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CONTENTS

Abstract

We study fiscal behaviour and the sovereign yield curve in the U.S. and Germany in the period 1981:I-2009:IV. The latent factors, level, slope and curvature, obtained with the Kalman filter, are used in a VAR with macro and fiscal variables, controlling for financial stress conditions. In the U.S., fiscal shocks have generated (i) an immediate response of the short-end of the yield curve, associated with the monetary policy reaction, lasting between 6 and 8 quarters, and (ii) an immediate response of the long-end of the yield curve, lasting 3 years, with an implied elasticity of about 80% for the government debt ratio shock and about 48% for the budget balance shock. In Germany, fiscal shocks entail no significant reactions of the latent factors and no response of the monetary policy interest rate. In particular, while (i) budget balance shocks created no response from the yield curve shape, (ii) surprise increases in the debt ratio caused some increase in the short-end and the long-end of the yield curve in the following 2nd and 3rd quarters.

Keywords: yield curve, fiscal policy, financial markets.
JEL Classification Numbers: E43, E44, E62, G15, H60.

Non-technical summary

In this paper, we use the macro-finance analytical framework of Diebold, Rudebusch and Aruoba (2006) and enrich their empirical model of the economy with variables representing fiscal policy as well as variables 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 empirically studies the dynamic relation between fiscal developments – government debt and the budget deficit – and the shape of the sovereign yield curves for the U.S. and for Germany. The shape of the yield curve is measured by maximum-likelihood estimates of the level, slope and curvature, obtained with the Kalman filter, following the state-space specification of the Nelson and Siegel (1987) model.

The yield curve latent factors and the fiscal variables are related in country-specific VAR models that further comprise the variables typically considered in macro-finance models – real output, inflation and the monetary policy interest rate – as well as a variable meant to control for the financial conditions. We contribute to the literature by specifying and estimating VAR models that are not *ex-ante* restricted in their lag length and which account for the dynamic effects of fiscal policy on the whole shape of the curve, rather than estimating the elasticity of a specific interest rate at a specific time-horizon as is more often the case in analyses of the relation between fiscal behaviour and sovereign yields.

The samples begin in the early 1980s and end in the last quarter of 2009, thus including at least two recessions (1992-93, 2001), the recent economic and financial crisis (2008-09), the Volcker chairmanship of the FED (1979-1987) in the U.S., and for the case of Germany, the reunification, the approval of the Maastricht Treaty (1992), and the creation of the euro (1999).

In the U.S., fiscal shocks have led to 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 two years (for budget balance shocks). Fiscal shocks further led to an immediate response of the long-end segment of the yield curve – with fiscal expansions leading to an increase in long-term sovereign yields – that lasts three years. At the height of the effects, our estimates imply an elasticity of long-term yields to a debt ratio shock of about 0.80 (10^{th}-11^{th} quarters after the shock) and an elasticity to a budget balance shock of about 0.48 (12 quarters after the shock). Our results differ from the findings of papers that found a smaller elasticity of long yields to the debt ratio than to the budget balance, although such studies do not consider the full yield curve latent factors as we do.

Moreover, shocks to the change in the debt ratio (comparable to a shock in the budget balance) 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. Highlighting the importance of studying fiscal shocks we could not reject the hypotheses that the change in the debt ratio causes, in the Granger sense, the shape of the yield curve. As regards the budget balance, Granger causality has only been found for the slope and the curvature.

The results for Germany differ markedly from those obtained for the U.S. 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 a decline in the concavity of the yield curve that implies an increase in both the short-end and the long-end of the yield curve; yet, such reaction is very quick and transitory, as it is statistically significant only during the 2nd and 3rd quarters after the shock. This can be seen as a response of capital markets to growing sovereign indebtedness also in the case of Germany. Such result seems due to the period before 1999, since, as the exploratory sub-sample analyses suggest, for both types of fiscal shocks, the impact of fiscal behaviour on the yield curve was mitigated after 1999. During 1981-1998, expansionary fiscal shocks have led to increases in the yields of the shortest and the longest maturities during the subsequent three quarters.

In Germany, fiscal shocks have been overall unimportant in accounting for the variance of the errors in forecasting 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 response analysis; second, budget balance shocks are somewhat relevant in accounting for errors in forecasting the level of the yield curve. In the case of Germany, the results from Granger causality tests agree with the impulse responses and forecast errors variance decompositions, as it is not possible to reject the hypothesis that either the debt ratio or the budget balance Granger-cause any of the yield curve factors.

1. Introduction

A relevant question, notably for policy makers, is to understand, as far as possible, what are the relations between fiscal developments and the shape of the sovereign yield curve, as well as the dynamic patterns of such relation. One can expect to observe both a bi-directional relationship and similarities across the main developed countries.

In the related literature there are a number of papers trying to uncover the relation of the main fiscal variables with the long-term end of the yield curve in specific time-horizons, and a few studies assess such relation at some additional points of the curve, namely its short-term end. 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 an approach to the yield curve characterisation 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 additional variables 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 empirically studies the dynamic relation between fiscal developments – government debt and the budget deficit – and the shape of the sovereign yield curves for the U.S. and for 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, Rudebusch and Aruoba (2006).

The yield curve latent factors and the fiscal variables are related in country-specific VAR macro-finance models that further comprise the variables typically considered in macro-finance models – real output, inflation and the monetary policy interest rate – as well as a variable meant to control for the financial conditions. The evidence is based on impulse response function analysis, forecast error variance decomposition and Granger causality tests. In this context, the novelty of our paper consists of the inclusion of fiscal variables and a control for financial conditions in an empirical model akin to the one of Diebold, Rudebusch and Aruoba (2006). We contribute to the literature by specifying and estimating VAR models that are not *ex-ante* restricted in their lag length and which account for the dynamic effects of fiscal policy on the whole shape of the curve, rather than estimating the elasticity of a specific interest rate at a specific time-horizon as is more often the case in analyses of the relation between fiscal behaviour and sovereign yields.

The samples begin in the early 1980s and end in the last quarter of 2009, thus including at least two recessions (1992-93, 2001), the recent economic and financial crisis (2008-09), the Volcker chairmanship of the FED (1979-1987) in the U.S., and for the case of Germany, the reunification, the approval of the Maastricht Treaty (1992), and the creation of the euro (1999).

Changes in policy regimes can be an issue for empirical work as they carry along the possibility of structural breaks in the VAR. We check whether the issue is relevant in the case of Germany, at the onset of the Economic and Monetary Union, however, not enough data area available for the pre-reunification period to check for a possible break due to the reunification.

As regards the US, changes in the fiscal regime are less clear than in the monetary policy regime. Nevertheless, almost all sample period corresponds to the Greenspan chairmanship of the FED and there is not enough data to test for a significant break during the Volker chairmanship. We have checked whether starting the sample at 1986 rather than in 1981changed qualitatively the results and found that it does not.

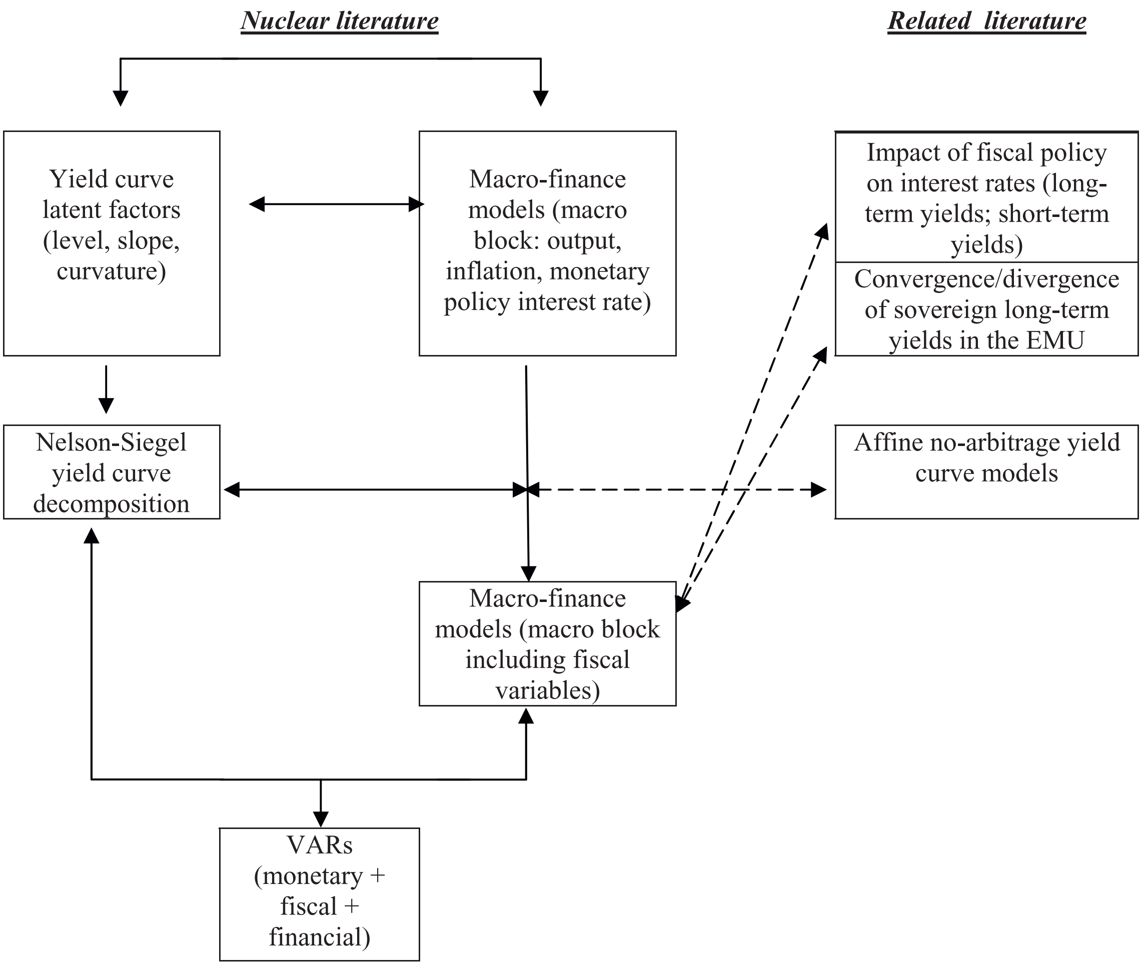
The paper is organised as follows. Section two gives an overview of the literature. Section three explains the methodology to obtain the yield curve latent factors and the VAR specifications. Section four conducts the empirical analysis reporting the estimates of the level, slope and curvature, as well as the VAR results. Finally, section five concludes.

2. Literature overview

Figure 1 shows the strands of literature that connect with this paper, distinguishing between nuclear and related literature. On the one hand, our study relates more closely with the analyses that describe the shape of the yield curve estimating three latent factors – level, slope and curvature – and then use these variables in VAR-based macro-finance models of the economy. On the other hand, the paper adds to the large literature that has estimated the sensitivity of interest rates to fiscal policy, as well as to the recent studies of the convergence/divergence of sovereign yields in Europe and in the U.S.

The extensive 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 - see *e.g.* Canzoneri, Cumby and Diba, 2002). While there are multiple theoretical channels motivating such *rationale* (an issue beyond the scope of this paper), the empirical evidence remains somewhat mixed (see *e.g.* the surveys by Barth, Iden, Russek and Wohar, 1991; Gale and Orzag, 2003; European Commission, 2004; and Terzi, 2007).

Figure 1 - Relation of this paper with the literature



Overall, the literature warrants the following main conclusions. First, there seems to be a significant impact of budget deficits and government debt on long-term interest rates, especially detected in studies that use budget deficits and debt projections, rather than current fiscal data (see *e.g.* Canzoneri, Cumby and Diba, 2002; Gale and Orzag, 2004; Laubach, 2009; Afonso, 2009; Hauner and Kumar, 2009). For instance, Schuknecht, von Hagen and Wolswijk (2010) report that the interest rate effects of budget deficits and government debt were significantly 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, Favero and Missale, 2003; Bernoth, von Hagen and Schuknecht, 2006; Faini, 2006; Paesani, Strauch and Kremer, 2006; and, for event studies, Afonso and Strauch, 2007; and Ardagna, 2009). Third, the relation differs across different initial levels of government debt ratios (see *e.g.* Faini, 2006; Ardagna, 2009; Ardagna, Caselli and Lane, 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, 2004; 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', following the creation of the EMU and/or the recent financial crisis, with a large part of the papers attributing a possible role to fiscal factors in such convergence (divergence). These studies have also typically looked at long-term yields, especially 10-year government bonds (see *e.g.* Attinasi, Checherita and Nickel, 2009; Haugh, Ollivaud and Turner, 2009; Sgherri and Zoli, 2009; Manganelli and Wolswijk, 2009; Barrios, Iversen, Lewandowska and Setzer, 2009, and Afonso and Rault, 2010), even when focusing on the relevance of fiscal events (see *e.g.* Codogno, Favero, and Missale, 2003; and Afonso and Strauch, 2007). In some cases, the empirical analysis has combined data from sovereign debt issued at several maturities (Schuknecht, von Hagen and Wolswijk, 2010). Yet another part of this research has focused on the determinants – including the 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 e.g. Nickel, Rother and Rülke, 2009; Alexopolou, Bunda and Ferrando, 2009).

While most of the literature relating fiscal developments with interest rates has looked at the long end part of the yield curve, some papers did analyse other segments of the curve. An early example is Elmendorf and Reifschneider (2002), who 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. Another example is Canzoneri, Cumby and Diba (2002), who have studied the effect of projections of cumulative budget deficits on the spread between 5-year (or 10-year) and 3-month Treasury yields. More recently, Geyer, Kossmeier and Pichler (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, Fratzscher, Gurkaynak and Swanson (forthcoming), used daily yields of maturities between two and ten 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.

Given our purpose of studying the dynamic relation between fiscal policy and the shape of the sovereign yield curves, another nuclear strand of literature has developed theoretical and empirical macro-finance models that explicitly consider the contour of the whole yield curve and model their dynamic interactions with macroeconomic variables. An important part of such literature has drawn on the Nelson and Siegel (1987) decomposition of the yield curve into three latent factors that together allow for a description of the yield curve shape at each moment.

Litterman and Scheinkman (1991) and Diebold and Li (2006) have interpreted the above mentioned latent factors as Level, Slope and Curvature, and the latter suggested a two-step procedure to estimate the factors recursively and iteratively. First, estimating the three factors by non-linear-least squares (conditional on some *a-priori* regarding the loadings of the slope and curvature at each maturity); second, using the estimates of the factors for forecasting the yield curve. Diebold, Rudebusch and Aruoba (2006) argued that such two-steps procedure is sub-optimal and suggested a one-step procedure based on a state-space representation of the Nelson-Siegel model and its estimation by maximum likelihood with the Kalman filter, which allows for estimating all the hyper-parameters along with the time-varying parameters, *i.e.* the curve latent factors.

So far, most of the analyses within this approach have focused on the relation between the yield-curve latent factors and monetary policy, inflation and real activity (see for example Diebold, Rudebusch and Aruoba, 2006; Carriero, Favero and Kaminska, 2006; Dewachter and Lyrio, 2006; Hordahl, Tristani and Vestin, 2006; Rudebusch and Wu, 2008; Hoffmaister, Roldós and Tuladhar, 2010). This may be explained by the fact that 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 seen as involving monetary policy – as well as on the relation of the Level with inflation expectations (see, for example, Ang, Piazzesi and Wei, 2006; Rudebusch and Williams, 2008 and the references therein).

While several studies such as Diebold, Rudebusch and Aruoba (2006) and Carriero, Favero and Kaminska (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, Piazzesi and Rudebusch, 2005; Christensen, Diebold and Rudebusch, 2009; Rudebusch, 2010, and the references therein). In this paper, we follow the Nelson-Siegel method to decompose the yield curve into latent factors, and focus on enhancing the empirical macro-finance model with fiscal policy variables.

Macro-finance analyses assessing the role of fiscal variables in the behaviour of the whole yield curve do not abound, but there are some papers in that vein, which thus relate closely to our paper. An early example is Dai and Philippon (2006), who have developed an empirical macro-finance model for the U.S. including, in the macro block, the monetary policy interest rate, inflation, real activity and the government budget deficit. Their model combines a no-arbitrage affine yield curve comprising a fairly large *spectrum* of maturities, with a set of structural restrictions that allow for identifying fiscal policy shocks and their effects on the prices of bonds of different maturities. The estimation of their over-identified no-arbitrage structural VAR allows them to conclude that government budget deficits affect long-term interest rates, albeit temporarily (with high long rates not necessarily turning into high future short-term rates). They estimate that a one percentage point increase in the deficit ratio increases the 10-year rate by 35 basis points after three years, with fiscal policy shocks accounting for up to 13 percent of the variance of forecast errors in bond yields. While focusing only on the US case and using rather intricate identifying restrictions, their result that fiscal shocks temporarily increase the yield curve slope merits attention, namely when assessing whether such result holds for Germany and whether it holds after controlling for the financial factors that have been important in the recent crisis.

Another example is Bikbov and Chernov (2006), who 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 percent) 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. Moreover, they find that jointly, they are as important as inflation and real activity in explaining the long part of the term structure and explain 50 percent of the slope variation. In particular, the slope is highly correlated with the growth in public debt, a result that they find consistent with the anecdotal evidence concerning the Clinton restrictive budget package on February 1993 as well as with the November 1999 increase in taxes, during which the yield curve slope decreased between 1.5 and 2 percentage points, due to the fall in long-term yields and no change in the short-term yields.

Finally, a paper that is closer to ours – as it uses the Nelson-Siegel decomposition of the yield curve, rather than a no-arbitrage model, and focuses on the effects of fiscal policy on the yield curve – 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 and looking at the whole yield curve rather than a range of maturities. Using quarterly data for 1991:II-2006:I, they estimated the yield curve Level, Slope and Curvature and then studied the relation between the debt-to-GDP ratio and the Level – interpreted as the long-run component of the curve – as well as the Curvature – the medium-run component – in a framework of Markov-switching regimes of expectations about fiscal policy. Their estimates capture the change, with the EMU, from a higher public finances expected risk to a lower risk expectations regime, with the estimated impact of the fiscal variables on the yield curve depending on the expectations regime. Under unfavourable fiscal expectations, they estimate that for every 10 percentage points of increase in the Italian debt-to-GDP ratio the yield curve level tends to increase by 0.43 percentage points; and that such increase in the debt-to-GDP ratio would imply on average an increase of 0.25 percentage points in the medium-term part of the yield curve.

3. Methodology

We contribute to the macro-finance literature at an applied level studying the relation between the shape of the sovereign yield curve and fiscal behaviour in a framework that is a development of the Rudebusch, Diebold and Aruoba's (2006) approach. 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 choice of the 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 U.S., 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 used by e.g. Diebold and Li (2006) and Diebold, Rudebusch and Aruoba (2006). Our choice for not following an arbitrage-free approach is motivated by the arguments set out by Diebold and Li (2006, pp. 361-362) and Diebold, Rudebusch and Aruoba (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, run separately for each country. In a first step, the three yield curve latent factors are estimated by maximum likelihood using the Kalman filter, as in Diebold, Rudebusch and Aruoba (2006). In the second step, 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),

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

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

Following Diebold and Li (2006) and Diebold, Rudebusch and Aruoba (2006), 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:

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

Clearly, L_t may be interpreted as the overall level of the yield curve, as its loading is equal for all maturities. The factor S_t has a maximum loading (equal to 1) at the shortest maturity which then monotonically decays through zero as maturities increase, while the factor C_t has a loading that is null at the shortest maturity, increases until an intermediate maturity and then falls 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]

As in Diebold, Rudebusch and Aruoba (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

[1] Diebold and Li (2006) assume λ=0.0609, which corresponds to a maximum of the curvature at 29 months, while Diebold, Rudebusch and Aruoba (2006) estimate λ=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.

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

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

where t=1,…..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

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

where t=1,…,T, and $\varepsilon_t(\tau_1)$, $\varepsilon_t(\tau_2),\ldots,\varepsilon_t(\tau_N)$ 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

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

$$y_t=\Lambda f_t+\varepsilon_t. \tag{6}$$

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: $E(f_t\eta_t^{'})=0$ and $E(f_t\varepsilon_t^{'})=0$.

Furthermore, following Diebold, Rudebusch and Aruoba (2006) it is assumed that the innovations of the measurement and of the transition systems are white noise and mutually uncorrelated

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

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 Kalman filter and the fixed-interval Kalman 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

$$\mathbf{X}_t = \mathbf{c} + \sum_{i=1}^{p} \mathbf{V}_i \mathbf{X}_{t-i} + \boldsymbol{\varepsilon}_t , \tag{8}$$

where X_t denotes the (8×1) vector of the m endogenous variables given by $\mathbf{X}_t \equiv \left[\pi_t \quad Y_t \quad f_t \quad i_t \quad fsi_t \quad L_t \quad S_t \quad C_t\right]'$, c is a (8×1) vector of intercept terms, V is the matrix of autoregressive coefficients of order (8×8), and the vector of random disturbances $\boldsymbol{\varepsilon}_t$. 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 recursive 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 don't affect them contemporaneously, 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 place the monetary policy interest rate, which may react contemporaneously to shocks to inflation, output and the fiscal variable but won't be able to 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 on the fiscal policy variable – because of the automatic stabilizers – but that fiscal shocks don't 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 U.S. 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; 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 1969:1-2010:2 and 1972:9-2010:3 respectively for the U.S. 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:I 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-Rudebusch-Aruoba (2006). The shortest maturity is three months and the longest 120 months.

We use the following macroeconomic variables: 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 suggested by Balakrishnan, Danninger, Elekdag and Tytell (2009). The FSI indicator is computed in order to give a composite overview of the overall financial conditions faced by each individual country considering seven financial variables (further detailed in the Appendix).

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. For the case of the U.S. 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).

4.2. Fitting the yield curve

In this section we present some further details on the maximum-likelihood estimation of the state-space model described in sub-section 3.1 and the estimation results for each country, with an emphasis on the estimated time-series of level, slope and curvature.

For the whole 17 maturities considered in Diebold, Rudebusch and Aruoba (2006), this implies that vectors y_t and ε_t have 17 rows, Λ has 17 columns and H has 17 columns/rows (see equations (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 for all countries: 9 elements of the (3×3) transition matrix A, 3 elements of the (3×1) mean state vector μ, 1 element (λ) in the measurement matrix Λ and 6 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 optimization involves, on the whole, the estimation of 36 hyper-parameters. The numerical optimization procedures used in this paper follow the standard practices in the literature, similar to those reported by Diebold, Rudebusch and Aruoba (2006).

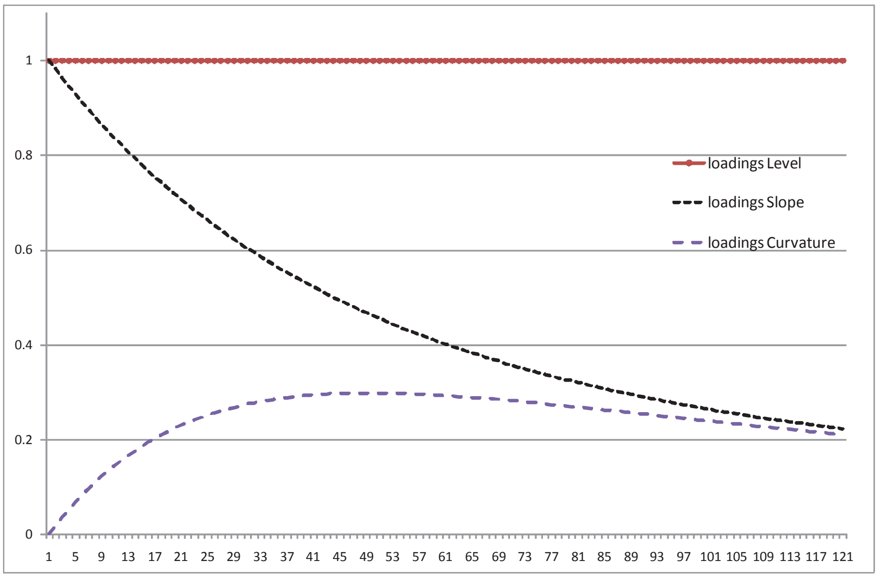
As regards the latent factors model assumed for the yield curve, it could be argued that, since the zero-coupon data used in this study are overall generated with the Svensson (1994) extension to the Nelson and Siegel (1987) model – see *e.g.* Gurkaynak, Sack and Wright (2007), for the US case – the 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 Diebold, Rudebusch and Aruoba (2006) and indeed 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 percent 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. U.S.

We now present the estimation results for the model of level, slope and curvature in the case of the U.S. As regards hyper-parameters, we restrict the analysis to λ and the implied loadings for the latent factors, reporting estimates and p-values of the remaining hyper-parameters in the Annex. Regarding parameters, we present and discuss thoroughly the time-series of time-varying estimates of level, slope and curvature (all codes, data and results are available from the authors upon request).

The estimate of λ (significant at 1 percent) 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 – in comparison with the patterns implied by the estimate in Diebold, Rudebusch and Aruoba (2006) – 0.077 – and the assumption in Diebold and Li (2006) – 0.0609 –, which imply maximums of C_t at 23 and 29 months, respectively. Figure 2 shows the loadings of the three latent factors implied by our estimate of λ. The divergence to the referred estimates in the literature is due to differences in the sample period and to a difference in the method of computation of the zero-coupon yields – with respect to this issue, it should be stressed that the methods used in computing the zero-coupon yields are consistent across the countries considered in this paper.

Figure 2. Loadings of L_t, S_t and C_t, U.S. 1961:6-2010:2



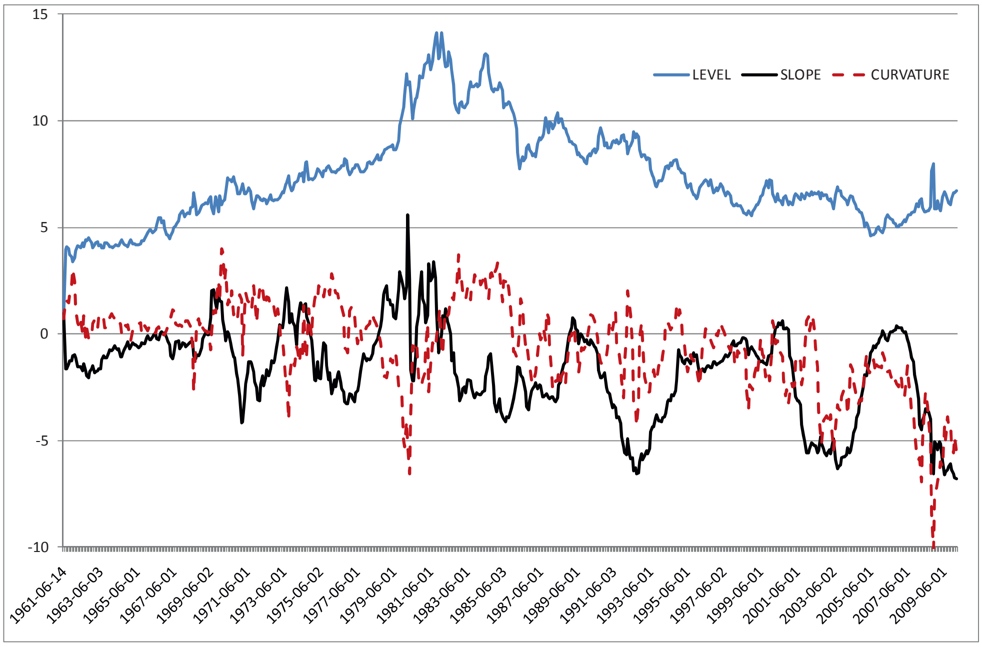
Note: The figure shows the loading of each latent factor at each maturity, expressed in months.

The estimates of the mean values of the three latent factors are reasonable and fairly precise (see Annex 1). The negative mean values estimated for S_t and C_t imply the typical shape of the yield curve as an ascending and concave curve, as expected. Moreover, all three latent factors follow highly persistent autoregressive processes, but, as usual in the literature, L_t is more persistent than S_t which, in turn, is more persistent than C_t. Our estimates indicate that the lagged value of the curvature, C_{t-1}, significantly drives the dynamics of the level, L_t (with a decrease in the degree of concavity associated with an increase in the level) and that the lagged value of the level, L_{t-1}, significantly drives the dynamics of the slope, S_t (with an increase in the level associated with an increase in the slope).

In addition, the innovations to the curvature, C_t, have a larger variance than those to the slope, S_t, which in turn have a higher variance than the innovations to the level, L_t. Such a result is consistent with the literature and with our *a priori* ideas. Overall, these results imply that L_t is the smoother latent factor, S_t is less smooth and C_t is the least smooth factor.

Figure 3 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 financial crisis (2008-2009).

Figure 3. Estimates of L_t, S_t and C_t, U.S. 1961:6-2010:2



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

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.

The curvature displays, as usual in the literature (and as expected given the hyper-parameters estimates discussed in the Annex), 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).

As a sensitivity check, in Figure 4 we present our estimates for each of the yield curve latent factor together with the corresponding empirical measures directly computable from the zero-coupon yields that are typically used in the literature as proxies for the latent factors:

$$Level = \left[\left(y_t(3)\right) + \left(y_t(24)\right) + \left(y_t(120)\right)\right]/3, \tag{9}$$

$$Slope = \left[\left(y_t(3)\right) - \left(y_t(120)\right)\right], \tag{10}$$

$$Curvature = \left[2 \times \left(y_t(24)\right) - \left(y_t(3)\right) - \left(y_t(120)\right)\right], \tag{11}$$

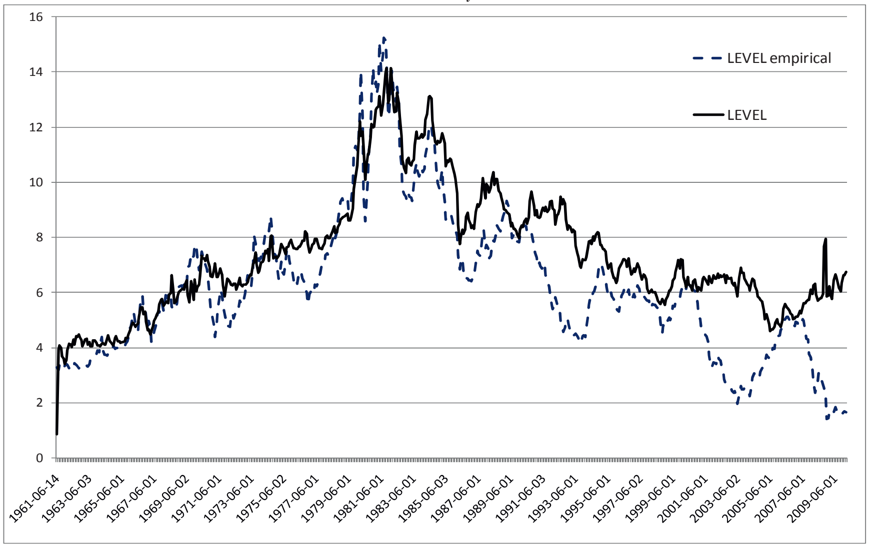
where $\left(y_t(m)\right)$ refers to the zero-coupon bond yield of maturity m (in months).

Our estimated time-series L_t follows quite closely the simple average of the zero-coupon yields of 3, 24 and 120 months of maturity (with a 86% correlation), except in the first half of the 1990s – a result also present in Diebold, Rudebusch and Aruoba (2006) –, in the first half of the 2000s and since the beginning of the financial crisis in mid-2007 (periods not covered in Diebold, Rudebusch and Aruoba, 2006). Overall, L_t depicts a smoother pattern, thus appearing to have a superior ability to capture the dynamics f the whole yield curve – as a level factor should – than the mere average of three out of the 17 considered maturities.

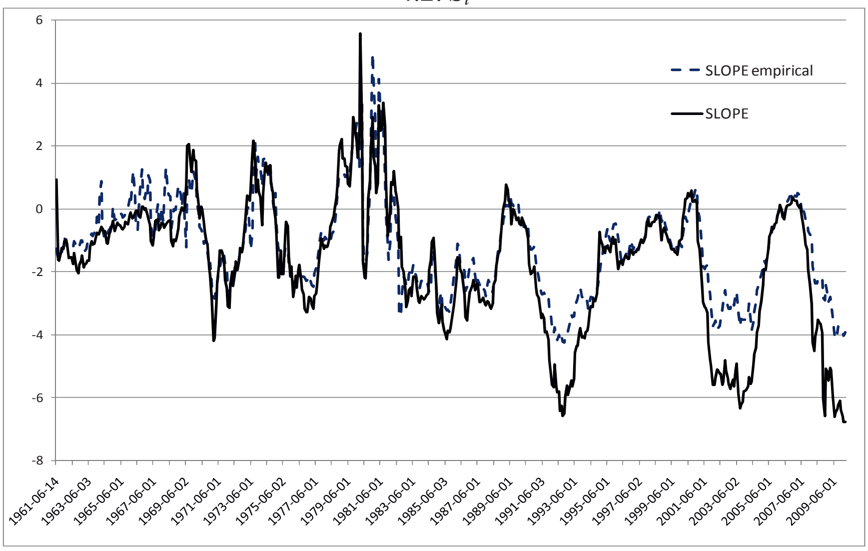
Our estimates of S_t have a very high correlation with the standard empirical proxy for the yield curve slope (93%), in line with the correlations typically seen in the related literature (see *e.g.* Diebold, Rudebusch and Aruoba, 2006). The main divergence between the two time-series are that our estimates display a higher variation since the 1990s, which generates deeper troughs in 1990-1994, 2001-2004 and at the end of the sample period since late 2007.

Figure 4. Estimates of L_t, S_t, C_t, and empirical proxy, U.S. 1961:6-2010:2

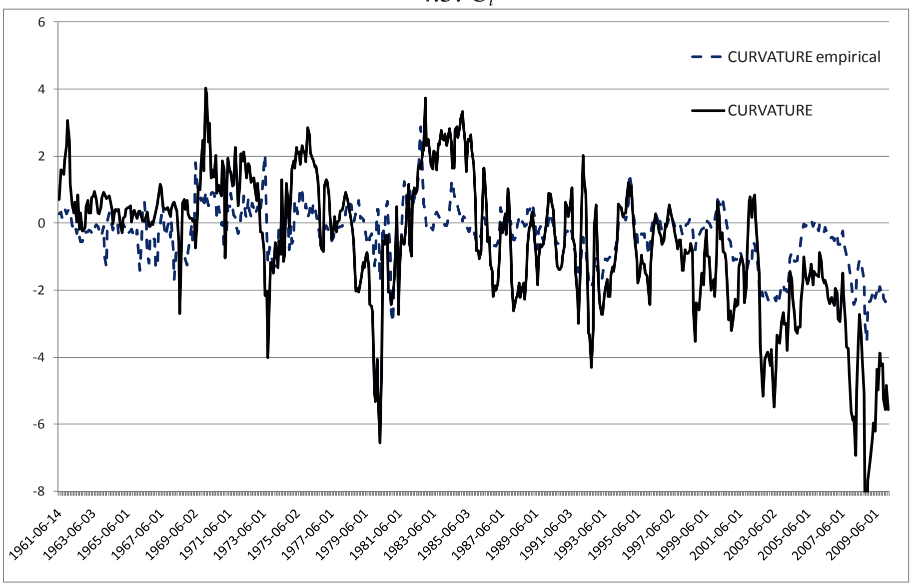
4.1. L_t



4.2. S_t



4.3. C_t



Note: Each chart compares, for each latent factor, the estimates obtained with maximum likelihood with the Kaman filter, as described in the text, with the corresponding empirical proxy.

The estimated time-series for C_t has a higher variability than its empirical proxy, as Figure 4.3 clearly shows. As a result, even though their movements are fairly close to each other, their correlation is only of 72%.

In the recent financial crisis, differently from what the empirical proxy is able to capture, our estimates point to persistent and sizeable negative values of C_t, corresponding to a less pronounced concavity of the yield curves, which, as shown in Figure 4.3, were steeply upward (as monetary policy rates were decreased abruptly to combat the crisis). Another visible difference between our C_t estimates and their empirical counterparts appear in the disinflationary episode, in which C_t signals a much more pronounced inversion of the curvature (to convexity) in association with the inversion of the slope indicated by both S_t and its proxy in Figure 4.3.

Overall, we can conclude that our estimates of the three yield curve latent factors, L_t, S_t and C_t, 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. The estimates are also in line, with an apparent advantage in some episodes, with the history described by their traditional empirical counterparts.

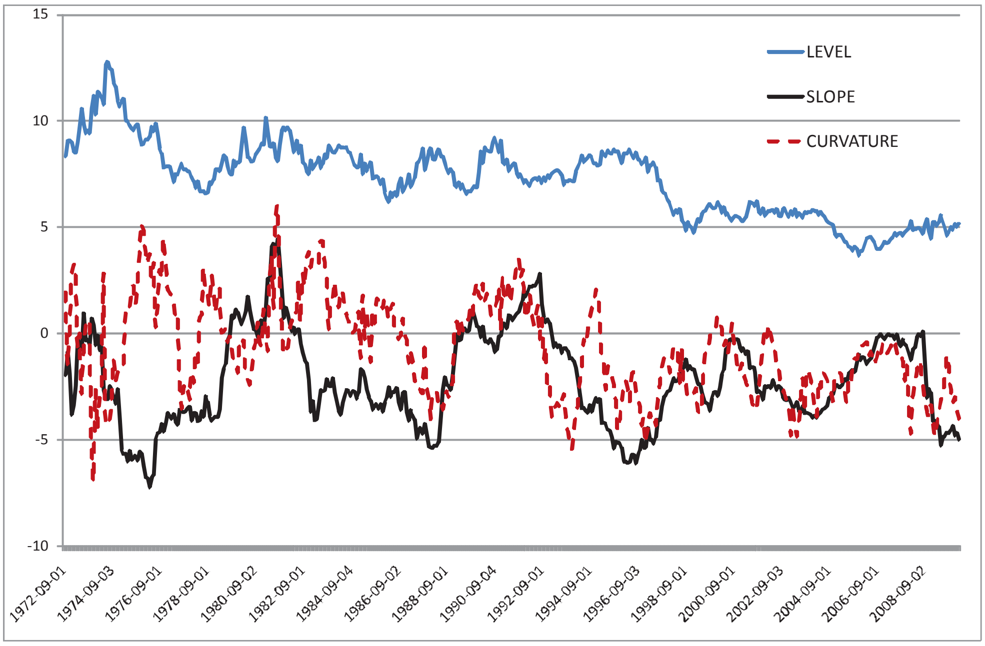
4.2.2. Germany

In this sub-section we present the estimates of the time-varying parameters – level, slope and curvature – for the case of Germany. As regards hyper-parameters, as in the U.S. case, we only discuss λ in the text and present further details in Annex 1 (all codes, data and results are available from the authors upon request).

The estimate of λ (which is significant at 1 percent) 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 U.S.

Figure 5 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 U.S. 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.

Figure 5. Estimates of L_t , S_t and C_t , Germany 1972:9-2010:3



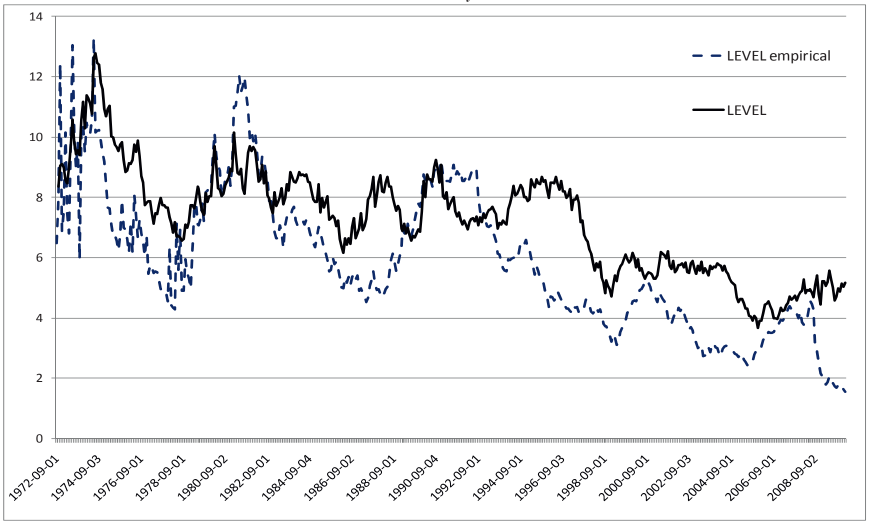
Note: The figure shows the values of the three latent factors at each month.

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 (1991). The curvature displays, as usual, a much higher variation than the slope and the level. As in the case of the U.S. there is an apparent positive correlation between S_t and C_t since the second half of the 1980s.

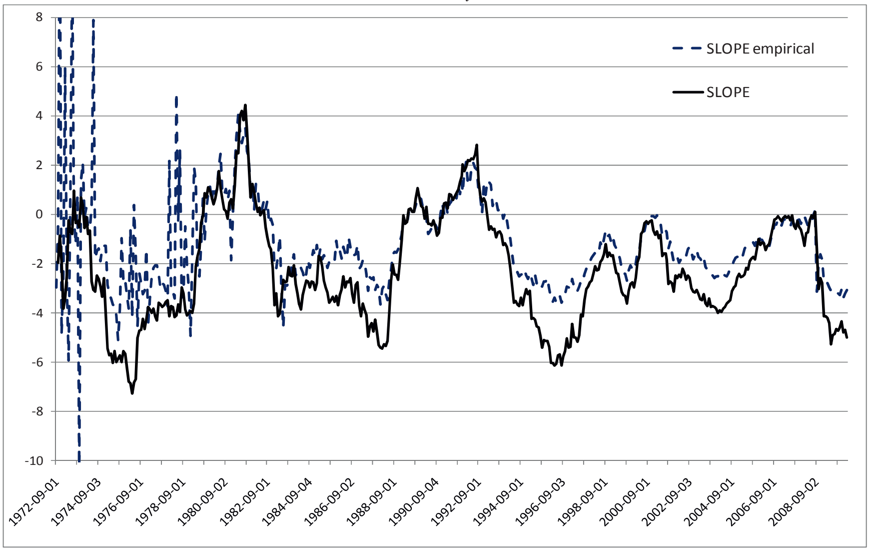
In Figure 6 we present the estimates for each of the yield curve latent factor together with the corresponding empirical measure typically used in the literature as *proxy* (as in the case of the U.S., using also equations (9), (10) and (11)). The correlations between the model estimates and the empirical measures are somewhat smaller than for the U.S., which is due, mostly, to the very high volatility of the zero-coupon yields at the beginning of the sample. For the whole sample, the correlations are of 80%, 68% and 27% respectively for the level, slope and curvature. For a sample beginning in 1980 – such as the one that will be used in the VAR analysis (then, after computing simple quarterly averages, to match the periodicity of the macro variables) – the correlations are of 77%, 94% and 69%, which is more in line with the results for the U.S. case.

Figure 6. Estimates of L_t, S_t, C_t, and empirical proxy, Germany 1972:9-2010:3

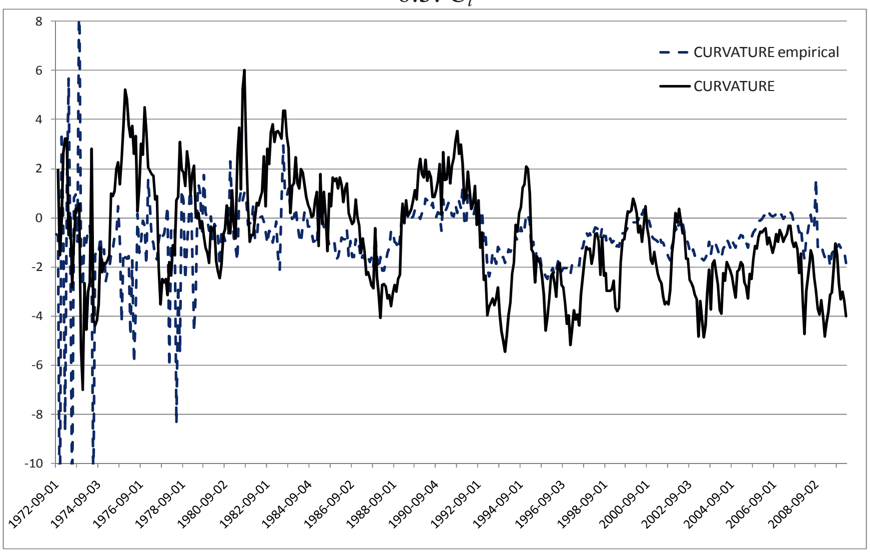
6.1. L_t



6.2. S_t



6.3. C_t



Note: Each chart compares, for each latent factor, the estimates obtained with maximum likelihood with the Kaman filter, as described in the text, with the corresponding empirical proxy.

4.3. VAR analysis

It could be argued that the estimation of the yield curve latent factors and of the macro-fiscal-finance VAR, for the sake of econometric consistency, should be performed simultaneously in an encompassing state-space model (by maximum-likelihood with the Kalman filter). In fact, that is the approach undertook by Diebold, Rudebusch and Aruoba (2006) in their macro-finance empirical analysis.

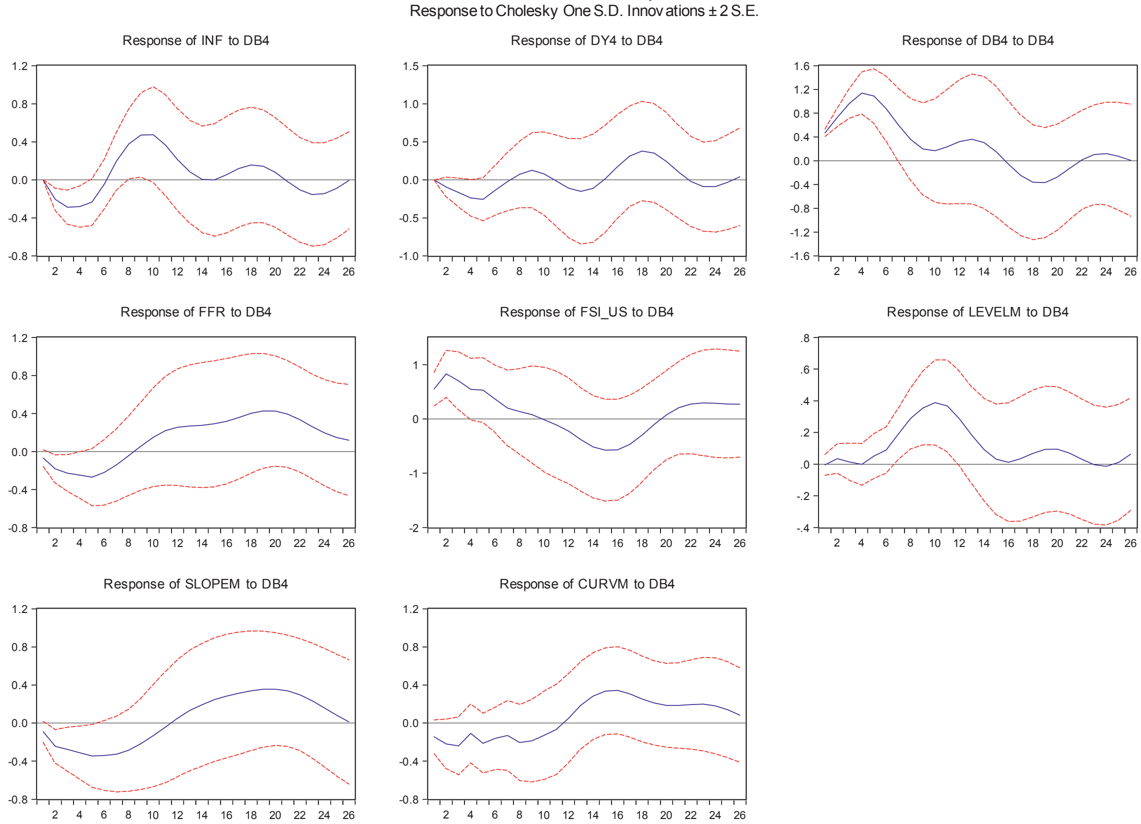
Our choice of separating the state-space modelling and estimation of the yield curve latent factors from the estimation and analysis of the macro-fiscal-finance VAR is based on two arguments. First, subsuming the estimation of the yield curve factors and of the VAR in a unique state-space model implies 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 U.S. and a VAR(2) for Germany (irrespectively 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 3.1, as only yield data are considered in its measurement system. Thus, using the previously estimated yield curve latent factors in a subsequent VAR analysis does not expose our framework to the generated regressor criticism put forward by Pagan (1994).

4.3.1. U.S.

4.3.1.1. Impulse response functions

In this section we report the impulse response functions (IRFs) of all the variables in the system 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 the usual two-standard error (95 percent) confidence bands. Overall, the results confirm that the system is stationary and may be summarized as follows (see Figure 7).

Figure 7. Impulse Response Functions to shock in annual change of the Government Debt-to-GDP ratio, U.S. 1981:I-2009:IV



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; LEVELM, SLOPEM, and CURVM, respectively level, slope and curvature latent factors.

The following comments arise from the analysis of the results. First, output growth and inflation fall and are significantly below their initial values during about 5 quarters. Most probably as a reaction to the deterioration in real activity and deceleration of prices, the monetary policy interest rate falls for about 5 quarters. Second, the surprise 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.

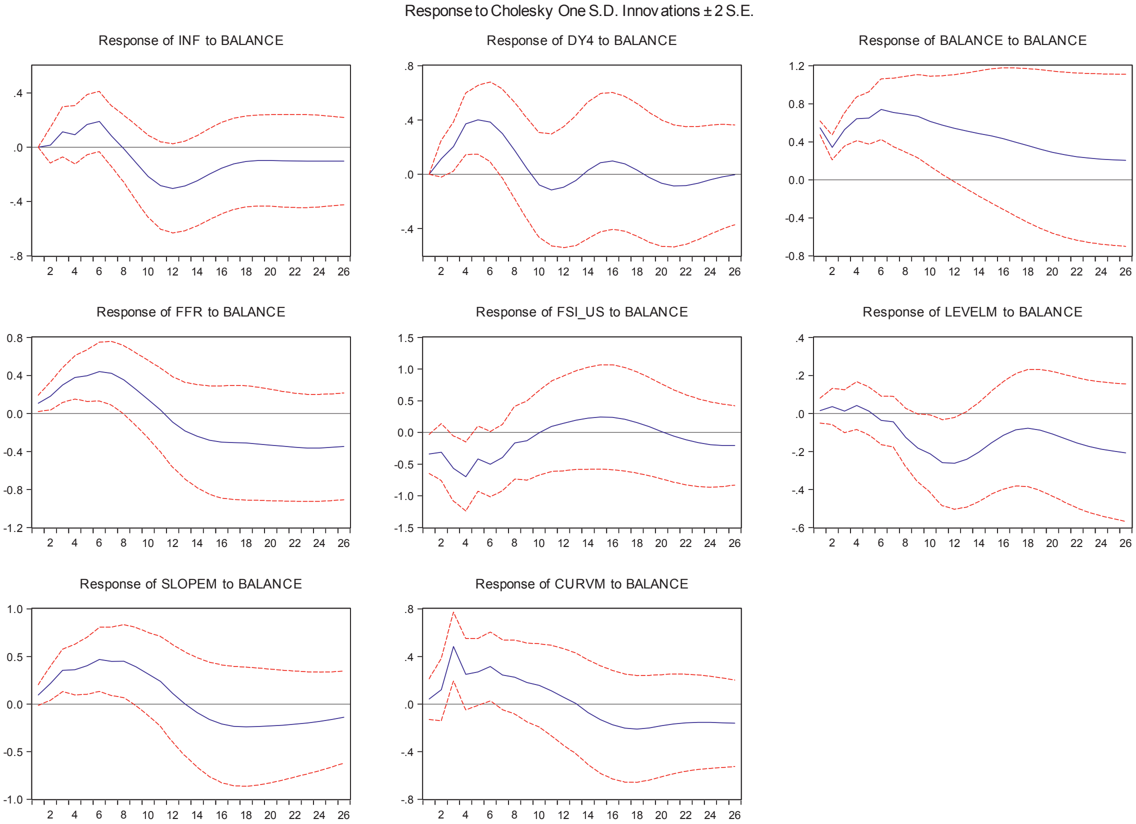
It is useful to split the dynamic response of the yield curve to the fiscal innovation into 3 phases: (i) the 6 initial quarters, (ii) quarters 7 through 12 and, (iii) the subsequent quarters. In phase (i) the slope of the yield curve increases and its level remains unchanged, at standard statistical levels of confidence. Since the latter means that the average yields do not change, the reactions of the slope and level combined imply that the yields at the shortest maturities fall – in line with the decrease in the monetary policy interest rate – and the long-end yields necessarily increase – also in line with the deterioration in the overall financial conditions index. In phase (ii) the slope starts falling and returns, statistically, to its original value, while the level of the yield curve increases to values that are statistically above the initial ones, remaining so until the 12th quarter. Combined, the reactions of the slope and of the level imply that the yields of the short-end maturities now increase and that the yields of the long-end of the yield curve remain above their original values. The rise in the shortest maturities yields is consistent with the response of the monetary policy rate. Finally, from the 12th quarter onwards, it is not possible to reject the hypothesis that the yield curve has returned to its initial shape, *i.e.* the original slope and level.

In short, a positive innovation to the rate of change of the debt-to-GDP ratio leads to an increase in the yields in the long-end maturities of the curve (which comprises, at the extreme, the usual 10 years maturity studied in most fiscal-finance analyses) during 12 quarters, *i.e.* 3 years. Indeed, an innovation of 0.47 percentage 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, which occurs in the 10th-11th quarters after the innovation (a conclusion that is warranted as the values of slope and curvature are essentially similar to their baselines).

We now move on to the impulse response functions of all the variables in the system to a positive innovation to the alternative fiscal variable, the budget balance ratio, with a magnitude of one standard deviation of the respective errors, together with the two-standard error confidence bands (see Figure 8). 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). Considering both the IRFs and their confidence bands, the results may be summarized 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. Most probably as a reaction to the improvement in real activity and 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 to 4 quarters horizon. Third, the positive innovation to the budget balance ratio leads to transitory significant responses of the yield curve slope and level, as well as to a significant reaction of the curvature that happens, in turn, during a very brief period.

Figure 8. Impulse Response Functions to shock in the Budget Balance, U.S. 1981:I-2009:IV



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.

In this case we can also divide the dynamic response of the yield curve to the balance-to-GDP ratio innovation into three phases (with the first one including a brief sub-phase): (i) the 8 initial quarters, (ii) quarters 9 through 12, (iii) the subsequent quarters. In phase (i) the slope of the yield curve falls and its level remains unchanged (notice that a budget balance increase implies an improvement of the fiscal position). The latter means that the average yields do not change and the combined reactions of the slope and of the level imply that the yields at the shortest maturities increase – in line with the increase in the monetary policy interest rate – and the long-end yields necessarily fall. During quarters three through seven after the innovation, one can reject, at 95 percent of confidence, the hypothesis that the curvature remains unchanged, in favour of a reduction in the curvature, further reinforcing the conclusion that yields at the long-end of the curve fall. Consistently, during a considerable part of this initial phase, the overall financial conditions improve, in reaction to the improvement in the fiscal position, even though the short-term interest rate increase. In phase (ii) the level is significantly below its initial value and the slope starts increasing, as does the curvature;

it is not possible to reject the hypothesis that the slope has returned to its original values. These reactions of the slope and of the level mean that the yields at the short-end maturities now decrease and that the yields of the long-end of the yield curve remain below their original values. Finally, from the 12th quarter onwards, it is not possible to reject the hypothesis that the yield curve has returned to its initial shape, *i.e.* the original slope and level.

Summarising, a positive innovation to the budget balance (in percentage of GDP) leads to a decrease in the yields of the long-end maturities of the curve (which comprises, at the extreme, the usual 120 months maturity) during 12 quarters, *i.e.* three years. An innovation (improvement) of 0.55 percentage points in the budget balance ratio is associated with a downward response of the longest maturities yields that amounts to 26 basis points in the 12th quarter after the innovation (when the slope and the curvature have returned to their baseline values and the level component is 26 points below its initial value).

4.3.1.2. Variance decompositions

For the case of the VAR including the change of the debt-to-GDP ratio as the fiscal measure, the results may be summarized 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 percent, 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).

Table 1. Annual Change in Debt-to-GDP Ratio Forecast Error Variance Decomposition, U.S. 1981:I-2009:IV.

1.1. Forecasting the Change of the Debt-to-GDP ratio								
Period	INF	DY4	DB4	FFR	FSI	L	S	C
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

1.2 Forecasting the Level of the Yield Curve								
Period	INF	DY4	DB4	FFR	FSI	L	S	C
4	1.527	15.549	0.324	0.983	1.402	73.729	1.059	5.422
8	4.491	9.898	16.469	6.3169	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

1.3. Forecasting the Slope of the Yield Curve								
Period	INF	DY4	DB4	FFR	FSI	L	S	C
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

1.4. Forecasting the Curvature of the Yield Curve								
Period	INF	DY4	DB4	FFR	FSI	L	S	C
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.

As panel 1.2 in Table 1 shows, the variance of the errors in forecasting the level of the yield curve at a 4-quarter horizon is mostly explained, as expected, by innovations to the level itself. Nevertheless, surprises to output growth and, although 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 explanations 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 percent in the 12 quarters horizon and is still around 28 percent at the horizon of six years. From the 8th quarter onwards the shocks to the financial stress indicator also account for around 12 percent 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 per cent of the error variance. Most importantly, fiscal surprises account for a much larger fraction of the forecast error variance of the yield curve level than any individual 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 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. As the forecast horizon widens, the part explained by monetary policy innovations falls gradually, but remains as large as 15 percent 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 explain a bit less than they do in the case of the forecast error variance of the level, but are still very much considerable in the case of the yield curve slope, and increase their contribution gradually as the forecast horizon widens, from 15 percent at the 8-quarter horizon to 22 percent 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, as expected, but that surprises to real output growth and the financial stress index also have important explanatory power, as also have 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 percent at horizons above 16 quarters. Innovations to the yield curve slope have similar explanatory power as do surprises to the overall financial conditions index.

We now move to the decomposition of the forecast errors variance for the balance-to-GDP ratio and the yield curve latent factors, for the selected horizons above considered for the case of the alternative fiscal policy variable. The results can be summarized as follows (see Table 2).

Table 2. Balance Forecast Error Variance Decomposition, U.S. 1981:I-2009:IV.

2.1. Forecasting the Budget Balance

Period	INF	DY4	BALANCE	FFR	FSI	L	S	C
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

2.2 Forecasting the Level of the Yield Curve

Period	INF	DY4	BALANCE	FFR	FSI	L	S	C
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

2.3. Forecasting the Slope of the Yield Curve

Period	INF	DY4	BALANCE	FFR	FSI	L	S	C
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

2.4. Forecasting the Curvature of the Yield Curve

Period	INF	DY4	BALANCE	FFR	FSI	L	S	C
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.

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 in Table 2). 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 percent of the variance of the error in forecasting the balance. At a horizon of eight 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 percent), even though innovations to the interest rate, financial conditions and output growth gradually gain some importance in explaining the variance of errors in forecasting the balance-to-GDP ratio.

As can be seem 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, as expected, by innovations to the level itself. Although to a lesser extent, surprises to output growth and to the curvature of the yield curve also explain sizeable parts of such variance. These features are quite similar to those seen in the case of the growth of the debt-to-GDP 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. Its explanatory power peaks somewhat later and at a lower proportion than it is the case of the government debt ratio (see panel 2.2 in Table 2). Most importantly, after the 16 quarters horizon, fiscal surprises and the financial stress indicator surprises account for a much larger fraction of the forecast error variance of the yield curve level than the macroeconomic variables, inflation and output, as well as, broadly, the monetary policy interest rate.

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 (see 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 to no less than 8 quarters, surprises to the fiscal balance consistently are the larger explaining factor for the variance of the errors in forecasting the yield curve slope, besides surprises to the slope itself, which makes fiscal policy the main explanation for errors in forecasting the slope. 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 what happens for the model with the debt ratio, in the specification including the budget balance ratio, fiscal innovations explain much more of the forecast error variance of the slope than of the level.

Finally, panel 2.4 of Table 2 reports 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, as expected, but that surprises to real output growth and the financial stress index also have important explanatory power. In comparison to what is seen in the system including the growth in the debt-to-GDP ratio, here 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 percent at horizons above 20 quarters. At horizons beyond the 4 quarters, surprises to the fiscal balance explain overall a larger part of the forecast error variance of the curvature than do surprises to real output growth and to the financial stress indicator.

4.3.1.3. Granger causality

In this section we present results for Granger causality tests between the fiscal variables and the yield curve latent factors. We have run the tests for two lag lengths, motivated by the analysis of the IRFs above. First, we have included four lags of all regressors, which is the lag length considered in the estimation of the VARs and should allow for capturing the most immediate inter-relations between fiscal and yield curve variables. Then, we have run the tests including 12 lags of all the regressors, the horizon after which, according to the IRFs, both the slope and the level of the yield curve return to their original values following fiscal innovations.

Table 3 (panel 3.1) shows that lags of the change in the debt-to-GDP ratio fail to statistically decrease the variance of the error in regressions explaining each and all of the yield curve factors, either at the 4-quarter and at the 12-quarter horizons. However, the results shows that the yield curve slope is a leading indicator of the change in the debt-to-GDP ratio once an horizon beyond the first 4 quarters is considered – specifically with a p-value of 3.9 percent within the 12-quarters horizon. In such an extended horizon, the slope improves the prediction of the yield curve level, in addition to purely autoregressive predictions, with a p-value of 2.8 percent. For both horizons considered, the curvature Granger-causes the yield curve level, at standard significance levels.

Table 3. Granger Causality between the fiscal variables and the Yield Curve latent factors, U.S. 1981:I-2009:IV

3.1. Debt-to-GDP ratio

	Lags in regressions: 4				Lags in regressions: 12			
	DB4	L	S	C	DB4	L	S	C
DB4	---	0.486	0.148	0.882	---	0.158	0.345	0.696
L	0.231	---	0.019**	0.129	0.266	---	0.063*	0.335
S	0.151	0.177	---	0.962	0.039**	0.028**	---	0.217
C	0.155	0.014**	0.184	---	0.673	0.081*	0.676	---

3.2. Budget balance

	Lags in regressions: 4				Lags in regressions: 12			
	BALANCE	L	S	C	BALANCE	L	S	C
BALANCE	---	0.650	0.019**	0.031**	---	0.311	0.199	0.003***
L	0.601	---	0.019**	0.129	0.445	---	0.063*	0.335
S	0.153	0.173	---	0.962	0.486	0.028**	---	0.217
C	0.401	0.014**	0.184	---	0.950	0.081*	0.676	---

Notes: DB4: annual change of the debt-to-GDP ratio; BALANCE - fiscal deficit in percentage of GDP; L - level of the yield curve; S - slope of the yield curve; C - curvature of the yield curve. Each entry shows the p-value for the rejection of the null hypothesis that the variable in each row does not Granger-cause the variable in each column (Significance levels: *** 1 percent; ** 5 percent; * 10 percent.).

We now move to the results for Granger causality tests between the budget balance and the yield curve latent factors, again for both 4 and 12 lag lengths (panel 3.2 of Table 3). The results are somewhat different from those obtained with the debt ratio. For a horizon of four lags the budget balance ratio significantly decreases the variance of the error in auto-regressions of the yield curve slope (p-value of 0.2 percent) and curvature (p-value of 3.1 percent). Such a result holds, in regressions including 12 lags, for the case of the curvature, but not of the slope. The results further show that none of the yield curve latent factors Granger-causes the budget balance ratio, at acceptable significance levels. Finally, while the slope is a leading indicator of the yield curve level, but only when the regressions are extended up to 12 lags (p-value of 2.8 percent), the curvature is a leading indicator of the yield curve slope irrespectively of the extension of the regressions (although with a somehow high p-value of 8 percent for the 12 lag regressions).

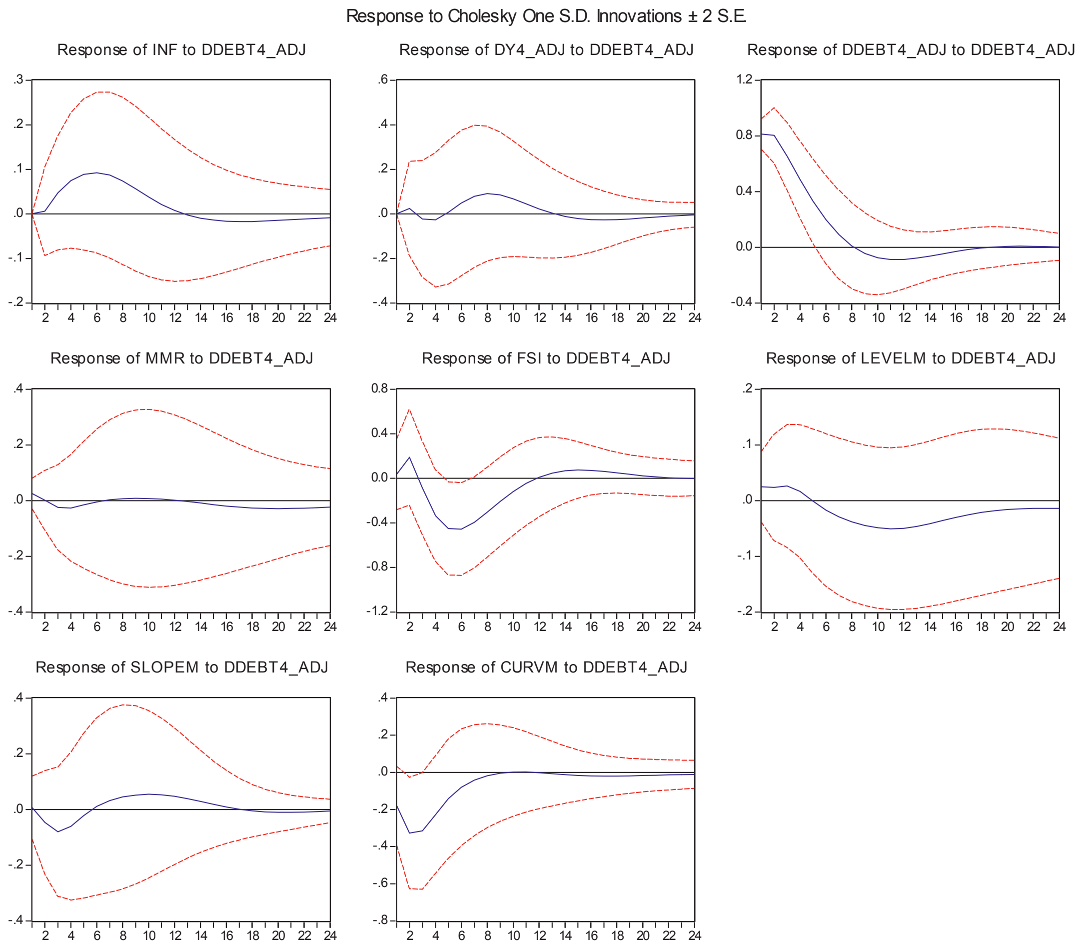
4.3.2. Germany

In this section we describe the results of the VAR analyses for the case of Germany. As in the previous sub-section, for the U.S. case, we report results for two VARs, each with an alternative measure of fiscal developments – the annual change in the government-to-GDP ratio and the budget balance ratio – sequentially looking at the impulse response functions, variance decomposition and Granger causality.

4.3.2.1. Impulse response functions

Figure 9 depicts the impulse response functions of all the variables in the system to a positive innovation to the annual change of the debt-to-GDP ratio, together with the two-standard error confidence bands.

Figure 9. Impulse Response Functions to shock in annual change of the Government Debt-to-GDP ratio, Germany 1981:I-2009:IV



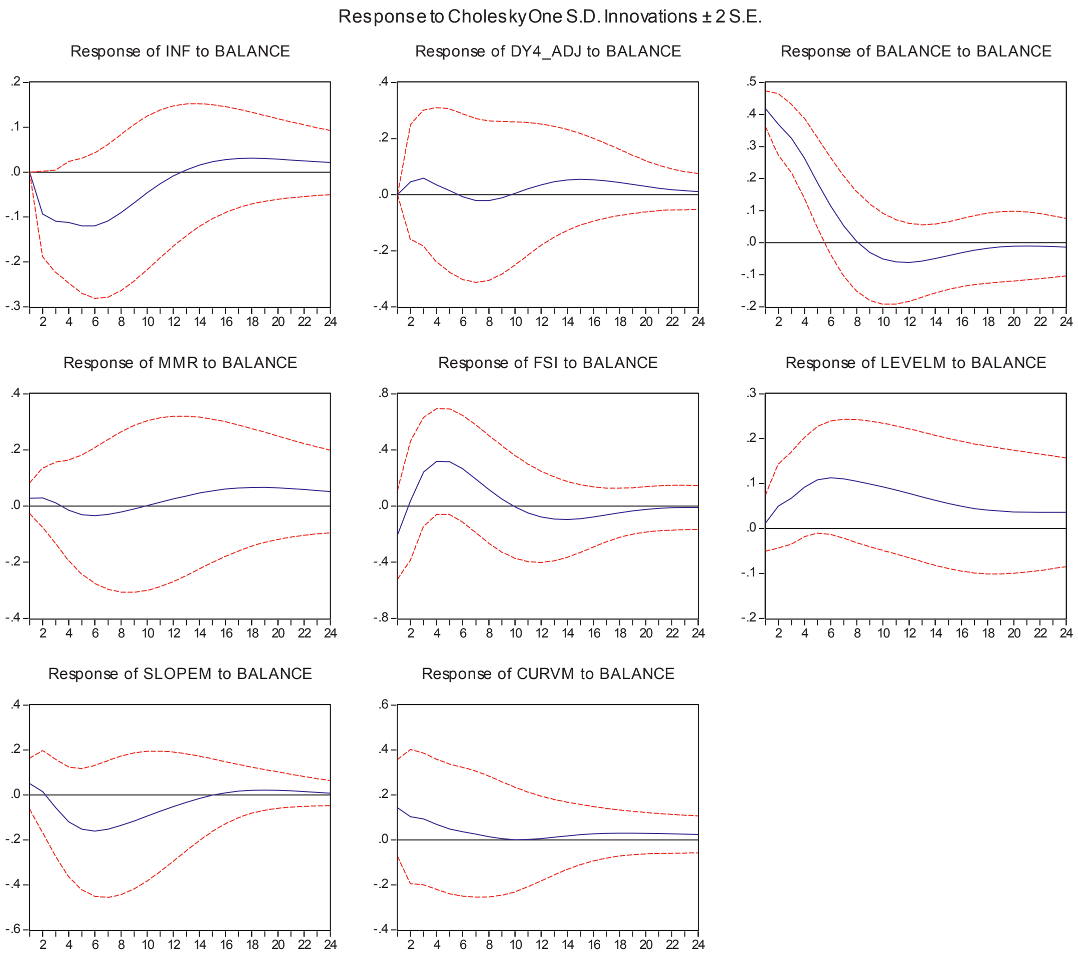
Notes: INF: inflation; DY4_ADJ: annual growth rate of real GDP (adjusted for the 1991 structural break); DDEBT4_ADJ: annual change of the debt-to-GDP ratio (adjusted for the 1991 structural break in GDP); MMR: money market interest rate; FSI: financial stress indicator; LEVELM, SLOPEM, and CURVM: level,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

The dynamic reactions are different from those estimated for the U.S. 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 significantly in the 5th and 6th quarters after the fiscal shock. Third, there is no statistically significant response of the yield curve level and slope, and only a very brief fall in the curvature during the 2nd and 3rd quarters after the fiscal shock.

In short, the noteworthy impact of a surprise increase in the annual change in the debt-to-GDP ratio is a fall in the medium-term component of the yield curve within the following year, with both a delay and duration of two quarters. Given that the level and the slope of the yield curve do not change, the decline in its concavity implies that the fiscal shock generates some upward pressures in both the short-end and the long-end of the yield curve during that period.

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

Figure 10. Impulse Response Functions to shock in the Budget Balance, Germany 1981:I-2009:IV



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.

Again, the dynamic reactions differ from those estimated for the U.S. Also in contrast to what has been found for the U.S. case, the IRFs of a budget balance ratio shock differ somewhat from those of a shock to the debt ratio. First, there is no significant reaction of real output and the market measure of the monetary policy interest rate consistently holds to its baseline value, but inflation significantly falls during the three quarters following the shock. Second, there is no significant reaction of the financial stress indicator apart from, to some extent, the upward response at the 4th quarter. Third, there is essentially no statistically significant response of the yield curve latent factors, level, slope and curvature, although the level picks up to some extent after 8 quarters.

4.3.2.2. Variance decompositions

Table 4 reports, for selected horizons, the decomposition of the forecast errors variance of the fiscal policy variable and the yield curve latent factors in the case of the VAR including the change in the debt-to-GDP ratio as indicator of fiscal behaviour.

Panel 4.1 shows that within the two-year forecast horizon most of the variance of the error in forecasting the change in the debt-to-GDP ratio comes from fiscal innovations. These innovations then lose some importance at longer forecast horizons, as surprises to output and the overall financial conditions gain importance in accounting for the forecast error variance. Innovations to the latent factors describing the shape of the yield curve are relatively unimportant, especially at the shorter horizons; in particular, the slope of the yield curve is less important than in the U.S. case.

A relevant result shown in panel 4.2 – which contrasts with the U.S. case – 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, as usual, 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 for an important part of the variance and, from the 16-quarter horizon onwards, real output has also a large role.

Table 4. Annual Change in Debt-to-GDP Ratio Forecast Error Variance Decomposition, Germany 1981:I-2009:IV.

4.1. Forecasting the Change of the Debt-to-GDP ratio

Period	INF	DY4_ADJ	DB4_ADJ	MMR	FSI	L	S	C
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	4.0174	4.549	2.717

4.2. Forecasting the Level of the Yield Curve

Period	INF	DY4_ADJ	DB4_ADJ	MMR	FSI	L	S	C
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

4.3. Forecasting the Slope of the Yield Curve

Period	INF	DY4_ADJ	DB4_ADJ	MMR	FSI	L	S	C
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

4.4. Forecasting the Curvature of the Yield Curve

Period	INF	DY4_ADJ	DB4_ADJ	MMR	FSI	L	S	C
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.

Similarly to what has just been detected for the level, and again differing from the U.S. 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 (see panel 4.3). 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 U.S.

Panel 4.4 shows that surprises to the yield curve curvature itself explain the largest part of the forecast error variance of the curvature, for all forecast horizons. The role of innovations to changes in the debt-to-GDP ratio in accounting for the variance of the error in forecasting the curvature is far larger than their role in accounting for the forecast error of the other two latent factors of the yield curve, but is still rather limited as it amounts to less than 8 percent (at the 4-quarter horizon).

We report in Table 5 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 5.1 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 considerable parts of that forecast error variance. At horizons between 8 and 16 quarters, innovations to the level and the slope of the yield curve together explain around 13 percent 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 yield curve factors account for 18 percent 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 5.2). Moreover, innovations to the budget balance ratio are moderately important in 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, and as panel 5.3 shows, innovations to the budget balance are unimportant in accounting for the variance of the forecasting errors of the yield curve slope – which contrasts, as happened with the debt ratio, with the results for the U.S. 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 5.4 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 U.S. 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.

Table 5. Budget Balance Forecast Error Variance Decomposition, Germany 1981:I-2009:IV.

5.1. Forecasting the Budget Balance								
Period	INF	DY4_ADJ	BALANCE	MMR	FSI	L	S	C
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
5.2. Forecasting the Level of the Yield Curve								
Period	INF	DY4_ADJ	BALANCE	MMR	FSI	L	S	C
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
5.3. Forecasting the Slope of the Yield Curve								
Period	INF	DY4_ADJ	BALANCE	MMR	FSI	L	S	C
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
5.4. Forecasting the Curvature of the Yield Curve								
Period	INF	DY4_ADJ	BALANCE	MMR	FSI	L	S	C
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.

4.3.2.3. Granger causality

In Table 6 we summarize the results of Granger causality tests between the fiscal variables and the yield curve latent factors in the case of Germany. Similarly to the U.S. case, we have run the tests for two lag lengths, the first corresponding to the order of the estimated VARs (2 lags) and the second corresponding to the larger lag length considered for the U.S. case (12 lags).

Panel 6.1 of Table 6 reveals that lags of the change in the debt ratio do not statistically decrease the variance of the error in regressions explaining each yield curve factor, either at the 2-quarter and at the 12-quarter horizons – a result similar to the one obtained for the U.S. That panel further shows that the yield curve slope is a leading indicator of the change in the debt-to-GDP ratio at both lag lengths – again, a result similar to the one found for the U.S. albeit in that case only for longer lengths.[2]

Table 6. Granger Causality between the fiscal variables and the Yield Curve latent factors, Germany 1981:I-2009:IV

6.1. Debt-to-GDP ratio								
	Lags in regressions: 2				Lags in regressions: 12			
	DB4_ADJ	L	S	C	DB4_ADJ	L	S	C
DB4	---	0.745	0.287	0.547	---	0.863	0.721	0.780
L	0.498	---	0.113	0.115	0.309	---	0.306	0.431
S	0.019**	0.040**	---	0.706	0.054*	0.164	---	0.989
C	0.769	0.079*	0.719	---	0.478	0.422	0.241	---

6.2. Budget balance								
	Lags in regressions: 2				Lags in regressions: 12			
	BALANCE	L	S	C	BALANCE	L	S	C
BALANCE	---	0.742	0.869	0.672	---	0.301	0.844	0.861
L	0.014**	---	0.113	0.115	0.175	---	0.306	0.431
S	0.016**	0.040**	---	0.706	0.049**	0.164	---	0.989
C	0.871	0.079*	0.719	---	0.781	0.422	0.241	---

Notes: DB4_ADJ: annual change of the debt-to-GDP ratio (with GDP adjusted for structural break in 1991); MMR: money market interest rate; BALANCE - fiscal balance in percentage of GDP (with GDP adjusted for structural break in 1991); L - level of the yield curve; S - slope of the yield curve; C - curvature of the yield curve. Each entry shows the p-value for the rejection of the null hypothesis that the variable in each row does not Granger-cause the variable in each column (Significance levels: *** 1 percent; ** 5 percent; * 10 percent.).

The Granger causalities between the (adjusted) budget balance ratio and the yield curve latent factors are in this case, and as can be seen in panel 6.2, fairly similar to the ones involving the change in the debt-to-GDP ratio. In short, the budget balance is not a leading indicator of any of the yield curve latent factor, as it does not add valuable information for their forecast in addition to their own past values, either at a 2 or at a 12 quarters lag length – a result that contrasts with the predictive power of the budget balance for the slope and curvature detected in the U.S. case. The slope consistently Granger causes the budget balance, irrespectively of the lag length considered. At short

[2] For a more thorough comparison with the U.S. we have further ran the Granger causality tests for four lags. The results, summarized in Annex 2, are broadly similar to the ones obtained with two lags.

lag lengths – either 2 or 4 quarters – the level of the yield curve is also a leading indicator of the budget balance – a result that is new, both in comparison to the results obtained for Germany with the debt indicator and in comparison to the budget balance results for the U.S.

4.3.3. 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, most notably, changes in the fiscal and monetary regimes. While such regimes changes are harder to pin down in the U.S. case, for Germany there is an obvious policy regime change around 1999, with the introduction of the euro. Hence, we now perform a VAR analysis for Germany splitting the sample into two sub-samples, 1981:I-1998:IV and 1999:I-2009:IV, for which we estimate, as above, VAR(2) models.[3] However, we consider this analysis merely exploratory, given the lack of degrees of freedom notably in the post-1999 sub-sample, and report in the text and present in Annex 2 only a summary of the results (further details are available from the authors upon request).

As figures A2.1 through A2.4 in Annex 2 show, the impulse response functions to fiscal shocks are indeed 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 more clear – 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 and both the short and the long-term yields increase.

Therefore, we obtain the interesting result that with the change in the monetary and fiscal regime, with the introduction of the Stability and Growth Pact two years earlier, and along with the deepening of the market for debt denominated in euros and of overall economic and financial integration in Europe, fiscal shocks turned out somehow to be

[3] 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.

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

5. Conclusion

In this paper we have studied the relation between fiscal behaviour and the shape of the yield curve in the U.S. and in Germany for the period 1981:I-2009:IV. Following a well-established tradition in the finance literature, we have described the shape of the yield curve with estimates of time-varying latent factors that represent its level, slope and curvature. We then estimated 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 – and a control for financial stress conditions. The analysis of the dynamics implied by the estimated VARs uncovered a set of basic stylized facts on the relation between fiscal behaviour and the shape of the yield curve in the U.S. and Germany, 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 U.S. and in Germany. Fiscal developments have generated significant responses of the yield curve that spread out through the subsequent three years in the U.S., 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, has detected stronger effects of fiscal variables on yields in the case of the U.S. compared to Europe (*e.g.* Codogno, Favero and Missale, 2003; Bernoth, von Hagen and Schuknecht, 2006; Faini, 2006; Paesani, Strauch and Kremer, 2006; Afonso and Strauch, 2007; Ardagna, 2009).

In the U.S., fiscal shocks have led to 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 two years (for budget balance shocks). Fiscal shocks further led to an immediate response of the long-end segment of the yield curve – with fiscal expansions leading to an increase in long-term sovereign yields – that lasts three years. At the height of the effects, our estimates imply an elasticity of long-term yields to a debt ratio shock of about 80 percent (10^{th}-11^{th} quarters after the shock) and an elasticity to a budget balance shock of about 48 percent (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 Phillipon (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, 2004; Kinoshita, 2006; Chalk and Tanzi, 2002), although such studies do not consider the full yield curve latent factors as we do.

We have complemented the evidence with forecast errors variance decompositions and Granger causality tests. 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 percent 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. Highlighting the importance of studying fiscal shocks we could not reject the hypotheses that the change in the debt ratio Granger-causes the shape of the yield curve. As regards the budget balance, Granger causality has only been found for the slope and the curvature of the yield curve.

The results for Germany differ from those obtained for the U.S. 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 a decline in the concavity of the yield curve that implies an increase in both the short-end and the long-end of the yield curve; yet, such reaction is very quick and transitory, as it is statistically significant only during the 2^{nd} and 3^{rd} quarters after the shock. Our exploratory analysis of the effects of fiscal shocks on the yield curve before and after 1999, has suggested 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 three quarters after the shock, with expansionary fiscal shocks leading to transitory increases in the yields of the shortest and of the longest 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. In the case of Germany, the results from Granger causality tests agree with the impulse responses and forecast errors variance decompositions, as it is not possible to reject the hypothesis that either the debt ratio or the budget balance Granger-cause any of the yield curve factors.

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 – Data sources

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, Sack and Wright (2007), updated and 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. Source: International Financial Statistics, IMF.

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

Government debt, Federal debt held by the public, FYGFDPUN, Millions of Dollars. Source: U.S. Department of the Treasury, Financial Management Service,

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

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. Source: Source: 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). Source: Statistische Angaben: 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) suggested by Balakrishnan, Danninger, Elekdag and Tytell (2009), available at (accessed May 2010)

http://www.imf.org/external/pubs/ft/wp/2009/update/wp09133.zip

The FSI computes the overall financial conditions faced by each individual country considering seven financial variables (previously demeaned and standardized): (i) the banking-sector beta, (ii) the TED spread – the 3-month LIBOR or commercial paper rate minus the government short-term rate –, (iii) the inverted term spread – the government short-term rate minus government long-term rate –, (iv) the corporate debt spreads – corporate bond yield minus long-term government bond yield –, (v) the stock market returns – the month-over-month change in the stock index multiplied by minus one –, (vi) the stock market volatility – measured as the 6-month (backward looking) moving average of the squared month-on-month returns – and (vii) the foreign exchange market volatility –the 6-month (backward looking) moving average of the squared month-on-month growth rate of the exchange rate (for details see the link above and the file therein).

Annex 1 – Hyper-parameters

Table A1.1 reports the estimates and corresponding significance levels of the hyper-parameters included in the transition matrix, for the U.S (see related analysis in the text).

Table A1.1. Transition matrices A and μ, U.S. 1961:6-2010:2

	L_{t-1}	S_{t-1}	C_{t-1}	μ
L_t	0.9875 ***	-0.0001	0.0133 ***	7.704 ***
S_t	-0.0006 ***	0.9695 ***	0.0231	-2.143 **
C_t	0.0197	-0.0006	0.9333 ***	-0.625 *

Notes: Each row shows the hyper-parameters of the transition equation for the respective latent factor. Significance levels: *** 1 percent; ** 5 percent; * 10 percent.

Table A1.2 reports estimates and significance levels of the hyper-parameters in the variance-covariance matrix of the innovations to the transition system, for the U.S (see related analysis in the text).

Table A1.2. Variance-covariance matrix Q, U.S. 1961:6-2010:2

	L_t	S_t	C_t
L_t	0.0875 ***	3.705E-06	9.832E-06 ***
S_t		0.2522 ***	2.467E-08
C_t			0.5594 ***

Notes: Significance levels: *** 1 percent; ** 5 percent; * 10 percent.

Table A.1.3 provides information on the innovations to the measurement equations – estimates and significance levels of their variance – as well as on the one-step-ahead prediction errors of the observable vector – mean and standard deviation. The innovations with higher variance are those to the equations of the yields of 3, 6, 9 and 12 months of maturity. Consistently, the one-step-ahead measurement errors of these maturities display the larger mean values and higher standard deviations. In comparison with the literature (Diebold, Rudebusch and Aruoba, 2006, Table 2) our measurement errors have higher mean values at those maturities but lower mean values at the remaining maturities, while overall the standard deviations of our errors are larger.

Table A1.3. Variance matrix of measurement innovations (H) and mean/standard deviations of measurement errors, U.S. 1961:6-2010:2

Maturity	Variance measurement innovations	Mean measurement errors	Standard Deviation measurement errors
3	0.22341 ***	-4.87155	64.32609
6	0.05425 ***	-5.08712	50.16713
9	0.01703 ***	-3.46297	45.70892
12	0.00445 ***	-1.94114	43.25009
15	0.00067 ***	-0.73576	41.66852
18	0.00000 ***	0.15319	40.48555
21	0.00026 ***	0.76714	39.49113
24	0.00064 ***	1.15708	38.59584
30	0.00098 ***	1.45169	36.97584
36	0.00079 ***	1.35044	35.52784
48	0.00018 ***	0.72135	33.11475
60	0.00000	0.13830	31.27960
72	0.00004 ***	-0.14723	29.89333
84	0.00004 ***	-0.12716	28.83799
96	0.00000 *	0.12463	28.03978
108	0.00012 ***	0.51733	27.46401
120	0.00067 ***	0.96980	27.10206

Notes: The first column is the main diagonal of matrix H, expressed in percentage points. The second and third columns are the first two empirical moments of the one-step-ahead forecast errors, expressed in basis points. Significance levels: *** 1 percent; ** 5 percent; * 10 percent.

Table A1.4 reports the estimates and corresponding significance levels of the hyper-parameters included in the transition matrix, for Germany. The estimated means for the latent factors are similar to those obtained for the US, although the mean level of the yield curve is somewhat smaller and the average yield curve has been somehow steeper. As normal, L_t is more persistent than S_t, which in turn is more persistent than C_t.

Table A1.4. Transition matrices *A* and μ, Germany 1972:9-2010:3

	L_{t-1}	S_{t-1}	C_{t-1}	μ
L_t	0.9732 ***	-0.00009	0.0275***	6.0235 ***
S_t	-0.01225	0.9687 ***	0.0307***	-2.9147 **
C_t	0.0892***	0.0234*	0.8572 ***	-1.6899

Notes: Each row shows the hyper-parameters of the transition equation for the respective latent factor. Significance levels: *** 1 percent; ** 5 percent; * 10 percent.

Table A1.5 reports estimates and significance levels of the hyper-parameters in the variance-covariance matrix of the innovations to the transition system, for Germany. While the variance of the innovations to L_t and C_t are similar to those estimated for the U.S. the variance of the innovations to the slope is markedly higher.

Table A1.5. Variance-covariance matrix *Q*, Germany 1972:9-2010:3

	L_t	S_t	C_t
L_t	0.1167***	5.872E-07**	6.396E-07***
S_t		0.2453***	1.442E-06*
C_t			1.1908 ***

Notes: Significance levels: *** 1 percent; ** 5 percent; * 10 percent.

Table A.1.6 provides, for Germany, the same information presented in table A1.3 for the U.S. The variability and the mean values of the one-step-ahead prediction errors for maturities of 3 and 6 moths are quite larger than those obtained for the U.S., as are the variance of the innovations to the measurement equations at those maturities. As maturities increase, the estimates and results are increasingly in line with those for the U.S.

Table A1.6. Variance matrix of measurement innovations (H) and mean/standard deviations of measurement errors Germany 1972:9-2010:3

Maturity	Variance measurement innovations	Mean measurement errors	Standard Deviation measurement errors
3	2.28424***	34.18545	153.18946
6	0.43499***	14.76647	75.29714
9	0.10119***	6.98754	48.86525
12	0.02243***	3.336367	39.91686
15	0.00310***	1.53812	37.10091
18	3.25971E-09**	0.65775	36.24207
21	0.00107***	0.25063	35.89211
24	0.00258***	0.08989	35.59082
30	0.00373***	0.08881	34.75297
36	0.00289***	0.22113	33.68060
48	0.00060***	0.45867	31.59276
60	2.525E-11***	0.56281	30.04124
72	0.00014***	0.57621	28.96569
84	0.00012***	0.54464	28.20496
96	1.46984E-10***	0.50245	27.71625
108	0.00036***	0.44897	27.52461
120	0.00190***	0.39675	27.68607

Notes: The first column is the main diagonal of matrix H, expressed in percentage points. The second and third columns are the first two empirical moments of the one-step-ahead forecast errors, expressed in basis points. Significance levels: *** 1 percent; ** 5 percent; * 10 percent.

Annex 2 – Additional VAR analysis for Germany

Table A2.1 shows that, for Germany, Granger causality tests run for a 4-quarter regression horizon, give essentially the same results as those obtained at the 2 and 12-quarter horizons and discussed in the text.

Table A2.1. Granger Causality between the fiscal variables and the Yield Curve latent factors at a 4-quarter horizon, Germany 1981:I-2009:IV

	DB4_ADJ	L	S	C		BALANCE	L	S	C
DB4_ADJ	-	0.847	0.447	0.716	BALANCE	-	0.328	0.731	0.873
L	0.468	-	0.599	0.107	L	0.009***	-	0.599	0.107
S	0.049**	0.099*	-	0.580	S	0.011**	0.099*	-	0.580
C	0.381	0.198	0.415	-	C	0.435	0.198	0.415	-

Notes: DB4_ADJ: annual change of the debt-to-GDP ratio (with GDP adjusted for structural break in 1991); MMR: money market interest rate; BALANCE - fiscal balance in percentage of GDP (with GDP adjusted for structural break in 1991); L - level of the yield curve; S - slope of the yield curve; C - curvature of the yield curve. Each entry shows the p-value for the rejection of the null hypothesis that the variable in each row does not Granger-cause the variable in each column (Significance levels: *** 1 percent; ** 5 percent; * 10 percent.).

Figures A2.1 through A2.4 show that, for Germany, the impulse response functions to fiscal shocks are different before and after the Stability and Growth Pact and the introduction of the euro. For instance, and consistently for shocks to the change in the debt ratio and shocks in the budget balance ratio, fiscal shocks have significant impacts over the yield curve shape before 1999 but not after 1999. Such impacts can be summarised as follows. During the three 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 level do not change, the transitory fall in concavity means that, during such period, the medium-term yields fall and both the short and the long-term yields increase.

Figure A2.1. Impulse Response Functions to shock in annual change of the Government Debt-to-GDP ratio, Germany 1981:I-1998:IV

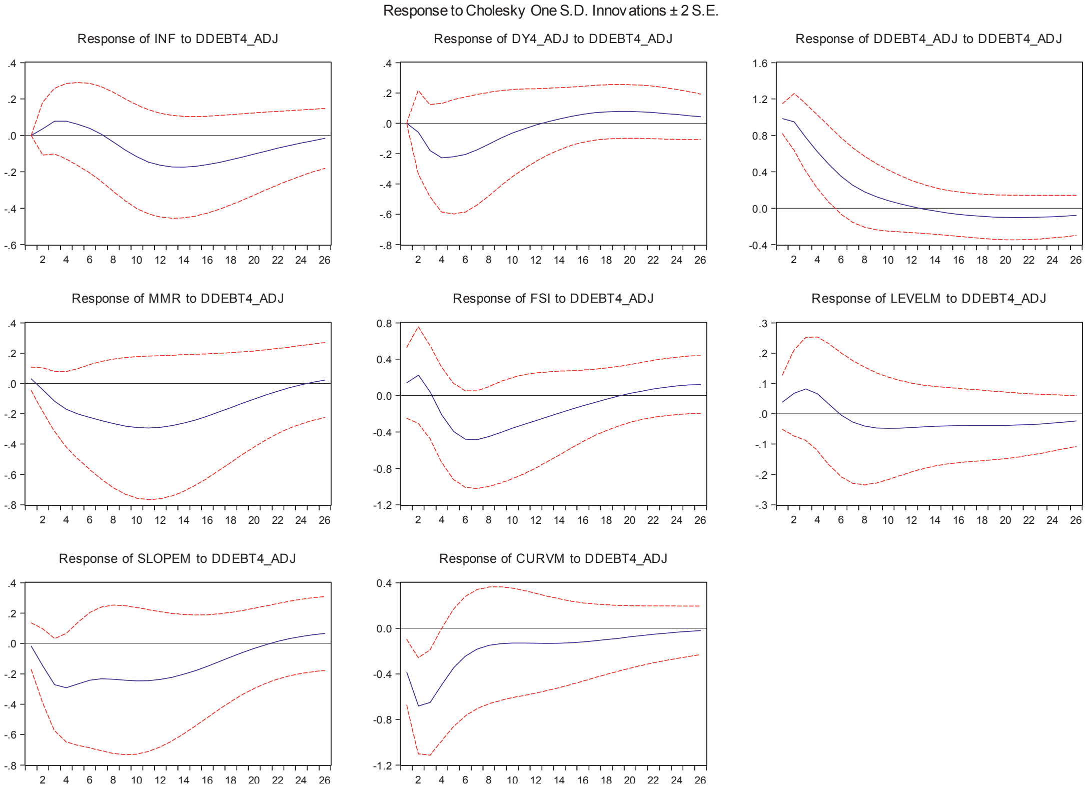

Figure A2.2. Impulse Response Functions to shock in annual change of the Government Debt-to-GDP ratio, Germany 1999:I-2009:IV

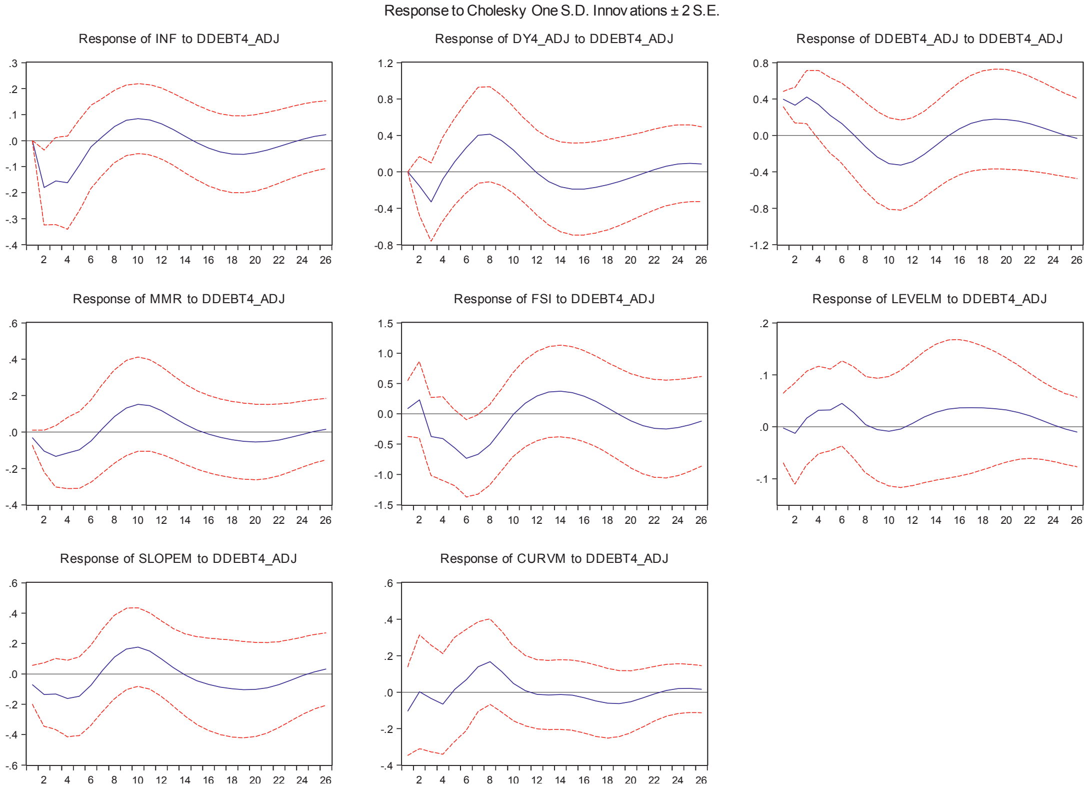

Figure A2.3. Impulse Response Functions to shock in the Budget Balance, Germany 1981:I-1998:IV

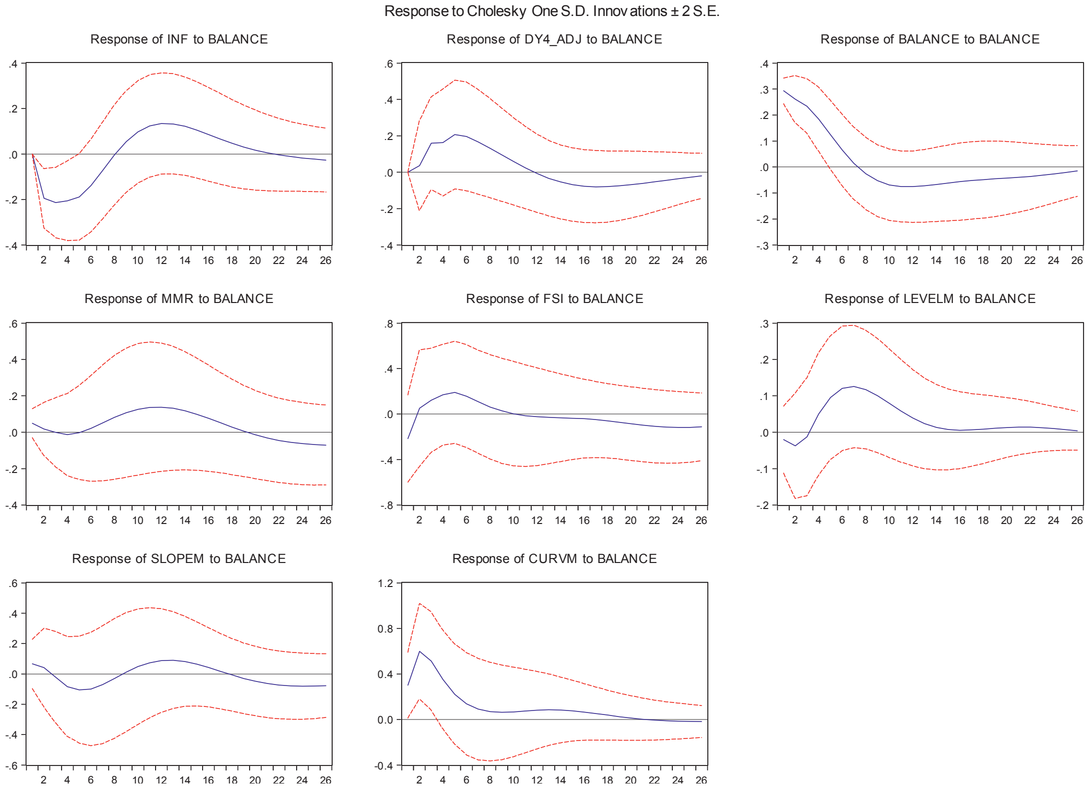

Figure A2.4. Impulse Response Functions to shock in the Budget Balance, Germany 1999:I-2009:IV