Yield Curve Dynamics and Fiscal Policy Shocks at the Lower Bound

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October 2017

Abstract: TBA

Keywords: Interest Rate, Fiscal Policy, Affine model

JEL: C38, C51, C58, E43, E47

Acknowledgements: The research of Adam Kučera was supported by the Grant Agency of Charles University, project no. 728016. The views are the authors' own and do not represent the official position of the Czech National Bank or the Slovak National Bank.

1 Introduction

This paper evaluates the channels and magnitude, how the U.S. fiscal policy affects the term structure of interest rates. Although the topic is not new, we bring multiple novelties. These include an identification of the shocks in the Ramey (2011) style, recognition of an importance of the fiscal policy uncertainty, distinguishing the ex-post effect through the government bond supply and an evaluation of the importance of the lower bound proximity with respect to the fiscal policy effects. In the paper, we show that all these elements are relevant for understanding the way how the fiscal policy affects the yield curve.

In the literature, the efforts to explain yield movements by macroeconomic and financial factors have been frequent. As discussed in De Pooter *et al.* (2010), these factors often include real activity and price dynamics, in some cases also the monetary policy. Among the most important contributions, Ang and Piazzesi (2003) extend the canonical affine Gaussian term structure model of Duffie and Kan (1996) by additional macro-factors and show their importance. Similarly, Diebold *et al.* (2006) combine the dynamic Nelson-Siegel model (Diebold and Li 2006) with macroeconomic variables and prove an improved forecasting performance of the extended model. In a competitive approach, the effects of macroeconomic shocks on the yield curve were evaluated using structural models (as in Rudebusch and Swanson 2012). In an important empirical paper, Wright (2011) promotes the importance of second moment – the uncertainty – of inflation for explaining variance of yields and especially the term premia.

Nevertheless, the effects of the fiscal policy on the yield curve were discussed less frequently. Dai and Philippon (2005) present a macro-finance no-arbitrage affine term structure model as of Ang and Piazzesi (2003) enriched by fiscal policy variables. Using the Blanchard and Perotti (2002) fiscal policy shocks identification, authors show that an expansionary fiscal shock moves the yields upwards. They explain the rise by (i) expectations about the future short rates, and (ii) an increase in the risk premia. Ardagna *et al.* (2007) use both a simple static estimation and a vector autoregression model to show for a panel of countries that an increase in the primary government deficit increases the long-term yields. However, in a case of an increase of the government debt, the yields are affected only for the above-averagely indebted countries. Laubach (2009) shows the upward effect of fiscal expansion on the long-term yields by comparing the budget deficit forecasts with the long-horizon forward rates. In a recent study, Bretscher *et al.* (2017) use a structural approach to show an effect of the fiscal policy shocks in terms of both the level and the uncertainty. Authors also show that the effect is amplified at the zero lower bound.

We follow the approach of Dai and Philippon (2005) by using an affine term structure model. However, since the lower bound on yields was binding over some part of the observed period, we utilize a shadow-rate affine term structure model introduced by Krippner (2013) with the Dynamic Nelson-Siegel identification (Christensen and Rudebusch 2014). Furthermore, we carefully identify the fiscal policy shocks. More specifically, we identify the ex-ante shocks long before their realization in the government budget, following the Ramey (2011) style. We also introduce ex-ante uncertainty shocks, being inspired by Wright (2011). Apart from these, we allow the fiscal ex-post shocks to have an effect, too, through the changes in government bond supply. We critically evaluate the choice of fiscal and control variables entering into the model, which we support by an extensive sensitivity testing. These updates of the baseline Dai and Philippon (2005) model are motivated by the actual economic and bond market situation as well as the recent research advances and allow to offer a deep insight into the mechanism through which the fiscal policy influences the term structure of interest rates.

As our novelty, we distinguish two types of fiscal policy shocks. Ex-ante shocks can be seen as a change in expectations about future fiscal policy; these shocks are propagated through changes in decisions of economic agents as discussed by Ramey (2011). We distinguish two sub-categories of ex-ante shocks: ex-ante level shocks, which we obtain from monthly changes in fiscal projections by CBO (2017), and ex-ante uncertainty shocks represented by the Fiscal policy uncertainty index of Baker *et al.* (2016).

Ex-post fiscal policy shocks influence the financial markets and the real economy at the moment the related fiscal policy steps are conducted. The motivation for using also the ex-post shocks is twofold. First, not all shocks are correctly anticipated, therefore the effect of the realization of the fiscal policy on the aggregate demand might differ from the ex-ante expected effects. Second, financing of the realized fiscal measures requires shifting the government bond supply, which is not influenced ex-ante. This bond supply channel is considered in the literature focused on the crowding-out effect of public deficits (for example Claeys *et al.* 2010), but is largely neglected or at least not specifically distinguished in the term structure modelling. Following the basic supply-demand relationship, to finance its additional spending (or deficit) after a fiscal policy shock, the government needs to offer an additional return to attract additional funds. The magnitude of the impact of the bond supply shift on yields is determined by the elasticity of the government bond demand. As Krishnamurthy and Vissing-Jorgensen (2007) or Grande *et al.* (2013) show, the government debt demand is downward-sloping.

According to our results, the ex-ante expansionary fiscal policy shocks as well as the ex-ante shocks to fiscal policy uncertainty decrease the yields of all maturities. Such finding differs from the results of Dai and Philippon (2005) as well as some other studies, which can be well explained by the different approach to the shock identification. Short end of the yield curve is affected the most due to a decrease in expected future short rates, whereas for longer rates, this decrease is compensated or even outweighed by a growth of the term premium. In other words, economic agents do not expect monetary policy tightening at the moment the ex-ante fiscal policy expansionary shocks appear, but rather loosening. This could be seen as a kind of support for the Barro-Ricardian equivalence. Additionally, the agents require higher risk premia after the ex-ante shocks. Such effects highlight the importance of expectations of economic agents, which became more cautious in case of an expected future fiscal expansion.

Contrary, the ex-post expansionary fiscal policy shocks increase the yields. Such finding is close is in line with the results of the Dai and Philippon (2005) and others. As we evaluate such effect into a detail, we further discover that the increase is firstly triggered by the shift of the government bond supply due to a need of financing of the additional spending. This supports the downward sloping bond demand. In a long-term, the effect of the bond supply dims out; however, the yields remain increased due to the real economic effects of the ex-post shock, which became gradually important.

As an additional contribution, we document the way how the lower bound proximity influences the yield responses to the fiscal policy shocks. The effect of the lower bound environment is well described for example in Krippner (2015) in terms of a difference between the observed and the shadow rates. Using our estimation, we verify and quantify these effects and show that the binding lower bound inhibits the yield response, both in terms of expected short rate path and the risk premium. This is in contrast with the results of the structural model of Bretscher *et al.* (2017). Economically, we explain such behavior by a presence of non-standard monetary policy tools, which are the first to be adjusted after either positive or negative shocks in the lower bound environment, which limits the impact on the yields.

The rest of paper is organized as follows: The next section introduces the term structure models and the methodology to estimate the linkages between the fiscal policy and the yield curve. Section 3 shows results of estimated term structure models, extracted factors and yield components. In Section 4, we evaluate and discuss the responses of yields to the fiscal policy impulses. Section 5 explains the effects of the lower bound proximity. Section 6 presents results of sensitivity analysis. Finally, Section 7 concludes.

TO DO

- Decrease the curve nahradit lepe, napr. decrease yields or shift the level etc.
- Source to figures and tables
- Rewrite abstract
- Hyperlinks to appendix

- Change formulations, so that the other variables (macroeconomic and financial) are denoted as control variables.
- Zkontrolovat unpublished citace, jestli uz se mezitim neobjevily v journalu
- Check units of variables and their responses, and rescale where necessary
- Zkratky: zkontrolovat prvni vyskyt
- zkontrolovat popis shock identification + LAG
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2 Methods

The methodology used in this paper follows of two steps. The first step aims at modeling yields. Since the yield curve comprises of multiple maturities (10 in the case of this paper), it is useful to reduce its dimensionality. Using a term structure model, the whole yield curve will be represented by three factors. In the second step, the evaluation of the actual linkages will be conducted. The yield factors will enter a vector autoregression (VAR) model together with a set of variables representing the fiscal policy and a set of control variables. Calculated impulse response functions will be used as the primary tool to infer the linkages.

Term Structure Models

The first step is the estimation of dynamic term structure (interest rate) models. We use three different models to obtain robust results. All models can be considered as factor models and therefore can be jointly defined using a state-space representation:

$$y_t\left(\tau_i\right) = f\left(\boldsymbol{L_t}, \tau_i\right) + \epsilon_{y,t}\left(\tau_i\right) \tag{1}$$

$$\boldsymbol{L_t} = \boldsymbol{\mu} + \boldsymbol{\Phi} \boldsymbol{L_{t-1}} + \boldsymbol{\epsilon_{L,t}} \tag{2}$$

Generally, in each model, a yield $y_t\left(\tau_i\right)$ of a maturity τ_i is a function $f\left(\bullet\right)$ of a set of latent (unobservable) factors $\boldsymbol{L_t}$ and the maturity. The factors $\boldsymbol{L_t}$ follow a first-order vector autoregression (VAR) process. Yields are subject to measurement errors $\epsilon_{y,t}\left(\tau_i\right)$ that are forming a vector error term $\boldsymbol{\epsilon_{y,t}} \sim \mathcal{N}\left(\boldsymbol{0}, \boldsymbol{R}\right)$. The vector $\boldsymbol{\epsilon_{L,t}} \sim \mathcal{N}\left(\boldsymbol{0}, \boldsymbol{Q}\right)$ represents random disturbances in the factor process. As usual for the basic state space representation, $\boldsymbol{\epsilon_{y,t}}$ and $\boldsymbol{\epsilon_{L,t}}$ are assumed to be mutually uncorrelated and $\boldsymbol{R}$ is assumed to be diagonal.

The basic utilized model is the **Dynamic Nelson-Siegel (DNS) model** introduced by Diebold and Li (2006). The function $f\left(\bullet\right)$ is in this case given by the Nelson and Siegel (1987) function:

$$y\left(\tau_i\right) = \beta_1 + \beta_2 \left(\frac{1 - e^{-\lambda \tau_i}}{\lambda \tau_i}\right) + \beta_3 \left(\frac{1 - e^{-\lambda \tau_i}}{\lambda \tau_i} - e^{-\lambda \tau_i}\right) \tag{3}$$

β_1, β_2, β_3 and λ are parameters. The three[1] β parameters represent the main features of the yield curve. β_1 is common for all maturities, so it represents a level of the yield curve. The factor loading of β_2 is equal to one for an infinitesimally small maturity and gradually decreasing to zero for growing maturities. β_2 can be hence defined as a negative slope of the yield curve: a positive β_2 means the

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[1] The function was further extended by Svensson (1995) by including an extra term to enhance a flexibility of the function when fitting the term structure. However, we do not use the additional element in order to maintain parsimony.

short end of the yield curve is above the long end. Finally, β_3 factor loading is zero for both zero and infinite maturity and reaches its maximum (approximately 0.2984) for some positive maturity. It is commonly interpreted as a curvature (a "hump") in the yield curve. Apart from β parameters, the λ parameter (the decay factor) influences the shape of the function as well. It determines the location of the β_3 factor loading maximum as well as the speed of the β_2 factor loading decay. The DNS model is formed by interpreting β_1, β_2 and β_3 as time-varying factors rather than parameters. Consequently, β factors represent the dynamic unobservable factors $\boldsymbol{L_t}$ from Equation 2. To obtain parameters of the model (the parameter λ and parameter matrices $\boldsymbol{\mu}$, $\boldsymbol{\Phi}$, $\boldsymbol{R}$ and $\boldsymbol{Q}$ from Equations 1 and 2), we use the maximum likelihood estimation; the β factors are obtained using Kalman filter.

The second framework is the **Affine Dynamic Nelson-Siegel (ADNS) model**. This model builds on an affine class of term structure models, which was popularized by (Duffie and Kan 1996). In this framework, the function $f(\bullet)$ in Equation 1 is given by no-a arbitrage assumption under the equivalent martingale (risk-neutral) measure. A basic building block of the affine models is a set of latent factors that drive an evolution of a short (instantaneous) rate (Krippner 2015). Under the risk-neutral measure, the expectations hypothesis holds and the longer yields can be therefore calculated as a mean of expected future short rates.[2] Dai and Singleton (2002) show a closed-form solution for the function $f(\bullet)$ under the risk-neutral measure. To obtain the state space model defined above, the dynamics of the factors (the transition equation) is defined under the data-generating (real-world) measure. To estimate the affine model, a set of identifying restrictions needs to be imposed (Krippner 2015). A popular approach was developed by Christensen *et al.* (2011), who extend the DNS model by no-arbitrage conditions. The resulting affine model includes three factors that can be in line with DNS interpreted as a level, a slope and a curvature of the yield curve. Similarly to DNS model, also ADNS model can be, thanks to its closed-form solution and linearity, estimated using MLE and Kalman filter. More details on the model equations and parametrization are included in the Appendix I.

The affine models allows to decompose yields into two components: a risk-neutral yield and a term premium. Each of the components reacts differently on shocks influencing the yields. The risk-neutral yield represents the yield as if the expectations hypothesis holds; it means, as if the long yields would be determined only by the expected paths of the short rate, without any risk premium. Consequently, this component reflect the expectations about the monetary policy, economic activity and the inflation. Contrary, the second component represents the remaining part of the yield and reflects the premium that investors require for uncertainty about future short rates. This premium grows in case of uncertainty

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[2] The expected future short rates represent the forward rates under the risk-neutral measures. However, to make them equal, the expected future short rates first need to be adjusted by an effect of the volatility on the expectations because of the Jensen's inequality. See Krippner (2015), p. 50 for details and the formula. Longer yields are then given directly by the forward rates.

about the future economic situation and policy measures. On the other hand, the premium decreases during flight-to-quality events, when the bonds are considered as a safe haven in a periods of financial market uncertainty.

In the analysis below, we use this decomposition to obtain a detailed insight into the responses of the yields to shocks. Methodologically, to obtain the components, the estimated ADNS model is first used to generate forecasts of the short rate under the data-generating measure. These forecasts can be considered as estimates of expectations about the future risk-free rate evolution consistent with the present shape of the yield curve. For each maturity, an average short rate forecast over the horizon equal to the maturity represents the risk-neutral yield. The term premium is calculated as a difference between the observed and the risk-neutral yield.

A **Shadow-rate ADNS model (SR-ADNS)** further extends the ADNS model. The purpose of the shadow-rate models is to reflect the fact that the yields in many countries approached their natural lower bound in the years following the Great Recession. The lower bound is present because of the existence of physical currency that bears zero yield. Any negative yield can be thus avoided by transferring the funds to the physical currency. The lower bound does not need to be equal to zero due to transaction costs, but can be expected to be reasonably close to it. When yields hit the lower bound, their dynamics is changed, since distribution of the future yield movements becomes asymmetric: they can move only upwards, although the timing and speed of a future lift-off remain uncertain. Such situation makes the results of the affine models, which are essentially Gaussian, invalid. Shadow-rate models therefore offer a way how to overcome this weakness of the canonical affine models.

A shadow yield[3] can be defined as a yield in a hypothetical, no-currency world. Consequently, they are not constrained by the lower bound. Technically, they are computed as a yield of a hypothetical shadow bond. As proposed by Black (1995), the price of this shadow bond equals to an observed bond price *plus* the price of a call bond option with a strike price equivalent to the lower bound yield (Christensen and Rudebusch 2014). A tractable approach to calculation of the option price and the shadow yields introduces Krippner (2013). An elegant implication of using the shadow-rate approach is their interpretation. The shadow short rate can be seen as a proxy for the overall monetary policy conduct, "as if" the monetary authority was not forced to use unconventional monetary policy tools at the lower bound. This is important for our analysis: the underlying dynamics of the shadow yield factors is not altered by the lower bound (unlike the factors of the observed yields), which allows to avoid a bias due to monetary policy structural changes when estimating responses of yields to various shocks.

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[3] In the text below, the term shadow rate denotes the shadow short rate only, whereas shadow yields are related to the rest of the yield curve.

As a model idetification, we utilize the SR-ADNS approach presented by Christensen and Rudebusch (2014) that is a shadow-rate extension of the ADNS model. Compared to ADNS, the SR-ADNS model setup differs only in the function $f(\bullet)$ in Equation 1. In the case of SR-ADNS model, the function is non-linear, which requires a different estimation technique. We utilize the extended iterative Kalman filter to obtain the estimates of the latent factors. The model parameters are obtained using the maximum likelihood estimation. Identically to the ADNS model, the latent factors SR-ADNS model can be interpreted as a level, a slope and a curvature of the shadow yield curve.

Measuring Impact of Shocks

The presented models are specified as "yield-only", since no observable variables (apart from yields themselves) are included. That implies that all underlying forces causing the yield movements are gathered in the latent yield factors. To understand the linkages, so-called macro-financial models were developed. In these models, the vector of latent factors $\boldsymbol{L_t}$ in Equation 2 is directly extended by observable variables, typically involving real activity, price dynamics and/or monetary policy variables. For the DNS framework, Diebold *et al.* (2006) allow the yield factors to evolve jointly with the observed variables. A pivotal work of Ang and Piazzesi (2003) introduces the observable variables into the ADNS framework. The macro-finance SR-ADNS model was shown by Bauer and Rudebusch (2016).

However, the additional factors makes the models larger. When measuring the response of yields to the basic macroeconomic dynamics (real activity, price dynamics and monetary policy), the model can be still parsimonious enough to obtain reasonable convergence of the likelihood maximization problem. However, in our case, to correctly identify fiscal policy shocks, we need to introduce multiple fiscal and control variables (see section 4). The number of variables makes the models (especially SR-ADNS model) too large to ensure reasonably fast and path-independent convergence of the estimation. To overcome this, we proceed in a different way: we use two separate steps described in this section, i.e. we (i) estimate "yield-only" term structure models and obtain their factors and (ii) estimate joint dynamics of the yield factors and observable variables outside the term structure models.

To model the dynamics of the yield latent factors and the observable variables, we use the first-order vector autoregression (VAR) model. The single order is used to keep the model parsimonious[4]. From the VAR model, responses of the yield latent factors to the impulses from observable variables are calculated. Afterwards, using the interest rate model parameters – the $f(\bullet)$ in the Equation 1 – we obtain the responses of yields themselves. Using the affine models, we also decompose the response of yields to the response of risk-neutral yields and the response of term premium.

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[4] Furthermore, the single lag is dominant in the term structure literature.

Although separating the estimation to two steps, the macroeconomic variables remain being spanned by the yield curve, similarly to Bauer and Rudebusch (2016). An alternative approach would be to use the model of Joslin *et al.* (2014) that allows for unspanned macro risks. However, at this research, we build on the argumentation of Bauer and Rudebusch (2015), and leave the unspanned risk models for future research.

We carefully set the identification of the model. Due to the two-step approach, the yield factors are assumed to include all relevant information affecting the yield curve. This includes the macroeconomic, financial and fiscal shocks. In order to explain the effects of these shocks on the yields, we use Choleski decomposition and order the yield factor at the end of the VAR vector. Such approach ensures that the yield movements triggered by shocks to the observable variables included into the model are correctly attributed to innovations to these variables. The innovations to the factors then represent only the residual movements unexplained by the innovations to other variables. The Choleski decomposition could seem as too simplifying regarding the fiscal policy shock identification. For example, Dai and Philippon (2005) use the Blanchard and Perotti (2002) approach to identify the fiscal policy shocks. However, as will be described in the section 4, we build on the narrative approach in the sense of Ramey (2011) to identify the bond demand shocks. In the light of such approach, we consider the Choleski decomposition as sufficient. We support this approach by a sensitivity testing including changing the variable ordering where justifiable.

3 Yield Factors and Components

In this section, we start by describing yield data. Afterwards, we show the results of the estimated interest rate models, especially the dynamics of the underlying factors. At the end of the section, we show estimates of the two components of yields and discuss their evolution in a context of the lower bound proximity.

Yield Data and Shadow Yields

The analysis is focuses on the U.S. Government bond yields. MATURITIES!! As a source of the yield curve data, we use constant maturity rates provided by FED (2017). Since we use macroeconomic variables observed with monthly frequency in the next section, we gather the end-of-month yields. The sample period ranges from December 1993 to June 2017. Start of the sample results from the availability of all necessary data. At the same time, the start of the sample period ensures a relative homogeneity of the U.S. monetary policy conduct over the whole sample. Although the response to the Great Recession could be considered as a structural shock, we believe that we solve this issue by using the shadow-rate model.

The evolution of the U.S. government bond yields over the selected period is presented in the Figure 1. In this period, the yield curve was mostly upward-sloping, with few exceptions prior to the 2001 and 2008 crises. Since the end of 2008, the lower bound proximity was apparently effective, as the short end of the yield curve was moving around the zero level with a limited volatility. Since the end of 2015, the lift-off of the short yields starts to take a place. On the other hand, the long end of the yield curve was gradually decreasing over the whole period.

Figure 1: Yield Data (in %, 12/1993–06/2017)

Note: The x-axis marks denote the end of a year.

As the first calculation step, we estimate the shadow-rate model (SR-ADNS). The parameters of the estimated model are included in the Appendix II. The shadow yields estimated by the model are displayed in the Figure 2. As explained in the previous section, the shadow yields can be viewed as a proxy for monetary policy steps that are not reflected by the short rates because of the lower bound. Consequently, over the lower bound period, the shadow yields should be significantly lower than the observed yields. In our results, this difference reached more than 500 basis points in the case of 3M yield.[5]

Estimated Yield Factors

In the model, both the shadow yields and the observed yields are driven by the latent yield factors. The latent factors resulting from our estimations are shown in the Figure 3. To test the validity of the

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[5] As Bauer and Rudebusch (2016) show, the path of the shadow short rate is quite volatile across shadow-rate model specifications and estimation periods. However, our analysis focuses on the whole yield curve rather than the short rates, and we discuss the direction of the yield responses in the first place. Consequently, we argue that this volatility does not significantly affect validity of our results.

Figure 2: Shadow Yields (in %, 12/1993–06/2017)

Note: The x-axis marks denote the end of a year.

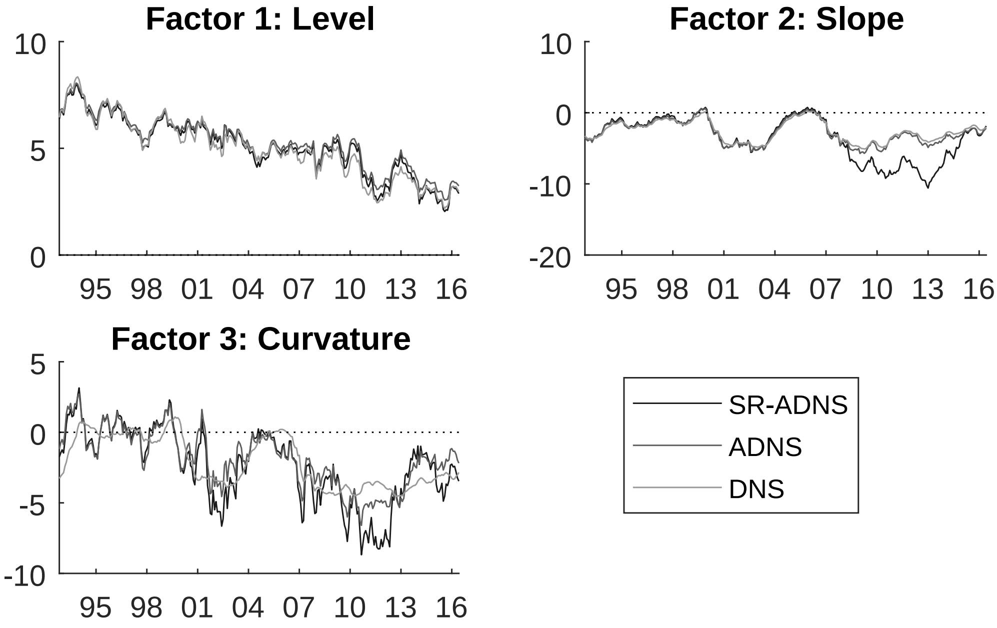
latent factors obtained by estimating the SR-ADNS model, we estimate also DNS and ADNS models, which builds on the no-arbitrage assumption, but does not reflect the lower bound proximity.

The first factor (level) estimation is almost identical across the models. It is gradually decreasing in line with the trend of the long end of the yield curve. The slope factor is different for the SR-ADNS model over the lower bound period. This confirms the ability of the SR-ADNS model to estimate dynamics not reflected by movements of the observed short yields. Finally, the third factor, curvature, is roughly similar across the models, especially for ADNS and SR-ADNS (again, except for the lower bound period). The differences can be in this case explained by the fact that the curvature of the yield curve is not directly anchored to either long or short end of the yield curve, and hence is more model-dependent. Overall, it can be concluded that the stability of the results across the model is very good, taking into account the mentioned differences. As a result, the convergence of the non-linear SR-ADNS model can be considered as satisfactory. For that reason, the VAR analysis described in the next section utilizes only the factors and parameters of the SR-ANDS model. The results of DNS and ADNS are shown as a part of the sensitivity analysis in the section 6.

Yield Decomposition

As a next step, we focus on the two yield components of the yield: the risk-neutral yield and the term premium. Each of the components includes important information about the perception of the bond market participants about its present and future stance. Results of the estimation for selected maturities are shown in the Figure 4 (left column). For the short maturity, the risk-neutral yield forms the prevailing portion of the yield. The term premium is low and with a limited volatility. Contrary, in

Figure 3: Yield Factors (multiplied by 100; 12/1993–06/2017)



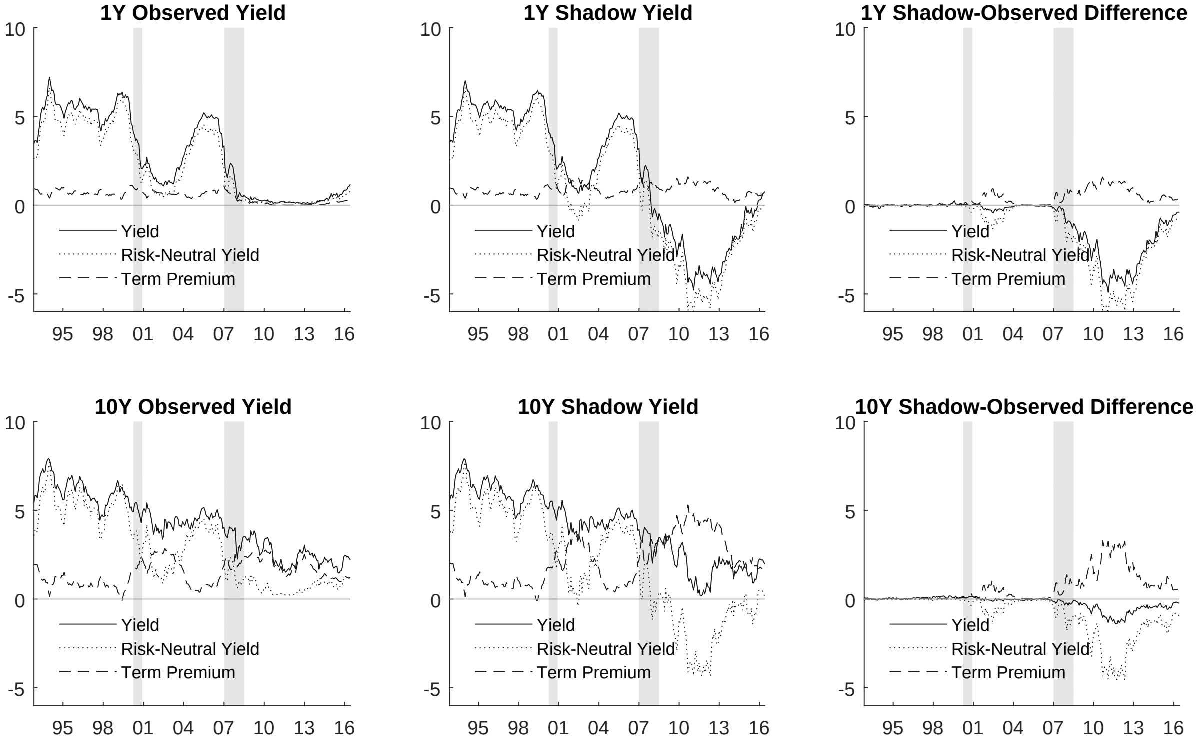
Note: The x-axis marks denote the end of a year.

case of yields of bonds with longer maturity, the importance of the term premium grows. This is in line with higher uncertainty related to the longer horizon, and hence greater divergence of the yields from the values implied by the expectation hypothesis.

Furthermore, our term premium is counter-cyclical (shaded areas in the figure represent NBER crises). Such evolution is in line with the results in the literature (Bauer *et al.* 2014, for instance). At the same time, the evolution of the term premium is heavily influenced by the lower bound proximity in the period following the 2007 crisis. This is intuitive: after hitting the lower bound, the uncertainty of the future short rate evolution is reduced to the uncertainty about the timing and extent of a future lift-off. Consequently, in case of the lower bound proximity, the term premium is expected to be lower than the term premium of yields sufficiently distant from the lower bound. This is also the case of U.S. yields: in the period after the 2007 crisis, the term premium increased less than after the 2001 crisis (see Figure 4, left column), although the uncertainty was generally higher, measured, for example, by the VIX index (CBOE 2017).

To evaluate the extent to which the term premium is influenced by the lower bound, we decompose also the shadow yields (Figure 4, middle column). The uncertainty related to the shadow rate evolution is not restricted by the bound. Consequently, the term premium of shadow yields does not decrease in the years following the 2007 crisis (unlike the term premium of the observed yields). Contrary, it fully reflects the overall uncertainty perceived after the crisis.

Figure 4: Yield Components (in %, 12/1993–06/2017)



Note: The x-axis marks denote the end of a year.

For example, in case of the 10-year U.S. government bond, the observed yield at the end of 2009 was 3.85%. Due to the lower bound proximity, the FED monetary policy used tools not directly reflected by the monetary policy rate, either the actual or the average expected over the 10-year horizon. For that reason, also the two components were influenced by the lower bound: the risk-neutral yield remained positive (1.41%), whereas the term premium reached 2.49%[6] – around 180 basis points above the level before the crisis (end of 2006). Contrary, in case of the shadow yields, the observed 10-year shadow yield was 3.67%. This value represents an artificial yield reflecting the full stance of the monetary policy, i.e. also tools not influencing the FED funds rate. The risk-neutral component of the yields was close to zero (0.60%), whereas the term premium reached 3.07% (+235 b.p. compared to the shadow term premium at the end of 2006).

That means that the effect of the lower bound is not very significant in terms of the difference between the shadow and observed yield – shadow yield (of a 10-year bond) was 18 b.p. lower than the observed yield at the end of 2009. However, this difference comprises of the opposite, mutually compensated differences of the two components, which are sizable. At the end of 2009, the 10-year shadow risk-neutral yield was 81 b.p. lower, compared to the observed yield. This difference reflects the

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[6] The difference between the observed yield and the sum of the risk-neutral yield and the term premium is formed by the measurement error.

expectations about expansionary monetary policy not fully reflected by expectations about dropping the monetary policy rate, as the lower bound approached. On the other hand, at the end of 2009, the 10-year term premium was 58 b.p. higher for the shadow yield, compared to the observed yield, whose term premium is compressed because of the lower bound.

These effects are illustrated by the Figure 4, right column. In the years following the recent crisis, the effects of the lower bound gradually increased (the term premium of the observed yields remained relatively low), reaching a peak in 2012. Such behavior of the term premium after the recent crisis could have strong implications for the evaluation of the responses of yields to the macro-financial factors calculated in the next section. To reflect this, we also evaluate the VAR impulse-responses in the environment of yields both in a proximity and in a distance from the lower bound in the section 5, and compare the results.

4 Impulse-Response Analysis

This section presents the results of the baseline VAR analysis. It is calculated on the full sample, using the yield factors extracted from the SR-ADNS model and variables from the Table 1 denoted by the star. Effects of the lower bound and different variable and model selection are discussed in the next sections. The evolution of the yield factors (Figure 3) is first linked with a set of macroeconomic, financial and fiscal variables in a VAR(1) model. Based on the estimation, we calculate responses of the yield factors to shocks into the other variables. Afterwards, using the estimated parameters of the SR-ADNS model (the measurement equation), we translate the responses of the yield factors back to the responses of the yields.

Fiscal Policy and Control Variables

As described in the section 2, in the VAR vector, the three yield factors from the SR-ADNS model are ordered beyond the observable variables. This is consistent with the end-of-month yield data. Such setup ensures that the yield factor movements are explained by the innovations to the observable variables, whereas the innovations to the yield factor themselves represent a source of the residual variation unexplained by the model. The variables ordered prior to the yield factors include the fiscal variables, whose impact the paper aims to evaluate, and a set of control variables reflecting the macroeconomic situation, the monetary policy and investor preferences.

We expect the fiscal policy to influence both through ex-ante and ex-post effects. Starting with the latter, at the moment the U.S. Treasury issues bonds to fund federal budged deficit in a particular period, the bond supply (a demand for additional funds) increases, which results in a growth of the yields[7]. At the same time, part of the fiscal policy steps can be unexpected, the ex-post channel hence influences also the aggregate demand and the real activity. The Table 1 includes the set of variables related to the fiscal policy. We consider the emergence of the ex-post fiscal policy shocks at the moment the government deficit, or, alternatively, a surprising spending was realized. The deficit is formed by evolution of both government income and spending. As the government income is tightly related to the economic conditions, we prefer to use solely the spending to ensure correct identification of the fiscal policy shocks relevant for the government bond supply. More specifically, we obtain the surprising spending by using the Hodrick–Prescott (HP) filter (Hodrick and Prescott 1997) over the monthly government outlays data from U.S. Treasury (2017). In the VAR vector, the surprising spending is ordered beyond the control variables to ensure identification of shocks independent on macroeconomic or financial conditions. The alternative specifications (use of deficit instead of surprising spending, different filtering of spending surprises) are evaluated in the sensitivity analysis.

Second, we evaluate also the ex-ante channel through which the fiscal policy influences the yields. In this case, we consider two sub-channels. First, being motivated by Ramey (2011), in the real economy sub-channel, the impulse leads to an improvement of economic conditions, which could trigger future monetary policy tightening and increase the risk-neutral yields. A positive economic conditions on the other hand may reduce the risk premium, reflecting investors' positive expectations about future economic development. Second, we admit the importance of second moment of the variables, following the argumentation Wright (2011). The shocks to government spending or debt level can increase the uncertainty perceived by the financial market participants about the future funding costs of the government. This can further increase required risk (credit) premium, but at the same time lead to a flight to quality behavior, which decreases the term premium instead.

Unlike the ex-post shocks, the identification of fiscal policy shocks affecting the bond demand requires a different approach. We follow the argumentation of Ramey (2011), who shows that the government spending shocks are anticipated long before they appear in the government balances. Ramey (2011) uses a news-based narrative approach to identify the shocks and shows that this approach leads to significantly different, often even opposite, results than the VAR approach including Blanchard and Perotti (2002) approach used in Dai and Philippon (2005). We follow the Ramey (2011) argumentation and use the narrative approach. In our case, to obtain monthly data, we use fiscal projections from CBO (2017). We infer the shocks from observing changes in projections up to 5 years ahead. We express these

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[7] From the microeconomics point of view, to attract additional investor to enter the bond market, the bond issuer needs to offer a higher yield. An additional investor requires higher risk-neutral yield, higher term premium or higher both components over the life of the bond. Therefore, the response of both yield components should be non-negative after the government bond supply shocks.

changes in real terms and discount them to the present[8]. It needs to be noted that unlike Ramey (2011), we use all U.S. budget income and outlays categories, i.e. not restrict the sample to defense spending only. To ensure the shocks are correctly identified, we use a set of control variables that help identify the business cycle shocks. Consequently, the shocks to fiscal variables may be seen as exogenous, i.e. unrelated to the business cycle. To obtain the uncertainty shocks, the narrative approach is used as we, using the news-based U.S. Fiscal policy uncertainty (FPU) index of (Baker *et al.* 2016).

To extend our results, we consider different series representing both the ex-ante and ex-post fiscal policy variables and a different ordering of the variables. The set of all considered variables is presented in Table 1. The rows denoted with star include those variables used in the baseline estimation, the rest of them is utilized for sensitivity testing.

Table 1: Fiscal and Control Variables

Fiscal Variables: Ex-post Channel	
	U.S. Government deficit (GDEF) *U.S. Treasury (2017); 12 month deficit as a fraction of outlays*
⋆	Gov. spending surprise: U.S. Government outlays HP-cyclical component (GOChp) *U.S. Treasury (2017), authors' comp.; HP-filtered cyclical component of log-value*
	Gov. spending surprise: U.S. Government outlays MA-cyclical component (GOCma) *U.S. Treasury (2017), authors' comp.; 12 month moving average cyclical component of log-value*
Fiscal Variables: Ex-Ante Channel	
⋆	Gov. spending shocks: Changes in fiscal projections (GSS) *CBO (2017)*
⋆	Gov. spending uncertainty: U.S. Fiscal policy uncertainty (FPU) index *Baker* et al. *(2016); Logarithm*
	Gov. spending uncertainty: U.S. Government spending uncertainty (GSU) index *Baker* et al. *(2016); Logarithm*
Control Variables	
⋆	Real activity: Industrial Production Index (IPI) *FRED (2017); Monthly log-difference, one month lag*
	Price Dynamics: Annual Consumer Price Index Change (CPI) *FRED (2017); Annual log-difference, one month lag*
⋆	Monetary policy: Adjusted monetary base (MBA) *FRED (2017); Monthly log-difference*
	Monetary policy: U.S. Monetary Policy Uncertainty (MPU) *Baker* et al. *(2016); Logarithm*
⋆	Uncertainty: Global Economic Policy Uncertainty Index (GEPU) *Baker* et al. *(2016); Logarithm*
	Uncertainty: VIX index (VIX) *CBOE (2017); Logarithm*

Note: The symbol ⋆ denotes the set of variables entering the baseline estimation; the other variables are used to test the sensitivity of results to the choice of variables.

The selection of control variables follows the outlined needs related to the correct shock identification and the related macro-financial literature. De Pooter *et al.* (2010) summarizes the common approach to include a real-activity variable, a price-dynamics variable and a monetary policy variable. From these,

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[8] **CONSIDER EXTENDING**

first, we employ the Industrial Production Index (IPI) as a proxy for the real activity. We prefer IPI to GDP growth because of its monthly periodicity. We use one-month lag for IPI, since the IPI value for particular month is published in the following month. For this reason, we order the IPI first in the VAR vector. In case of the variable representing the price dynamics, we utilize the annual CPI inflation. Nevertheless, as is shown in the sensitivity analysis, the added value of including this variable is limited, as it is not crucial for identification of the fiscal policy shocks (unlike the other control variables).

To represent monetary policy, we employ the monetary base. It roughly coincides with the FED balance sheet, which allows to reflect the full stance of the monetary policy. As a result, the variable is able to reflect also the monetary policy steps not reflected by the FED funds rate changes. Although the variable is ex-post, we argue that it includes the forward-looking elements about the future monetary policy conduct[9]. Finally, the monetary base represents the basis of the growth of the financial system balance sheet; an amount of the excess liquidity (actual level, not expected value) in the financial system strongly influences decisions about the portfolio allocation with respect to the extra funds. U.S. Government bonds represent an important flight-to-quality asset in these decisions.

Apart from the economic variables, we consider also a variable incorporating the general uncertainty perceived by the financial markets. The variable will be ordered beyond the macroeconomic variables, which allows to interpret the innovations to this variable as either macro-unrelated (i.e. caused by non-economic events only) or as an over-reaction to the macroeconomic news. The motivation for this inclusion of non-economic shocks to uncertainty into the model can be found in recent events that triggered flight to quality behavior inducing a growth of demand for the U.S. bonds. An example of such event is the Brexit referendum in the UK in June 2016, which led the U.S. yields to hit their record lows in July 2017, although the U.S. economic situation was generally improving at that period. As a proxy for the general uncertainty, we use the Global Economic Policy Uncertainty Index (GEPU) as calculated by Baker *et al.* (2016). Using this proxy ensures that the innovations to variables representing the fiscal policy uncertainty truly do not include any additional source of uncertainty, since these are controlled by GEPU. As a competitive specification utilized to test robustness of our results, we consider also the VIX index (CBOE 2017).

Since we use Choleski decomposition to identify the stocks, the variable ordering is crucial. Following the arguments above, we order the IPI first; MBA is ordered as the second, since we assume that FED will react to other shocks with some delay. The global uncertainty proxy GEPU is ordered afterwards. Although the calculation of GEPU is delayed, we use unlagged version, since the reaction of markets

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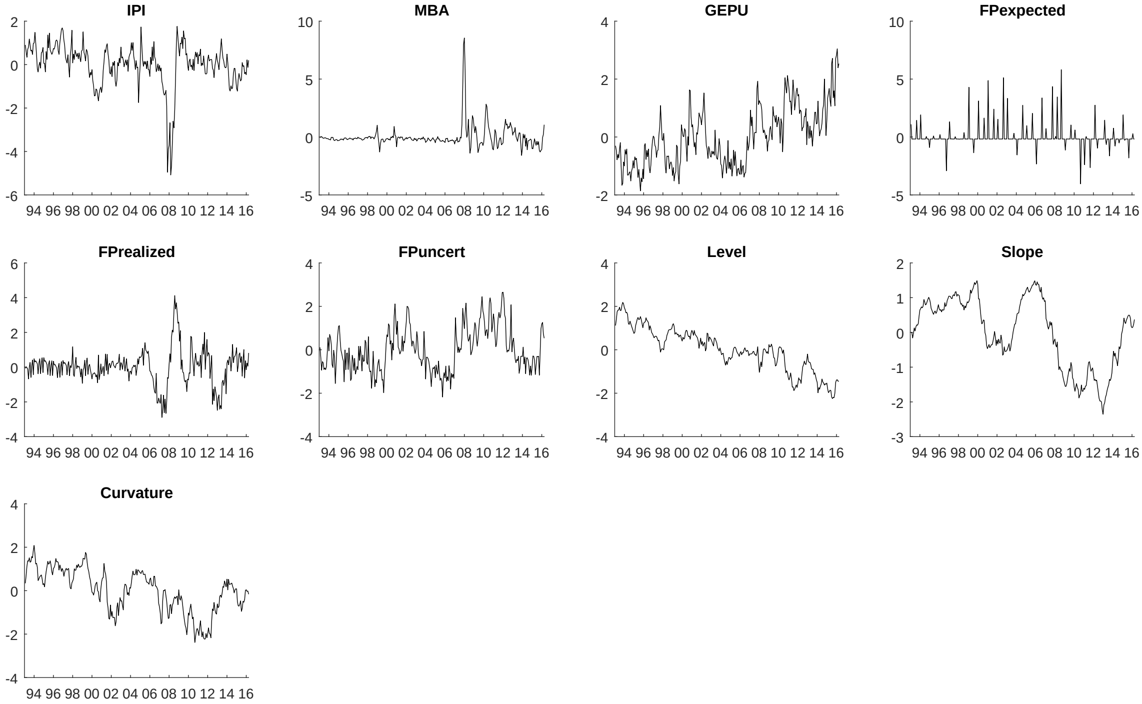
[9] For example, in case of the FED funds rate (FFR) changes, the particular change is usually strongly anticipated in the previous months. However, the approval of the change of FFR itself usually sets a basis of the expectations about the next move, which is then only gradually corrected by new information.

is related to the actual growth of uncertainty rather than to a publication of the measure (unlike IPI). Follow the fiscal polisy varaibles: the government ex-ante spending shocks(GSS), the ex-post shocks (GOChp) and the fiscal uncertainty shocks (FPU). In total, together with three yield factors ordered at the end of the VAR vector, the variables form an 8-dimensional vector. The final set of the variables is illustrated by the Figure 5.

Figure 5: VAR Variables (12/1993–06/2017)



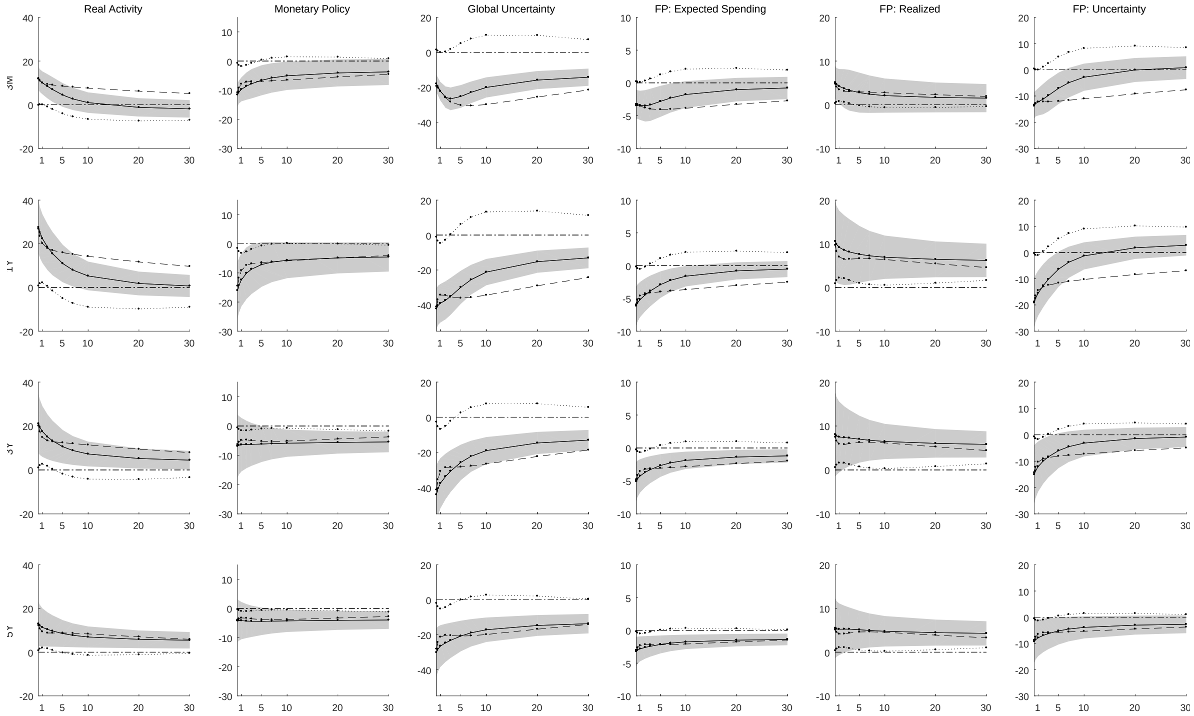
Note: The x-axis marks denote the end of a year. The units of the y-axes are not displayed, they follow the definition of the variables outlined in the Table 1.

Results

Using the nine variables, a VAR(1) model is estimated. The single lag is used mainly because of the relatively large dimension of the model, whereas the information criteria do not strictly prefer any other number of lags. We use bootstrapping to obtain confidence intervals of the estimated parameters and responses. Model diagnostics are included in Appendix III.

Using the estimated VAR model, the responses of yield factors to shocks to fiscal and control variables are calculated. Using the estimated term structure model parameters (of Equation 1), the responses of yield factors are then translated to responses of yields. Following the translation, it is also possible to split the response of yields to a response of the two components: the risk-neutral yield and the term premium. Results for selected response horizons are shown in Figure 6 (the black line). One standard deviation confidence bands are displayed in gray[10]. In the same figure, the response of yields is decomposed to a response of the risk-neutral yield (dashed) an the response of the term premium (dotted).

Figure 6: Responses of the Yield Curve



Note: Each column represents impulse of the given variable; rows show responses for various horizons. Black line is the response of the yield curve, with gray areas showing a single standard deviation confidence bands. Dashed a dotted lines show responses of yield components: the risk-neutral yield and the term premium. The x-axis marks denote maturities along the yield curve. Response of yields is measured in basis points. The impulses are normalized to one standard deviation of VAR innovations.

The control variables response follows an economic intuition. A positive shock to real activity pushes the risk-neutral yields gradually upwards, which can be explained by growing expectations about a monetary policy tightening. The term premium slightly increases for the short maturities after this shock, as the uncertainty about the monetary policy reaction is important in this case; for longer maturities, the term premium however decreases significantly, since the overall uncertainty about the long-term evolution of the yield levels decreases with improving economic conditions. For longer yields, this compensates the growth of the risk-neutral yield, so that the response of the longer yields is insignificant. Such contradictory behavior for longer yields became widely accepted after 2005 as an explanation of so-called Greenspan's conundrum (FRB 2017).

A positive shock to MBA (an expansionary monetary policy surprise) decreases the risk-neutral yield

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[10] Using the single standard deviation confidence bands for measuring effects of the fiscal policy is common in the literature – see Ramey (2011) **VERIFY**

curve along all maturities. This relates to the very nature of the monetary expansion, when the drop of yields is linked with the monetary policy conduct, either directly through monetary rates or indirectly through asset purchases or any other unconventional policy. The effect of GEPU shocks on the yields is significantly determined by the response of both components. First, the risk-neutral rates decrease, since the uncertainty shock leads to worsening expectations about both the future economic activity and the monetary policy tightening. Second, the term premium rises for the long yields, but decreases for the short yields. We consider two competitive forces beyond such rotation of term premia: the overall growth of risk premia because of negative information and the role of the U.S. government bonds as a safe haven. For short yields, the downward effect of the save haven exceeds the risk premium growth; for the longer yields, opposite holds.

The fiscal policy effects differ for the ex-post and ex-ante shocks. The ex-ante level shock (GSS) decreases yields along the curve due to the decreased future short rate path. Such finding highlights the negative effects of increased expected future government spending on the (expected) real activity. Similar result documented Ramey (2011) for the relation of consumption and the government spending. It also offers an insight into the interaction of the monetary and fiscal policy, where the expected fiscal expansion at the end results in expected monetary expansion as well (or at least a lower probability of the tightening). Part of the explanation can be seen in terms of the uncertainty, since the FPU variable is ordered behind the expected spending shock variable. Furthermore, the the effect is lower for the longer yields, since the term premium reacts oppositely: it increases in the response to the ex-ante fiscal shock. Such behavior is not surprising, since the fiscal policy shock may bring uncertainty about future government financing and hence result in a in increased risk premia.

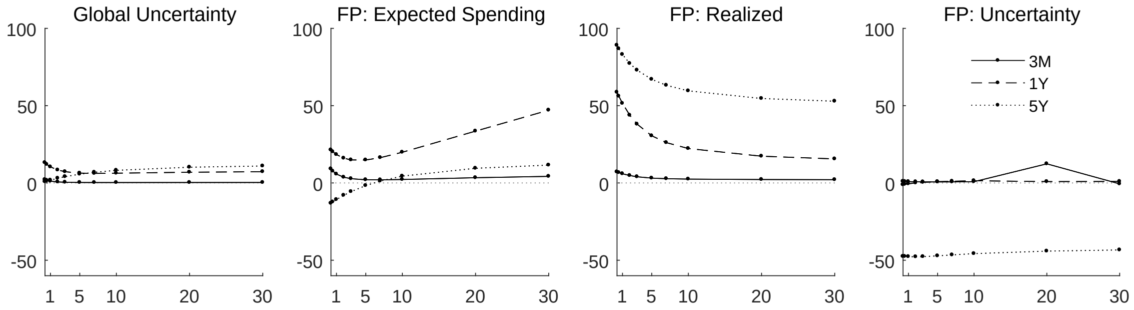
Contrary, the realized fiscal policy shock react oppositely. Unexpected fiscal realized shock (note that the expected spending shock is ordered prior to the realized) pushes the whole yield curve up, almost exclusively because of an increase in the risk-neutral yields. Such movement has financial explanation, since the government needs to increase the bond supply to obtain funds to finance the additional deficit. Simultaneously, an economic channel works: the realized fiscal policy expansion increases the aggregate demand and consequently positively affects the real activity, which results in yields increase.

Finally, the FPU shocks works in a similar way as the ex-ante level spending shock: it decreases the risk-neutral rates and increases the risk premia. That means that the fiscal policy uncertainty reduces expectations about the restrictive monetary policy, but at the same time, increase the required risk premia. However, in this case, the effect of the term premia is very strong for the long rates, so that the long rates slightly increase at the 1Y response horizon. Consequently, the yield curve rotates.

Importance of the Real Channel

To obtain further insight into the transmission channel of the shocks, we calculate the extent to which the non-macroeconomic shocks are transmitted through the real channel. In practice, in the estimated VAR(1) parameter matrices, we set the elements related to the macroeconomic variables equal to zero in order to obtain the non-macro IRFs; the real channel then forms the residuum to the original IRFs. Figure 7 shows the responses propagated through the real channel as a share of the full responses from Figure 6; the shares are shown for various response horizons.

Figure 7: Share of the Real Channel in the Responses



Note: The figure shows the share of the real channel (in percent) on the overall response of the yield curve to the other than macroeconomic impulses.

As Figure 7 shows, the propagation of the ex-ante level shocks through the real channel is limited, and is important mostly in the medium term (1Y) and for the longer yields at the first place. The real channel works in the same direction in this case, i.e. the yields are further decreased in a case of the expansionary shock. The same direction is followed also for the ex-post shocks propagation. In this case, however, the real channel gradually becomes highly important, especially for the short-end of the yield curve. That means that ex-post expansionary fiscal shocks first increases the yields through the adjusted bond supply (see Figure 6), however, gradually, the persistent increase of the yields is being maintained through a positive real effect of the additional aggregated demand.

The real propagation of the uncertainty shocks is less significant. In case of the FPU shock propagation, on the 5Y horizon, the real propagation goes against the total yield response. This would indicate a positive response of the economic situation several years after the original FPU shock. However, on the 5Y horizon, the total response is already non-significant, hence such conclusion is rather questionable.

5 Consequences of the Lower Bound Proximity

Due to the non-linearity of the measurement equation (Equation 1) of the SR-ADNS model, the response of the yields depends not only on the *response* of the yield factors, but also on their *level*. It means that the steady state, to which the impulse-responses are related, matters as well. This is particularly important for interpreting the response of the two yield components; the term premium can behave counter-intuitively close to the lower bound. Furthermore, in case the shadow yields are significantly below the lower bound, the sensitivity of the observed yields to the shocks can be significantly reduced. Since the estimation period includes periods of both high interest rates and the lower bound proximity, the interpretation of responses of the yields could be imprecise. Consequently, to understand the actual effect of macro-financial factors on the yields and their components under various conditions, we will compute responses of yields for two sets of steady states, reflecting both pre-crisis and post-crisis level of the yields.

As explained above, following the non-linearity of the SR-ADNS model, a response of yields does not depend only on the dynamics response of the yield factors, but also on their actual values (the steady state assumed in the IRFs). Consequently, in Figure 8, we compare the response of yields estimated using the full period sample to the results estimated using two sub-periods divided by the beginning of the Lehman Brother crisis. We plot the results for the 12M horizon response only, however the commented findings are valid in general. The solid lines show the original response, the dashed lines the response in the environment ending in September 2008 (henceforth "normal times"), and the dotted lines the response in the lower-bound environment starting in October 2008 (henceforth "bound times").[11]

In case of all shocks, the responses of yields in the normal times has a higher magnitude than in the bound times (Figure 8). Furthermore, in the normal times, the effect is mostly largest for the short rate, and gradually decreases for the longer rates. In case of the bound times, the effect on the short rate is restricted, and the shocks has highest impact on the medium to long maturities. Such evolution follows the reaction of the monetary policy on the shocks (both realized and expected). In the normal times, the positive shock is followed by a monetary policy tightening, which forces the short rate up; the long rates respond less, as the cyclical growth of short rates is expected to vanish. Contrary, in the lower bound times, the positive shocks leads to a restriction of the unconventional monetary policies, which are reflected by the shadow short rate, but not by the observed short rate. Consequently, the response of the short rate end of the yield curve is very limited. Thanks to the gradual normalization of the monetary policy, a monetary policy rate increase is expected in some future, which affects the

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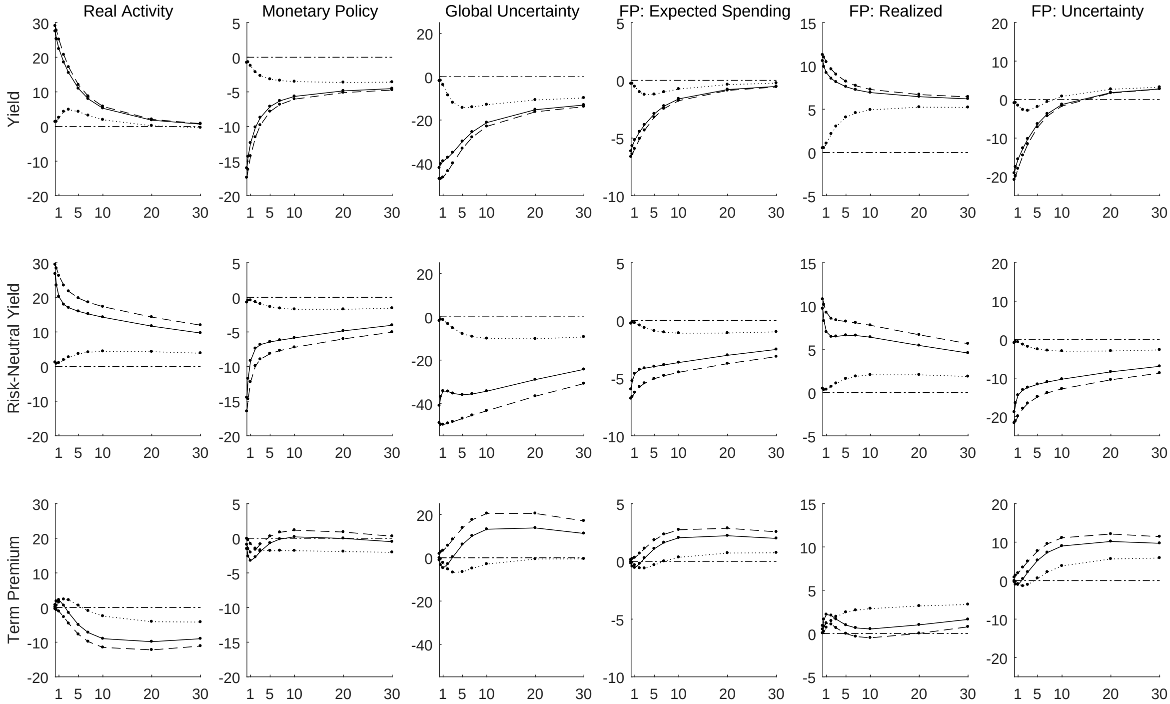
[11] The fact that the response differs close to the lower bound, is not new (compare Krippner (2013) or Christensen and Rudebusch (2014)), however, in the discussion below, we offer a new view on the compressed term premium.

Figure 8: Comparison of Responses for Various Steady States (12M Response Horizon)



Note: Each column represents impulse of the given variable; rows show responses for particular series (yields or the components). Solid line is the response calculated on the whole sample; dashed line shows responses in case the yield steady state is at the level of the yields prior the recent crisis; dotted line shows responses at the lower-bound environment. The x-axis marks denote maturities along the yield curve. Response is measured in basis points. The impulses are normalized to one standard deviation of VAR innovations.

yields of longer maturities.

In case of the bound times, for relatively small shocks and shadow yields relatively far from the observed ones, such intuition approximately holds for both positive and negative shocks. In case the positive shock would directly influence the short rate (i.e. FED would both unveil the unconventional monetary policies and increase the monetary policy rate), the effect would be asymmetric and, moreover, the short rate would react as well (either immediately or after some time). In any case, the magnitude of the response would be still significantly below the response of the normal times, which makes such discussion generally valid.

Slightly less intuitive is the response in the term premium. Although response of the term premium forms lesser part of the overall yield response, it still presents an important channel of the shocks propagation. As shown in Figure 4, the lower bound proximity compresses the term premium, since the variability of the observed yields is restricted. This consequences is apparent also from the changed responses in Figure 8. For the shorter rates, in case impulses reflecting some kind of uncertainty, the response of term premium in the bound times even has an opposite sign (i.e. negative) compared to the normal times. The explanation of such behavior is as follows: in the normal times, all these shocks rise uncertainty about the future yields path and hence the risk premia. However, in the bound times, the shocks leading to expansionary monetary policy work oppositely. Such shocks mean that the period of using unconventional monetary policy instruments will continue and hence the yields will be kept fixed to zero for some time, which actually reduces the uncertainty and the term premia.

6 Sensitivity Analysis

After the responses of yields are calculated and discussed, a sensitivity analysis is conducted at the end of the section, evaluating the sensitivity of our results to different specifications.

WITH INFLATION

ALTERNATIVE VARIABLES

ALTERNATIVE ORDERING

SHORTER SAMPLE

DIFFERENT YIELD FACTORS

DIFFERENT LAGS

7 Discussion and Conclusions

Follow the fiscal spending literature and comment on the differences. Most importantly, compare exact numbers!!

References

Ang, A. and M. Piazzesi (2003): “A No-Arbitrage Vector Autoregression of Term Structure Dynamics with Macroeconomic and Latent Variables.” *Journal of Monetary Economics* **50(4)**: pp. 745–787.

Ardagna, S., F. Caselli, and T. Lane (2007): “Fiscal Discipline and the Cost of Public Debt Service: Some Estimates for OECD Countries.” *The BE Journal of Macroeconomics* **7(1)**.

Baker, S. R., N. Bloom, and S. J. Davis (2016): “Measuring Economic Policy Uncertainty. [available at: http://www.policyuncertainty.com/][Accessed on: August 18, 2017].” *The Quarterly Journal of Economics* **131(4)**: pp. 1593–1636.

Bauer, M. and G. Rudebusch (2015): “Resolving the Spanning Puzzle in Macro-Finance Term Structure Models.” *Technical report*, CESifo Group Munich.

Bauer, M. D. and G. D. Rudebusch (2016): “Monetary Policy Expectations at the Zero Lower Bound.” *Journal of Money, Credit and Banking* **48(7)**: pp. 1439–1465.

Bauer, M. D., G. D. Rudebusch, and J. C. Wu (2014): “Term Premia and Inflation Uncertainty: Empirical Evidence from an International Panel Dataset: Comment.” *The American Economic Review* **104(1)**: pp. 323–337.

Black, F. (1995): “Interest Rates as Options.” *the Journal of Finance* **50(5)**: pp. 1371–1376.

Blanchard, O. and R. Perotti (2002): “An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output.” *the Quarterly Journal of economics* **117(4)**: pp. 1329–1368.

Bretscher, L., A. Hsu, and A. Tamoni (2017): “Level and Volatility Shocks to Fiscal Policy: Term Structure Implications.” *2017 meeting papers*, Society for Economic Dynamics.

CBO (2017): “Outlook for the Budget and the Economy.” Congressional Budget Office. [online], [September 19, 2017]. [available at: https://www.cbo.gov/topics/budget/outlook-budget-and-economy].

CBOE (2017): “VIX Index.” Chicago Board Options Exchange. [online], [August 19, 2017]. [available at: http://www.cboe.com/products/vix-index-volatility/vix-options-and-futures/vix-index].

Christensen, J. H., F. X. Diebold, and G. D. Rudebusch (2011): “The Affine Arbitrage-Free Class of Nelson–Siegel Term Structure Models.” *Journal of Econometrics* **164(1)**: pp. 4–20.

Christensen, J. H. and G. D. Rudebusch (2014): “Estimating Shadow-Rate Term Structure Models with Near-Zero Yields.” *Journal of Financial Econometrics* .

Claeys, P., R. Moreno, and J. Suriñach (2010): “Fiscal Policy and Interest Rates: The Role of Financial and Economic Integration.” In “Progress in Spatial Analysis,” pp. 311–336. Springer.

Dai, Q. and T. Philippon (2005): “Fiscal Policy and the Term Structure of Interest Rates.” *Technical report*, National Bureau of Economic Research.

Dai, Q. and K. J. Singleton (2002): “Expectation Puzzles, Time-varying Risk Premia, and Affine Models of the Term Structure.” *Journal of Financial Economics* **63(3)**: pp. 415–441.

De Pooter, M., F. Ravazzolo, and D. J. Van Dijk (2010): "Term Structure Forecasting Using Macro Factors and Forecast Combination." *FRB International Finance Discussion Paper 993* .

Diebold, F. X. and C. Li (2006): "Forecasting the Term Structure of Government Bond Yields." *Journal of econometrics* **130(2)**: pp. 337–364.

Diebold, F. X., G. D. Rudebusch, and S. B. Aruoba (2006): "The Macroeconomy and the Yield Curve: A Dynamic Latent Factor Approach." *Journal of econometrics* **131(1)**: pp. 309–338.

Duffie, D. and R. Kan (1996): "A Yield-Factor Model of Interest Rates." *Mathematical finance* **6(4)**: pp. 379–406.

FED (2017): "Interest Rates - Historical Data." Federal Reserve Board. [online], [July 12, 2017]. [available at: http://www.federalreserve.gov/releases/h15/data.htm].

FRB (2017): "Testimony of Chairman Alan Greenspan. Federal Reserve Board's semiannual Monetary Policy Report to the Congress. February 16, 2005." The Federal Reserve Board. [online], [August 23, 2017]. [available at: https://www.federalreserve.gov/boarddocs/hh/2005/february/testimony.htm].

FRED (2017): "Federal Reserve Economic Data - FRED - St. Louis FED." Federal Reserve Bank of St. Louis. [online], [July 15, 2017]. [available at: https://fred.stlouisfed.org/].

Grande, G., S. Masciantonio, and A. Tiseno (2013): "The Elasticity of Demand for Sovereign Debt. Evidence from OECD Countries (1995-2011)." *The Sovereign Debt Crisis and the Euro Area* p. 83.

Hodrick, R. J. and E. C. Prescott (1997): "Postwar US Business Cycles: An Empirical Investigation." *Journal of Money, credit, and Banking* pp. 1–16.

Joslin, S., M. Priebsch, and K. J. Singleton (2014): "Risk Premiums in Dynamic Term Structure Models with Unspanned Macro Risks." *The Journal of Finance* **69(3)**: pp. 1197–1233.

Krippner, L. (2013): "A Tractable Framework for Zero-Lower-Bound Gaussian Term Structure Models." *CAMA Working Paper* .

Krippner, L. (2015): *Zero Lower Bound Term Structure Modeling: A Practitioner's Guide.* Springer.

Krishnamurthy, A. and A. Vissing-Jorgensen (2007): "The Demand for Treasury Debt." *Technical report*, National Bureau of Economic Research.

Laubach, T. (2009): "New Evidence on the Interest Rate Effects of Budget Deficits and Debt." *Journal of the European Economic Association* **7(4)**: pp. 858–885.

Nelson, C. R. and A. F. Siegel (1987): "Parsimonious Modeling of Yield Curves." *Journal of business* pp. 473–489.

Ramey, V. A. (2011): "Identifying Government Spending Shocks: It's All in the Timing." *The Quarterly Journal of Economics* **126(1)**: pp. 1–50.

Rudebusch, G. D. and E. T. Swanson (2012): "The Bond Premium in a DSGE Model with Long-Run Real and Nominal Risks." *American Economic Journal: Macroeconomics* **4(1)**: pp. 105–43.

Svensson, L. E. (1995): "Estimating Forward Interest Rates with the Extended Nelson & Siegel Method." *Sveriges Riksbank Quarterly Review* **3(1)**: pp. 13–26.

U.S. Treasury (2017): “Interest Rate Statistics.” U.S. Department of the Treasury. [online], [August 12, 2017]. [available at: https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/default.aspx].

Wright, J. H. (2011): “Term Premia and Inflation Uncertainty: Empirical Evidence from an International Panel Dataset.” *The American Economic Review* **101(4)**: pp. 1514–1534.

Appendices

Appendix I: Affine Model Representation

Some content...

Appendix II: SR-ADNS Model Parameters

Some content...

Appendix III: VAR Model Diagnostics

Lag analysis

Some content...

Appendix IV: Additional IRFs

Some content...