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# Expected and unexpected bond excess returns: Macroeconomic and market microstructure effects

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## Abstract

This paper shows that order flow determines future bond excess returns. This effect cannot be captured by macroeconomic or forward rate information. To understand how these variables influence future bond excess returns, we decompose excess returns into expected and unexpected excess returns. Expected returns crucially depend on the available information set which is spanned by order flow, forward rates and macroeconomic variables. Thus, the predictability of bond excess returns stems from the strong linkage of expected excess returns to available economic information and order flow. The analysis of unexpected excess returns reveals contemporaneous order flow and changes of the economic environment as main drivers.

JEL-Classification: E43, E44, E47, G14

Keywords: yield curve, bond return predictability, term structure, order flow, macroeconomic factor analysis

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# 1 Introduction

Buying a long-term bond and selling it after a one-month holding period returns on average a positive excess return. Which kind of information drives bond market excess returns? The literature refers to macroeconomic variables and forward rates. This paper widens the spectrum by introducing order flow which reflects information incorporation through trading (Evans and Lyons, 2002).<sup>1</sup> A theoretical motivation directly relates order flow to risk premia as it coincides with

*"... speculative demands from varying risk tolerance"*

Evans and Lyons (2002, p. 173).

Empirical hypothesis tests start with regressions of bond excess returns on bond order flow:<sup>2</sup>

$$rx_t = 0.0449OF_t^{QE} + 0.3571^{***}OF_t + \epsilon_t; R^2 = 0.1447 \quad (1)$$

where  $OF_t^{QE}$  is order flow at days when the FED conducts "Permanent Open Market Operations" and  $OF_t$  when not. Forecasting one-month ahead excess returns reveals a significant slope coefficient:

$$rx_{t+1} = -0.1142OF_t^{QE} + 0.00019^{**}OF_t + \epsilon_t; R^2 = 0.0410. \quad (2)$$

What is the economic significance of these regressions? We see two. First, order flow influences contemporaneous excess returns which suggests it as bond pricing factor. Causality should run in the way described in equation (1), as order flow mirrors information incorporation through trading (Brandt and Kavajecz, 2004; Green, 2004; Pasquariello and Vega, 2007; Fricke and Menkhoff, 2011; Menkveld et al., 2012). Second, order flow has forecasting power and should therefore be linked to expected excess returns. This paper tests the holding of these implications.

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<sup>1</sup>Order flow is a measure of signed trades and indicates buying pressure in financial markets (assuming that buys are coded positive).

<sup>2</sup>Data are taken from the Gurkaynak et al. (2007) data set to construct the US zero coupon yield curve for 01/1999–10/2011. Bond excess return is the difference between the return of holding a long-run bond for one month and selling it and the one-month yield. Order flows are monthly aggregates and are derived from the "on-the-run" ten-year Treasury bond future contract. The 5% (1%) significance level is marked with a \*\* (\*\*\*)

For a deeper understanding of bond excess return predictability, we decompose excess returns into expected and unexpected excess returns. In the core of the paper, we regress raw bond excess returns and on both expected and unexpected excess returns on economic variables. Beside well established variables like macroeconomic factors (Ludvigson and Ng, 2009) and forward rates (Cochrane and Piazzesi, 2005), we follow the market microstructure literature and consider bond market order flow. Neither the use of forward rates nor macroeconomic variables can capture all information which order flow offers. Thus, order flow seems to incorporate a risk factor which cannot be captured by other public available variables.

In our analysis we adopt the Adrian and Moench (2011) term structure model which implies a decomposition of monthly excess returns into an expected and an unexpected innovation term. Expected excess returns crucially depend on the available information set which is spanned by order flow, forward rates and macroeconomic variables. These variables explain between 50% and 70% of expected excess returns. Thus, the predictability of bond excess returns stems from the strong linkage of expected excess returns to available economic information and order flow. The analysis of unexpected excess returns reveals contemporaneous order flow and changes of the economic environment as main drivers.

Analyzing expected and unexpected excess returns offers two important implications. First, bond excess returns reveal a close relation to public information – macro variables and forward rates – which underlines the need of macro-finance term structure models (see Wu, 2006; Rudebusch and Wu, 2008). However, the information incorporation through order flow is still missing in the term structure model literature.

Second, empirical studies mainly reject the pure expectation hypothesis (Fama and Bliss, 1987; Bekaert and Hodrick, 2001). Three reasons are discussed in the literature. Either bond investors' expectations are not rational, long interest rates overreact to short rates or a time-varying risk premium is present (see Campbell and Shiller, 1991). The high explainable power of expected excess returns seems to rule out irrational expectations and supports the view of a business-cycle dependent risk premium (Ludvigson and Ng, 2009; Cooper and Priestley, 2009).

The comprehensive contribution of the paper is as follows. We establish bond market order flow as an additional determinant of bond market excess returns. Beside order flow, the empirical part of the paper is built on forwards rates and macroeconomic variables. Especially variables which

are associated with the real economy reveal an impact on bond excess returns and underline a business cycle pattern of the bond risk premium (Ludvigson and Ng, 2009).

This paper is organized in the following steps: Section 2 reviews the existing literature. Section 3 outlines the econometric approach, Section 4 describes the data and Section 5 provides and interprets the main results. Robustness tests in Section 6 confirm the main findings and Section 7 concludes.

## 2 Literature Overview

The predictability of bond excess returns is firstly documented by Fama and Bliss (1987). The difference between an  $n$ -year forward rate and the one-year yield includes information about the future  $n$ -year excess return of a bond. Cochrane and Piazzesi (2005) find that a linear combination of forward rates, called CP-factor, explains one third of one-year ahead excess returns. Additional, Kessler and Scherer (2009) and Sekkel (2011) confirm the economic importance of the CP-factor for international bond markets.

Duffee (2011) shows that excess returns covary with expectations about the future path of the short-term yield which reveal a close relation to changes of the whole yield curve - the "*level*". This finding consists with Cochrane and Piazzesi (2008) who show that the risk premium is a compensation for shifts of the yield curve's level.<sup>3</sup>

Beside yield curve variables, economic variables bear pricing implications for the term structure of interest rates. For example, Joslin et al. (2011) show that the market prices of risk of the term structure's level, slope and curvature are affected by macroeconomic variables, real output and inflation. This mechanism explains the counter-cyclical pattern of bond excess returns and the predictive power of industrial production and the output gap for excess returns (Cooper and Priestley, 2009; Duffee, 2011). Ludvigson and Ng (2009) apply a factor analysis approach to a broad set of economic variables and document a close relation of the real economy, inflation and financial variables to one-year ahead bond excess returns.

Our consideration of order flow for the analysis of bond risk premia is inspired by different strands of the literature. A theoretical motivation directly relates order flow to risk premia as it coin-

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<sup>3</sup>The first three principal components of the term structure are labeled as level, slope and curvature.

cides with "*speculative demands from varying risk tolerance*" (Evans and Lyons, 2002, p.173). Additional, Harvey (1989) claims out that investors who expect an economic downturn demand long-term bonds. These portfolio shifts will induce positive order flow. Empirical applications suggest the existence of an indirect channel as order flow owns a *level effect* on the term structure (see Brandt and Kavajecz, 2004).

Following the argumentation of Joslin et al. (2010), level effects might stem from an economic-driven change of the market prices of risk. Green (2004), Pasquariello and Vega (2007) and Menkveld et al. (2012) document the incorporation of macroeconomic information into prices through order flow. Underwood (2009) and Brandt et al. (2007) show that order flow determines contemporaneous spot- and future market returns. For the bond future market, Fricke and Menkhoff (2011) reveal that contracts with a higher market share of order flow stronger influence other bond future contracts. Moreover, order flow forecasts future economic variables (Evans and Lyons, 2009; Rime et al., 2010). Thus, order flow can be understood as an additional source of economic information.

Further motivation for the consideration of order flow in the context of bond excess returns stems from two market microstructure effects on excess returns. First, Li et al. (2009) show that the probability of informed trading (PIN) is a determinant of bond excess returns. However, the computation of the PIN-measure bases on the concept that order flow is a medium how information is incorporated into prices. Second, the price process of bonds matters for excess returns. Macroeconomic news lead to strong price shifts, so-called jumps (Lahaye et al., 2011). Wright and Zhou (2009) and Duyvesteyn et al. (2011) point out that the intensity of jumps predicts future excess returns, even after the inclusion of the CP-factor. Additional, Duyvesteyn et al. (2011) suggest that the jump intensity is a proxy of the market's interpretation of macroeconomic news. As discussed above, order flow might be a more appropriate candidate. Further motivation to consider order flow is given by Lahaye et al. (2011) who show that announcement releases and liquidity shocks are the key drivers of jumps. Liquidity shocks are caused by abnormal trading activities into or out of the market. The market microstructure literature suggests the use of order flow to model liquidity shocks. Thus, order flow is related to jumps too. To disentangle the effects of order flow, information incorporation or market's illiquidity, we explicitly control for illiquidity by including the Amihud (2002) liquidity measure.

### 3 Term structure modeling and estimation

This section introduces the Adrian and Moench (2011) term structure model (AMTSM) and the results for the US zero-coupon yield curve between 01/1999 and 10/2011. The yield curve is constructed from the Gurkaynak et al. (2007) data set. We derive market prices of risk from a three-step OLS-estimator and decompose excess returns into an expectation- and an innovation term.<sup>4</sup> For the term structure analysis we use the following notations and definitions.  $p_t^{(n)}$  defines the log price of a zero-coupon bond with maturity  $n$  at time  $t$  and  $y_t^{(n)}$  the implied yield of a bond which matures in  $n$  month. The log forward rate at time  $t$  for payments between period  $t + n - 1$  and  $t + n$  is expressed as

$$f^{(n-1 \rightarrow n)} = p_t^{(n-1)} - p_t^{(n)} \quad (3)$$

and the log one-period return for holding an  $n$ -period bond is

$$r_{t+1}^{(n)} = p_{t+1}^{(n-1)} - p_t^{(n)}. \quad (4)$$

The difference of the holding period return in (4) and the return of a one-period bond, the yield  $y_t^{(1)}$ , defines the log excess return  $rx$ :

$$rx_{t+1}^{(n)} = p_{t+1}^{(n-1)} - p_t^{(n)} - y_t^{(1)} \quad (5)$$

and  $\bar{rx}_t^{(N)}$  the average excess return for bonds with a maturity up to  $N$  months at time  $t$ :

$$\bar{rx}_t^{(N)} = \frac{1}{N} \sum_{n=1}^N rx_t^{(n)}. \quad (6)$$

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<sup>4</sup>Beside Adrian and Moench (2011), Joslin et al. (2010) consider ordinary least squares estimations in a Gaussian dynamic term structure models (GDTSM).

### 3.1 Term structure modeling

This section discusses the theoretical background of the AMTSM with *spanned* and *unspanned* factors, both together denoted as  $X_t$ . In detail, spanned pricing factors depend on the first  $K^s$  principal components of the yield curve and their innovations.

The core elements of the model are affine structures of log bond prices to market prices of risk and of market prices of risk to the yield curve.

At the first step we model the dynamics of the first  $K^s$  principal components of interest rates with a maturity of  $n=\{3,4,\dots,120\}$  months, state vector  $X_{t+1}^s$ , as a VAR(1)-process with the innovation term  $\nu_{t+1}$  which has, conditional on  $X_t^s$ , a mean of zero and variance  $\Sigma$ :

$$X_{t+1}^s = \mu + \Phi X_t^s + \nu_{t+1}. \quad (7)$$

Note, that we use demeaned yields for the estimation of principal components which sets the vector  $\mu$  in equation (7) to zero.

The second step relates log one-month excess returns,  $rx_{t+1}$ , to the state variables  $X_t$  and the innovation term  $\nu_{t+1}$ . Bond market investors know the vector  $X_t$  at time  $t$  to form expectations about the future excess return of maturity  $(n-1)$ ,  $rx_{t+1}^{(n-1)}$ . Therefore, we formulate the expected future excess return as a term which depends on a constant and the available information set at time  $t$  which is represented by  $X_t$ . The vector  $\nu_{t+1}$  reflects unexpected term structure innovations of the first  $K^s$  factors and has also pricing implications for excess returns.

Without *unspanned* factors, we rewrite the log excess holding period return as a function of an expected return, a convexity adjustment term, return innovations which are related to  $\nu_{t+1}$  and a priced error term,  $e_{t+1}$ , with variance  $\widehat{\sigma}^2$ :

$$rx_{t+1}^{(n-1)} = \beta^{(n-1)'}(\lambda_0 + \lambda_1 X_t^s) + \frac{1}{2}(\beta^{(n-1)'}\Sigma\beta^{(n-1)} + \sigma^2) + \beta^{(n-1)'}\nu_{t+1} + e_{t+1}^{(n-1)}. \quad (8)$$

To compute parameters we transform equation (8) to

$$rx_{t+1}^{(n-1)} = \alpha^{(n-1)} + \beta^{(n-1)'}\nu_{t+1} + c^{(n-1)'}X_t^s + e_{t+1}^{(n-1)}. \quad (9)$$



*Unspanned* factors enrich the state vector to  $X_{t+1} = [X_{t+1}^s, X_{t+1}^u]'$  where  $X_{t+1}^u$  represents unspanned factors. The latter ones forecast future interest rates but are unrelated to the short rate and therefore do not impact the current yield curve. Thus, the market prices of unspanned risk factors are set to zero. More specific, we subdivide  $\beta^{(n)}$  into spanned and unspanned related components,  $\beta^{(n)} = [\beta_s^{(n)}, \beta_u^{(n)}]'$ . The existence of unspanned factors restricts  $\beta_u^{(n)}$  to be set to zero. Thus, the pricing equation of excess returns, equation (8), transforms to

$$rx_{t+1}^{(n-1)} = \beta_s^{(n-1)'}(\lambda_s^0 + \lambda_s^1 X_t) - \frac{1}{2}(\beta_s^{(n-1)'}\Sigma_{ss}\beta_s^{(n-1)} + \frac{1}{2}\sigma^2) + \beta_s^{(n-1)'}\nu_{t+1}^s \quad (10)$$

where  $\Sigma_{ss}$  denotes the upper  $K_s \times K_s$  coefficients of  $\Sigma$ .  $\lambda_s^0$  and  $\lambda_s^1$  are the first  $K_s$  upper rows of  $\lambda^0$  and  $\lambda^1$ . We derive coefficients by estimating (9) with spanned and unspanned factors and define  $\hat{\alpha} = (\hat{\alpha}^{(1)}, \dots, \hat{\alpha}^{(N)})$ ,  $\hat{\beta} = (\hat{\beta}^{(1)'}, \dots, \hat{\beta}^{(N)'})$  and  $\hat{c} = (\hat{c}^{(1)'}, \dots, \hat{c}^{(N)'})$ . Finally, we derive the quasi prices of risk of spanned factors,  $\lambda_0$  and  $\lambda_1$ , from the following conditions:

$$\hat{\lambda}_s^0 = (\hat{\beta}_s' \hat{\beta}_s)^{-1} \hat{\beta}_s' (\hat{\alpha} + \frac{1}{2}(\hat{B}^{s*} \text{vec}(\hat{\Sigma}_{ss}) + \hat{d}_e)) \quad (11)$$

$$\hat{\lambda}_s^1 = (\hat{\beta}_s' \hat{\beta}_s)^{-1} \hat{\beta}_s' \hat{c}_s \quad (12)$$

with  $B^{s*} = [\text{vec}(\beta_s^{(1)} \beta_s^{(1)'})', \dots, \text{vec}(\beta_s^{(N)} \beta_s^{(N)'})']$  and  $\hat{d}_e = \hat{\sigma}^2 i_N$ .  $i_N$  is a  $N \times 1$  vector of ones.

Beside affine excess returns, log bond prices also follow affine processes which depend on the state vector  $X_t$  and an error term  $u_t$ :

$$\ln P_{t+1}^n = A_n + B_n' X_{t+1} + u_{t+1}. \quad (13)$$

A reformulation of (13) leads to the following restrictions for bond pricing which can be solved recursive (see Adrian and Moench, 2011):

$$A_n = A_{n-1} + B_{n-1}'(\mu - \lambda_0) + \frac{1}{2}(B^{(n-1)'}\Sigma B^{(n-1)} + \sigma^2) - \delta_0 \quad (14)$$

$$B_n' = B_{n-1}'(\Phi - \lambda_1) - \delta_1' \quad (15)$$

$$A_0 = 0; B'_0 = 0 \tag{16}$$

$$\beta'_n = B'_n. \tag{17}$$

The starting parameters are defined as  $A_1 = -\delta_0$  and  $B_1 = -\delta_1$ . We derive the parameters  $\delta_0$  and  $\delta_1$  from a linear projection of the log one-month interest rate,  $y_t^{(1)}$ , on a constant and  $X_t$ .  $\delta_0$  is the intercept coefficient and  $\delta_1$  the coefficient vector of  $X_t$ . If (17) holds, the estimation of the model is exact. The estimation process is discussed in the following.

### 3.2 Term structure estimation

This section discusses the estimation properties of the AMTSM with *spanned* and *unspanned* factors. Beside pricing factors which are extracted from interest rates (spanned factors), recent literature suggests the existence of *unspanned* factors (see Duffee, 2011; Joslin et al., 2010; Wright, 2011). These *unspanned* factors forecast future interest rates but perform poor for explaining current yields. Previously considered unspanned factors are industrial production (Duffee, 2011; Joslin et al., 2010), consumer prices (Duffee, 2011; Joslin et al., 2011; Wright, 2011) and GDP growth (Wright, 2011). To ensure comparison to the closest related paper, we follow Adrian and Moench (2011) and define unspanned information as the first two principal components of monthly core CPI, monthly core PCE inflation and the real activity index from the Federal Reserve Bank of Chicago.

The choice of the number of *spanned* factors might be twofold. Classical factors like level, slope and curvature describe nearly completely the interest rate pattern and thus suggest to consider three spanned factors. However, Cochrane and Piazzesi (2005) document that the fourth and fifth term structure factor are strong determinants of excess returns. According to Adrian and Moench (2011), we prefer a model specification with five *spanned* term structure factors. Model selection bases on three objective measures which all underline a better performance of the five factor model. Briefly, we discuss the five factor case for pricing excess returns with a maturity of  $n = \{6, 18, 24, \dots, 60, 84, 120\}$  months.<sup>5</sup>

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<sup>5</sup>As Adrian and Moench (2011), we also compare the observed and model-implied first and second moment of interest rates. For the sake of brevity we do not discuss them as both moments are perfectly described by the five factor model.

First, we use equation (17) and compare model implied (equation (15)) and regression based betas (equation (9)) at Figure 1. The estimated betas show only small deviations from their implied values which suggests a good fit of the term structure model.

Second, we follow Almeida et al. (2011) and estimate a modified  $R^2$  statistic for expected excess returns:

$$R_n^2 = 1 - \frac{\text{mean}[(rx_{t+1}^{(n)} - \mathbb{E}_t[rx_{t+1}^{(n)}])^2]}{\text{var}[rx_{t+1}^{(n)}]}. \quad (18)$$

The  $R^2$ s decrease from 20% at the maturity of six months to 15% for ten-year bonds but are always higher than for the three factor case.

Third, we analyze the model fit by comparing model-implied and observed interest rates. The five factor model reveals smaller deviations for one-, two-, five- and ten-year bonds which underline the good fit of the model.

Duffee (2011) and Joslin et al. (2011) point out that the consideration of five spanned and some unspanned factors might cause over-fitting which results in miscalibrated yields outside the considered maturities. We address to this issue by computing absolute deviations of observed and model-implied interest rates for maturities of 180, 240, 300 and 360 month of the three and five factor model. For all maturities the five factor specification reveals lower deviations and the Wilcoxon rank sum test rejects the null hypothesis of equal medians at the one percent level. Thus, we find a clear preference for a term structure model with five spanned factors.

The first three term structure factors load in a well known pattern on the yield curve.<sup>6</sup> The first factor can be labeled as the "*level effect*" of the yield curve as it smoothly increases with longer maturities. The second factor steepens the yield curve which characterizes the "*slope effect*". A "*curvature effect*" is revealed by the third factor. Additional, the fourth and the fifth factor negligibly influence the yield curve. This effect is consistent with findings of Adrian and Moench (2011), Cochrane and Piazzesi (2005) and Duffee (2011) who document that those factors with low impact on yields heavily load on excess returns. In sum, the five factor model will be a more appropriate model than the three factor specification. Table 1 reports the estimated market prices of risk,  $\lambda_0$  and  $\lambda_1$ .

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<sup>6</sup>We follow Adrian and Moench (2011) and define yield loadings as  $-\frac{1}{n}B_n$ .

## 4 Data

This section discusses the estimation of the Cochrane-Piazzesi-factor (short: CP-factor), US macro factors and order flow. We extract order flow from trading data of the ten-year US treasury bond future between 01/1999 and 10/2011. The estimation period of the CP-factor and the macro factors corresponds to the available trading data. The data sample covers two recessions (03-11/2001 and 12/2007-06/2009), two asset price bubbles (dot-com and sub-prime), the European debt crisis (2009-2011) as well as some calm periods.

### 4.1 CP-factor

The CP-factor is a linear combination of the one-year yield and forward rates. Cochrane and Piazzesi (2005) suggest to derive the weights of the components from a regression of the average one-year excess returns of the maturities  $n=\{12,24,\dots,60\}$  months,  $\bar{r}x_{t+12}$ , on an intercept, the one-year yield and forward rates for maturities of two to five years:

$$\bar{r}x_{t+12} = \gamma_0 + \gamma_1 y_t^{(12)} + \gamma_2 f_t^{(12 \rightarrow 24)} + \gamma_3 f_t^{(24 \rightarrow 36)} + \gamma_4 f_t^{(36 \rightarrow 48)} + \gamma_5 f_t^{(48 \rightarrow 60)} + \varepsilon_{t+1}. \quad (19)$$

Table 2 reports the regression results for maturities of two to five years for the time period 01/1999 to 10/2011.<sup>7</sup>

### 4.2 Order flow

Order flow estimation bases on the US ten-year bond future contract which owns the highest trading volume in the US bond future market. Brandt and Kavajecz (2004) suggest focusing on the more informative "on-the-run" bonds as they provide a higher liquidity than "off-the-run" bonds. We incorporate this finding and make use of a daily "auto roll" procedure which compares maturity-equivalent bond futures and include the one with the highest trading volume. We construct order flow by comparing trade prices with the available bid and ask price (Lee and

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<sup>7</sup>Note, that the annual horizon for calculating and forecasting excess returns in equation (19) diverts from the monthly excess return in the term structure model (see equation (8)). This divergence avoids to have one-month excess returns as exogenous variable and an equivalent proxy, the CP-factor, as endogenous variable in latter regressions.

Ready (1991)-algorithm) and code order flow to be buyer-initiated if the trade price is equal or above the ask price and vice versa. Order flow is aggregated on a monthly basis.

Melvin et al. (2009) point out that central bank interventions affect the price impact of order flow. Therefore, we allow order flow to own diverting effects for days when the FED announces or conducts market operations which are related to the quantitative easing program or not.  $OF^{QE}$  presents order flow at days with "Permanent Open Market Operations" (POMO) and/or FOMC meetings since 2008.  $OF$  subsumes order flow at all other days.

### 4.3 Estimation and interpretation of macroeconomic factors

We follow Ludvigson and Ng (2009) and apply a factor analysis approach and consider the first  $k$  macroeconomic factors of the US.<sup>8</sup> The optimal number of factors,  $k$ , is derived from the Bai and Ng (2002) information criterion.

*Estimation:* We derive US macro factors (further LN-factors) from the Ludvigson and Ng (2009) data set. Variables are transformed in a way which ensures stationarity. Outliers in the transformed time series are handled as missing values and any detected seasonality is corrected by an X11-ARIMA process (see Marcellino, 2003).

The economy is sufficiently well described by the first four factors. The factors describe more than 30% of the variation in the macroeconomic variables whereby the first factor explains 12%. The inclusion of the second and third factor more than doubles the explainable variance to 27% and the last factor adds five percent. Consistent with Ludvigson and Ng (2009), the factors' persistence reveal strong heterogeneity. The first factor reveals the highest first order autocorrelation with 0.56 and the fourth factor owns a lag-dependence of -0.31.

*Interpretation:* To derive an economic intuition of the macro factors, we regress each time series on the underlying four macro factors and plot the marginal  $R^2$ s at Figure 2. The interpretation of the macro factors corresponds to Ludvigson and Ng (2009). The first factor,  $LN_1$ , reveals a close relation to several industrial production- and employment components. Thus, we see  $LN_1$  as the *real factor*.  $LN_2$  loads on several inflation and interest rate measures what propose

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<sup>8</sup>The following shows a brief description of the principal component analysis. Define the matrix of economic observations as the  $[T \times N]$  matrix  $X$ . The  $[T \times k]$  factor matrix consists of  $\sqrt{T}$  multiplied with the  $k$  largest eigenvalues of the matrix  $[XX]'$ . For a detailed discussion see Stock and Watson (2002).

that this factor is an *inflation factor*. The third macro factor mainly captures interest rates and their spreads. We name  $LN_4$  *unemployment* factor as it loads on *real activity* variables, mainly unemployment and industrial production.

## 5 Determinants of excess returns

This section identifies the pricing implications of the CP-factor, economic variables and order flow for (1) excess returns, (2) expected returns and (3) return innovations. We analyze bonds with a maturity of two-, five- and ten years and additional mean returns of two- to ten-year bonds. For the sake of brevity we do not report results for the CP-factor as single regressor. However, in order to compare our results, the last row of each table presents the changes of the adjusted  $R^2$ s to a regression with the CP-factor.

Section 5.1 considers the CP-factor, macroeconomic variables and order flow to forecast excess returns. Section 5.2 discusses the relation of these variables to expected excess returns. Section 5.3 relates return innovations to order flow and economic innovations. All coefficients and standard errors of the following regressions are block bootstrapped (see Politis and Romano, 1994; Politis and White, 2004).

### 5.1 Forecasting excess returns

At the first step, we discuss the forecasting properties of the CP-factor and macroeconomic variables for excess returns. This methodology is comparable to Ludvigson and Ng (2009) and can be understood as benchmark.<sup>9</sup> At the second step, we discuss order flow's ability to forecast future excess returns. Table 3 reports regression results for subsequently including lagged variables of the CP-factor, macro factors and order flow.

The CP-factor forecasts excess returns at all maturities whereby the  $R^2$ s lay in a narrow range between seven and nine percent for all maturities. Panel A reports results of regressing excess returns on the CP-factor and US macro factors. The effect of the economic state variables is more pronounced for longer maturity bonds as adjusted  $R^2$ s gradually increase by 5.8% at the shortest

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<sup>9</sup>The formulation of the regression is comparable to Ludvigson and Ng (2009). However, we analyze one-month excess returns instead of one-year excess returns.

maturity and by 9.0% at the longest. With the exception of the two-year maturity, the strongest impact stems from the *inflation* factor  $LN_2$ . However, note that the pure interest rate factor,  $LN_3$ , reveals no impact on excess returns. These results suggest that it is inflation, instead of interest rates, which drives excess returns and supports the view of the existence of an inflation risk premium (see Buraschi and Jiltsov, 2005). Beside inflation, the real economy matters for excess returns. At the shortest maturity, the first real factor owns the highest impact on future excess returns whereby the negative sign suggests that a lower economic activity coincides with a higher risk premium. For maturities beyond two years, the importance of the real economy switches from the real factor to the *unemployment* factor. Again, an economic downturn, now higher unemployment, comes along with higher excess returns. In sum, our results consist with the view of a countercyclical bond risk premium (see Ludvigson and Ng, 2009; Wright and Zhou, 2009).

Next, we explore the role of *order flow* by regressing excess returns on the CP-factor and order flow (Panel B). For all maturities the inclusion of order flow increases the adjusted  $R^2$ s whereby the strongest effect exists for shorter maturities and vanishes for long-term bonds. In the absence of the FED's quantitative easing operations, the order flow coefficient is positive and significant for maturities up to five years. How to interpret this effect? Following the argumentation of Harvey (1989), expectations about an economic downturn increase the demand for long-term bonds and lead to positive order flow. As Panel A document countercyclical excess returns, we should expect a positive relation between order flow and excess returns.

At days when the FED conducts permanent open market operations (POMO) or announces information related to the "Large-Scale Asset Purchase" (LSAP) program, positive order flow coincides with lower excess returns. Although the coefficients are insignificant, they are consistent with the two ways how the FED's program worked. First, announcements of a more relaxed monetary policy lead by arbitrage to a higher demand for outstanding Treasury bonds (and future contracts). Second, the FED's market operations lead to an excess demand for bonds. However, these market operations signal the willingness to calm outcomes of the financial crisis which lead to a lower risk premium. Moreover, LSAP announcements lowered the risk premium of long-term interest rates (see Gagnon et al., 2011).

On an intraday basis, Green (2004) and Pasquariello and Vega (2007) show that order flow

incorporates information related to economic announcements. On a monthly basis, one might question whether order flow and economic factors represent the same kind of information. Comparing Panel A and B suggests that the answer is "no". Macroeconomic information is more important for long-term bonds, whereas the effect of order flow is more pronounced for short-term contracts.

Panel C addresses to this point by including all previous considered variables in the regressions. Higher  $R^2$ s and consistent significance of the variables underline the hypothesis that order flow incorporates information which is not spanned by traditional pricing factors.

## 5.2 Forecasting expected excess returns

This section discusses if the predictive power of macroeconomic factors and order flow stems from a compensation for bearing economic risk. If so, this effect is captured by model-implied expected returns. The economic motivation for forecasting expected excess returns directly stems from their definition in equation (8):

$$\mathbb{E}_t[rx_{t+1}^{(n-1)}] = \beta^{(n-1)'}(\lambda_0 + \lambda_1 X_t). \quad (20)$$

If expectations are rationally formed we will observe a strong relation between the exogenous variables at time  $t$  and the expected excess returns at  $t+1$  which are nurtured by information at time  $t$ .

First, we analyze how the CP-factor interacts with expected returns. Although the CP-factor is constructed from yearly excess return series, it mirrors the pattern of one-month expected returns nearly perfectly and regressions report  $R^2$ s between 56% and nearly 70%.<sup>10</sup>

Table 4, Panel A presents results for including macro factors. Economic variables increase  $R^2$ s between 1.5% and more than 15%, whereby the strongest impact is detected at the shortest maturity. Consistent with Section 5.1, inflation- and real economy-related information are significant pricing factors and underline the relation of excess returns to the business cycle. Additional, interest rate spreads in form of  $LN_{3,t}$  own significant coefficients for maturities up to five years.

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<sup>10</sup>Both, expected returns and the CP-factor are slightly downward sloping. However, we reject non-stationarity tests with and without trend.



It illustrates that public available risk measures, such as yield spreads and the CP-factor, capture important information for the formation of expected bond excess returns.

Panel B reveals that the effect of order flow is more pronounced for shorter maturities. However, at the ten-year maturity order flow is significant at least at the ten percent level. The coefficients' interpretation corresponds to Section 5.1 where higher order flow coincides with higher excess returns. Again, order flow at days with quantitative easing operations of the FED coincides with lower excess returns.

Panel C shows that the order flow effect is robust to the inclusion of the CP-factor and economic variables. Again, order flow seems to incorporate information which can not be captured by pure economic information.

In sum, our results confirm the view that economic information matters for expected returns Brandt and Wang (2003). Going further, the findings explain how future excess returns depend on the economy and contain one major implication. Kim (2007) claims out that the predictability of excess returns might lead to a failure of the rational expectation hypothesis. In this context, Campbell and Shiller (1991) argue that the predictability of interest rates contradicts rational expectations. However, our results reveal that available information explain the lion's share of expected returns.<sup>11</sup>

### 5.3 Explaining excess return innovations

Section 5.2 reports that expected excess returns strongly depend on the set of available macroeconomic information. The following exercise reveals that return innovations are an outcome of the flow of information. In detail, the flow of information is the contemporaneous order flow and changes of the economic- and forward rate variables.

As observed above, the importance of the CP-factor increases for longer maturities.  $R^2$ s increase from nearly 0% at the two-year maturity to more than 20% at the longest considered maturity.

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<sup>11</sup>Given rationality, return innovations have to be unpredictable by any variables. Unreported results document nearly no forecasting power of the CP-factor, economic information and order flow for return innovations which is underlined by  $R^2$ s between zero and three percent. In sum, the formation of expected excess returns is consistent with investors' rationality.

Including macro factors further enhances our understanding of unexpected bond excess returns (Table 5, Panel A). In line with realized and expected excess returns, inflation and interest rate spreads are main drivers of returns.

At Panel B we replace macro factors by order flow to capture the flow of information through trading. Jumps of the  $R^2$ s of nearly 10% reveal that order flow is a major driver of return innovations. Including macro factors (Panel C) underline the previous finding that order flow offers information which cannot be represented by economic factors. This impression is underlined by simply summing up the changes of the  $R^2$ s at Panel A and B which correspond to the changes at Panel C.

Next, we turn the focus to realized excess returns (see Table 6). Results map the findings for excess return innovations at Table 5. To keep it short, the CP-factor is more important for longer maturities and  $LN_2$  and  $LN_3$  are the main economic drivers of excess returns. However, compared to order flow, the effect of macroeconomic factors is negligible for maturities up to five years.

## 6 Robustness tests

This section discusses the robustness of the derived results in three ways. First, we extend the set of control variables by (1) controlling for the short term rate, (2) considering liquidity risk and (3) volatility innovations. Second, we conduct subsample analysis by excluding (1) the financial crisis and (2) by analyzing the effect of order flow in times of financial stress and market uncertainty. Third, we analyze the behavior of the model implied error terms  $e$  and thus control for any model misspecification.

### 6.1 Extending the set of control variables

(1) Viceira (2012) underlines the importance of the short-term interest rate for bond excess returns. The short-term rate might reflect *inflation* and *real economy* uncertainty and therefore presents a natural candidate for explaining excess returns. We include first differences of the short term rate to ensure stationarity.

(2) Li et al. (2009) point out that liquidity risk appears as additional pricing factor for US bond excess returns. For each month we define *liquidity risk* as the average of the daily Amihud (2002) "price impact - volume" ratios which are defined as

$$liquidity\ risk_t = \frac{|r_t|}{volume_t} \quad (21)$$

where  $r_t$  is the daily return of the ten-year Treasury bond future and  $volume_t$  is the contract's trading volume at day  $t$ .

(3) Adrian and Moench (2011) discuss a positive relation between bond returns and the Merrill Lynch *Move* index which represents implied volatilities from options on Treasury future contracts. At this point, we follow the FX literature and consider volatility innovations as an excess return determinant (Menkhoff et al., 2012). Innovations are modeled as differences of the monthly *Move* index. Results also hold for volatility levels.

The upper panel of Table 7 shows results for forecasting expected returns and the lower panel reports results for regressing realized returns on contemporaneous order flow and changes of all other state variables.

*Expected returns* do not reveal any exposure to the short rate, liquidity risk or volatility innovations. The only exception is the ten-year maturity where volatility reveals some impact on returns. Turning the focus to the order flow coefficients reveals no changes of signs or significances.

*Excess returns* reveal a strong relation to contemporaneous innovations in the short term rate which qualifies it as additional control variable (see Table 7). The negative sign confirms our expectation as the short-term rate is a cyclical indicator. A drop of the short-term rate, mirroring an (expected) economic downturn, coincides with higher excess returns (a counter-cyclical variable). The inclusion of the short-rate lifts  $R^2$ s by ten percent at the ten-year maturity and by more than 60% at the two-year maturity. Including interest rate innovations kicks out the inflation factor for two- and five-year excess returns. Both maturities reveal a strong exposure to the short-term rate which proxies economic uncertainty (see Viceira, 2012). Uncertainty about long-run inflation seems to be limited as the inflation factor remains significant at the ten-year maturity and the change of the  $R^2$  is the lowest of all maturities.

Liquidity risk reveals a positive relation to contemporaneous excess returns of the two-year contract. The interpretation of the coefficient is straight forward. Investing under higher liquidity risk has to be compensated by higher (excess) returns.

The negative signs of volatility innovations contradict expectations which complicates the interpretation. Therefore, we conduct subsample analysis with respect to volatility innovations to access the robustness of order flow.

To sum up, the inclusion of further control variables does not rule out the linkage between order flow and excess returns and thus underlines results of Section 5.

## 6.2 Subsample analysis

(1) *Excluding the financial crisis:* The order flow effect might be driven by the financial crisis. Beber et al. (2009) discuss the "*flight-to-quality*"- and "*flight-to-liquidity*"-phenomenons which coincide with higher market uncertainty and portfolio rebalances toward safer and more liquid assets such as bonds. The ten-year bond future order flow might be affected by these phenomenons as the underlying contract is seen as a safe-haven investment and the future contract offers an outstanding trading liquidity. We address to this problem and follow Thornton and Valente (2011) by excluding the financial crisis period January 2007 to December 2009 from our sample and rerun regressions. We only report results for realized returns. Results also hold for expected excess returns.

Table 8 shows the results for excluding the financial crisis. Results consist with previous findings and again underline the importance of order flow for excess returns.

(2) *Regime shifts:* We sort the sample with respect to (i) the FED's St. Louis Financial Stress Index (STLFSI) and (ii) volatility innovations.<sup>12</sup> Financial stress controls for the "*flight-to-quality*"-phenomenon. Given that order flow mainly mirrors a search for quality and liquidity in times of stress, the order flow coefficient should increase with financial stress. An increase of volatility should reflect higher uncertainty. Pasquariello and Vega (2007) and Menkveld et al. (2012) show that the importance of order flow increases with higher uncertainty. Adrian and Moench (2011) reveal a relation between bond excess returns and bond market volatility (*Move*

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<sup>12</sup>Note that high financial stress and volatility states are not exclusively related to the financial crisis. The sorted time series are chronological mixed.

index). Further, Underwood (2009) reveals that the effect of bond order flow depends on the level of the CBOE volatility index (VIX) which is the average model-implied volatility of S&P 100 index options. Thus, we sort for bond market volatility (*Move* index) and stock market volatility (VIX). We apply a rolling regression approach to average excess returns and set the sample length to 30. Figure 3 plots of the slope parameters of the derived order flow coefficients. We start with financial stress. The impact is highest in calm periods and sharply decreases for medium stress. During high stress periods the order flow effect slightly increases. Especially the high slope coefficients during calm periods contradict the hypothesis that the order flow effect is solely driven by a "flight-to-quality".

Next, we discuss the pattern for the *Move* index. Consistent with Pasquariello and Vega (2007) and Menkveld et al. (2012), we find that order flow owns a higher importance during times of market uncertainty. Sorting for equity volatility does not show the same pattern as for sorting for bond market volatility. For VIX, the estimated coefficients do not show a unique pattern. Some peaks are located at medium volatility periods whereas high and low volatility states are marked by small order flow coefficients. These results support findings of Underwood (2009) but rule out that order flow is driven by a search for liquidity or quality.

### 6.3 Explaining the error term $e$

A misspecification of the term structure model would bias results. Beside Section 5.3, where the predictability of excess return innovations is mainly denied, we again address to the concern of model misspecification. Another possibility to detect the failure of the model will be a systematic relation of the model implied error terms  $e$  of equation (8) and any exogenous variables. Therefore, we run regressions of error terms on lagged and differenced values of the CP-factor, macro factors and order flow. The model's correctness is marked by no significant relation between the error terms and the exogenous variables.

Forecasting error terms relates to the question if  $e_{t+1}$  captures any systematic component which is related to time  $t$  variables. A correct model subsumes all available information in time  $t$  in the expected excess return term. Table 9 shows the results for forecasting the error term. At

no individual maturity, neither two years nor ten years, we observe any predictability which is underlined by negative  $R^2$ s. The one-year yield turns out to be significant for the error terms of five- and ten-year bonds. However, the positive signs conflict with results of Table 7 where the short rate own negative signs. Analyzing the relation between the error terms and contemporaneous changes of the economic variables deals with the question if the model correctly picks up the impact of term structure innovations  $\nu_t$ . Panel B reports the results. The CP-factor and the real factor reveal some impact on error terms. However, signs switch from positive to negative and reveal no systematic pattern.

In sum, we see these results as confirmation of a correct model specification.

## 7 Conclusion

This study adds bond market's order flow as an additional variable for forecasting bond excess returns. We use a large economic data sets for the US and construct macro factors. Additionally, we include the Cochrane and Piazzesi (2005)-factor to control for information provided by forward rates. The information of order flow is neither captured by macroeconomic variables nor by forward rates. Thus, our analysis suggests that order flow incorporates a risk factor.

The effect of order flow is consistent with the view that order flow incorporates information (see Brandt and Kavajecz, 2004; Pasquariello and Vega, 2007; Menkveld et al., 2012). Moreover, order flow might explain why other microstructure effects are priced in excess returns. Li et al. (2009) argue that information risk is a determinant for bond market excess returns. An additional predictor is the intensity of strong bond price movements which can be induced by information releases or liquidity reasons (Wright and Zhou, 2009). Both variables are by definition directly related to order flow.

To understand the pricing implication of order flow and public information we apply the Adrian and Moench (2011) term structure model and decompose excess returns into expected returns and return innovations. Expected excess returns crucially depend on the available information set which is spanned by order flow, forward rates and macroeconomic variables. Return innovations are unpredictable but reveal a strong dependence on contemporaneous order flow and changes of the economic environment.

This article sheds some light on the reasons for the high rejection rate of the expectation hypothesis (Fama and Bliss, 1987; Bekaert and Hodrick, 2001). The strong linkage between expected excess returns and (non-)public available information can rule out one argument for its failure: irrational expectations.

Evidence for a time-varying risk premium is strong. We detect a counter-cyclical pattern in both excess returns and the expectation components. This result underlines the business-cycle dependence of excess returns (Ludvigson and Ng, 2009; Cooper and Priestley, 2009; Duffee, 2011).

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## A Tables and Figures

Table 1: Market prices of risk

pricing factor	maturity					
	$\lambda_0$	$\lambda_{1,1}^s$	$\lambda_{1,2}^s$	$\lambda_{1,3}^s$	$\lambda_{1,4}^s$	$\lambda_{1,5}^s$
$X_1$	0.0261	0.0067	-0.0616	-0.0309	-0.0252	-0.0453
$X_2$	0.0316	0.0536	-0.1098	-0.0617	0.0135	-0.0745
$X_3$	-0.0328	-0.0022	0.0133	-0.2173	0.1808	0.0485
$X_4$	-0.0256	0.0296	0.1149	-0.0081	-0.1476	-0.1650
$X_5$	0.0848	0.0575	-0.0766	0.0369	-0.1866	-0.2138

This table reports the model implied market prices of risk of spanned pricing factors of equation (11) and (12) of the five-factor term structure model. The prices are used for calculations of expected excess returns in equation (8).

Table 2: Cochrane-Piazzesi regression coefficients

Variable	coeff.	maturity			
		2-year	3-year	4-year	5-year
const.	$\gamma_0$	-2.79	-4.60	-5.93	-7.21
$y^{(1)}$	$\gamma_1$	0.84	0.77	0.14	-0.74
$y^{(2)}$	$\gamma_2$	1.65	5.15	9.92	14.91
$y^{(3)}$	$\gamma_3$	-14.79	-30.24	-45.97	-60.11
$y^{(4)}$	$\gamma_4$	22.50	43.67	63.33	79.67
$y^{(5)}$	$\gamma_5$	-9.38	-17.99	-25.65	-31.63
adj. $R^2$		0.26	0.23	0.23	0.24

This table shows regression results of one-year excess holding bond returns with maturities of two- to five years on standardized values of the one-year yield and on forward rates with a maturity of two- to five years. The time period reaches from 01/1999 to 10/2011.

Table 3: Forecasting excess returns

excess returns						
maturity						
Variable	2-year			5-year		
	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C
$CP_{t-1}$	0.2558***	0.2823***	0.2481***	0.2452***	0.2949***	0.2427***
$OF_{t-1}^{QE}$		-0.0522	-0.0013		-0.0617	-0.0237
$OF_{t-1}$		0.1889**	0.1606**		0.1831**	0.1606**
$LN_{1,t-1}$	-0.1844**		-0.1762**	-0.0846		-0.0819
$LN_{2,t-1}$	0.1590**		0.1531**	0.2238***		0.2202***
$LN_{3,t-1}$	0.1209*		0.0986	0.1027		0.0784
$LN_{4,t-1}$	0.0872		0.0975	0.1469**		0.1556**
adj. $R^2$	0.1397	0.1035	0.1536	0.1536	0.1085	0.1675
$\Delta R^2$	0.0579	0.0217	0.0718	0.0658	0.0207	0.0797
maturity						
Variable	10-year			mean		
	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C
$CP_{t-1}$	0.1957***	0.2613***	0.199**	0.2544***	0.2866***	0.2375***
$OF_{t-1}^{QE}$		-0.0128	0.0061		-0.0476	-0.0161
$OF_{t-1}$		0.1144	0.0996		0.1728**	0.1500**
$LN_{1,t-1}$	0.0012		-0.0018	-0.0864		-0.0798
$LN_{2,t-1}$	0.3065***		0.3067***	0.2444***		0.2376***
$LN_{3,t-1}$	0.0523		0.0404	0.0989		0.0823
$LN_{4,t-1}$	0.1526**		0.1478**	0.1425 *		0.1450**
adj. $R^2$	0.1594	0.0708	0.1587	0.1595	0.1058	0.1707
$\Delta R^2$	0.0895	0.0009	0.0888	0.0709	0.0172	0.0821

This table reports regression results of two-year, five-year, ten-year and average excess returns on standardized values of the CP-factor, order flow and macro factors. The last row of this table reports the change of the adjusted  $R^2$  compared to a reduced regression which only includes a constant and the CP-factor. Regression coefficients and standard errors are block-bootstrapped with 10,000 bootstrap samples. The 10% (5%, 1%) significance level is marked with a \* (\*\* / \*\*\*).

Table 4: Forecasting expected excess returns

expected excess returns						
maturity						
	2-year			5-year		
Variable	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C
$CP_{t-1}$	0.7508***	0.7260***	0.7289***	0.7864***	0.7827***	0.7742***
$OF_{t-1}^{QE}$		-0.1520**	-0.0755*		-0.1117**	-0.0683
$OF_{t-1}$		0.1604***	0.1205**		0.1589***	0.1369***
$LN_{1,t-1}$	-0.3585***		-0.3488***	-0.1892**		-0.1684**
$LN_{2,t-1}$	0.0924**		0.0812**	0.0983**		0.0926**
$LN_{3,t-1}$	0.1561***		0.1313***	0.1103***		0.0867**
$LN_{4,t-1}$	0.0251		0.0263	0.0381		0.0420
adj. $R^2$	0.7115	0.5856	0.7227	0.6776	0.6542	0.6910
$\Delta R^2$	0.1566	0.0307	0.1678	0.0476	0.0242	0.0610
maturity						
	10-year			mean		
Variable	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C
$CP_{t-1}$	0.8188***	0.8231***	0.8102***	0.8116***	0.8073***	0.8002***
$OF_{t-1}^{QE}$		-0.0555	-0.0379		-0.1124**	-0.0639
$OF_{t-1}$		0.1004*	0.0841*		0.1499***	0.1245**
$LN_{1,t-1}$	-0.0485		-0.0487	-0.1921**		-0.1841***
$LN_{2,t-1}$	0.1264***		0.1231***	0.1065***		0.1010***
$LN_{3,t-1}$	0.0577		0.0431	0.1118***		0.0909**
$LN_{4,t-1}$	0.0409		0.0456	0.0397		0.0418
adj. $R^2$	0.6907	0.6816	0.6936	0.7189	0.6857	0.7301
$\Delta R^2$	0.0151	0.0060	0.0180	0.0550	0.0218	0.0662

This table shows regression results of two-year, five-year, ten-year and average expected excess returns on standardized values of the CP-factor, order flow and macro factors. The last row of this table reports the change of the adjusted  $R^2$  compared to a reduced regression which only includes a constant and the CP-factor. Regression coefficients and standard errors are block-bootstrapped with 10,000 bootstrap samples. The 10% (5%, 1%) significance level is marked with a \* (\*\* / \*\*\*).

Table 5: Explaining excess return innovations

excess return innovations						
maturity						
	2-year			5-year		
Variable	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C
$\Delta CP_t$	0.0302	-0.0286	0.0688	-0.2448***	-0.3007 ***	-0.2024**
$OF_t^{QE}$		0.0403	0.0540		0.0970	0.0974
$OF_t$		0.3137***	0.3057***		0.2723***	0.2708***
$\Delta LN_{1,t}$	0.0229		0.0275	-0.0144		-0.0082
$\Delta LN_{2,t}$	-0.1541**		-0.1551**	-0.1858**		-0.1860**
$\Delta LN_{3,t}$	0.2043***		0.1893**	0.1545**		0.1458**
$\Delta LN_{4,t}$	-0.0286		-0.0479	-0.053		-0.0619
adj. $R^2$	0.0441	0.0989	0.1383	0.1540	0.2019	0.2397
$\Delta R^2$	0.0392	0.0940	0.1334	0.0364	0.0843	0.1221
maturity						
	10-year			mean		
Variable	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C
$\Delta CP_t$	-0.3582***	-0.4216***	-0.3286***	-0.2422***	-0.3010***	-0.1917**
$OF_t^{QE}$		-0.0058	-0.0140		0.0980	0.0997
$OF_t$		0.3368***	0.3424***		0.2785***	0.2747***
$\Delta LN_{1,t}$	-0.0405		-0.0373	-0.0177		-0.0085
$\Delta LN_{2,t}$	-0.1817**		-0.1931***	-0.2042***		-0.1986***
$\Delta LN_{3,t}$	0.1562**		0.1351**	0.1557*		0.1576**
$\Delta LN_{4,t}$	-0.0526		-0.0748	-0.0479		-0.0705
adj. $R^2$	0.2478	0.3126	0.3524	0.1625	0.2058	0.2521
$\Delta R^2$	0.0384	0.1032	0.1430	0.0449	0.0882	0.1345

This table shows regression results of two-year, five-year, ten-year and average one-month excess return innovations on standardized values of the change of the CP-factor, order flow and changes of the macro factors. The last row of this table reports the change of the adjusted  $R^2$  compared to a reduced regression which only includes a constant and the change of the CP-factor. Regression coefficients and standard errors are block-bootstrapped with 10,000 bootstrap samples. The 10% (5%, 1%) significance level is marked with a \* (\*\* / \*\*\*).

Table 6: Explaining excess returns

excess returns						
maturity						
	2-year			5-year		
Variable	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C
$\Delta CP_t$	-0.1030	-0.1633**	-0.0668	-0.3666***	-0.4278***	-0.3352***
$OF_t^{QE}$		-0.0704	-0.0698		-0.0102	-0.0126
$OF_t$		0.3601***	0.3551***		0.3347***	0.3318***
$\Delta LN_{1,t}$	0.0243		0.0148	-0.0363		-0.0312
$\Delta LN_{2,t}$	-0.1461*		-0.1685**	-0.1573**		-0.1695**
$\Delta LN_{3,t}$	0.1658**		0.1367*	0.1540**		0.1306*
$\Delta LN_{4,t}$	-0.0338		-0.0556	-0.0445		-0.0684
adj. $R^2$	0.0617	0.1472	0.1750	0.2409	0.3119	0.3426
$\Delta R^2$	0.0271	0.1126	0.1404	0.0296	0.1006	0.1313
maturity						
	10-year			mean		
Variable	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C
$\Delta CP_t$	-0.4971***	-0.5630***	-0.4586***	-0.3582***	-0.4216***	-0.3286***
$OF_t^{QE}$		0.0443	0.0407		-0.0058	-0.0140
$OF_t$		0.2716***	0.2742***		0.3368***	0.3424***
$\Delta LN_{1,t}$	-0.0889		-0.0898	-0.0405		-0.0373
$\Delta LN_{2,t}$	-0.2083***		-0.211***	-0.1817**		-0.1931***
$\Delta LN_{3,t}$	0.1431**		0.1311**	0.1562**		0.1351**
$\Delta LN_{4,t}$	-0.0628		-0.0785	-0.0526		-0.0748
adj. $R^2$	0.4080	0.4286	0.4828	0.2478	0.3126	0.3524
$\Delta R^2$	0.0532	0.0738	0.1280	0.0384	0.1032	0.1430

This table shows regression results of two-year, five-year, ten-year and average one-month excess returns on standardized values of the change of the CP-factor, order flow and changes of the macro factors. The last row of this table reports the change of the adjusted  $R^2$  compared to a reduced regression which only includes a constant and the change of the CP-factor. Regression coefficients and standard errors are block-bootstrapped with 10,000 bootstrap samples. The 10% (5%, 1%) significance level is marked with a \* (\*\* / \*\*\*).



Table 7: Interest rate and volatility innovations, liquidity risk and excess returns

expected excess return				
maturity				
Variable	2-year	5-year	10-year	mean
$CP_{t-1}$	0.6953***	0.7645***	0.8004***	0.7754***
$OF_{t-1}^{QE}$	-0.0841*	-0.0744*	-0.0399	-0.0731*
$OF_{t-1}$	0.0987**	0.1260**	0.0765	0.1135**
$LN_{1,t-1}$	-0.3224***	-0.1588**	-0.0392	-0.1690**
$LN_{2,t-1}$	0.0898**	0.0973**	0.1351***	0.1136***
$LN_{3,t-1}$	0.1093***	0.0765	0.0301	0.0723
$LN_{4,t-1}$	0.0287	0.0398	0.0361	0.0383
$\Delta y_{t-1}^{(1)}$	-0.0567	-0.0254	-0.0258	-0.0370
$liquidity\ risk_{t-1}$	0.0614	0.0128	-0.0173	0.0170
$\Delta\ move\ index_{t-1}$	0.0277	0.0402	0.0723**	0.0501
adj. $R^2$	0.7255	0.6877	0.6929	0.7285
excess returns				
maturity				
Variable	2-year	5-year	10-year	mean
$\Delta CP_t$	0.0186	-0.2559***	-0.3836***	-0.2432***
$OF_t^{QE}$	0.0235	0.0530	0.0876*	0.0613
$OF_t$	0.1045***	0.1567***	0.1716***	0.1567***
$\Delta LN_{1,t}$	-0.0063	-0.0457	-0.0917*	-0.0531
$\Delta LN_{2,t}$	-0.0287	-0.0773	-0.1685***	-0.0963**
$\Delta LN_{3,t}$	0.0664**	0.0881*	0.1136**	0.0956**
$\Delta LN_{4,t}$	-0.0285	-0.0431	-0.0494	-0.0447
$\Delta y_t^{(1)}$	-0.8479***	-0.6015***	-0.3656***	-0.6107***
$\Delta\ liquidity\ risk_t$	0.0799**	0.0491	0.0365	0.0544
$\Delta\ move\ index_t$	-0.0816**	-0.1265***	-0.1775***	-0.1380***
adj. $R^2$	0.8376	0.6729	0.6131	0.6975

This table shows regression results of two-year, five-year, ten-year and average excess returns on standardized values of changes of the CP-factor, order flow, changes of the macro factors and of the one-year interest rate and liquidity risk. Liquidity risk is defined as the monthly average of liquidity risk as it is defined in equation (21). The last row of this table reports the change of the adjusted  $R^2$  compared to corresponding  $R^2$  of Table 3 Panel C. Regression coefficients and standard errors are block-bootstrapped with 10,000 bootstrap samples. The 10% (5%, 1%) significance level is marked with a \* (\*\* / \*\*\*).

Table 8: Predicting excess returns in the absence of the financial crisis 2007–2009

excess return				
maturity				
Variable	2-year	5-year	10-year	mean
$CP_{t-1}$	0.1974**	0.1935**	0.1486*	0.1899**
$OF_{t-1}^{QE}$	0.0407	0.0527	0.0649	0.0561
$OF_{t-1}$	0.0797***	0.0686**	0.0078	0.0571**
$LN_{1,t-1}$	-0.1338	-0.0594	-0.0236	-0.0669
$LN_{2,t-1}$	0.0735	0.1129	0.1136	0.1103
$LN_{3,t-1}$	0.1481*	0.1803**	0.1689*	0.1790**
$LN_{4,t-1}$	0.1784**	0.2206***	0.1955**	0.2140**
$\Delta y_{t-1}^{(1)}$	0.1307	0.1597	0.1472	0.1567
$liquidity\ risk_{t-1}$	0.2666***	0.2279**	0.1825**	0.2329**
$\Delta\ move\ index_{t-1}$	-0.0734	-0.1558*	-0.1258	-0.1380*
adj. $R^2$	0.1486	0.1307	0.0752	0.1264

This table reports regression results of two-, five-, ten-year and average bond excess returns on standardized values of the CP- and macro factors, order flow, changes of the one-year rate and liquidity risk (equation (21)). The analysis excludes the financial crisis period between January 2007 and December 2009 (Thornton and Valente, 2011). Regression coefficients and standard errors are block-bootstrapped with 10,000 bootstrap samples. The 10% (5%, 1%) significance level is marked with a \* (\*\* / \*\*\*).

Figure 1: Regression coefficients and model-implied parameters

These figures compare the regression coefficients  $\beta^{(n)}$  from equation (9) with the model implied coefficients  $B_n$  from equation (15). The blue line represents the regression coefficients for all considered maturities  $n=\{1, \dots, 120\}$ . The red data points show the recursive estimated  $B_n$  coefficients. Factors' numeration corresponds to the first five term structure factors.

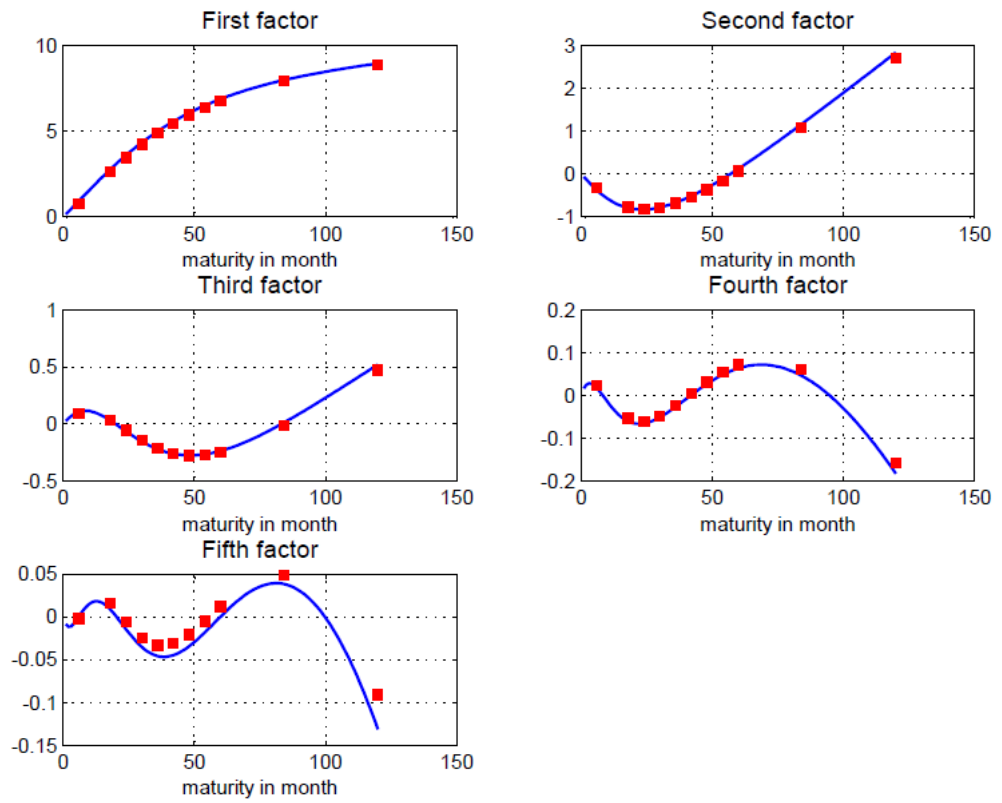


Figure 2: Marginal R-squares of the US macro factors

This figure plots the marginal R-squares which are derived from regressing all Ludvigson and Ng (2009) macro time series on the corresponding US macro factor. The time period is 01/1999–10/2011. M,C&F represents Money, Credit and Finance.

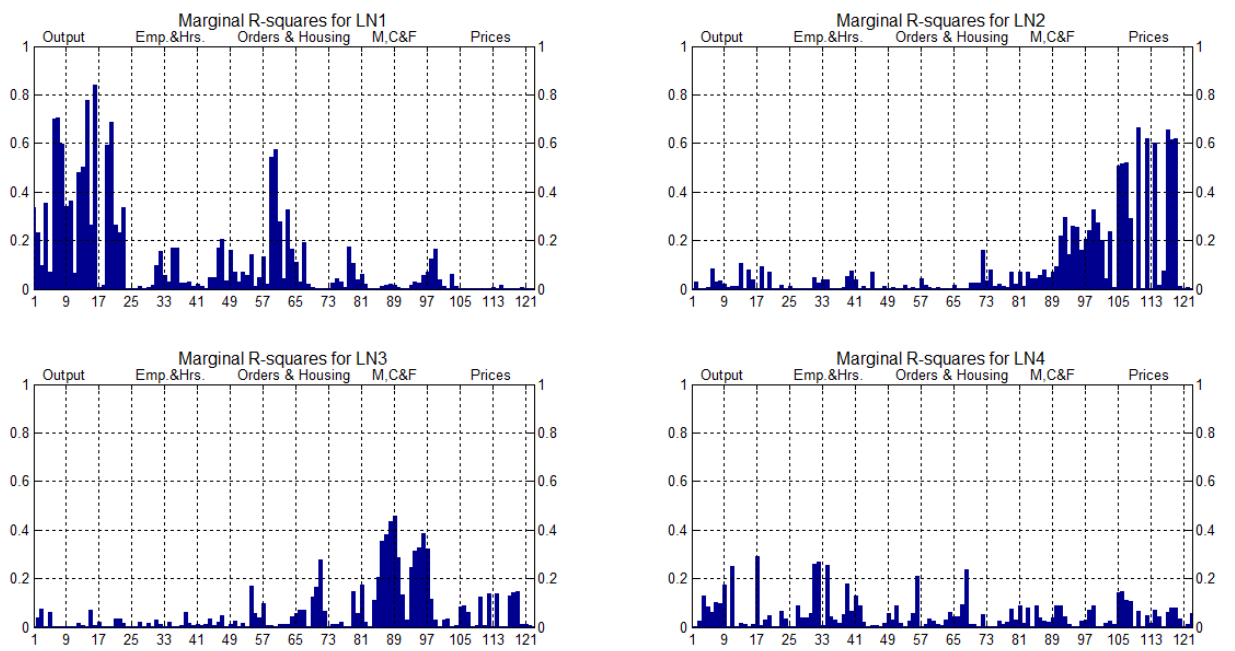


Figure 3: State-dependent effect of order flow

This figure shows order flow coefficients of rolling regressions of excess returns on lagged standardized values of the CP-factor, order flow, macro factors, short rate, liquidity risk and volatility innovations. The sample is sorted with respect to financial stress (STLFSI), bond market volatility (Move index) and equity market volatility (VIX).

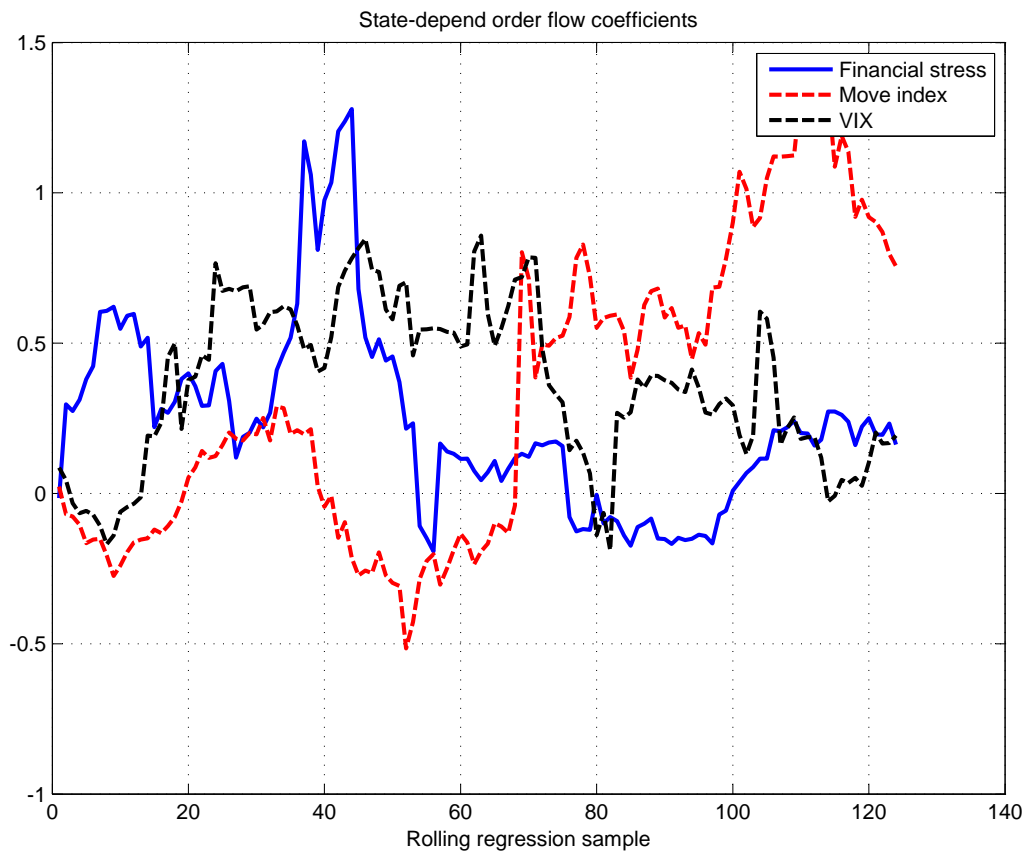


Table 9: The relation of pricing factors and error terms

error term				
maturity				
Variable	2-year	5-year	10-year	mean
$CP_{t-1}$	0.0450	0.0985	0.1210	0.1597
$OF_{t-1}^{QE}$	0.0517	-0.0558	-0.0419	-0.0372
$OF_{t-1}$	-0.0664	-0.0243	-0.0341	-0.0790
$LN_{1,t-1}$	0.0932	-0.1127	-0.1063	-0.0877
$LN_{2,t-1}$	0.0227	-0.0566	-0.0503	-0.0623
$LN_{3,t-1}$	0.1717*	-0.0221	-0.0171	0.0844
$LN_{4,t-1}$	0.0810	-0.0011	0.0095	0.0299
$\Delta y_{t-1}^{(1)}$	-0.0124	0.1839*	0.1667	0.2438**
$liquidity\ risk_{t-1}$	-0.0491	0.0437	0.0289	0.0297
$\Delta\ move\ index_{t-1}$	0.0022	-0.0039	-0.0192	0.0471
adj. $R^2$	-0.0063	-0.0047	-0.0084	0.0225
$\Delta R^2$	-0.0067	-0.0120	-0.0173	0.0074
maturity				
Variable	2-year	5-year	10-year	mean
$\Delta CP_t$	0.1463	-0.1836**	-0.1893**	-0.0936
$OF_t^{QE}$	-0.0831	0.0118	0.0334	-0.0312
$OF_t$	-0.1673**	0.1368	0.1303	0.0626
$\Delta LN_{1,t}$	-0.1656**	0.2025**	0.1929**	0.1671**
$\Delta LN_{2,t}$	-0.1674**	0.0839	0.0933	-0.0122
$\Delta LN_{3,t}$	-0.0803	0.0011	-0.0058	-0.0418
$\Delta LN_{4,t}$	-0.0750	0.0024	-0.0075	-0.0451
$\Delta y_t^{(1)}$	-0.0307	0.0379	0.0277	-0.0033
$liquidity\ risk_t$	0.0298	-0.0859	-0.0758	-0.1563*
$\Delta\ move\ index_{t-1}$	0.0204	-0.0058	-0.0104	-0.0137
adj. $R^2$	0.0533	0.0422	0.0492	0.0095
$\Delta R^2$	0.0332	0.0110	0.0137	-0.0030

This table shows regression results of two-year, five-year, ten-year and average error terms of equation (8) on standardized levels and changes of the CP-factor, order flow, changes of the macro factors and of the one-year interest rate and liquidity risk. Liquidity risk is defined as the monthly average of liquidity risk as it is defined in equation (21). The last row of this table reports the change of the adjusted  $R^2$  compared to a regression with the CP-factor as only regressor. Regression coefficients and standard errors are block-bootstrapped with 10,000 bootstrap samples. The 10% (5%, 1%) significance level is marked with a \* (\*\* / \*\*\*).