.373	0.151
8	1.049	10.52	25.401	18.450	2.383	10.329	28.939	2.921
12	2.199	9.067	26.615	15.772	2.423	8.501	30.610	4.809
16	2.410	9.054	26.574	16.592	2.444	8.288	29.658	4.978
20	2.325	9.219	28.243	15.492	2.522	7.972	29.568	4.656
24	2.353	9.116	29.462	14.998	3.111	7.581	28.878	4.498
<i>2.4. Forecasting the curvature of the yield curve</i>								
4	1.958	13.717	11.621	1.304	17.147	2.221	7.461	44.567
8	6.343	15.293	16.442	1.123	14.758	3.529	7.738	34.771
12	6.433	15.211	15.986	1.823	15.763	4.171	8.439	32.170
16	6.534	13.446	18.113	2.131	20.086	3.733	7.346	28.606
20	5.569	11.568	23.562	3.298	21.093	3.309	6.107	25.491
24	5.208	10.707	24.948	6.001	19.468	3.127	5.559	24.979

Notes: INF – inflation; DY4 – annual growth rate of real GDP; Balance – budget balance in percentage of GDP; FFR – federal funds rate; FSI – financial stress indicator; L – level of the yield curve; S – slope of the yield curve; C – curvature of the yield curve. Each row shows the percentage of the variance of the error in forecasting the variable mentioned in the title of the table, at each forecasting horizon (in quarters) given in the first column.

Response to Cholesky One S.D. Innovations ± 2 S.E.



Notes: INF: inflation; DY4_ADJ: annual growth rate of real GDP (adjusted for the 1991 structural break); DDEBT4_ADJ: annual change of the debt-to-GDP ratio (adjusted for the 1991 structural break in GDP); MMR: money market interest rate; FSI: financial stress indicator; LEVELM, SLOPEM, and CURVM: level, slope and curvature latent factors.

Fig. 8. Impulse response functions to shock in annual change of the Government debt-to-GDP ratio, Germany 1981:I–2009:IV.

in output and inflation, monetary policy is muted and so there is no reason for the markets to change the short yields. The fact that the level of the yield curve does not change significantly may be explained as follows. First, the growth of the debt ratio returns much quicker to its baseline value (statistically, after 4 quarters, vs 8 in the case of the US) and so markets are less likely to consider the shock as a threat for fiscal sustainability. Second, the German fiscal and monetary policy framework is known to be stronger, and so fiscal policy is perceived as less likely to become unsustainable and require any abnormal inflation. Finally, it should be noted that if the financial stress indicator was excluded from the VAR, the effects of fiscal shocks on the yield curve would be similar. Hence, in contrast to what happens in the US, in Germany the fiscal stance does not seem to have a relevant effect on the financial conditions.

In Fig. 9, we show the shape of the yield curve at selected quarters after a 100 basis points shock to the rate of change of the Debt-to-GDP ratio. The average shape of the yield curve in Germany

1981:I–2009:IV is shown as a solid black line. In accordance with the impulse response functions shown in Fig. 8, the only significant change in the yield curve shape is a small and very brief decrease in the curvature (a fall in its degree of concavity) at the 2nd and 3rd quarters after the shock. The dashed red line describes the shape of the yield curve at quarter 2 (when the curvature effect reaches its maximum), showing that the curve does not change much and confirming that most of the changes occur at the medium-term maturities. As mentioned above, the impact on the curvature rapidly vanishes and, as both level and slope do not change significantly, the yield curve quickly returns to its baseline shape.

We report in Fig. 10 the impulse response functions (with two-standard errors confidence bands) of the variables to a positive innovation to the budget balance ratio.

Also in contrast to what has been found for the US case, the IRFs of a budget balance ratio shock differ somewhat from those of a shock to the debt ratio, in the case of Germany. First, there is no

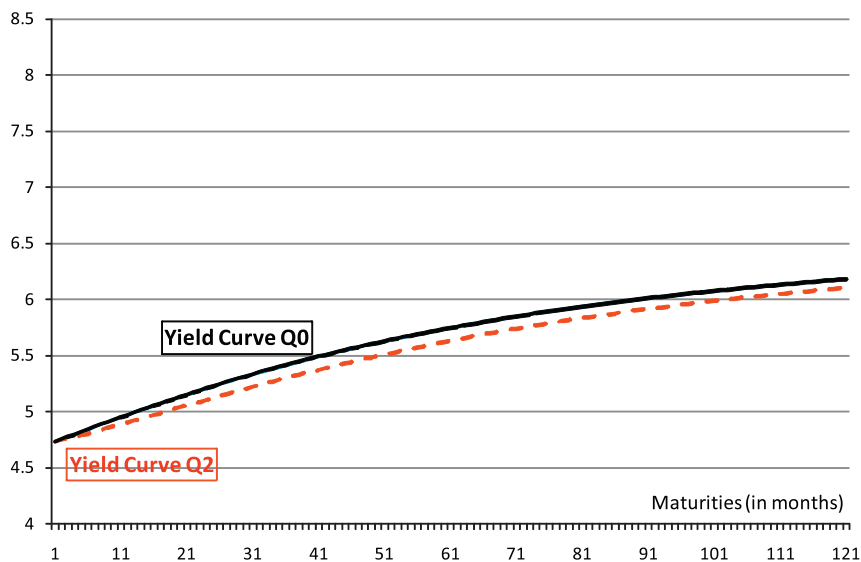


Fig. 9. Shape of yield curve at selected quarters after a 100 basis points shock to the annual change of the debt-to-GDP ratio, Germany 1981:1–2009:IV.

significant reaction of real output and the market measure of the monetary policy interest rate keeps to the baseline value, but inflation significantly falls during the 3 quarters following the shock. Second, there is no significant reaction of the financial stress indicator. Third, there is no statistically significant response of any of the yield curve latent factors, level, slope and curvature. Again, the slope does not change because monetary policy does not react significantly. The level does not change significantly because the budget balance ratio returns very quickly to its baseline value (statistically, after 4 quarters, vs 12 in the US case) and, as argued before, the German fiscal and monetary policy framework has a very strong credibility. The impact of fiscal balance shocks would be identically non-significant if the financial conditions indicator was excluded from the VAR and the effects of the shock on the yield curve factors would not change. Overall, we conclude that, in contrast to what happens in the US, in Germany the fiscal policy stance does not seem to have any relevant effect on the financial conditions of the economy and on the yield curve.

To sum up, it should be stressed that in this case, we do not find a reaction of monetary policy after a fiscal shock, and the slope of the yield curve remains essentially unchanged. Moreover, there is also no response from the level of the yield curve, which can be seen as a belief by the economic agents that a fiscally dominant regime will not arise, and that the monetary authorities will stick with their inflation control objective.

4.3.2.2. Variance decompositions. Table 3 reports the decomposition of the forecast errors variance of variables in the system in the case of the VAR including the change in the debt-to-GDP ratio. Panel 3.1 shows that within the 2-year forecast horizon most of the variance of the error in forecasting the change in the debt ratio comes from fiscal innovations. Afterwards, surprises to output and the overall financial conditions gain importance in accounting for the forecast error variance. Innovations to the latent factors are relatively unimportant, especially at the shorter horizons; in particular, the slope of the yield curve is less important than in the US case.

A relevant result in panel 3.2, contrary to the US, is that innovations to the debt-to-GDP ratio are unimportant in explaining the variance of the error in forecasting the level of the yield curve, irrespectively of the forecast horizon. While shocks to the level itself account for most of the variance of the forecast errors at short horizons,

from the 8-quarter horizon onwards inflation and the curvature of the yield curve account now for an important part of the variance and, from the 16-quarter horizon onwards, real output has also a large role.

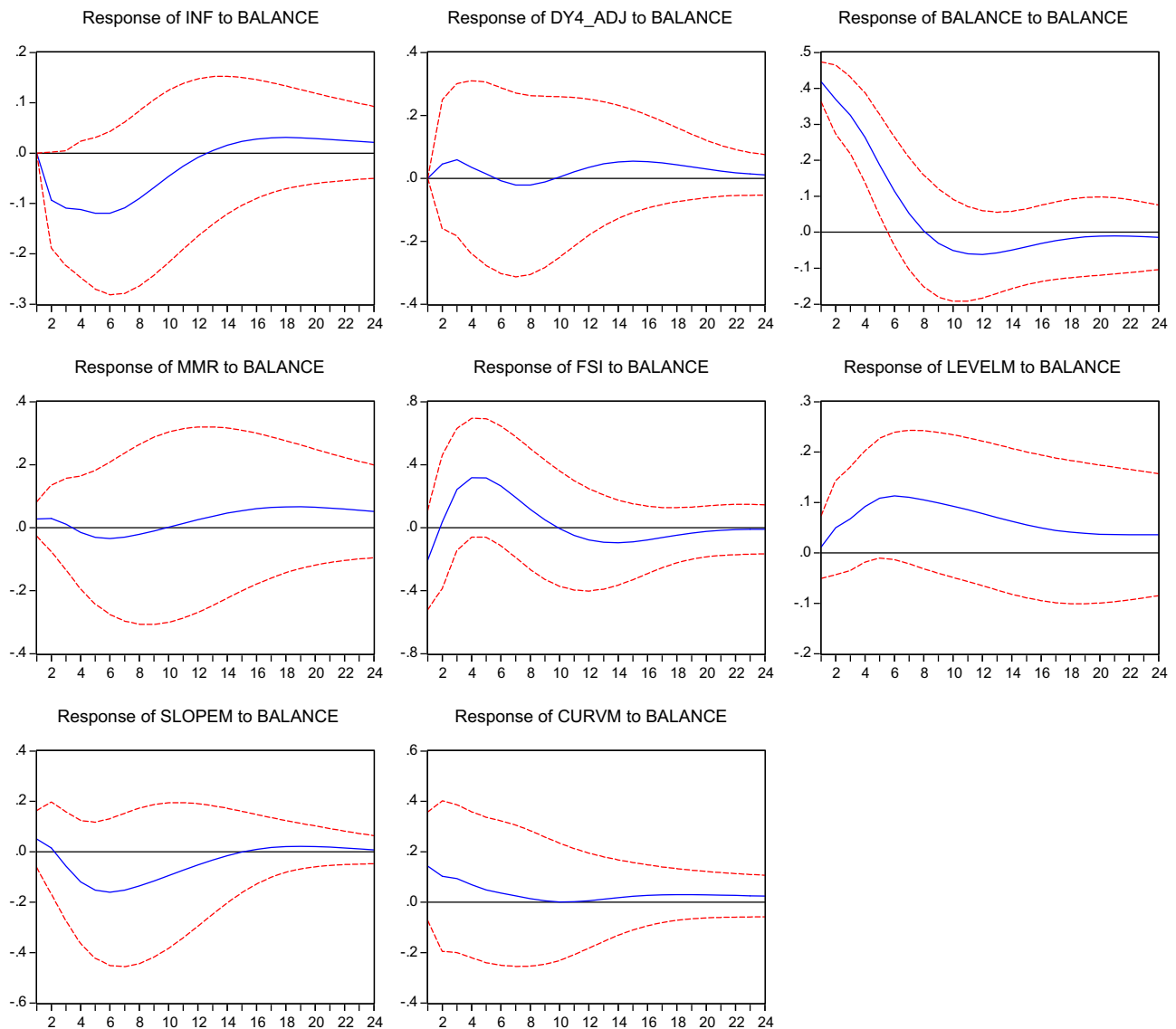
Similarly to what has just been detected for the level, and again differing from the US case, the innovations to the debt-to-GDP ratio are unimportant in explaining the variance of the error in forecasting the slope of the yield curve, irrespectively of the forecast horizon (panel 3.3). Most of such variance is accounted for by surprises to the monetary policy interest rate, inflation and output growth. The very large importance of the money market interest rate implies that the results for Germany seem even more consistent with the monetary policy hypothesis for explaining the power of the yield curve slope to predict economic activity than in the results for the US

Panel 3.4 shows that surprises to the yield curve curvature itself explain the largest part of the forecast error variance of the curvature. The role of innovations to changes in the debt-to-GDP ratio, after the 4th quarter, is less important than their role in accounting for the forecast error of the other two latent factors of the yield curve, and is rather limited as it amounts to less than 8% (at the 4-quarter horizon).

For completeness, we report in Table 4 the decomposition of the forecast errors variance of the budget balance ratio and the yield curve latent factors, for the same selected horizons.

As panel 4.1 shows, at the 4-quarter horizon most of the variance of the error in forecasting the budget balance-to-GDP ratio arises from the fiscal innovations, but from the 8-quarter horizon onwards surprises to the financial stress indicator and to output explain also play a considerable role. At horizons between 8 and 16 quarters, innovations to the level and the slope of the yield curve together explain around 13% of the variance of the error in forecasting the budget balance, and while their importance slightly decreases from the 20-quarters horizon on, the curvature gains importance and the three yield curve factors jointly account for 18% of the error variance.

Innovations to the level of the yield curve are the larger explanation for the variance of the error in forecasting the level itself, but the financial stress index and the curvature of the yield curve are also important explanatory factors (as well as output growth, after the 16 quarter-horizon – see panel 4.2). Moreover, innovations to the budget balance ratio are moderately important in

Response to Cholesky One S.D. Innovations ± 2 S.E.

Notes: INF: inflation; DY4_ADJ: annual growth rate of real GDP (adjusted for the 1991 structural break); BALANCE: budget balance ratio (to GDP adjusted for the 1991 structural break); MMR: money market interest rate; FSI: financial stress indicator; LEVELM, SLOPEM, and CURVM: level, slope and curvature latent factors.

Fig. 10. Impulse response functions to shock in the Budget Balance, Germany 1981:I–2009:IV.

accounting for the variance of the error in forecasting the level of the yield curve, recording a degree of relevance similar to that of inflation and a bit higher than that of the monetary policy interest rate (until the 16-quarter horizon).

In addition, panel 4.3 shows that innovations to the budget balance are unimportant in accounting for the variance of the forecasting errors of the yield curve slope, in line with the debt ratio results. Most of that variance is explained by innovations to output growth and by innovations to the monetary policy interest rate, as well as, to a smaller but constant extent, by surprises to the slope itself and inflation.

Finally, panel 4.4 shows that innovations to the budget balance ratio are unimportant in accounting for the variance of the forecast errors of the yield curve curvature. Such findings differ from the US case and, for this particular yield curve latent factor, are also in contrast to what has been found in the previous VAR, with the

change in the debt ratio as fiscal indicator for Germany. Innovations to the yield curve curvature itself explain, by and large, the bulk of the forecast error variance of the curvature. As regards the remaining variables, only surprises to the yield curve level, output growth and, to a lesser extent, the financial stress index, accounts for non-trivial parts of that error variance.

4.3.2.3. Sub-sample analysis. It could be argued that the VAR analyses carried out in the previous sub-sections may suffer from econometric instability because of changes in the structure of the economies as well as changes in the fiscal and monetary regimes. While such regimes changes are harder to pin down in the US case, for Germany there would be an obvious policy regime change around 1999, with the introduction of the euro. Hence, we also performed a VAR analysis for Germany splitting the sample into two sub-samples, 1981:I–1998:IV and 1999:I–2009:IV, for which we

Table 3

Annual change in debt-to-GDP ratio forecast error variance decomposition, Germany 1981:I–2009:IV.

Period	INF	DY4_ADJ	DB4_ADJ	MMR	FSI	L	S	C
<i>3.1. Forecasting the change of the debt-to-GDP ratio</i>								
4	3.249	11.239	69.381	2.304	7.7192	3.244	2.334	0.529
8	2.736	21.276	50.920	2.543	12.630	4.587	3.909	1.398
12	3.983	20.922	48.450	3.869	12.848	4.379	3.885	1.665
16	4.678	22.273	45.094	5.420	12.172	4.055	4.436	1.873
20	4.568	23.037	43.531	5.713	12.163	3.975	4.585	2.428
24	4.747	23.005	43.101	5.682	12.183	4.017	4.549	2.717
<i>3.2. Forecasting the level of the yield curve</i>								
4	4.052	0.462	0.437	2.549	10.136	77.405	0.2738	4.686
8	12.862	1.209	0.570	3.780	11.409	58.602	0.825	10.745
12	11.899	7.102	1.239	6.368	11.672	45.774	0.697	15.250
16	10.126	12.991	1.353	7.971	12.676	36.486	0.659	17.738
20	9.714	15.637	1.232	8.323	13.279	31.840	0.613	19.362
24	9.930	16.531	1.154	8.298	13.565	29.606	0.556	20.359
<i>3.3. Forecasting the slope of the yield curve</i>								
4	17.708	16.824	0.479	41.921	0.063	10.701	12.064	0.242
8	18.551	25.935	0.376	33.387	0.239	7.238	12.992	1.284
12	17.751	26.874	0.591	32.166	0.488	6.859	13.324	1.947
16	18.000	26.739	0.647	32.000	0.491	6.839	13.266	2.018
20	18.031	26.760	0.649	31.949	0.500	6.811	13.284	2.017
24	18.021	26.763	0.655	31.938	0.501	6.811	13.284	2.027
<i>3.4. Forecasting the curvature of the yield curve</i>								
4	0.915	6.614	7.793	2.302	4.949	9.427	1.979	66.022
8	1.582	8.647	7.211	3.335	6.372	8.434	3.856	60.563
12	1.554	9.337	6.886	4.229	6.437	8.491	3.955	59.111
16	1.646	9.824	6.725	4.530	6.499	8.542	3.879	58.356
20	1.759	10.218	6.621	4.671	6.657	8.519	3.810	57.746
24	1.876	10.472	6.540	4.728	6.804	8.499	3.756	57.326

Notes: INF: inflation; DY4_ADJ: annual growth rate of real GDP (corrected for structural break in 1991); DB4_ADJ: annual change of the debt-to-GDP ratio (with GDP adjusted for structural break); MMR: money market interest rate; FSI: financial stress indicator; L: level of the yield curve; S: slope of the yield curve; C: curvature of the yield curve. Each row shows the percentage of the variance of the error in forecasting the variable mentioned in the title of the table, at each forecasting horizon (in quarters) given in the first column.

estimate, as above, VAR(2) models.¹² However, we consider this analysis merely exploratory, given the lack of degrees of freedom notably in the post-1999 sub-sample, and report in here only a summary of the results.¹³

The impulse response functions to fiscal shocks are somewhat different: fiscal shocks have had significant impacts over the yield curve shape before 1999 but not after 1999. The impacts before 1999 are identical for shocks to the change in the debt ratio and shocks in the budget balance ratio and are similar – albeit clearer – to those obtained for the debt ratio in the whole sample. In short, during the 3 quarters after the shock, a fiscal expansion leads to no change in the level and slope of the yield curve but to a decrease in its curvature, *i.e.* a decrease in its degree of concavity. Since the slope and the level do not change, the transitory fall in concavity means that during such period, the medium-term yields fall (as well as, although less and maybe not significantly, the long-term yields).

Therefore, we obtain the interesting result that with the change in the monetary and fiscal regime at the onset of the EMU – and maybe in association with the introduction of the Stability and Growth Pact 2 years earlier, and with the deepening of the market for debt denominated in euros as well as of the overall economic and financial integration in Europe – fiscal shocks turned out

¹² Another potential regime change in the case of Germany would be the reunification in 1991, but this cannot really be tested since our available data sample only starts in 1981.

¹³ Detailed results are available from the authors.

Table 4

Budget balance forecast error variance decomposition, Germany 1981:I–2009:IV.

Period	INF	DY4_ADJ	BALANCE	MMR	FSI	L	S	C
<i>4.1. Forecasting the budget balance</i>								
4	2.046	11.696	71.119	1.284	4.906	3.136	5.731	0.082
8	2.501	18.959	47.488	1.209	15.252	5.554	8.674	0.362
12	2.807	18.437	44.129	4.325	15.306	5.827	8.258	0.911
16	2.914	21.343	38.076	7.244	14.145	5.216	8.229	2.833
20	2.735	23.365	34.359	7.965	14.153	4.976	7.932	4.516
24	3.181	23.634	32.907	7.934	14.231	5.011	7.611	5.491
<i>4.2. Forecasting the level of the yield curve</i>								
4	2.639	0.588	3.317	2.575	10.817	76.019	0.379	3.666
8	9.617	1.104	7.608	3.836	12.731	55.104	0.815	9.186
12	8.636	6.484	8.169	6.121	13.994	42.128	0.651	13.816
16	7.430	11.906	7.237	7.468	15.275	33.869	0.638	16.177
20	7.312	14.564	6.506	7.898	15.812	29.753	0.585	17.571
24	7.626	15.621	6.145	7.960	16.033	27.625	0.530	18.462
<i>4.3. Forecasting the slope of the yield curve</i>								
4	13.529	17.972	0.821	42.745	0.152	10.975	13.064	0.742
8	13.714	28.237	2.647	32.952	0.140	7.172	13.186	1.952
12	13.159	29.348	3.171	31.757	0.154	6.771	13.117	2.522
16	13.680	29.091	3.170	31.474	0.169	6.713	13.081	2.622
20	13.785	29.030	3.192	31.408	0.171	6.684	13.116	2.616
24	13.780	29.022	3.207	31.402	0.178	6.681	13.116	2.615
<i>4.4. Forecasting the curvature of the yield curve</i>								
4	0.587	6.763	1.182	2.094	4.764	11.097	2.261	71.252
8	1.148	8.939	1.104	3.088	6.148	9.861	4.092	65.621
12	1.156	9.764	1.057	4.207	6.139	9.731	4.144	63.803
16	1.275	10.360	1.064	4.568	6.169	9.653	4.046	62.866
20	1.411	10.751	1.114	4.696	6.345	9.577	3.966	62.140
24	1.533	10.988	1.153	4.744	6.535	9.525	3.907	61.615

Notes: INF: inflation; DY4_ADJ: annual growth rate of real GDP (adjusted for the 1991 structural break); BALANCE: budget balance ratio (to GDP adjusted for the 1991 structural break); MMR: money market interest rate; FSI: financial stress indicator; L: level of the yield curve; S: slope of the yield curve; C: curvature of the yield curve. Each row shows the percentage of the variance of the error in forecasting the variable mentioned in the title of the table, at each forecasting horizon (in quarters) given in the first column.

somehow to be less immediately connected with the shape of the yield curve in the main country of the euro area.

4.3.3. Financial stress shocks

One of the results uncovered in the previous sub-sections is that financial conditions have played a role in the identification and transmission of fiscal shocks to the yield curve in the US but not in Germany. Given that an analysis of the effects of financial stress shocks on the yield curve is missing in the literature, we also briefly assess the effects of such shocks.

The impulse response functions to a financial stress indicator shock may be summarised, in the case of the US, as follows.¹⁴ First, output growth and inflation decline significantly for about a year, but monetary policy does not react. The responses of output and inflation are as expected and the lack of reaction of the federal funds rate is reassuring that financial conditions shocks and fiscal shocks (to which monetary policy reacted) are well identified – which is quite relevant for our next conclusion. Second, the fiscal variable deteriorates for about 4 (5) quarters in the case of the growth of the debt ratio (balance ratio) with a statistically stronger impact on the balance ratio, in line with expectations. Third, the immediate impact on the yield curve is an expected fall in its curvature during 2 quarters, meaning that the difference between yields is distributed more proportionally along the yield curve, implying that the pick-up in yields is now smaller at the short-end of the curve and, therefore, that the short-term risks have gained importance relative to medium-term risks. Fourth, there is no significant change in the

¹⁴ For the sake of space conservation the detailed results are not shown, but are available from the authors upon request.

slope, which confirms the association between the slope and monetary policy reaction to the cyclical state of the economy in the literature and in our analysis of fiscal shocks. Fifth, a year after the financial shock, the level of the yield curve starts increasing and peaks at the 10th quarter, remaining significantly above its baseline value between about 1 year and a half and 3 years after the shock (7–10 quarters in the case of the growth of the debt ratio, 7–12 in the case of the balance ratio).

In terms of the forecast error variance decompositions, during the first 2 years, the financial stress shock plays a larger role in accounting for the variance of the forecast error of the balance ratio than of the growth in the debt ratio (10% vs 3%, at the 4 quarter horizon). Second, the change in the debt ratio accounts for a larger proportion of the variance of the forecast error of the financial stress indicator than the balance ratio, respectively 22% and 15%, at the 1 year to 1 year and a half horizon. Therefore, financial conditions have a sharper impact on the deficit (via the interests on the debt) and government debt has a stronger effect on financial conditions than a budget shock.

Moreover, the financial stress shock has no relevant role in explaining the slope, has an immediate role in accounting for errors in forecasting the curvature (11% and 14%, respectively for the debt growth and the budget balance ratio, at quarter 2) and is quite important in accounting for the variance of the error in forecasting the level of the yield curve at horizons from about 2 years (13% and 30% at the 11th quarter peak, for the debt and the budget balance ratio, respectively).

Regarding Germany, after a positive financial stress shock, output growth declines significantly for about a year and a half to 2 years (6 quarters in the model of the debt ratio, 8 quarters in the balance ratio model), but inflation and monetary policy do not react. The absence of response of inflation can seemingly be associated, again, to the credibility of the nominal anchor in that country.

Second, the debt ratio (budget balance ratio) deteriorates significantly for 6 (8) quarters. Again, this confirms the expectations and shows that in Germany, while fiscal policy shocks do not affect significantly the overall financial conditions, negative shocks to the financial environment deteriorate fiscal conditions. At the econometric level this is reassuring for the identification of these shocks, and from an economic perspective it is informative about the credibility associated to fiscal and monetary policy in Germany.

Third, there is an immediate fall in the curvature during 2 quarters, similarly to the US and as expected, meaning that the relative importance of short-term risks (*vis-à-vis* medium term risks) has increased. However, in the case of Germany these effects are rather small and barely significant. Fourth, as expected in view of the lack of monetary policy reaction, there is no significant change in the slope of the yield curve. Lastly, the level of the yield curve falls on impact and remains below its baseline value for very long (statistically for 6 quarters and 16 quarters, respectively for the debt and budget balance ratios). Still, in VAR models estimated from 1999:I onwards, the level of the yield curve is virtually unchanged after shocks to the financial stress indicator.

In terms of the forecast error variance decomposition, a financial stress shock plays a comparable role in accounting for the variance of the forecast error of the growth in the debt ratio and of the budget balance ratio (13% *vis-à-vis* 10%, at the 10 quarter horizon). Second, the debt ratio accounts for a larger proportion of the variance of the forecast error of the financial stress indicator than the balance ratio (respectively 8% and 5%, at the 2 years horizon), but both are much smaller than in the US case. Hence, there has been in this case essentially an impact of fiscal developments on the financial conditions. As regards the yield curve, the forecast error variance decompositions essen-

tially confirm that the financial stress shock has no relevant role in explaining the slope and has some limited immediate role in accounting for errors in forecasting the curvature (around 4% at quarter 2 and 6% from quarter 8 onwards). For the level, financial shocks explain a large proportion of its forecast error variance, which at short horizons is higher in the debt ratio model (9% *vis-à-vis* 5% at quarter 1) but then levels out at around 11% from the 12th quarter onwards. However, for the post-EMU years, the effects of the financial stress shocks on the variance of the errors of forecasting the level essentially vanish.

5. Conclusion

In this paper, we study the relation between fiscal behaviour and the shape of the yield curve in the US and Germany for the period 1981:I–2009:IV. Following a well-established tradition in the finance literature, we describe the shape of the yield curve with estimates of time-varying latent factors that represent its level, slope and curvature. We estimate country-specific VAR models similar to those of an also well-established macro-finance literature, developed with the addition of a fiscal variable – the change in the debt-to-GDP ratio and, alternatively, the budget balance as percent of GDP – as well as a control for financial stress conditions. The analysis of the dynamics implied by the estimated VARs uncovers a set of basic stylised facts on the relation between fiscal behaviour and the shape of the yield curves, which add to the literature that has focused essentially on the effect of fiscal policy on a sub-set of sovereign yields, especially long-term yields.

The results of our paper indicate that, during the last three decades, fiscal behaviour has had a different impact on the yield curve in the US and in Germany. Fiscal developments have generated significant responses of the yield curve that spread out through the subsequent 3 years in the US, while they generated virtually no significant reactions of the shape of the yield curve in Germany. Our results are thus consistent with the literature that, with distinct approaches, detects stronger effects of fiscal variables on yields in the case of the US compared to Europe (e.g. Codogno et al., 2003; Bernoth et al., 2006; Faini, 2006; Paesani et al., 2006; Afonso and Strauch, 2007; Ardagna, 2009).

In addition we can also recall other relevant underpinnings for these results. First, economies with financial systems more based on the banking sector (Germany) rather than on capital markets (US), tend to absorb more easily additional sovereign debt issuance. Moreover, in economies featuring a lower savings rate, which is the case of the US *vis-à-vis* Germany,¹⁵ sovereign yields have been found to increase more as a response to increases in the budget deficit (see Baldacci and Kumar, 2010). Second, Afonso et al. (2011) report that government revenues have been more persistent in Germany than in the US, while government spending has been more persistent in the US, which implies better fiscal sustainability conditions in Germany, and, therefore, an understandable lower responsiveness of the yield curve to fiscal developments in the case of Germany.

On the other hand, Davig and Leeper (2011) report that in the 1990s in the US there was a mix of passive monetary policy and active fiscal policy, which supports our results in the sense that monetary policy reacts to fiscal policy developments. In the same vein, Assenmacher-Wesche (2006) mention that the Bundesbank attached over that period a higher relative weight to inflation than the Fed, implying a more active monetary regime in the case of

¹⁵ The gross saving rates of the US and Germany averaged 15.7% and 22% respectively in the period 1981–2009 (source: European Commission). According to the BIS, in the 1990s, bank loans versus capital market financing ratios were below 50% in the US and around 95% in Germany.

Germany, and, therefore in this case, a significant absence of response from monetary policy to fiscal developments.

In the US, fiscal shocks bring about an immediate response of the short-end of the yield curve that is apparently associated with the reaction of monetary policy to the macroeconomic effects of fiscal developments. Such reaction lasts a year and a half (for debt ratio shocks) and 2 years (for budget balance shocks). Subsequently, fiscal shocks led to a response of all segments of the yield curve – with fiscal expansions leading to an increase in the level of sovereign yields – that lasts 3 years. At the height of the effects, our estimates imply an elasticity of long-term (120 months) yields to a debt ratio shock of about 80% (10th–11th quarters after the shock) and an elasticity to a budget balance shock of about 48% (12 quarters after the shock). The estimated duration of the impact of fiscal shocks on long-term yields is consistent with the findings in Dai and Philippon (2006) and our estimate for the elasticity of long-term yields to the budget balance is not substantially different from their estimate. Yet, our results differ from those in papers that found a smaller elasticity of long yields to the debt ratio than to the budget balance (e.g. Laubach, 2009; Engen and Hubbard, 2005; Kinoshita, 2006; Chalk and Tanzi, 2002), although such studies do not consider the full yield curve latent factors as we do, and do not necessarily measure each elasticity at the height of the dynamic impact as we do.

Our macro-finance framework and econometric methods allow for new and more thorough evidence on the behaviour of the shape of the yield curve, specially its level. By including fiscal variables in an otherwise standard macro-finance model, we show that besides the well-established link with the low frequency movements of inflation (target or expectations), the long-end (level) of the yield curve is associated with fiscal sustainability – i.e. low frequency fiscal developments – as it only reacts to fiscal developments after several quarters of deviation from baseline values.

We complement the evidence with forecast errors variance decompositions. Shocks to the change in the debt ratio account for most of the variance of the errors in forecasting the level of the yield curve at horizons above 1 year and explain 40% of such variance at a 12 quarter horizon. Such shocks also account for substantial, albeit smaller, fractions of the variance of the error in forecasting the slope and the curvature of the yield curve. Shocks to the budget balance ratio are also relevant in accounting for the variance of the errors of the yield curve factors.

The results for Germany differ from those obtained for the US. On the one hand, fiscal shocks entail no comparable reactions of the yield curve factors. On the other hand, they generate no significant response of the monetary policy interest rate. The results also differ across the two alternative fiscal variables. Shocks to the budget balance ratio create no response from any component of the yield curve shape, while a surprise increase in the change of the debt ratio causes some decline in the concavity of the yield curve that implies a very quick and transitory fall in mid-term yields that is statistically significant only during the 2nd and 3rd quarters after the shock. The lack of a significant reaction of monetary policy to fiscal shocks – and the consequent lack of reaction of the yield curve slope – seems associated with the well-known strong credibility of monetary institutions and policy in Germany. The lack of significant reaction of the yield curve level (long-end of the yield curve) seems associated with the strong credibility of the country's fiscal policy framework and with a much quicker return of fiscal variables to their baseline values after a shock, i.e. the fact that fiscal actions are more likely to be rapidly reversed in Germany than in the US. Notably, as shown in Figs. 8 and 10, in Germany shocks to the change in the debt ratio as well as shocks to the budget balance

ratio, fade away after 4 quarters; in contrast, as Figs. 4 and 6 show, in the US case, shocks to the change in the debt ratio vanish only after 8 quarters and shocks to the budget balance ratio disappear only after 12 quarters.

Our exploratory analysis of the effects of fiscal shocks on the yield curve before and after 1999, suggests that the results found for shocks to the change in the debt ratio seem more due to the period before 1999, when they are recorded for both fiscal measures. Indeed, in the period 1981–1998, fiscal shocks have led to a significant impact on the curvature of the German yield curve in the 3 quarters after the shock, with expansionary fiscal shocks leading to transitory decreases in the yields of the medium-term maturities.

The impulse response analysis has been complemented with forecast errors variance decompositions. In Germany, fiscal shocks have been overall unimportant in accounting for the variance of the forecast errors of the yield curve latent factors, with two exceptions. First, the debt ratio shocks explain a not negligible part of the errors in forecasting the curvature – consistently with the impulse responses; second, the budget balance shocks are somewhat relevant in accounting for errors in forecasting the level of the yield curve.

Finally, one needs to be aware that the sovereign debt of the two countries under analysis are usually seen as a safe haven, both in times of fiscal stress in other countries, and when economic conditions deteriorate globally.

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Appendix A. Appendix – data sources

A.1. US

Zero-coupon yields (1961:6–2009:12)

Maturities of 12, 24, 36, 48, 60, 72, 84, 96, 108 and 120 months: companion data to Gurkaynak et al. (2007), available at (accessed April 2010) <http://www.federalreserve.gov/econresdata/researchdata.htm>.

Maturities of 3, 6, 9, 15, 18, 21 and 30 months: computed by the authors with the Nelson–Siegel–Svensson formula and the coefficients made available at <http://www.federalreserve.gov/econresdata/researchdata.htm>

GDP, GDP deflator: International Financial Statistics, IMF.

Federal funds rate: 11160B...ZF... International Financial Statistics, IMF.

Government debt: Federal debt held by the public, FYGDPUN, Millions of Dollars. US Department of the Treasury, Financial Management Service.

Government budgetary position: Federal Government Current Receipts and Expenditures, Bureau of Economic Analysis.

A.2. Germany

Zero-coupon yields (1972:9–2010:03)

Maturities of 6, 12, 18, 24, 30, 36, 48, 60, 72, 84, 96, 108 and 120 months: Bundesbank (data made available on April 2010).

Maturities of 3, 9, 15, 21 months: computed by the authors with the Nelson–Siegel–Svensson formula and the coefficients made available by the Bundesbank.

GDP, GDP deflator: International Financial Statistics, IMF.

Monetary policy rate: Lombard rate, Germany, 1980:1–1998:4. Marginal lending facility, ECB, 1999:1–2009:4.

Government debt: Central, state and local government debt; Total debt, excluding hospitals (BQ1710, BQ1720). Statistische Angabben: Umrechnungsart: Endstand, Euro, Millions, Bundesbank.

Government spending: General government budgetary position; Expenditure, total (BQ2190). Euro, Millions, Bundesbank.

Government revenue: General government budgetary position; Revenue, total (BQ2180). Euro, Millions, Bundesbank.

Financial stress index (FSI): Balakrishnan et al. (2009), (accessed May 2010) <http://www.imf.org/external/pubs/ft/wp/2009/update/wp09133.zip>.

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