The Term Structure of Expectations and Bond Yields∗

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Abstract

Bond yields can be decomposed into average expected future short rates and term premiums. We characterize the expected path of short rates using a unique dataset comprising all available U.S. surveys of professional forecasters and obtain term premiums as the difference between observed government bond yields and survey-based expected short rates. We show that term premiums are the main drivers of bond yields, accounting for the bulk of variation in levels and nearly all of the variation in changes. Furthermore, term premiums, not expected rates, are the dominant source of co-movement between yields of different maturities as well as the ability of the yield curve to predict real output growth. Monetary policy, financial and uncertainty shocks are important drivers of term premiums. In sum, our results imply that term premiums are key to understanding macro-financial dynamics.

Keywords: Term premiums, Expectation formation, Survey forecasts, Monetary policy, Business cycle fluctuations

JEL Classification: D84, E44, G12

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1 Introduction

The simplest model of the term structure of interest rates is the expectations hypothesis. According to this model, movements in yields on default-free government bonds reflect variations in the average short rate that investors expect to prevail over the life of the bond. However, a large body of work in finance, starting with Fama and Bliss (1987) and Campbell and Shiller (1991), has challenged the empirical validity of the expectations hypothesis. It is now a widely accepted tenet that bond yields can be decomposed into investors’ expectations about the path of future short-term interest rates as well as a time-varying term premium.

The decomposition of bond yields into expected future short rates and term premiums plays a prominent role in modern theories of macroeconomics and finance. For example, the term structure of interest rate expectations is the centerpiece of the monetary transmission mechanism (Clarida et al. (2000)). Moreover, the choice of the optimal maturity structure of government debt should depend on the size and variation of term premiums (Greenwood et al. 2015). This decomposition also reveals information about investors’ risk preferences and their relative contribution to movements in asset prices (Cochrane 2005).

Crucially, the existing literature treats these two components of bond yields as unobservable and relies on models to decompose yields into their constituent components. Perhaps unsurprisingly, then, different models produce starkly different conclusions regarding what is the main driving force of bond yields. Fuhrer (1996), Rudebusch and Wu (2008), and Christiano et al. (2014), for example, find a dominant role of the expectations component. Indeed, this assumption is embedded in most general equilibrium macroeconomic models where the expectations hypothesis is the only transmission mechanism of monetary policy (Woodford 2003, Smets and Wouters (2007)). This also resonates with many policy-makers’ views: “[...]Monetary policy probably influences the term premium on Treasury securities to some extent. However, in all likelihood, the more important means by which monetary policy affects Treasury yields is through the effect of policy on the expected future path of short-term interest rates.” (Bernanke (2005)). Conversely, a number of authors including Joslin et al. 2011, Adrian et al. 2013 and Ang and Piazzesi 2003, have argued that term premiums are the main factor behind the variation of yields, with the direct implication that monetary policy can only tightly control longer-term yields to the extent that it can influence term premiums. This view is consistent with episodes during which the link between short and long-term rate appeared to have weakened over the past decade (Backus and Wright (2007), Hanson et al. (2017)).

In this paper, we rely on the identity by which the term premium of an n-maturity bond
is defined as

\[
\text{term premium} = \text{yield on an } n\text{-maturity bond} - \text{expected average path of short rates over } n \text{ periods.}
\]

We obtain expected short term rates explicitly and solely from survey forecasts and term premiums as the simple difference between observable yields and these survey-based expected short rates. Hence, we measure term premiums without making any assumptions about their dynamics across time and maturities. More specifically, we do not need to specify a stochastic discount factor, assume a data generating process for yields, or make assumptions about the number and nature of the factors driving term structure dynamics. This is an important advantage over the existing literature as these modeling assumptions crucially affect the implied decomposition of bond yields into expected short rates and term premiums. In the same vein, as our approach relies on using all observable data on professional forecasters’ short rate expectations, it provides measures of the expected path of future policy rates and term premiums which, by construction, are consistent with the (perceived) lower bound on nominal interest rates in the U.S. Moreover, since surveys are available in real time and do not get revised, the forecasts reflect the information set available to investors at each point in time.

Because our survey-based term premiums represent the residual between yields and expected short rates, we can remain agnostic about what specifically they represent. For example, they might reflect shifts in investors’ risk attitudes, differences between the expectations of the marginal investor and consensus expectations, or frictions in the bond market which prevent the elimination of arbitrage opportunities. Moreover, it is important to emphasize that the above identity does not make any implicit assumptions about the rationality of survey-based short rate expectations which is implicitly the case in most statistical models of the term structure.

We obtain short rate expectations from a unique dataset comprising the universe of surveys of professional forecasts of the 3-month T-bill interest rate, CPI inflation, and real GDP growth corresponding to over 600 survey-horizon pairs at a monthly frequency. Our analysis focuses primarily on the sample 1983–2016 for which we have a wealth of survey information especially at longer forecast horizons. Despite the wealth of survey data that we collect we do not observe the entire term structure of expectations at each period.\footnote{Kozicki and Tinsley (2012) describe this succinctly and accurately as “...the incomplete sampling design of available surveys.”} Moreover, for some horizons we observe multiple forecasts across different surveys. Thus, we follow Kozicki and
Tinsley (2012) and rely on a parsimonious parametric model to obtain “consensus” term structures of expectations. We show that a simple monthly vector autoregression (VAR) with time-varying long-run means approximates the multivariate term structure of professional forecasts very well. By accommodating low frequency movements in expectations, the model is able to capture structural changes and learning. The model provides a simple and transparent method to extract the common information across surveys and consistent proxies for missing observations, especially for the short rate for which fewer forecasts are available. An additional contribution of the paper is the construction of a universal consensus term structure of expectations from U.S. professional forecasters for three key macroeconomic variables: output growth, inflation and the short-term interest rate.

With the survey-implied expected short rates at hand, we begin by documenting the evolution of the term structure of expectations and show two key facts. First, the term structure of interest rate behaves in accordance with standard monetary theory. In particular, expected real short rates closely track expected nominal short rates, consistent with a strong degree of perceived nominal rigidities. We further observe that the expected short rate path steepens towards the end of monetary easing and flattens at the end of tightening cycles. Moreover, short-term ex ante real rates strongly comove with expected real rates multiple years out, consistent with systematic monetary policy managing medium-term expectations. Second, interest rate expectations display substantial volatility at all forecast horizons including medium to long-term horizons. Relative to the standard deviation of changes in nominal forward rates, changes in real and nominal short-rate expectations are around 70% as volatile at the one-year horizon and remain at around 40% as volatile at forward horizons beyond three years.\(^2\)

Despite the considerable volatility of expected rates, we find that their contribution to the variation in bond yields is close to negligible at all but short maturities. In fact, we show that expectations about future values of the short rate display low correlation with yields at medium to longer maturities. Consequently, we find that term premiums are the dominant source of variation in bond yields. Beyond the one-year horizon, forward term premiums account for the bulk of variation in the level of forward rates and virtually all of the variation in changes. While expected real rates are a key determinant for the level and variation of forward rates at the one year horizon, their importance diminishes rapidly along the maturity spectrum and is negligible beyond the three year horizon. Inflation expectations account for roughly one-third of the variation in the level of yields across maturities, but

\(^2\)This finding contrasts with common macro models where agents have perfect information about a time-invariant steady state and are more in line with models that involve shifting-end point such as Kozicki and Tinsley (2001), or models with learning such as Eusepi and Preston (2016). See also Gürkaynak et al. (2005b).
play only a minor role in explaining changes in yields. In sum, our results thus show that even when measuring short rate expectations using the universe of existing survey data, the expectations hypothesis utterly fails at explaining medium to long-term bond yields.\(^3\)

After establishing that term premiums explain the bulk of the time series variation of bonds yields, we show that they also display strong co-movement across maturities—stronger in fact than either expected short rates or forward yields themselves. This is consistent with the main finding of Cochrane and Piazzesi (2005, 2008) who document a strong factor structure in expected excess bond returns based on predictive regressions of excess bond returns on past forward rates.\(^4\) We can thus conclude that term premiums, not expectations of future short rates, are the primary driving force behind the co-movement of yields across maturities. This strong co-movement is particularly surprising as we obtain term premiums solely from observed forwards and from survey expectations.

Finally, we show that term premiums interact strongly with macroeconomic conditions. First, we find that fluctuations in term premiums have significant predictive power for quarterly growth rates of real output growth up to two years in the future—a difficult feat given the small amount of serial correlation in this series. This finding is all the more remarkable as the yield spread has, at best, only marginal predictive power for future output growth over our sample (as opposed to earlier samples). Second, we evaluate the response of expected rates and term premiums to a host of structural shocks that have been identified in the macroeconomic literature. To this end, we construct impulse responses of the constituent components of yields. We consider policy shocks, which include measures of monetary and fiscal surprises; “demand” shocks comprising shocks to financial conditions and uncertainty; and “supply” shocks, which cover oil shocks and news about total factor productivity. Over our sample period, policy and demand shocks have significant and long-lasting effects on term premiums. Financial shocks, in particular, are shown to have sizable effects even in the pre-crisis sample. A tightening of financial conditions as measured by an innovation to corporate spreads tends to compress term premiums across the maturity spectrum—possibly reflecting a shift in preferences toward “safer” assets. Moreover, unexpected tightenings of monetary policy compress term premiums. This is consistent with the notion that, by lowering both expected consumption growth and inflation, an unexpected increase in the policy rate raises the payoff of nominal bonds precisely when consumption growth is expected to

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3This is in contrast to e.g. Froot (1989) who found some support for the expectations hypothesis for longer maturities using three and six months ahead rate forecasts from the Goldsmith-Nagan survey.

4Cochrane (2015) observes: “This one-factor structure of expected returns, not the presence of higher-order factors on the right hand side, or their tent-shaped coefficients, was the major message of Cochrane and Piazzesi (2005), (2008).” Recall that forward term premiums may be written as the linear combination of expected returns at different maturities.
be low. Therefore, investors require less compensation for holding these bonds. In contrast, the effects of supply shocks appear to have shorter duration. Our results suggest that the dominant paradigm in which term premiums are driven by shocks which drive inflation and output in opposite directions (e.g., supply shocks) and according to which surprise inflation represents “bad news” may be less representative for the last 30 years of the U.S. economy (Piazzesi and Schneider 2007, Rudebusch and Swanson 2012).

The paper proceeds as follows. We discuss related literature in the following subsection. Section 2 presents the data while Section 3 introduces the model used to extract the “consensus” term structures of survey expectations. Section 4 provides the decomposition of U.S. Treasury yields into expected short rates and term premiums and establishes stylized facts about both components. Section 5 links these decompositions to macroeconomic dynamics. Section 6 discusses our main results in relation to a range of statistical models. Section 7 concludes. A Data Appendix provides further details about the survey data and construction and a Supplementary Appendix provides additional results.

1.1 Related Literature

A large literature has attempted to decompose observable government bond yields into their expectations and term premium components. The modeling approaches used run the gamut from arbitrage-free term structure models to structural general equilibrium models.

In the finance literature, term structure models are often used to characterize the joint evolution of government bond yields. These models frequently impose the absence of arbitrage opportunities and explicitly allow for time variation in term premiums (see Duffie 2001, Piazzesi 2003, Singleton 2006, and Gürkaynak and Wright 2012 for surveys). While this literature finds that models featuring time-varying term premiums provide a better in-sample fit and more accurate forecasts of bond yields, the plausibility of the expected path of future policy rates implied by these models is rarely scrutinized. Although many term structure models are solely based on the information in yields (e.g., Duffie and Kan 1996, Dai and Singleton 2000, Duffee 2002, Cochrane and Piazzesi 2005, Joslin et al. 2011, Adrian et al. 2013), another strand of the literature introduces macroeconomic variables in these models (see, e.g., Ang and Piazzesi 2003, Wright 2011, Joslin et al. 2014).

In the macroeconomics literature there have been a few recent contributions focusing on explaining the behavior of yields both with statistical models and in a general equilibrium framework. Two examples for the latter are De Graeve et al. (2009) and Rudebusch and Wu (2008) who report an important role for the expectations hypothesis in explaining the variation of yields using DSGE models. Dewachter and Lyrio (2008), Dewachter et al. (2011)
estimate a DSGE model where learning is explicitly modeled and document that movements in the expected path of interest rates capture a substantial fraction of the variation in long-term rates. An alternative literature utilizes time-varying coefficients to accommodate perceived structural changes or learning effects in the data generating process. Cogley (2005) investigates time variation in yields using a state space model with time-varying parameters while Laubach et al. (2007) adopt a VAR model where the coefficients are estimated using a constant-gain algorithm. Kozicki and Tinsley (2001, 2005) and Fuhrer (1996) focus on a monetary policy rule with time varying coefficients. In general, these papers tend to find a much larger role for the expectations hypothesis in explaining movements in bond yields.

Our paper is also linked to the literature using actual expectations data to inform and discriminate between economic models (see Manski 2004 for an overview). For example, survey data have been used to discriminate between models of information frictions (see, for example, Mankiw et al. 2003, Patton and Timmermann 2010, Coibion and Gorodnichenko 2012, Andrade and Le Bihan 2013, Andrade et al. 2016), inform models of investment decisions (Gennaioli et al. 2015), and to estimate the elasticity of intertemporal substitution (Crump et al. 2015). There is also a literature which uses survey data to understand the behavior of asset prices (see, for example, Froot 1989, Frankel and Froot 1987, Greenwood and Shleifer 2014, Barberis et al. 2015, Armona et al. 2016).

Seminal works using survey data for understanding the term structure of interest rates are Friedman (1979) and Froot (1989). In response to prior work, these authors emphasize that regression-based tests of the expectations hypothesis are, in fact, joint tests of the expectations hypothesis and rational expectations. To bypass this concern they use survey data of expected interest rates. Friedman (1979) finds that the expectations hypothesis alone does not explain the short end of the yield curve, but instead that term premiums exist and also vary. Froot (1989) uses survey data on near-term rate expectations and finds that the expectations hypothesis fails at short maturities but cannot be rejected at medium-term maturities.

Only a few other papers have used survey data on expected future short rates to inform the model-implied path of policy expectations. Specifically, Kim and Wright (2005), Kim and Orphanides (2012), and Piazzesi et al. (2015) use affine term structure models to jointly fit government bond yields and selected survey forecasts of short rates. The primary difference between these approaches and ours is that (1) they use information from yields across the maturity spectrum to inform the models; (2) they utilize a stationary VAR to govern the dynamics of their variables; (3) they use only a small subset of available survey data. Furthermore, in Kim and Wright (2005), Kim and Orphanides (2012), and Piazzesi et al. (2015)) survey data and yields are modeled with a small number of state variables
and allow for substantial deviations of model-implied expectations from observed policy rate expectations. We show in Section 6 that the implications for the behavior of expected rates and term premiums are very different in these models.

Moreover, while the primary objective of our paper is to characterize the term structures of expectations and the implied term premiums, there are a number of papers which have evaluated the accuracy of those forecasts relative to statistical models.\(^5\)

## 2 Data

In this paper we use, to the best of our knowledge, the universe of professional forecasts for the United States in the post-war era. Our forecast data are obtained from nine different survey sources: (1) Blue Chip Financial Forecasts (BCFF); (2) Blue Chip Economic Indicators (BCEI); (3) Consensus Economics (CE); (4) Decision Makers’ Poll (DMP); (5) Economic Forecasts: A Worldwide Survey (EF);\(^6\) (6) Goldsmith-Nagan (GN);\(^7\) (7) Livingston Survey (Liv.); (8) Survey of Primary Dealers (SPD); (9) Survey of Professional Forecasters (SPF).

We focus on three variables – output growth, inflation and the short-term interest rate. For output growth we use forecasts of real GNP growth prior to 1992 and forecasts of real GDP growth thereafter. For inflation we use forecasts of growth in the consumer price index (CPI). We choose CPI over alternative inflation measures such as the GDP deflator for two reasons. First, Treasury Inflation Protected Securities (TIPS) have coupon and principal payments indexed to the CPI. Second, CPI forecasts are available more frequently and for a longer history than alternative inflation measures. Finally, we use the 3-month Treasury bill (secondary market) rate as our measure of a short-term interest rate as it is by far the most frequently surveyed short-term interest rate available.\(^8\)

We use essentially all available forecasts for these three variables covered in the eight surveys.\(^9\) To provide a sense of the wealth of survey data used, our results are based on 602 variable-horizon pairs spanning the period 1955 to 2016. In the Data Appendix we give more explicit details about each individual survey, however, we want to emphasize here that the survey data differ in frequency, forecast timing, target series, sample availability and forecast

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\(^5\)In fact, Ang et al. (2007), Croushore (2010), and Faust and Wright (2013) among others document that professional forecasters’ inflation predictions outperform those implied by a wide range of time series models at various forecast horizons. Similarly, Cieslak and Povala (2014) argue that professional forecasts of short-term interest rates cannot be outperformed by a number of different statistical models.

\(^6\)To our knowledge, the only other paper to use these survey data is Ehrbeck and Waldmann (1996).

\(^7\)We thank Kenneth Froot for sharing the Goldsmith-Nagan survey data.

\(^8\)For example, forecasts of the Federal Funds rate, the target rate of US monetary policy are only available in two of the eight surveys we consider (BCFF and SPD).

\(^9\)We exclude some series for technical reasons discussed in the Data Appendix.
To ease notation we use the following conventions. Q1 represents a one-quarter ahead forecast, Q2 represents a two-quarter ahead forecast and so on. Y1 represents a one-year ahead forecast, e.g., a forecast for the year 2014 made at any time in 2013. Y2 represents a two-year ahead forecast and so on. Y0-5 represents a forecast for the average value over the years ranging from the current year to five years ahead, e.g., a forecast for the average annual growth rate of GDP from 2014 through 2019 made at any time in 2014. Y1-6, Y2-7 and so on are defined similarly. Y6-10 represents a forecast for the average value over the years ranging from six years ahead to 10 years ahead, e.g., a forecast for the average annual growth rate of GDP from 2020 through 2024, made at any time in 2014. Within each of these sub-categories the exact form of the target variable may vary. For example, a forecast for the year 2014 may be queried based on annual average growth or Q4/Q4 growth. Throughout the paper we ensure that the survey data are treated in a consistent manner with respect to the target variable to ensure that all comparisons are appropriate. See the Data Appendix for further details.

Table 1 provides a bird’s eye view of the survey data series we use in the paper. Near-term survey forecasts (target period is up to two years ahead) are available for the longest sample with CPI forecasts from the Livingston Survey beginning in the mid-1940s. Medium- and long-term forecasts (target period includes three years ahead and longer) are available for real output growth and inflation starting in the late 1970s, however, a more comprehensive set of long-term forecasts (target period is five or more years ahead) for all three variables is available only starting in the mid-1980s. At all horizons there are relatively fewer forecasts for the 3-month Treasury bill than for output growth and inflation.

In the discussion of our results we focus on the period 1983-2016, representing the great moderation and recession. This period includes the majority of the available survey forecasts with over 75% of the total number of series used available in this 30 year time span. Although there are survey forecasts for the TBILL spanning short-, medium- and long-term horizons, they are still underrepresented in the sample as compared to GDP and CPI forecasts. More details about each survey are provided in the Data Appendix.

3 Fitting the Term Structure of Expectations

We characterize the term structure of expectations by using all available surveys of professional forecasters in the U.S. for real output growth, inflation, and the short term interest rate. In practice, survey expectations are available from a number of different surveys at some forecast horizons whereas at other horizons no survey forecasts are observed. In order
to trace out the full path of consensus expectations at all horizons and to avoid unduly
overweighting a particular survey, we rely on a simple parametric model to fit all available
survey data. The model thus serves three purposes. First, it allows us to assess whether
a relatively simple multivariate time-series model can capture the joint dynamics of survey
forecasts across the three major macroeconomic variables. Second, by using a model we can
provide consistent proxies for the missing observations and/or horizons for each survey and
are thus able to extract the common information across different surveys in a coherent way.
Finally, since we observe fewer forecasts for short-term interest rates than we do for output
and inflation, a multivariate model allows us to exploit the dependence structure across
variables and horizons to inform the term structure of forecasts of the short-term interest
rate.

To this end, we assume that the true state of the macroeconomy is captured by the
random vector \( z_t = (g_t, \pi_t, \bar{i}_t)' \) representing real output growth, \( g_t \), inflation, \( \pi_t \), and the
short-term interest rate \( i_t \). \( z_t \) evolves according to,

\[
\begin{align*}
    z_t - \bar{z}_t &= x_t \\
    x_t &= \Phi x_{t-1} + \nu_t,
\end{align*}
\]

or alternatively,

\[
    z_t - \bar{z}_t = \Phi (z_{t-1} - \bar{z}_{t-1}) + \nu_t,
\]

where \( x_t \) represents the factors driving the short to medium-term fluctuations in the economy
with \( i.i.d. \) Gaussian innovations, \( \nu_t \sim \mathcal{N}(0, \Sigma) \). In contrast, \( \bar{z}_t \) represents the factors driving
the long-term, slow-moving aspects of the economy represented by \( \bar{z}_t = (\bar{g}_t, \bar{\pi}_t, \bar{\bar{i}}_t)' \). The first
two elements are assumed to follow the multivariate random walk,

\[
\begin{pmatrix}
    \bar{g}_t \\
    \bar{\pi}_t
\end{pmatrix} = \begin{pmatrix}
    \bar{g}_{t-1} \\
    \bar{\pi}_{t-1}
\end{pmatrix} + \eta_t,
\]

with \( i.i.d. \) Gaussian innovations, \( \eta_t \sim \mathcal{N}(0, \Sigma^\eta) \) where \( \Sigma^\eta \) is diagonal. The third element,
\( \bar{\bar{i}}_t \), is a linear function of long-run growth and inflation via the Fisher equation,

\[
    \bar{\bar{i}}_t = \psi \cdot \bar{g}_t + \bar{\pi}_t + \xi_t,
\]

where \( \xi_t \) is an independent random walk with innovation variance \( \sigma^2 \) which captures changes
in household preferences and other determinants of \( \bar{\bar{i}}_t \). The parameter \( \psi \) links the real
interest rate to the growth rate of the economy and can be interpreted as the inverse of the intertemporal elasticity of substitution. Such a relationship between the real interest rate and long-term output growth commonly emerges from dynamic general equilibrium models with intertemporally optimizing households.

Throughout the paper let a superscript “A” or “S” denote variables related to actual or survey forecasts, respectively. The observed data are related to the true state of the economy via,

\[
\begin{pmatrix}
y_t^A \\
y_t^S
\end{pmatrix} = \begin{bmatrix} H_t^A \\ H_t^S \end{bmatrix} Z_t + \begin{bmatrix} \varepsilon_{y,A}^t \\ \varepsilon_{y,S}^t \end{bmatrix}, \quad Z_t = FZ_{t-1} + V\kappa_t
\]

where \( Z_t = (z_t, z_{t-1}, z_{t-2}, z_{t-3}, z_{t-4}, x_t, \bar{z}_t)' \) is the 21 \( \times \) 1 state vector, \( F = F(\Phi, \psi) \) is the 21 \( \times \) 21 transition matrix and \( V = V(\psi) \) is a 21 \( \times \) 6 matrix which maps the 6 underlying shocks, stacked in \( \kappa_t \), to the appropriate elements of the state vector. The presence of the four lags in the state vector are essential for mapping monthly growth rates to quarterly growth rates. This is because quarterly growth in variables such as GDP or CPI are measured as the growth rate of the average value of the variable in the current quarter relative to the average value of the variable in the previous quarter.\(^{10}\)

We now discuss the state-space model features in detail. First, \( y_t^A \) contains quarter-over-quarter annualized real GDP growth (available once a quarter), month-over-month annualized CPI inflation (available monthly), and the 3-month TBILL rate (available monthly).\(^{11}\) We assume that the true state of real output growth and inflation are measured with error whereas interest rates are perfectly observed. The measurement error in output growth and inflation accounts for the presence of publication lags and data revisions which prevents forecasters from perfectly observing these variables in real time. Moreover, when making predictions forecasters aim to filter from the actual data the underlying, persistent factors as evidenced by the fact that forecasts, even at very short horizons, are considerably less volatile than realized variables.

Thus we assume \( \varepsilon_{y,t}^{g,A} = (\varepsilon_{g,t}^{g,A}, \varepsilon_{\pi,t}^{\pi,A}, 0)' \) where \( \varepsilon_{g,t}^{g,A} \) and \( \varepsilon_{\pi,t}^{\pi,A} \) are mean-zero, i.i.d., mutually independent Gaussian innovations. We assign the observation of real GDP growth to the last month of the quarter which ensures that forecasters in the model have the largest information set when they observe the noisy measure of \( g_t \). Thus, in the last month of each quarter when

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\(^{10}\) This can be formally justified via a Taylor series expansion. See the Appendix and Crump et al. (2014) for further details and examples. More generally, for both the actual and the survey data we make repeated use of this linear approximation of different measures of growth rates to the underlying monthly annualized growth rates.

\(^{11}\) We obtain real GDP growth from the Bureau of Economic Analysis, headline CPI inflation from the Bureau of Labor Statistics and the 3-month Treasury bill rate from the H.15 release of the Federal Reserve Board.
all three variables are observable, $H_t^A$ is of the form

$$
H_t^A = \begin{bmatrix}
\frac{1}{5} & 0 & 0 & \frac{2}{5} & 0 & 0 & \frac{3}{5} & 0 & 0 & \frac{2}{5} & 0 & 0 & \frac{1}{5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
.$$  

The second set of observable variables includes all survey forecast data discussed in Section 2 corresponding to the $602 \times 1$ vector $y_t^S$. We assume individual observation errors for each survey to be mean-zero, i.i.d., mutually independent Gaussian innovations. To ensure a parsimonious model we group the variances of these Gaussian variables by the target variable of interest and the horizon of the forecast (but not by the specific survey). In particular we group forecast horizons by: very short term, up to two quarters ahead, short term, up to two years ahead, medium term, from three to four years ahead, and long term, five or more years ahead. To populate the matrix $H_t^S$ we require the target variable, the specific transformation (e.g., annual average growth), the forecast horizon, and the parameters $\Phi$ and $\psi$.

To illustrate how $H_t^S$ is formed, consider the following two examples (additional details are provided in the Data Appendix):

**Example 1** Consider the case of a Y1 forecast, e.g., a forecast of annual average growth of real GDP in the year 2013 (i.e., the average value of the level of real GDP in 2013 as compared to 2012) formed in January 2012. This can be approximated by the linear combination,

$$
\sum_{j=1}^{23} w_j \hat{g}_{t+j}, \quad \hat{g}_{t+j} = e_g^j F^j Z_t
$$

where $e_g = (1, 0, \ldots, 0)'$ selects the appropriate row of the forecasted state and the weights, $w_j$, are “tent-shaped” of the form $w_j = \min(j, 24 - j)/24$. Here, $g_t$ is the annualized monthly real GDP growth rate in January 2012 and $\hat{g}_{t+j}$ is the model-implied forecast for real GDP growth $j$ periods ahead. Thus, the corresponding row in $H_t^S$ for this survey forecast series is equal to $\sum_{j=1}^{23} w_j e_g^j F^j$.

**Example 2** The SPD surveys respondents on their forecasts of “longer-run” real GDP growth, i.e., $\tilde{g}_t$. In this case the corresponding row of $H_t^S$ is simply $e_\tilde{g} = (0, \ldots, 0, 1, 0, 0)'$, i.e., a vector with all elements equal to zero except for a one corresponding to the first element of $\tilde{g}_t$. 

11
3.1 Discussion of Model

While our model is simple and parsimonious, it allows for time-variation in the long-run mean. This feature has been shown to capture well the dynamic properties of both actual economic variables as well as survey expectations.\textsuperscript{12} Moreover, there is direct survey evidence that expectations of longer-run values for economic and financial variables vary over time. For example, the SPF annually queries respondents on their value of NAIRU, the SPD includes questions on “longer-run” values of output, inflation and the target interest rate, and the FOMC members themselves report, in the Survey of Economic Projections, the value that key macroeconomic variables would be expected to converge to under appropriate monetary policy and in the absence of further shocks to the economy. All these predicted long-run values show some degree of time variation. A multivariate forecasting model featuring time-varying long-run means is also consistent with evidence from the cross-section of professional forecasters. In fact, Andrade et al. (2016) show that both the multivariate specification and shifting endpoints are essential to matching the empirical properties of forecaster disagreement.

The shifting endpoints \((\bar{g}_t, \bar{\pi}_t, \bar{i}_t)\) also play a crucial role in matching survey forecasts at all horizons in our model. Intuitively these time-varying means capture perceived structural changes in the economy and agents’ learning more generally. In addition to time variation in the long-run means, our model features the mean-reverting component \(x_t\) which captures cyclical deviations from the trend. The expectations-formation process that we model thus implies that forecasters filter from the observed data temporary factors as well as slow-moving changes in fundamentals. As already discussed, the observation errors in real output growth and inflation (equation (3.6)) have two potential interpretations: first, they capture an informational constraint as market participants have imperfect information about the true state \(z_t\) of the macroeconomy; second, agents endeavor to filter out the very high-frequency fluctuations in output and inflation that are not useful for forecasting their evolution beyond one quarter ahead.

The model is estimated at the monthly frequency for the sample starting in January 1955 and ending in September 2016 using maximum likelihood. Recall that the observation equation (equation (3.6)) has time-varying coefficients to account for missing observations in actual and survey data. We fix the value of \(\sigma\), the volatility of the innovation to \(\bar{\zeta}\), because longer-run forecasts of short-term interest rates are available only at irregular frequencies.

We set the value to $\sigma = 0.01$.\footnote{We choose 0.01 motivated by the fact that the “longer-run” forecast for the Federal Funds Rate from the SPD, once differenced, has a standard deviation of 0.05. Since the bulk of the variation in $\tilde{\bar{i}}$ should come from long-run inflation and output we set $\sigma = 0.01$ which represents 20% of sample standard deviation from the SPD. Note that our results are robust to other values of $\sigma$ in this range.}

While the estimated parameter values are provided in Table 5 in the Supplementary Appendix, we emphasize three important features here. First, the volatility of the two drifts is significantly smaller than the volatility of the short-term shocks, consistent with fundamentals changing slowly over time. Second, the estimated relationship between the drifts for the nominal short-rate, output growth and inflation is: $\tilde{\bar{i}}_t = \bar{\pi}_t + 0.92 \cdot \bar{g}_t + \bar{\zeta}_t$. The coefficient of the output growth drift, which is the inverse of the intertemporal elasticity of substitution parameter in dynamic optimization models is modestly above one and thus not inconsistent with values commonly assumed in the macroeconomics and finance literature.

Our parsimonious model captures the behavior of survey-based expectations surprisingly well, as evidenced by the good fit of the model to the 602 forecast series. While we document the fit of the model series by series in the Supplementary Appendix, Figure 1 shows actual and fitted survey forecasts for selected forecast-horizons. We group these into short-term, medium-term and long-term forecasts, respectively. As shown by the figure, the model is flexible enough to simultaneously match survey-based forecasts at very different horizons.\footnote{Note that long-run forecasts in Figure 1 are for assorted horizons and so do not perfectly align with the single fitted series. In the Supplementary Appendix we report the actual survey data against the exact matched fitted series from the model for every survey series.}

This is also confirmed by the small magnitudes of the observation error variances.

4 Yields, Expected Short Rates, and Term Premiums

In this section we study the properties of the two components of the yield curve: expected short-term interest rates and term premiums. We first show that short rate expectations from professional surveys vary substantially across time and display a considerable amount of variation relative to actual bond yields. We further document that the behavior of these forecasts is consistent with conventional views about the monetary policy transmission mechanism. We then study long-horizon forecasts and link their evolution to fundamental economic variables such as the long-run equilibrium real rate, $r^*_t$ and the perceived inflation target, $\pi^*_t$. Long-term expectations of the ex-ante real short rate have fluctuated around 2% since the early 1980s, but have dropped below 1% since the end of 2014. Long-term inflation expectations declined markedly until the late 1990s and have remained stable since then.

We next define (forward) term premiums as the difference between observed (forward) bond yields and survey-based expected short rates. Term premiums have contributed mean-
ingfully to the secular decline in yields over the last 30 or so years. Moreover, we show using variance decompositions that beyond the one-year horizon they account for almost all of the variation in bond yields at higher frequencies. This is a surprising result especially since expectations display substantial volatility. The finding can be reconciled by the fact that expected short rates and (forward) bond yields feature little correlation at medium to long maturities. Finally, we show that the dominant source of co-movement in forwards across maturities is due to co-movement of term premiums rather than expected short rates.

4.1 Expected Short Rates and Monetary Policy Transmission

Our data allows us to study the expected paths of future nominal and real rates as well as inflation at any specific point in time. Figure 2 displays a number of “hair charts” which are a convenient way to summarize the evolution of these expected paths over time. Specifically, in each chart the black solid lines show the actual nominal or real short-term rates and the persistent component of inflation, and the grey lines show the expected path of each of the three variables over the next ten years.

The top panel of Figure 2 displays the evolution of expected nominal short rate paths since the early 1980s. The expected paths of nominal short rates vary substantially over time, typically flattening at the end and steepening before the beginning of monetary tightening cycles, as professional forecasters respond to the predictable component of monetary policy. While expected nominal short rates display a significant degree of volatility, the shape of the expected path of inflation (middle panel) has shown far less variation, remaining mostly flat around the prevailing level of inflation. Professional forecasters perceive the persistent component of inflation to approximately follow a random walk. Consistent with nominal rigidities preventing prices from adjusting in the short term, movements in expected nominal short rates translate almost one to one to expected real short rates, shown in the bottom panel.

Moreover, monetary policy decisions, implemented through the nominal short rate, affect the expected path of real rates multiple years into the future, as shown in the left column of Figure 4. This is consistent with the standard monetary transmission mechanism, for example in the new Keynesian framework, see Woodford (2003). A systematic response of monetary policy to the economy (i.e. via a policy rule) coupled with a high degree of transparency provides the link between short-term interest rate changes and movements in

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15Since professional forecasts of the 3-month Treasury bill tend to be for averages over the target period, throughout the paper monthly and quarterly yields are also averages over the corresponding period.

16It is worth emphasizing that these measure of expectations based on survey forecasts, in contrast with many model-based expectations, are consistent with a zero lower bound on nominal interest rates.
medium-term expectations (Bernanke 2005).

Finally, we see a positive correlation between the ex-ante real interest rate and expected inflation, consistent with the “Taylor principle” being satisfied (Figure 4, right column). That is, the short-term nominal interest rate responds more than proportionally when inflation is above target, with the goal of inducing a reduction in aggregate demand, see Clarida et al. (2000). Over our sample we thus see no evidence of the Mundell (1963) and Tobin (1965) effect which predicts a negative correlation between real rates and (expected) inflation.\footnote{See also Ang et al. (2008) for a discussion.}

In sum, the observed patterns of expected nominal and real short rates as well as inflation show that surveys provide reasonable proxies for market participants’ expectations as viewed through the lens of economic theory. This may not be surprising, as expectations about short term rates are commonly considered the key channel through which monetary policy affects long-term rates. In Section 4.3.2, we study the relative importance of expected short rates and inflation for the variation in bond yields and assess the dynamic interactions between the components of bond yields and the macroeconomy in Section 5.

4.2 Long-Run Expectations

The expected ten-year paths of short rates and inflation shown in Figure 2 converge to each variable’s time-varying, long-run mean extracted from all available surveys of professional forecasters. These long-run projections reflect forecasters’ perceptions of macroeconomic fundamentals rather than cyclical variation. A first look at the evolution of long-run forecasts shows that they have all varied substantially over the past thirty years. The long-run expected nominal short rate has gradually declined from about 8 percent in the mid 1980s to about 3.5 percent in 2016. Much of this decline is accounted for by a secular reduction in the expected long-run level of inflation, which dropped from about 6 percent in the early 1980s to a level of around 2.5 percent until the late 1990s. Since then, the perceived inflation target has remained extremely stable, only showing a small dip around the Great Recession. Interestingly, the long-term expected real short rate has remained fairly stable around two percent over the thirty year period starting in 1983, but has begun to decline after 2011, reaching below 1 percent by the end of 2014. This is best illustrated in the top panel of Figure 3, showing the evolution of the endpoint forecast for the real rate (red line). This reduction of expected long-run real rates is consistent with recent evidence on the decline of the \textit{natural} real rate of interest. Among others, Summers (2014), Johannsen and Mertens (2016), Holston et al. (2017), Del Negro et al. (2017) have argued that long-run equilibrium real rates in the U.S. have seen a secular decline over the past decades, and have again
dropped strongly around the recent financial crisis. While there is a considerable degree of sampling uncertainty around proposed estimates of long-run real short rates, a growing consensus is emerging that the long-run real rate of interest has indeed declined considerably. To illustrate this, the top panel of Figure 3 displays the updated estimates of natural interest rate from Laubach and Williams (2003) –black lines. The different measures broadly co-move but also show some important differences. Most importantly, in contrast to professional forecasters’ long-run expectations the natural rate estimates drop sharply around the financial crises and hover around zero since then.

The explanations offered for this decline differ and include, among others, demographic changes, a widespread productivity slow-down, an increased demand for liquid Treasury securities and other secular shifts in global savings and investment decisions. While our estimates of the perceived long-run real rate do not allow us to disentangle between these different explanations, we can measure the role of long-run expectations for real GDP growth expectations in reducing the perceived real rate. The bottom panel in 3 shows the forecasters’ perceived growth rate of real GDP in the long-run (red line) compared with the updated estimates from Laubach and Williams (2003). Forecasters’ expectations are significantly more volatile than the estimates from Laubach and Williams. Looking at the most recent period, a non-trivial part of the decline in the long-run expectations about the real rate can be attributed to a reduction in long-run expectations about output growth. Conversely, the estimates from Laubach and Williams (2003) suggest a key role to factors not directly related to long run growth.

4.3 Term Premiums

In this section, we first show how to obtain spot and forward term premiums from observed yields and expectations. We then establish a set of stylized facts about term premiums and their role for explaining the dynamics of bond yields.

The term premium for an \( n \) period bond can be obtained from observed yields and expectations via the following identity:

\[
y_t(n) = \frac{1}{n} \mathbb{E}_t [i_t + i_{t+1} + \cdots + i_{t+n-1}] + tp_t(n),
\]

where \( y_t(n) \) is the continuously compounded yield on an \( n \)-month discount bond, \( i_t \) is the risk-free nominal short rate at time \( t \), and \( tp_t(n) \) is the nominal term premium. The term premium is thus simply given by the difference between observed yields and what would be the yield predicted by the (pure) expectations hypothesis, i.e. the average expected future short rate over the life of the bond. It is important to emphasize that this is simply an
identity; there are no implicit assumptions about the rationality or bias of expectations or the data generating process for yields, expectations, or term premiums.

In order to separate longer-term from short-term expectations, we conduct our analyses in terms of forward rates, defined as the current yield of an \( n \)-year bond maturing in \( n + m \) years:

\[
f_t(n, m) = \frac{1}{n} [(n + m)y_t(n + m) - my_t(m)]
\]

Since the model is estimated at a monthly frequency, we construct annual forward rates as the annual average of monthly forward rates. We then define forward term premiums as the difference between \( f_t(n, m) \) and the consensus expected short-term rate over the \( n \) years \( m \) years hence (i.e., a forward version of equation (4.1)):

\[
 tp_t^{fwd}(n, m) = f_t(n, m) - \frac{1}{n} \sum_{i=m+1}^{n+m} \mathbb{E}_t [i_{t+i}]
\]

For example, at our monthly sampling frequency the 9Y1Y forward term premium, i.e., the term premium embedded in a one-year bond, nine years in the future, would be defined as:

\[
 tp_t^{fwd}(12, 108) = f_t(12, 108) - \frac{1}{12} \sum_{i=109}^{120} \mathbb{E}_t [i_{t+i}]
\]

A convenient way to gain intuition about forward rates versus yields is to consider the case where term premiums are zero at all maturities. Then 1-period forward rates, \( \{f_t(1, i) : i = 1, \ldots\} \) would be given by \( \mathbb{E}_t [i], \mathbb{E}_t [i_{t+1}], \mathbb{E}_t [i_{t+1}], \ldots \), whereas yields, \( \{y_t(n) : n = 1, \ldots\} \) would be

\[
 \mathbb{E}_t [i], \frac{1}{2} (\mathbb{E}_t [i] + \mathbb{E}_t [i_{t+1}]), \frac{1}{3} (\mathbb{E}_t [i] + \mathbb{E}_t [i_{t+1}] + \mathbb{E}_t [i_{t+3}]), \ldots
\]

In other words, once adjusted for term premiums, forwards reflect the expectation of the short rate at a specific horizon in the future whereas yields reflect the average expected short rate up to that horizon. Accordingly, the term premium on a bond with \( n \) months to maturity simply reflects the average one-month forward term premium from 1 through \( n \) :

\[
 tp_t(n) = \frac{1}{n} \sum_{i=1}^{n} tp_t^{fwd}(1, i).
\]

Since we collect data on inflation expectations we can further decompose expected nom-
inal future short rates into expected real short rates and expected inflation,

$$tp_t^{wd}(n, m) = f_t(n, m) - \frac{1}{n} \sum_{i=m+1}^{n+m} \mathbb{E}_t[r_{t+i} + \pi_t + \pi_{t+i+1}],$$

where $r_t$ is the *ex-ante* real short rate, i.e., $i_t = r_t + \mathbb{E}_t[\pi_{t+1}]$. In the next section, we describe the evolution of expected rates and term premiums and evaluate their relative importance in explaining the variation of observed yields.

### 4.3.1 Empirical Properties of Term Premiums

In the remainder of this section we establish a set of stylized facts about term premiums. Figure 5 provides a decomposition of several nominal Treasury forward rates into expected future real short rates, expected future inflation and as well as the forward term premium for the sample from 1983 through 2016. Figure 5 shows these components for the 1Y1Y, 4Y1Y and 9Y1Y forward horizons (top, middle, and bottom panel, respectively). The chart shows that at the one-year, one-year (1Y1Y) maturity, expected real short rates and inflation explain much of the low-frequency variation in the forward rate while the term premium mainly contributes to variation at higher frequencies. All three components have contributed to the decline in short-term Treasury yields observed over the past several decades, albeit in different ways. First, average annual expected inflation one year hence decreased from about six percent in the mid 1980s to about 2–2.5 percent in the late 1990s, and has since leveled out. Second, average expected real short rates one-to-two years out have fluctuated between levels of 4.5 percent and one percent until the early 2000s, but have displayed a pronounced decline in the aftermath of the financial crisis dropping substantially below negative one percent between 2012 and 2015. Third, the 1Y1Y forward term premium has declined from about three percent in the early 1980s to around zero in the early 2000s and has hovered around that level since.

The middle and bottom panel of Figure 5 show the evolution of expected real rates, expected inflation, and term premiums for intermediate and long horizons. Medium-to-long term expected real short rates and expected inflation have evolved as discussed in 4.2. Expected inflation declined from elevated levels in the 1980s to levels around 2–2.5 percent in the late 1990s and has since remained in this range. Notably, real short rate expectations at intermediate and long maturities behave somewhat differently than those at the shorter horizon. While expected real short rates have fluctuated around 2% from the early 1980s until recently, it is only in the past few years that they have fallen out of this range to a level well below 1% at the end of our sample. Finally, as for the 1Y1Y horizon, the term premium
at intermediate and long horizons show a secular decline over the sample. They have largely
remained at negative levels since 2010, except for a brief period of time around the “taper
tantrum” episode of 2013. To summarize, all three components of bond yields contribute to
the secular decline of interest rates observed over the past several decades, albeit the timing
of the declines varies. Term premiums explain virtually all of the variation of bond yields at
higher frequencies.

4.3.2 The Relative Importance of Expected Short Rates and Term Premiums

Having shown that expected short rates, expected inflation, and term premiums have all
varied considerably over the past several decades, we now turn to the relative importance
of all three components for the variation of forward yields. Table 2 provides variance de-
compositions for both the level (upper panel), the monthly (middle) and the annual changes
(lower panel) of the one-year yield and one-year forward rates from one through nine years
out. For each maturity, the variance decomposition is obtained by computing the ratio of
the covariance of the (change in) forwards with (the change in) their individual components,
divided by the variance of the forwards:

\[
\frac{\text{Cov}(ft_{(n,m)}, \text{end}_{(n,m)})}{\text{Var}(ft_{(n,m)})} + \frac{\text{Cov}(ft_{(n,m)}, \sum_{i=m+1}^{n} \varepsilon_i[t+i])}{\text{Var}(ft_{(n,m)})} + \frac{\text{Cov}(ft_{(n,m)}, \sum_{i=m+1}^{n} \varepsilon_i[t+i+1])}{\text{Var}(ft_{(n,m)})}
\]

where \(n\) and \(m\) follow the notation introduced in the previous section. These decom-
positions highlight the pivotal role of term premiums in accounting for yield curve variation.
Expected real rates explain about 60% of the variation of the one-year yield while expected
inflation and term premiums account for about 30% and 10%, respectively. Expected real
rates remain a meaningful driver of (the level of) forward rates up to three years out (i.e.,
the 1Y1Y and 2Y1Y forward rates), explaining 43 percent of the variation at the one-year
ahead forward horizon and about 30 percent at the two-year ahead forward horizon, but their
importance then declines sharply going out the maturity spectrum accounting only for about
10% at forward horizons beyond four years out. Conversely, term premiums only explain a
small amount of variation at the very short end, but account for more than 50 percent of the
variation in forward rates at longer maturities. The share of variance explained by expected
inflation is relatively stable at a little above 30% across the maturity spectrum.

Since forward rates are very persistent, it is instructive to also look at the decomposition
of annual and monthly changes into the three components. It turns out that the contribution
of term premiums to the variation of monthly changes in forward rates is substantial at all
horizons and increases from 75 percent at the one-year forward horizon to over 90% at longer
forward horizons. In contrast, expected real short rates only account for 18 percent of the
month to month variation at the one-year forward horizon, and this contribution quickly drops to zero at longer maturities. Expected inflation also accounts for a negligible share of the variance of forward rate changes across maturities. The bottom panel shows the variance decomposition of the twelve-month changes. Term premiums continue to play a dominant role, with their relative importance between what is found for levels and monthly changes.

Given that we have shown that expected real short rates and expected inflation both vary considerably, how can we explain the dominant role of term premiums in accounting for the variability of bond yields? Figure 6 sheds light on this issue. The top-left panel re-iterates that nominal rate expectations at all forecasting horizons are fairly volatile when compared to yields: their volatility ranges from 40% for 12-month changes to 50% for monthly changes, at horizons higher than three years. However, the left panel shows that expectations do not co-move very strongly with yields beyond very short forecasting horizons. This is what explains the relatively low “betas” shown in the bottom left panel. Finally, the bottom right panel shows that low correlation between term premiums and expectations, at all forecasting horizons. It suggests different factors driving these two components of yields.

The importance of term premiums for variations in Treasury yields is not driven by the recent financial crisis and the large-scale asset purchases undertaken by the Federal Reserve. In Table 3, we repeat the variance decompositions ending the sample in December 2007. These show that term premiums played an even larger role before the financial crisis. In sum, these variance decompositions show that term premiums are by far the most important driver of interest rates. As Treasury yields directly affect the rates at which firms and consumers lend and borrow, our results suggest that term premiums might have important effects on economic activity. This will be investigated in the next section.

Using yields from Treasury inflation protected securities (TIPS) and our survey-based inflation expectations, we can further decompose the survey-based term premium into a real term premium and an inflation risk premium. Unfortunately, this decomposition is only possible starting in 1999 when the TIPS data became available. Figure 16 in the Supplementary Appendix suggests that during this recent period, most of the variation in medium and long-term forward term premiums was due to movements in real term premiums.\footnote{Note that during the first four years of the sample liquidity factors make inflation compensation difficult to interpret. We thus only show 4Y1Y and 9Y1Y forwards because liquidity in the TIPS market is concentrated in these maturity ranges.}

4.3.3 Co-Movement of Term Premiums Across Maturities

A long literature in finance has documented that government bond yields feature substantial co-movement across maturities (e.g., Garbade 1996, Scheinkman and Litterman 1991).
Based on our yield curve decompositions we can parse out the sources of the co-movement. Figure 7 shows twelve-month changes in short and long-maturity forward rates (top panel), expected rates (middle panel), and forward term premiums (bottom panel) for the same maturities. The figure clearly documents that survey-based term premiums co-move much more strongly than survey-based expected future short rates, or forwards themselves, across maturities. In fact, twelve month changes in long- and short-term forward expected rates are only weakly correlated whereas changes in forward term premiums are almost one to one. This demonstrates that the primary driving force behind the co-movement of forwards across maturities is from term premiums and not expectations of future short rates.

Note that the strong co-movement in term premiums is a feature of the data and is not imposed in any way by our methodology. Since term premiums equal average expected short-term excess returns over the life of a bond this finding is, however, consistent with a strong factor structure in expected excess returns as has been argued by Cochrane and Piazzesi (2005). Interestingly, we observe a break in this co-movement after the last recession. This might be capturing the effects of the unconventional monetary policy actions undertaken during that period, with their effects particularly strong on term premiums of longer-term bonds.

5 The Yield Curve and Economic Activity

5.1 Predictive Regressions

A long-standing strand of the literature in macroeconomics and finance has shown that the yield curve is informative about future economic activity and inflation – see, for example, Mishkin (1990), Estrella and Hardouvelis (1991), Estrella and Mishkin (1998) and Rudebusch et al. (2007). In particular, a decline of the term spread between long- and short-term yields has been documented to predict a decline in inflation and a decline in economic activity. While there is no general consensus in the literature as to why term spreads predict future economic activity and inflation, the predictive power has mainly been attributed to movements in the expected path of the short term rate (i.e. the expectations hypothesis). More precisely, a falling term spread is viewed as reflecting lower expected short-term rates in the future, i.e. a monetary policy easing, in response to low expected economic activity. In this spirit, Estrella (2005) obtains a predictive relation between term spreads and economic activity and inflation in a simple New-Keynesian framework. In line with this channel, some

\footnote{Cochrane and Piazzesi (2005) use this factor structure to construct a bond return forecasting factor (the “CP factor”) as a linear combination of forward rates.}
studies (see, for example, Ang et al. 2006 and Rosenberg and Maurer 2008) have found that only the expected rates component predicts economic activity but not term premiums.20

Using our survey-based decompositions of Treasury yields, we now reassess which of the components of Treasury term spreads predicts economic activity. We start by decomposing the term spread of a bond of maturity \( n \) as:

\[
TS_t(n) \equiv y_t(n) - i_t = \left( \frac{1}{n} \sum_{i=1}^{n} E_t[i_{t+i}] - i_t \right) + tp_t(n),
\]

where, in the second equality, we have decomposed the term spread into the average expected short rate over the next \( n \) periods less the current short rate (an “expected” term spread) and the \( n \)-period term premium. We then run regressions of the form:

\[
\Delta g_{t+h} = \beta_0 + \beta_1 \cdot tp_t(120) + \beta_2 \cdot \left( \frac{1}{n} \sum_{i=1}^{120} E_t[i_{t+i}] - i_t \right) + \xi^g_{t+h},
\]

where \( \Delta g_{t+h} \) represents the rate of growth of real GDP from period \( t + h - 1 \) to period \( t + h \), and \( \xi^g_{t+h} \) is an innovation. In contrast to much of the literature on the predictive power of the term spread for future activity and inflation, we choose to use marginal rates of growth as inference in regressions with overlapping dependent variables may be fraught with difficulties (see, e.g., Hodrick 1992, Valkanov 2003, Müller 2014, and Cattaneo and Crump 2014).

Table 4 shows the results of the predictive regressions of real GDP growth on the 10-year/three-month Treasury term spread and its components.21 The table has two panels: the upper panel covers the sample period from 1983–2016, the bottom panel the sample period from 1983–2007.22 In each panel, we report predictive regressions for horizons ranging from \( h \in \{1, 2, \ldots, 12\} \) quarters for two specifications. The first row shows the results of simply regressing on the 10-year/three-month term spread (labeled “Term Spread”), the second for regressing on the term premium (“10-Year Term Premium”) and the expected path of future nominal short rates less the current three-month yield (“Expected Term Spread”).

Starting with the sample from 1984–2016 (upper panel), we see that the predictive power

\[\text{Hamilton and Kim (2002), using ex-post term observed short rates as a measure of expected short rates, and Favero et al. (2005), using various different statistical models, find some evidence that the term premium predicts economic activity in the earlier part of our sample.}\]

\[\text{In unreported results we also find that using the five-year Treasury yield to define the term spread produces qualitatively similar results.}\]

\[\text{For these regressions, we restrict ourselves to the sample period starting in 1983 as this is when the coverage of survey data is particularly strong. In unreported results for the full sample from 1964 onwards, we confirm the widely documented result that the term spread has had strong predictive power for future real growth.}\]
of the term spread itself has largely faded. At almost all forecast horizons, the predictive coefficients are not statistically distinguishable from zero for standard hypothesis tests. This is in line with recent research (e.g., Schrimpf and Wang 2010) which has shown that the predictive power of the term spread has weakened significantly in the post-1983 sample. As monetary policy is characterized by a more active monetary policy stance in this period (e.g., Clarida et al. 2000), this finding is also consistent with the New Keynesian model by Estrella (2005) discussed above.

Looking at the predictive regressions on the expected rate path and term premium components of the term spread, however, we find that the term premium strongly predicts future economic activity up to ten quarters ahead. This is documented by the sizable and highly statistically significant coefficients in the regressions on the two components. This finding is in contrast to Ang et al. (2006) who attribute the dominant role to the expectations hypothesis component in similar regressions, albeit for the sample period 1964–2001. As their term spread decomposition results from an affine model with constant coefficients, it is subject to the criticisms of VAR-based models we discuss in Section 6.1.23

The strong predictive power of the term premium component is not driven by the last few years in the sample. The bottom panel of Table 4 reports the results when the sample is ended in 2007 which excludes the zero lower-bound period. While both the predictive coefficients on the term premium and the regression $R^2$s are somewhat smaller in magnitude over this sample, the results are very similar to the full post-1983 sample. Specifically, the term premium remains a strongly statistically significant predictor of future real growth up to seven quarters ahead.

Combined, our results thus show that the term premium obtained from survey expectations is economically important as it captures predictive information about future real growth even when the overall term spread does not. This suggests that there is valuable information in term premiums for the design and evaluation of macroeconomic models.

5.2 Macroeconomic Shocks

In the previous section we have shown that term premiums have predictive power for economic activity. We next investigate the economic driving forces affecting their dynamics. Specifically, we assess how term premiums and short rate expectations respond to different structural macroeconomic shocks that have been identified in the literature. While most general equilibrium macroeconomic models ignore term premiums, a few approaches have recently emerged that explicitly accommodate their role. This is typically done either by

23 In unreported results, we find that our results are robust to including the level of the nominal short rate in the predictive regressions, as suggested by Ang et al. (2006).
exploring alternative specifications of risk preferences or by introducing financial frictions.\textsuperscript{24} In both frameworks, term premiums respond to macroeconomic shocks and, in turn, changes in term premiums contain predictive information about economic activity.

In order to evaluate the impact of macroeconomic shocks on the components of the yield curve, we estimate impulse responses of both expected short-term rates and term premiums using the approach in Romer and Romer (2004) and Romer and Romer (2010). Precisely, we estimate the equation

\[ t p_t = a + \sum_{i=0}^{N} b_i \epsilon_{t-i} + \sum_{j=1}^{M} c_j t p_{t-j} + e_t \]  \hspace{1cm} (5.2)

where \( \epsilon_t \) denotes the structural shocks, \( e_t \) captures an unobserved disturbance, and similarly for expected short rates. The lag lengths denoted by \( N \) and \( M \) are chosen using the Bayesian information criterion (BIC). To ensure that our conclusions are not unduly influenced by the flexibility of the specification in equation (5.2), we also provide results from a more parsimonious (nested) model given by \( c_1 = -1, c_j = 0, \forall j \neq 1 \) in the Supplementary Appendix. This specification corresponds to a regression of the contemporaneous changes in expected rates and term premiums on each macroeconomic shock. Perhaps surprisingly given this tighter specification, these additional regressions imply similar effects as the impulse responses from equation (5.2).\textsuperscript{25}

We group the macroeconomic shocks into three broad categories: “policy”, “demand” and “supply shocks”. The first category comprises both monetary and fiscal policy shocks. In the second category, we consider financial and uncertainty shocks which in many economic models have “demand-like” features as they induce a positive comovement between inflation and economic activity. In contrast, supply shocks are generally viewed as having opposite effects on inflation and economic activity. Here we focus on oil and total factor productivity (TFP) shocks as typical examples of supply shocks.

Figures 8–11 display the responses of expected future short rates and term premiums to each of these shocks. In more detail, they show impulse responses to a one standard deviation shock on the expected rates and term premium components of the one-year rate

\[ \Delta t p_t = a + b \epsilon_t + e_t, \]  \hspace{1cm} (5.3)

and similarly for expected short rates.

\textsuperscript{24}Rudebusch and Swanson (2008) and Christoffel et al. (2011) find a role for term premiums by introducing consumption preferences with habit formation, Piazzesi and Schneider (2007), Rudebusch and Swanson (2012) and van Binsbergen et al. (2012) instead rely on Epstein and Zin recursive preferences. In models such as Chen et al. (2012), Gertler and Karadi (2013), and Carlstrom et al. (2014) term premiums arise because of financial frictions that drive a wedge between short-term deposits collected from households and long-term lending rates.

\textsuperscript{25}Specifically, we estimate the equation
one year and four years forward, respectively. In addition, the Supplementary Appendix reports impulse responses up to nine-year forwards. In each chart, the black line represents the median impulse response, while the shaded areas display the nominal coverage rates of 68, 90 and 95 percent, respectively.

An important feature of our survey-based expected rates and term premiums is that they can display quite different responses to shocks at different horizons. This is because the model we use to fit the term structures of consensus expectations allows independent variation of short-term components from long-term trends. Note that this is generally not the case for standard VAR models with constant long-run means. Indeed, we verified that expected rates and term premiums implied by these models display fairly uniform responses at short- and long-term maturities.\textsuperscript{26}

**Policy shocks** We consider monetary policy shocks based on Kuttner (2001) who uses surprises in federal funds futures on FOMC announcement days. The measure is the only shock series with a monthly frequency and is available from November 1988 onwards; to avoid issues with the zero lower bound period we only consider it through December 2007. Figure 8 shows that a contractionary monetary policy shock has large and persistent effects on expected rates. In fact, both one-year and four-year forward expected short rates increase significantly, suggesting that medium-term expectations are not approximately time-invariant as implied by most macroeconomic models which assume a steady state which is perfectly understood by agents. This point has been made in Gürkaynak et al. (2005b) who, however, use forward rates that are unadjusted for term premiums.

Figures 8 and 17 further show that term premiums decline across all horizons, with stronger and more persistent impulse responses at long maturities.\textsuperscript{27} This result accords with the theoretical predictions of, e.g., Rudebusch and Swanson (2012). In their model a contractionary monetary policy shock implies a decline in both economic activity and inflation and leads to a lower term premium. Intuitively, by lowering both expected consumption growth and inflation, an increase in the policy rate raises the payoff of nominal bonds precisely in periods when consumption growth is expected to be low and thus marginal utility is high. Therefore, investors require less compensation for holding these bonds.

The decline in term premiums subsequent to a contractionary monetary policy shock contrasts with the VAR evidence in Gertler and Karadi (2015). These authors instead attribute the bulk of the positive response of long-term rates to a contractionary monetary policy shock to an increase in term premiums. Of note, their estimates of short rate expectations

\textsuperscript{26} These results are available upon request.

\textsuperscript{27} The monetary policy shock has stronger effects on seven-year and nine-year forwards.
and term premiums are based on a constant parameter VAR (see Section 6.1). Interestingly, when they add a measure of short-term survey forecasts of the three-month Treasury bill rate to the VAR, they find a stronger reaction of short-term expectations to the monetary shock. An increase in term premiums following a Kuttner shock is also found by Abrahams et al. (2016). Using an affine term structure model and daily data on nominal Treasury yields and TIPS, these authors decompose term premiums into real term premiums and inflation risk premiums and find that while the inflation risk premium declines slightly in response to a contractionary monetary policy shock, this is offset by an increase in the real term premium.

In the Supplementary Appendix we also consider as alternative monetary policy shocks the “target” and “future policy path” factors, as suggested by Gürkaynak et al. (2005b) — GSS henceforth. While the effects of a target shock are very similar to those of the Kuttner shock, we find that the GSS path shock only has an effect on the expected rate at short horizons and has no significant effects on term premiums.

In terms of fiscal shocks, we use the Mertens and Ravn (2012) modification of the Romer and Romer (2010) measure of exogenous tax changes relative to GDP which is constructed using a narrative analysis of US tax policy in the post-war period and excludes anticipated tax changes. The impulse responses in Figure 8 show that the fiscal shock induces a statistically significant and fairly persistent decline in term premiums at medium and long-term maturities but does not significantly affect the expected path for the short-term rate. While this finding could reflect a diminished risk to the fiscal outlook, to our knowledge no structural model discusses the implications of tax changes for term premiums. That said, Dai and Philippon (2006) and Laubach (2009), among others, show that fiscal deficits raise term premiums using reduced form affine term structure models.

In the Supplementary Appendix, we consider a second fiscal shock due to Ramey (2011), which captures unexpected changes in the present discounted value of federal government defense spending that are due to foreign political events, relative to GDP. This measure, which is available for the sample period 1959Q1–2010Q4, is constructed using narrative analysis from newspaper and magazine articles and has very few non-zero observations over the sample we consider in this paper. Not surprisingly, our results then show no significant effects on either expected rates or term premiums across the maturity spectrum.

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28 Their decomposition implies that unexpected changes in federal funds futures up to a maturity of one year are driven by both a target rate shock as well as a shock to the expected path of policy rates that is independent of changes in the current funds rate target.

29 The Supplementary Appendix also includes the impulse responses to the original Romer and Romer (2010) shock, which deliver similar results.
**Demand Shocks.** A recent macroeconomic literature has emphasized the importance of “financial shocks” for explaining business cycle dynamics (e.g., Gilchrist and Zakrajšek 2012, Justiniano et al. 2010, and Christiano et al. 2014). Here, we label such innovations “demand shocks” as they typically move output and inflation in the same direction. We consider two measures of such shocks, which are both meant to capture exogenous changes to corporate spreads. The first is derived from a VAR which includes the excess bond premium described in Gilchrist and Zakrajšek (2012). The second measure is given by the spread shocks identified using the DSGE model in Del Negro et al. (2013). As can be seen from Figure 9 and from Figures 20, 24, and 25 in the Supplementary Appendix, both shocks produce a persistent decline in expected rates up to four years ahead and of term premiums across all maturities. The effects on the term premium are consistent with theoretical predictions: by inducing a positive co-movement between economic activity and inflation the financial shocks lower the term premium. The difference with respect to monetary policy shocks is that expected rates fall as the monetary authority reacts to the negative demand shock. An alternative explanation for the observed decline in term premiums involves investors’ risk attitudes: a negative demand shock may trigger “flight-to-quality” flows as investors switch from risky assets to safer government bonds. Consistent with this view, term premiums decline across different maturities.

We consider two additional “demand” shocks which are based on different measures of macroeconomic uncertainty. The first is due to Jo and Sekkel (2016) and is derived from SPF survey forecast errors for various macroeconomic indicators such as real GDP, the unemployment rate, industrial production and housing starts. The second uncertainty shock is obtained from Basu and Bundick (2015) who identify it using a VAR including the

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30 The VAR includes the growth rate of private consumption expenditures and real business investment growth and real GDP, together with inflation measured by the GDP deflator, the excess bond premium, the excess return on the stock market, the ten-year Treasury yield and the effective federal funds rate. The model is estimated at the quarterly frequency over the sample 1973Q1–2010Q3 and uses a recursive identification scheme.

31 The model uses the following observables: real GDP and total hours worked (both in per capita terms), the core PCE deflator, the labor share, the federal funds rate and a spread between the BAA ten-year corporate rate and the ten-year Treasury yield. The shock series is available for the sample period 1983Q1–2014Q4.

32 The Supplementary Appendix further shows that the impulse responses obtained using the pre-crisis sample are very similar, documenting that this finding is not driven by the financial crisis.

33 Interestingly, the impulse response of term premiums does not appear consistent with financial frictions as modeled in Carlstrom et al. (2014) in which a negative financial shock increases the term premium.

34 Specifically, uncertainty shocks are obtained as innovations to the conditional, time-varying standard deviation of a factor that is common to the forecast errors for the different indicators. This shock measure is available at a quarterly frequency for the sample 1968Q4–2014Q1. We thank Soojin Jo and Rodrigo Sekkel for providing this series. This measure of uncertainty is shown to have comparable effects on economic activity as the one recently proposed in Jurado et al. (2015), who compute a measure of uncertainty from a stochastic volatility model estimated in a data-rich environment.
Chicago Board of Options Exchange Volatility Index (VXO) as a measure of uncertainty, in addition to selected macroeconomic variables.\textsuperscript{35} As Figure 10 shows, an unexpected increase in both measures of uncertainty implies a decline in the term premium on impact. Although the impulse responses for the term premium are qualitatively similar to those obtained for the spread shocks, they are less precisely estimated and display considerably less persistence. This may partly reflect the small number of sizable uncertainty events over our sample. A notable difference between the two uncertainty shocks is that the one by Basu and Bundick (2015) implies a significant and persistent decline in expected short term rates both at short and longer term maturities.

**Supply Shocks.** As “supply” shocks we consider two oil shock measures and a total factor productivity (TFP) shock which are often discussed in the macro literature. The first supply shock, discussed in Hamilton (1996, 2003) defines positive oil price shocks as the difference between the current price of oil and the maximum price over the past twelve months. In other periods the shock is set to zero. The series we use is quarterly and is available from 1951Q1–2007Q4.\textsuperscript{36} The second measure we use is the oil supply shock series computed in Kilian (2008), which measures exogenous oil production disruptions across OPEC countries. This measure is available at the quarterly frequency for the sample 1971Q1-2004Q3.

Figure 11 provides the impulse responses to a positive oil price shock based on Hamilton (1996, 2003) and a positive oil quantity shock from Kilian (2008). The oil quantity shock implies a significant response of medium-to-long maturity term premiums on impact. Specifically, the term premium declines when oil supply increases. That said, the impulse responses are imprecisely estimated beyond the first quarter. In the case of the price shock, the median response predicts that the initial increase is offset in the following quarters and the impulse response is very imprecisely estimated. As in the case of uncertainty shocks above, this lack of precise estimates might reflect the small number of sizable shocks observed in our sample. Turning to expected rates, the quantity measure does not imply any significant response, while the price shock appears to affect positively medium and long-term rate expectations.

The last supply shock we consider measures news about future TFP and is taken from Barsky and Sims (2011). These authors use a VAR including non-durable and services real consumption expenditures, real GDP, per-capita hours worked and a measure of TFP adjusted using capacity utilization. They identify the news shock as the innovation that

\textsuperscript{35}Specifically, they use real GDP, consumption, investment, hours worked, the GDP deflator, the M2 money stock, and a measure of the stance of monetary policy and use a recursive identification with the VXO ordered first. The shock series is available for the period 1986-2014. We thank Susanto Basu and Brent Bundick for providing this series.

\textsuperscript{36}We thank Olivier Coibion for providing this shock series.
best explains future TFP at a ten year horizon and is orthogonal to current TFP shocks.\textsuperscript{37} The shock series is available at a quarterly frequency for the sample period 1983Q3–2007Q3 which roughly spans the Great Moderation. As can be seen from Figure 11, a positive news shock produces a decline in the term premium at medium-to-long maturities on impact. However, as in the case of the oil shocks the effect is not statistically significant beyond the first quarter.\textsuperscript{38}

In sum, we find that negative (positive) supply shocks result in an increase (decrease) in the term premium on impact. This is consistent with the models of e.g. Piazzesi and Schneider (2007) and Rudebusch and Swanson (2012) who argue that shocks which imply a positive response of consumption growth and a negative response of inflation should lower the term premium. Our finding that the term premium does not react significantly to supply shocks beyond the first quarter may suggest a diminished importance of supply shocks in our sample period. In contrast, financial shocks have large and persistent effects on term premiums, which complements the finding discussed above that such shocks play a dominant role in explaining business cycle dynamics over the past several decades.

6 Discussion

The vast literature treating expected rates and term premiums as unobserved components of yields reaches conflicting conclusions about their relative role for the dynamics of the term structure of interest rates. Using survey-based expectations obviates this problem. In this section we first compare our survey-based expected interest rate paths (and term premiums) with different model-based paths and show the sensitivity of the latter decompositions to model specification. Finally, we conclude the section by discussing some empirical regularities of survey expectations.

6.1 Comparison with Statistical Models

In the previous section we have discussed the decomposition of yields into expected rates and term premiums based on survey expectations. As already mentioned in the Introduction, a large literature has instead decomposed yields using statistical models of the term structure of interest rates. Here, we compare the survey-based term premium and expected

\textsuperscript{37}We use the same shock series as in Coibion and Gorodnichenko (2012).

\textsuperscript{38}In the Supplementary Appendix, we also consider technology shocks identified as in Galí (1999) from a VAR including changes in labor productivity, in hours and in the GDP deflator with the restriction that only technology shocks have long-run effects on labor productivity. This shock, which is not obtained using direct estimates of TFP, appears to have some impact on expected rates but not on term premiums.
rates components with those from a few different statistical models. Figure 12 displays the
time series of expected average nominal short rates at the 1Y1Y, 4Y1Y and 9Y1Y forward
horizons. In each of the panels, the gray solid lines represent the expected average short
rates implied by the survey data. In order to highlight the importance of accounting for
changes in the expected long-run mean of the short rate, we contrast the results from the
previous section with those obtained from two stationary VARs. First, we consider a VAR
in the level, slope, and curvature factors of the yield curve. Second, in line with a large lit-
erature on macro-finance term structure models we consider an additional VAR augmented
with measures of real activity and inflation.

Stationary VARs are a useful benchmark because standard affine term structure models
are largely unconstrained VARs in the model factors, and hence short rate expectations and
term premiums implied by such models can essentially be derived from such a VAR. The short rate expectations implied by a VAR thus crucially depend on the estimated
long-run mean as well as the speed of mean reversion of the yield factors. As the factors
are typically quite persistent, these parameters are difficult to pin down and their estimates
might thus differ across samples. We therefore provide VAR-based short rate expectations for
two samples. The blue dashed line represents expected average nominal short rates implied
by a VAR estimated over the full sample 1968–2016, the purple dash-dotted line instead
represents those forecasts implied by a VAR estimated over the subsample 1990–2007. We
choose this specific subsample as it is the one used by, for example, Wright (2011) and
Joslin et al. (2014), two prominent references for term premium estimates obtained from
macro-finance affine term structure models.

As the figure shows, both VAR specifications estimated over the subsample imply medium
to long-term average expected short rates that are nearly constant, consistent with a sub-
stantial degree of mean reversion in the short rate. In contrast, the VAR using only yields,
estimated over the full sample, implies medium-to-long-term forecasts of the average short
rate that are substantially more volatile and essentially mimic the evolution of the short rate
itself. In contrast, the VAR which additionally includes macroeconomic variables, displays
very different dynamic properties for different forecast horizons. At short horizons, during
the zero-bound period, the model-based forecast is for sharply negative short-term rates,
which is largely influenced by the marked decline in real activity at that time. At longer

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\[39\] Following e.g. Diebold and Li (2006) and Diebold et al. (2006), we define the level factor as the three-
month TBill \((y(3))\), the slope factor as the ten-year Treasury note \((y(120))\) minus the three-month TBill,
and the curvature factor as \((y(120) - y(3)) - (y(60) - y(3))\). These three factors are highly correlated
with the first three principal components of nominal Treasury yields.

\[40\] Following Joslin et al. (2014) we use the three-month moving average of the Chicago Fed National
Activity Index as an indicator of real activity. As a measure of inflation we use year-over-year core CPI
inflation.
horizons, forecasts for short-term rates appear to be fairly stable around a constant value of about 4.5% showing no evidence of the downward trend displayed by the yields-only VAR.

These findings underscore that the specific choice of sample period and the choice of state variables matter immensely for the average expected short rate implied by statistical models. What is more, the long-run predictions of the short rate from surveys have deviated sizably from those implied by these models. This is especially true in the early 1980s, in the early 2000s, and in the zero lower bound period where survey-based and model-implied expected long-term future short rates have differed by up to two percentage points. This comparison demonstrates that survey-based expected rates display very different behavior as compared to constant parameter VAR models where the estimated degree of persistence and the estimated long-run mean of the short rate can vary substantially.

In Figure 13 we show the term premiums corresponding to these models of expected rate paths.\footnote{In Figure 15 in the Supplementary Appendix we also compare to the two publicly-available yield curve decompositions based on Kim and Wright (2005) and Adrian et al. (2013).} In the top panel of each column we show the implied term premiums for the 1Y1Y maturity. Survey-based term premiums are much more volatile than all of their VAR-based counterparts and can differ markedly in level. For example, at the height of the financial crisis, the VAR supplemented with macroeconomic data implies an almost 400 basis point difference. At intermediate and longer maturities (middle and bottom panel) there are also noteworthy differences—especially at the beginning and the end of the sample when rates were particularly high and low. Moreover, the economic implications of the term premiums can be very different even in the middle of the sample. For example, survey-based term premiums at intermediate maturities were comfortably negative during the early 2000s which was not the case for their VAR counterparts. All that said, term premiums based on surveys or those based on statistical models do show some commonalities: they are broadly trending down over the sample and they roughly co-move at business-cycle frequencies.\footnote{Combined, the common trend and the co-movement at business cycle frequencies imply that survey-based and VAR model-based expected bond returns are positively correlated both in levels and in changes. This is in contrast to Greenwood and Shleifer (2014) who find that model- and survey-based equity risk premiums co-move negatively. See also Cieslak and Povala (2015).} \footnote{Using factors extracted from a large cross-section of macroeconomic variables to predict bond yields and returns, Moench (2008) and Ludvigson and Ng (2009) also find that they are strongly counter-cyclical. Ghysels et al. (2014) document substantially less counter-cyclicality in expected excess bond returns when using real-time instead of final revised macroeconomic variables or factors.} This is hardly surprising in light of the results in Section 4.3 where we have shown that expected short rates play a minor role in explaining the variation in intermediate- and longer-term yields.

We have documented earlier that our survey-based term premiums correlate stronger across maturities than the expected rate components. An alternative is to study the co-
movement between the two components themselves. The top panel of Figure 14 provides the correlations between monthly changes in the expected rate path and term premium at the 1Y1Y, 4Y1Y and 9Y1Y forward horizons, respectively. The charts show a modest negative correlation between the two components at all three horizons. We also compute these correlations for the statistical models considered above. Maybe not surprisingly, there are notable differences between the models also in terms of the comovement between the yield curve components. While the yields-only VAR model implies a positive correlation at short and intermediate horizons, the sign of the co-movement changes at long horizons. Except for the Kim and Wright (2005) model which features strongly positive correlations at all horizons, the remaining statistical models considered imply varying degrees of negative co-movements.

7 Conclusion

A long literature has used models fitted to the term structure of interest rates to decompose bond yields into the expected path of future short rates and term premiums, treating both as unobserved. In this paper, we obtain term premiums as the difference between government bond yields and expected average short rates from surveys of professional forecasters. We characterize the expected path of nominal and real short-rates as well as inflation using a unique date set which captures the universe of U.S. macroeconomic survey forecasts covering over 600 survey-horizon pairs.

Term premiums are the driving force of movements in bond yields accounting for the bulk of variation in levels and nearly all of the variation in changes. Furthermore, term premiums, not expected rates, are the dominant source of co-movement of yields across maturities. We also find that the term premium, not the term spread or the expected path of future short rates, predicts quarterly real output growth. Moreover, macroeconomic factors are important drivers of term premiums with demand shocks playing the most prominent role.

Our findings have important implications for both macroeconomics and finance. The vast majority of structural macroeconomic models do not include term premiums, but instead assume the expectations hypothesis holds, at least to a first-order approximation. Our results therefore suggest that incorporating time varying term premiums is necessary in order to account for the observed variation of long-term bond yields.
8 Data Appendix

In this section we provide additional details about the survey data we use in the paper. Table 1 provides a succinct summary of the surveys, variables and horizons which are available. In general, we use all available professional survey data for our three candidate variables of interest. Any exception is listed in this Data Appendix. To proceed we will first provide greater detail on how we map survey forecasts to our modeling framework discussed in Section 3. Forecasts for the three-month Treasury bill rate are either a simple average over a period or end of period. For the latter we assign these forecasts to the last month in the period. For real output growth and inflation, survey forecasts come in three possible forms: quarter-over-quarter annualized growth, annual average growth and Q4/Q4 growth. The distinction between these growth rates are best illustrated through examples. In these examples we will ignore measurement error for simplicity. Let \( G_{2013Q1} \) and \( G_{2013Q2} \) be the level of real GDP in billions of chained dollars in the first and second quarter of 2013, respectively. Then, the quarter average annualized growth rate is defined as \( 100 \cdot ((G_{2013Q2}/G_{2013Q1})^4 - 1) \). In our model we filter a month-over-month (annualized) real GDP growth rate series. To map the monthly series into this specific quarterly growth rate we use

\[
100 \cdot ((G_{2013Q2}/G_{2013Q1})^4 - 1) \approx \frac{1}{9} (g_{2013m2} + 2 \cdot g_{2013m3} + 3 \cdot g_{2013m4} + 2 \cdot g_{2013m5} + g_{2013m6}),
\]

where, for example, \( g_{2013m2} \) represents month-over-month annualized real output growth in February 2013.

Annual average growth rates follow a similar pattern. For example, let \( G_{2012} \) and \( G_{2013} \) be the average level of real GDP in billions of chained dollars in the years 2012 and 2013, respectively. Then the annual average growth rate is \( 100 \cdot (G_{2013}/G_{2012} - 1) \) which we approximate via,

\[
100 \cdot (G_{2013}/G_{2012} - 1) \approx \frac{1}{24} (g_{2012m2} + 2 \cdot g_{2012m3} + 3 \cdot g_{2012m4} + \cdots + 12 \cdot g_{2013m1} \\
+ 11 \cdot g_{2013m2} + 10 \cdot g_{2013m3} + \cdots + 2 \cdot g_{2013m11} + g_{2013m12}).
\]

Finally, Q4/Q4 growth rates are calculated, for example, by \( 100 \cdot (G_{2013Q4}/G_{2012Q4} - 1) \) and approximated via

\[
100 \cdot (G_{2013Q4}/G_{2012Q4} - 1) \approx \frac{1}{12} (g_{2013m1} + g_{2013m2} + g_{2013m3} + \cdots + g_{2013m12}).
\]

The above shows that certain survey forecast horizons will implicitly include time periods which have already occurred. To avoid taking a stand on how forecasters treat past data (e.g., do forecasters use realized data, filtered versions or another measure?) we exclude all survey forecast horizons that include past months’ values of \( y_t \). The only exception we make is to include current quarter (Q0) and one-quarter ahead (Q1) forecasts for real output growth (which extend back, at most, four months and one month, respectively). We do so to help pin down monthly real output growth since the actual series is only available at a quarterly frequency. Finally, for simplicity, forecasts which involve averages over multiple years are mapped as simple averages over the corresponding horizons. We now briefly discuss the individual surveys:

**Blue Chip Economic Indicators** The Blue Chip Economic Indicators (BCEI) is a survey of professional forecasters that has been running since 1976. The survey is typically released on the 10th of each month, and is based on 50-plus responses that have been collected during the first week of the same month. The survey focuses primarily on economic variables such as those in the NIPA tables, but also includes forecasts for the unemployment rate, total industrial production, housing starts, and vehicle sales as compared to the Blue Chip Financial Forecasts Survey but also includes forecasts for the 3-month Treasury bill. The
participants of the survey range from large commercial banks, broker dealers, insurance companies, large manufacturers, economic consulting firms, GSEs and others. Quarterly forecasts of the 3-month Treasury bill are the average yield in the quarter. Quarterly forecasts of CPI and GNP/GDP are quarter average annualized growth rates. Annual forecasts for the 3-month Treasury bill are the annual average yield in the year and annual forecasts of CPI and GNP/GDP are annual average growth rates. Beginning in March 1979, BCEI began querying respondents on their forecasts for a selection of variables over the following five years. Later that year, these special questions included longer horizons including 6-to-11 years ahead. These biannual questions have generally been conducted in the March and October surveys. Blue Chip Economic Indicators is owned by Wolters Kluwer.

Blue Chip Financial Forecasts The Blue Chip Financial Forecasts Survey (BCFF) is a monthly survey of about 50 professional forecasters that has been running since 1982. The survey is typically released on the first day of the month, and is based on participants’ responses that have been collected during the last week of the previous month. The survey focuses primarily on financial variables such as interest rates (as compared to the BCEI) but also includes forecasts for major macroeconomic variables (such as output and inflation). The participants of the survey range from broker-dealers to economic consulting firms and the identity of the participants is linked to their shorter-term forecasts (out to as much as six-quarters ahead). For longer horizons the consensus (i.e., mean) forecast is provided for each variable. Quarterly forecasts of the 3-month Treasury bill are the average yield in the quarter. Quarterly forecasts of CPI and GNP/GDP are quarter average annualized growth rates. Annual forecasts for the 3-month Treasury bill are the annual average yield in the year and annual forecasts of CPI and GNP/GDP are annual average growth rates. Beginning in 1983, BCFF began querying respondents on their forecasts for a selection of variables over the following five years (once in 1983 and twice in 1984 and 1985). Starting in 1986 these biannual special questions included longer horizons including 6-to-11 years ahead. Between March 1986 and March 1996 longer-run forecasts are provided in the March and October surveys. From December 1996 onward, long-run forecasts are provided in the June and December releases. The only exception to this rule is that long-run forecasts were provided in the January 2003 survey instead of the December 2002 survey. Blue Chip Financial Forecasts is owned by Wolters Kluwer.

Consensus Economics The Consensus Economics survey is a monthly survey of professional forecasters that has been running since 1989. The survey respondents range from Economists at financial institutions to those at non-financial firms or universities. In addition to the United States, the data includes simultaneous surveys for Canada, Mexico, China, Japan, and over fifty other countries in Europe, Asia, and Latin America. The identity of the participants is linked only to their shorter-term annual forecasts; quarterly forecasts and longer-term forecasts only report summary statistics. Annual forecasts for real GDP and CPI inflation are annualized growth rates. Since 1993, the survey also reports quarter average annualized growth rates for these two variables. Forecasts for the 3-month Treasury bill are provided for horizons of 3-months and 12-months ahead along with additional quarterly forecasts which represent the end of quarter value (the additional quarterly forecasts begin in 1990). Longer-term forecasts out as far as 10 years ahead are available for all three variables (3-month Treasury bill forecasts begin in 1998) and are currently released four times per year. Consensus Economics is a management-owned company.

Decision-Makers Poll The Decision-Makers Poll is a survey that began in September 1978 and was conducted initially by Richard B. Hoey. The survey was discontinued in March 1991 but then reinstated for only five months in March 1993. The survey did not have a fixed frequency but starting in 1981 it was conducted at least four times a year and included participants from various firms. The number of respondents varied
from 175 to 500 according to Levin and Taylor (2013). We do not have access to the full data set; however, we obtain the data available from 1978 to 1987 from Havrilesky (1988). Early papers which used these data include Holland (1984), Darin and Hetzel (1995), Levin and Taylor (2013).

Economic Forecasts: A Worldwide Survey Economic Forecasts: A Worldwide Survey, published by North-Holland, was begun in 1984 and collected forecasts for a number of countries including the United States. The survey ended in 1995. Victor Zarnowitz served as the original Editor for all forecasts related to the United States and was later replaced by Phillip Braun. The survey provides short-term quarterly and annual forecasts of a number of economic variables including real GDP and the three-month Treasury Bill. Quarterly forecasts for real GDP are quarter average annualized growth rates and annual forecasts are annual average growth rates. Forecasts for the the three-month Treasury bill are average over the period. Note that earlier issues report, four times per year, the most recent Survey of Professional Forecasters as an individual forecast. We have removed this entry when calculating the consensus forecast. Finally, as mentioned in the text, to our knowledge, the only other paper to use these data is Ehrbeck and Waldmann (1996).

Goldsmith-Nagan The Goldsmith-Nagan survey is a quarterly survey that began in September 1969 and ended in 1986. The survey participants were executives and economists at banks and other financial institutions and only the consensus expectation for various interest rates and maturities (e.g., 3-, 6-, and 12-month T-bills) are reported according to Prell (1973). The surveys were conducted at the end of each quarter and the Q1 forecast represents the end of quarter value for the following quarter. We do not include the Q2 forecasts as they appear excessively volatile. Early papers which used these data include Prell (1973), Friedman (1979), Friedman (1980), and Froot (1989).

Livingston Survey The Livingston Survey was begun in June 1946 by Joseph Livingston, but was taken over in 1990 by the Federal Reserve Bank of Philadelphia. The survey is conducted twice a year in June and December and was conducted when Livingston worked at the Philadelphia Inquirer. He sent his survey to professional Economists. The survey queries respondents on all three of our variables. Annual real GDP forecasts are annual average growth rates. Note that the target CPI measure is the index value in the last month of the quarter. Prior to 2004, the survey asked for the value of the not seasonally adjusted index; however, restricting the estimation to data which is not affected by this issue does not materially change our results. For some horizons the base year used by the forecasters are unclear and so we exclude all forecasts where the forecasters’ base year is unknown. Quarterly and annual forecasts for the 3-month Treasury bill are end of period forecasts.

Survay of Primary Dealers The Survey of Primary Dealers (SPD) is conducted by the the Trading Desk of the New York Fed one to two weeks before each regularly scheduled Federal Open Market Committee meeting. As the name implies the survey respondents are the current (at the time of the survey) Primary Dealers to the Federal Reserve Bank of New York. The survey began in 2004; however, we use only the publicly available data which begins in 2011 and has included questions on quarterly and annual real GDP growth and 5-year/5-year (Y6-10) forward CPI inflation. Annual GDP forecasts are requested for Q4/Q4

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45 For more details on this survey see Golay et al. (2013).
46 See https://www.newyorkfed.org/markets/pridealers_current.html for more information.
growth rates to match the convention used in the FOMC’s Summary of Economic Projections (SEP). In addition, the survey includes forecasts on “longer-run” real GDP growth which corresponds to the variable $\bar{g}_t$ (see Section 3). The survey also includes both short-run and longer-run forecasts for the Federal Funds rate (FFR). We only use the longer-run forecasts for the FFR as the distinction between the two interest rates should be minimal in the longer run. The public data report median rather than mean values as the central tendency of the cross-section of forecasts and so we use this measure. We have verified, using non-public data, that the median and mean values are similar.

**SPF** The Survey of Professional Forecasters (SPF) is conducted on a quarterly basis by the Federal Reserve Bank of Philadelphia (FRBP). The survey began in the fourth quarter of 1968 and, at that time, was conducted by the American Statistical Association (ASA) and the National Bureau of Economic Research (NBER) before being taken over by the FRBP in the second quarter of 1990. The forecasts are anonymous but are given specific industry identifiers which were updated in 2007. The survey includes forecasts of all three variables we consider and, more recently, has included longer-term forecasts over the next 10 years for real GDP, CPI and the TBILL starting in the early 1990s; however, forecasts whose target period start in 3 or more years were introduced for CPI in 2005 and real GDP and TBILL in 2009. Growth rates for real GDP are based on average levels across variables and real GNP was not explicitly surveyed before the third quarter of 1981. Unlike the other surveys, annual CPI inflation is measured as Q4/Q4 growth rates rather than annual average growth. Following the discussion in the documentation of the survey we drop the appropriate observations in 1986Q1, 1990Q1 and 1990Q2. We assign the survey period during the middle month of each quarter based on the description in SPF documentation.

**References**


Gertler, M., Karadi, P., 2013. QE 1 vs. 2 vs. 3...: A framework for analyzing large-scale asset purchases as a monetary policy tool. International Journal of Central Banking 9, 5–53.


Jo, S., Sekkel, R., 2016. Macroeconomic uncertainty through the lens of professional forecasters, staff working paper.


Laubach, T., Tetlow, R. J., Williams, J. C., 2007. Learning and the role of macroeconomic factors in the term structure of interest rates, working paper.


### Table 1: Summary of Surveys

This table provides a summary of the forecast data available from each survey: Blue Chip Financial Forecasts (BCFF), Blue Chip Economic Indicators (BCEI), Consensus Economics (CE), Decision Makers’ Poll (DMP), Goldsmith-Nagan Survey (GN), Economic Forecasts: A Worldwide Survey (EF), Livingston Survey (Liv.), Survey of Primary Dealers (SPD), and the Survey of Professional Forecasters (SPF). NT refers to horizons of two years or less while LT refers to horizons including more than two years in the future. For ongoing surveys, the reported frequency of questions pertaining to longer-term forecasts refer to the current scheduled frequency. Forecasts for output growth (R GDP) are based on real GNP growth prior to 1992 and real GDP growth after. M3 and M12 signify forecasts of 3-months and 12-months ahead, respectively. Entries of the form Q0-Q6 imply that horizons Q1, Q2, ..., Q6 are available; all other notation is defined in Section 2.

<table>
<thead>
<tr>
<th>Survey Sample (full)</th>
<th>BCFF</th>
<th>BCEI</th>
<th>CE</th>
<th>DMP</th>
<th>EF</th>
<th>GN</th>
<th>Liv.</th>
<th>SPD</th>
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<td>Monthly</td>
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<td>8 per year</td>
<td>Quarterly</td>
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<tr>
<td><strong>R GDP:</strong></td>
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<td>1978-present</td>
<td>1989-present</td>
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<td>1989-present</td>
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<td>Quarterly</td>
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<td><strong>R GDP:</strong></td>
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<td>2012-present</td>
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<td>1991-present</td>
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<th>SPF</th>
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<td>Q1-2, Q3-4, Y2, Y0-9</td>
<td>Q0-Q2, Y1, Y2</td>
<td>Q0-Q4, Y2, Y0-9</td>
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<td>Q0-Q6, Y2</td>
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<td>Q2-Q8, Y1, Y2</td>
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<td>M3</td>
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<td><strong>R GDP:</strong></td>
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<td>Y3, Y4, Y5, Y6, Y1-10, Y7-11</td>
<td>Y3-Y10</td>
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<td>Y0-9</td>
<td>Y3, LR</td>
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<td>n/a</td>
<td>Y0-9</td>
<td>Y5-10</td>
<td>Y0-4, Y0-9</td>
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<tr>
<td><strong>TBILL:</strong></td>
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<td>Y3-Y10</td>
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<td>Y3, Y0-9</td>
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Table 2: Variance Decompositions for Yield Components: Full Sample

This table presents variance decompositions for the one-year yield and one-year forward rates ranging from one though ten-years out. For each maturity, the numbers shown represent the ratio of the covariance of the respective forward with its individual components (average expected real short rate, average expected inflation, and term premium) divided by the variance of the forward. The top panel provides variance decompositions for forward rates in levels, and the bottom panel for the first difference of the forward rates. The sample period is March 1983-September 2016.

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<td>0.43</td>
<td>0.29</td>
<td>0.20</td>
<td>0.15</td>
<td>0.12</td>
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<td>0.34</td>
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<td>0.07</td>
<td>0.03</td>
<td>0.01</td>
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<td>Avg Exp Inflation</td>
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<td>0.07</td>
<td>0.06</td>
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<td>0.05</td>
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<tr>
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<td>Avg Exp Real Rate</td>
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<td>0.17</td>
<td>0.16</td>
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<td>0.12</td>
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<tr>
<td>Fwd Term Premium</td>
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<td>0.34</td>
<td>0.57</td>
<td>0.75</td>
<td>0.87</td>
<td>0.92</td>
<td>0.95</td>
<td>0.96</td>
<td>0.97</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Table 3: Variance Decompositions for Yield Components: Pre-Crisis Sample

This table presents variance decompositions for the one-year yield and one-year forward rates ranging from one though ten-years out. For each maturity, the numbers shown represent the ratio of the covariance of the respective forward with its individual components (average expected real short rate, average expected inflation, and term premium) divided by the variance of the forward. The top panel provides variance decompositions for forward rates in levels, and the bottom panel for the first difference of the forward rates. The sample period is March 1983-December 2007.

<table>
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<tr>
<td>Fwd Term Premium</td>
<td>0.17</td>
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<td>0.97</td>
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Table 4: Predictive Regressions for RGDP Growth

This table presents results for predictive regressions from equation (5.1) with dependent variable quarter-over-quarter annualized real gross domestic product (RGDP) growth. Each column denotes the forecast horizon in quarters. The term spread is the 10-year yield less the three-month Treasury bill and the expected term spread is the expected average path of short-term rates less the three-month Treasury bill. Newey-West standard errors using 12 lags are reported in parantheses. The top panel provides results for the sample March 1983–September 2016 and the bottom panel for the March 1983–December 2007 sample.

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<td>0.228</td>
<td>0.299</td>
<td>0.397</td>
<td>0.480*</td>
<td>0.522</td>
<td>0.609*</td>
<td>0.537</td>
<td>0.509</td>
<td>0.383</td>
<td>0.223</td>
<td>0.155</td>
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<tr>
<td></td>
<td>(0.230)</td>
<td>(0.211)</td>
<td>(0.223)</td>
<td>(0.248)</td>
<td>(0.285)</td>
<td>(0.326)</td>
<td>(0.354)</td>
<td>(0.360)</td>
<td>(0.334)</td>
<td>(0.322)</td>
<td>(0.313)</td>
<td>(0.304)</td>
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<tr>
<td><strong>R^2</strong></td>
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<td>0.011</td>
<td>0.019</td>
<td>0.035</td>
<td>0.053</td>
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<td>(0.220)</td>
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<td>0.773***</td>
<td>0.808***</td>
<td>0.788**</td>
<td>0.835**</td>
<td>0.766*</td>
<td>0.783**</td>
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<td>(0.248)</td>
<td>(0.231)</td>
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<td>(0.162)</td>
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<td>0.416**</td>
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<td>0.020</td>
<td>0.007</td>
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Figure 1: Examples of Fitted Values

These figures show model-implied forecasts (grey) against observed survey data. Q3 forecasts for CPI are used so as to include the Q3-4 Livingston Survey forecast. “Long-run” denotes assorted longer-run forecasts out to a maximum of 11 years.
Figure 2: Nominal and Real Expected Path of Short-Term Interest Rates

These figures show the evolution of the secondary market 3-month Treasury bill available from the H.15 release of the Federal Reserve Board, underlying inflation as measured by $\pi_t$ discussed in Section 3, and the ex-ante real short-term interest rate, measured as the difference between the secondary market 3-month Treasury bill rate and one-month ahead expected inflation $E_t[\pi_{t+1}]$, as discussed in Section 3. The grey lines represent the term-structure of forecasts for the corresponding series at that point in time out ten years. The sample period is March 1983–September 2016.
Figure 3: Long-Run Expected Real Rates and Real GDP Growth

These figures show the evolution of long-run expectations for the real short-term interest rate (top chart) and real GDP growth (bottom chart). Each chart also plots the estimated natural rate of interest, $r^*_t$, and trend growth rate from the model of Laubach and Williams (2003). The sample period is 1983Q1–2016Q3.
Figure 4: Expected Real Rates and Expected Inflation

These figures show the evolution of the ex-ante real short-term interest rate and expected inflation. Expected inflation is measured as the one-month ahead forecast, $E_t[\pi_{t+1}]$, as discussed in Section 3 and the real short-term interest rate is the difference between the secondary market 3-month Treasury bill rate from the H.15 release of the Federal Reserve Board and expected inflation. The bottom row shows the corresponding scatterplot to the time-series plot in the left row.
Figure 5: The Components of Treasury Yields

These figures show the decomposition of Treasury (forward) yields into the expected path of short-term (forward) real interest rates, expected (forward) inflation and the (forward) nominal term premium as discussed in Section 4. Treasury (forward) yields are (based on) the zero coupon bond yields from the Gurkaynak et al. (2007) dataset available on the Board of Governors of the Federal Reserve’s research data page. The sample period is March 1983–September 2016.
Figure 6: Term Structures of Expectations and Forwards

These figures show different aspects of the term structure of various second moments of forward expectations and forward rates. The top left panel displays the relative standard deviation of changes in expectations compared to changes in forward rates by forward maturity. The top right panel shows the correlation coefficient between changes in expectations compared to changes in forward rates by forward maturity. The bottom left panel shows the “beta” between changes in expectations and changes in forward rates by forward maturity (i.e., the covariance divided by the variance of changes in forward rates). Finally, the bottom right panel shows the correlation coefficient between changes in expectations compared to changes in forward term premiums by forward maturity. The black solid line denotes 1-month changes whereas the dotted line denotes 12-month changes.
Figure 7: Co-Movement of Expected Rates and Term Premiums

These figures show 12-month changes in the expected path of forward short-term nominal interest rates (top chart) and the forward term premium (bottom chart) as discussed in Section 4. Treasury (forward) yields are (based on) the zero coupon bond yields from the Gurkaynak et al. (2007) dataset available on the Board of Governors of the Federal Reserve’s research data page. The sample period is March 1983–September 2016.
Figure 8: Impulse Response of Yield Decompositions: Policy Shocks

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.

**Kuttner (2001):** 1988m11–2007m12

- Expected Rates (1Y1Y)
- Expected Rates (4Y1Y)
- Term Premium (1Y1Y)
- Term Premium (4Y1Y)

**Mertens and Ravn (2012):** 1983Q1–2006Q4

- Expected Rates (1Y1Y)
- Expected Rates (4Y1Y)
- Term Premium (1Y1Y)
- Term Premium (4Y1Y)
Figure 9: Impulse Response of Yield Decompositions: Demand Shocks

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.

**Gilchrist and Zakrajšek (2012):** 1983Q1–2010Q3

- Expected Rates (1Y1Y)
- Expected Rates (4Y1Y)
- Term Premium (1Y1Y)
- Term Premium (4Y1Y)

**Del Negro et al. (2013):** 1983Q1–2014Q4

- Expected Rates (1Y1Y)
- Expected Rates (4Y1Y)
- Term Premium (1Y1Y)
- Term Premium (4Y1Y)
Figure 10: Impulse Response of Yield Decompositions: Demand Shocks

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.

Jo and Sekkel (2016): 1983Q1–2014Q4

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Figure 11: Impulse Response of Yield Decompositions: Supply Shocks

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.

- **Kilian (2008):** 1983Q1–2004Q3
- **Hamilton (2003):** 1983Q1–2007Q1
- **Barsky and Sims (2011):** 1983Q1–2007Q3
Figure 12: Expected Path of Short-Term Interest Rates

These figures show the survey-based rate expectations component of forward yields as discussed in Section 4 along with the corresponding measures based on two VAR specifications. The first (labeled “VAR”) uses only the level, slope, and curvature of the yield curve as variables, see Section 6.1. The second (labeled “Macro VAR”) augments this model with two additional series: (i) the 3-month moving average of the Chicago Fed National Activity Index obtained from the Federal Reserve Bank of Chicago’s economic data page; (ii) year-over-year core CPI inflation obtained from the Bureau of Labor Statistics. Treasury forward yields are based on the zero coupon bond yields from the Gurkaynak et al. (2007) dataset available on the Board of Governors of the Federal Reserve’s research data page. Model-based term premiums are shown for estimations using the full sample 1968–2016 (labelled “FS”) and the subsample 1990–2007 (labelled “SS”).
Figure 13: Term Premiums

These figures show the survey-based term premium component of forward yields as discussed in Section 4 along with the corresponding measures based on two VAR specifications. The first (labeled “VAR”) uses only the level, slope, and curvature of the yield curve as variables, see Section 6.1. The second (labeled “Macro VAR”) augments this model with two additional series: (i) the 3-month moving average of the Chicago Fed National Activity Index obtained from the Federal Reserve Bank of Chicago’s economic data page; (ii) year-over-year core CPI inflation obtained from the Bureau of Labor Statistics. Treasury forward yields are based on the zero coupon bond yields from the Gurkaynak et al. (2007) dataset available on the Board of Governors of the Federal Reserve’s research data page. Model-based term premiums are shown for estimations using the full sample 1968–2016 (labelled “FS”) and the subsample 1990–2007 (labelled “SS”).
These figures show scatterplots of the monthly change in expected future short rates and the change in the forward term premium for selected maturities. The sample period is July 1990-September 2016.
Supplementary Appendix for “Term Structure of Expectations and Bond Yields”

Richard K. Crump, Stefano Eusepi & Emanuel Moench
Table 5: Estimated Parameters

This table provides the estimated parameters described in Section 3. The bottom panel gives the variance of the observation errors for each variable and horizon class. “VST” denotes very short term forecasts, “ST” denotes short term forecasts, “MT” denotes medium term forecasts, and “LT” denotes long term forecasts.

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<th>( \Sigma^\nu )</th>
<th>( \Sigma^\eta )</th>
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\[
\begin{bmatrix}
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0.0631 \\
0.0940 \\
0.0453
\end{bmatrix}
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0.0632 \\
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0.0223 \\
0.0774
\end{bmatrix}
\begin{bmatrix}
0.0785 \\
0.0278 \\
0.0646 \\
0.0678
\end{bmatrix}
\]
Figure 15: Decomposition of Forward Rates

These figures show the decomposition of forward yields into the expected path of forward short-term nominal interest rates and the forward term premium as discussed in Section 4 along with the corresponding measures based on the methods of Adrian et al. (2013) (ACM) and Kim and Wright (2005) (KW). The ACM and KW forward yield components are based on data obtained from the Federal Reserve Bank of New York’s data & indicators page and the Board of Governors of the Federal Reserve’s research data page, respectively. Treasury forward yields are based on the zero coupon bond yields from the Gurkaynak et al. (2007) dataset available on the Board of Governors of the Federal Reserve’s research data page.
These figures show the nominal and real forward term premiums as discussed in Section 4. Nominal and real Treasury forward yields are based on the zero coupon bond yields from the Gurkaynak et al. (2007) and Gurkaynak et al. (2010) datasets available on the Board of Governors of the Federal Reserve's research data page.
These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.

**Kuttner (2001):** 1988m11-2007m12

**Gürkaynak et al. (2005b):** Target Shock, 1990m2-2004m12
Figure 18: Impulse Response of Yield Decompositions

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.

Gürkaynak et al. (2005b): Path Shock, 1990m2-2004m12

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Romer and Romer (2010): 1983Q1-2007Q4

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Figure 19: **Impulse Response of Yield Decompositions**

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.

**Mertens and Ravn (2012):** 1983Q1–2006Q4

**Ramey (2011):** 1983Q1–2010Q4
Figure 20: Impulse Response of Yield Decompositions

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.


Del Negro et al. (2013): 1983Q1–2014Q4
Figure 21: Impulse Response of Yield Decompositions

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.

Jo and Sekkel (2016): 1983Q1-2014Q4

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Figure 22: Impulse Response of Yield Decompositions

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.


These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.


Figure 24: Impulse Response of Yield Decompositions (Pre-Crisis)

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.


Gilchrist and Zakrjšek (2012): 1983Q3-2007Q4
Figure 25: **Impulse Response of Yield Decompositions (Pre-Crisis)**

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.

**Del Negro et al. (2013):** 1983Q1–2007Q4

**Jo and Sekkel (2016):** 1983Q1–2007Q4
Figure 26: Impulse Response of Yield Decompositions (Pre-Crisis)

These figures show impulse response functions based on equation (5.2) corresponding to individual macroeconomic shocks. The black line represents the median response across simulations whereas the green shaded regions represent 68%, 90%, and 95% nominal coverage rates. All results are based on 10,000 simulations.

Table 6: Changes in Yield Decompositions and Policy Shocks

This table displays results from regressions of the change in the yield decomposition variable on the candidate policy shock. The shock series from Kuttner (2001) and Gürlaynak et al. (2005a) have a sample period of 1988m11-2007m12 and 1990m2-2004m12, respectively. OLS standard errors are shown in parantheses. *** ** and * denote significance at the 1%, 5%, and 10% levels, respectively. All regressions include a constant term.

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Table 7: Changes in Yield Decompositions and Policy Shocks (cont’d)

This table displays results from regressions of the change in the yield decomposition variable on the candidate policy shock. The shock series from Mertens and Ravn (2012), Romer and Romer (2010) and Ramey (2011) are restricted to a sample period of 1983Q1-2006Q4, 1983Q1-2007Q4 and 1983Q1-2010Q4, respectively. OLS standard errors are shown in parentheses. *** ** and * denote significance at the 1%, 5%, and 10% levels, respectively. All regressions include a constant term.

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<th>∆9Y1Y Exp Rates</th>
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<td>-0.014 (0.032)</td>
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<th>∆9Y1Y Term Prem</th>
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<td>0.024 (0.026)</td>
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<th>∆9Y1Y Term Prem</th>
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<td>0.009 (0.022)</td>
<td>0.002 (0.022)</td>
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<th>∆71Y1Y Term Prem</th>
<th>∆9Y1Y Term Prem</th>
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<th>∆9Y1Y Term Prem</th>
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<tbody>
<tr>
<td>Mertens-Ravn (2012)</td>
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<td>0.040 (0.052)</td>
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<td>0.027 (0.048)</td>
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<td>112</td>
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<td>0.005 0.005 0.005 0.003</td>
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15
Table 8: Changes in Yield Decompositions and Demand Shocks

This table displays results from regressions of the change in the yield decomposition variable on the candidate demand shock. The shock series from Gilchrist and Zakrajšek (2012), Del Negro et al. (2013) and Jo and Sekkel (2016) are restricted to a sample period of 1983Q1-2010Q3, 1983Q1-2014Q4 and 1983Q1-2014Q4, respectively. OLS standard errors are shown in parentheses. *** ** and * denote significance at the 1%, 5%, and 10% levels, respectively. All regressions include a constant term.

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<th>(\Delta 71Y1Y) Exp Rates</th>
<th>(\Delta 9Y1Y) Exp Rates</th>
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<td>Gilchrist-Zakrajšek (2012)</td>
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<td>0.003</td>
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16
Table 9: Changes in Yield Decompositions and Supply Shocks

This table displays results from regressions of the change in the yield decomposition variable on the candidate demand shock. The shock series from Kilian (2008), Hamilton (2003), Barsky and Sims (2011) and Galí (1999) are restricted to a sample period of 1983Q1-2004Q3, 1983Q1-2007Q4, 1983Q1-2007Q3 and 1983Q1-2007Q3, respectively. OLS standard errors are shown in parentheses. *** ** and * denote significance at the 1%, 5%, and 10% levels, respectively. All regressions include a constant term.

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</table>
Figure 27: Fitted Survey Data  
Series 1–20

These figures show the survey data (yellow and blue) and the model-implied fitted survey data (orange). BCFF designates the Blue Chip Financial Forecasts survey; BCEI, the Blue Chip Economic Indicators survey; CE, the Consensus Economics survey; DMP, the Decision Maker’s Poll; EF, Economic Forecasts: A Worldwide Survey; Liv, the Livingston Survey; SPD, the Survey of Primary Dealers; and SPF, the Survey of Professional Forecasters.
Figure 28: Fitted Survey Data

Series 21-40

Fitted Survey Data

Series 21-40
Figure 29: Fitted Survey Data
Series 41–60
Figure 30: **Fitted Survey Data**
*Series 61–80*

![Fitted Survey Data Series 61–80](image-url)
Figure 31: Fitted Survey Data
Series 81–100
Figure 32: Fitted Survey Data
Series 101–120
Figure 33: Fitted Survey Data
Series 121–140


CE GDP: Y5
Fourth month of year

BCFF GDP: Y5
Fifth month of year

CE GDP: Y5
Seventh month of year

BCFF GDP: Y5
Ninth month of year

BCEI GDP: Y5
Tenth month of year

CE GDP: Y6
Eleventh month of year

BCFF GDP: Y6
Eleventh month of year

BCEI GDP: Y5
Third month of year

CE GDP: Y5
Fourth month of year

BCFF GDP: Y5
Fifth month of year

CE GDP: Y6
Seventh month of year

BCFF GDP: Y5
Ninth month of year

BCEI GDP: Y6
Tenth month of year

CE GDP: Y7
First month of year

CE GDP: Y7
Fourth month of year

CE GDP: Y7
Seventh month of year

CE GDP: Y7
Tenth month of year

24
Figure 34: **Fitted Survey Data**

*Series 141–160*

![Fitted Survey Data Diagram](image-url)
Figure 35: **Fitted Survey Data**  
*Series 161–180*
Figure 36: Fitted Survey Data
Series 181–200
Figure 37: **Fitted Survey Data**

*Series 201-220*

[Series of graphs showing fitted survey data for different months and years.]
Figure 38: Fitted Survey Data
Series 221-240
Figure 39: Fitted Survey Data
Series 241-260
Figure 40: Fitted Survey Data
Series 261–280
Figure 41: Fitted Survey Data
Series 281–300
Figure 42: Fitted Survey Data
Series 301–320
Figure 43: Fitted Survey Data
Series 321–340

Fitted Survey Data
Series 321–340
Figure 44: Fitted Survey Data
Series 341–360
Figure 45: Fitted Survey Data
Series 361–380
Figure 46: Fitted Survey Data
Series 381–400

CE  TBILL: 3 Months Ahead
Second month of quarter

Liv CPI: Y0-Y9
Eleventh month of year

SPF CPI: Y0-Y9
Sixth month of year

DMP CPI: Y0-Y9
Twelfth month of year

Liv CPI: Y0-Y9
Ninth month of year

SPF CPI: Y0-Y9
Fourth month of year

Fitted Survey Data

Liv CPI: Y0-Y9
Tenth month of year

Liv CPI: Y0-Y9
Eleventh month of year

Liv CPI: Y0-Y9
Seventh month of year

Liv CPI: Y0-Y9
Fifth month of year

Liv CPI: Q1
First month of quarter

BCFF TBILL: Q1
First month of quarter

BCFF TBILL: Q1
First month of quarter

CE TBILL: Q1
First month of quarter

CE TBILL: 12 Months Ahead
Twelfth month of year

CE TBILL: 12 Months Ahead
Twelfth month of year

CE TBILL: 3 Months Ahead
Twelfth month of year

CE TBILL: 3 Months Ahead
Twelfth month of year
Figure 47: Fitted Survey Data

Series 401-420
Figure 48: Fitted Survey Data
Series 421-440
Figure 49: Fitted Survey Data
Series 441-460
Figure 50: Fitted Survey Data
Series 461–480
Figure 51: Fitted Survey Data
Series 481–500
Figure 52: Fitted Survey Data
Series 501–520
Figure 53: Fitted Survey Data  
Series 521-540

Series 521540
Figure 54: Fitted Survey Data  
Series 541–560
Figure 55: Fitted Survey Data
Series 581–580

CE TBILL: Y2
Seventh month of year

CE TBILL: Y2
Tenth month of year

CE TBILL: Y3
First month of year

CE TBILL: Y3
Fourth month of year

CE TBILL: Y3
Seventh month of year

CE TBILL: Y3
Tenth month of year

CE TBILL: Y4
First month of year

CE TBILL: Y4
Fourth month of year

CE TBILL: Y4
Seventh month of year

CE TBILL: Y4
Tenth month of year

CE TBILL: Y5
First month of year

CE TBILL: Y5
Fourth month of year

CE TBILL: Y5
Seventh month of year

CE TBILL: Y5
Tenth month of year

CE TBILL: Y6
First month of year

CE TBILL: Y6
Fourth month of year

CE TBILL: Y6
Seventh month of year

CE TBILL: Y6
Tenth month of year

CE TBILL: Y7
First month of year

CE TBILL: Y7
Fourth month of year

CE TBILL: Y7
Seventh month of year

CE TBILL: Y7
Tenth month of year
Figure 56: Fitted Survey Data
Series 581–602