The Term Structure of Expectations and Bond Yields*

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Abstract

Bond yields can be decomposed into expected short rates and term premiums. We directly measure the former using all available U.S. professional forecasts and obtain the latter as the difference between bond yields and survey-based expected short rates. While the behavior of nominal and real short rate expectations is consistent with standard macroeconomic theory, term premiums account for the bulk of the cross-sectional and time series variation in yields. They also largely explain the yield curve's reaction to a host of structural economic shocks. This dramatic failure of the expectations hypothesis highlights the importance of term premiums for macro-financial transmission.

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

JEL Classification: D84, E44, G12

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1 Introduction

The expectations hypothesis, stating that yields on government bonds reflect the average short rate that investors expect to prevail over the life of the bond, is a fundamental building block of economic theory, with key implications for the study of business cycle fluctuations, asset pricing and for policy design (see, e.g., Woodford (2003), Smets and Wouters (2007)). Yet, a large body of work in finance, starting with Fama and Bliss (1987) and Campbell and Shiller (1991), has challenged its empirical validity: it is now widely accepted that bond yields can be decomposed into investors' expectations about future short rates as well as a time-varying term premium, suggesting an additional and potentially important alternative economic transmission mechanism operating via the term structure of interest rates.

The challenge with identifying the channels through which the macroeconomy and the yield curve interact is that the two components of bond yields are commonly treated as *unobserved*. No-arbitrage term structure models are typically used to characterize the joint evolution of bond yields and decompose them into expected short rates and term premiums (see Piazzesi (2003) for a survey). Within this class of models, a wide range of empirical specifications has been applied, sometimes leading to starkly different decompositions of bond yields. While some authors (e.g. Haubrich et al. (2012), Bauer et al. (2012)) argue that term premiums move little and expectations explain the bulk of variation in longer-term yields, others document an important role for term premiums (see e.g. Wright (2013), Adrian et al. (2013) and Joslin et al. (2014)). No consensus has yet emerged as to what is driving the yield curve and how it responds to policy changes and, more generally, aggregate shocks driving the business cycle.

In this paper, we take a different approach. Starting from the original identity by which the term premium of an n-maturity bond is defined as

$$\begin{aligned} \textit{term premium} \;&=\; \textit{yield on an } n\textit{-maturity bond} \\ &\qquad\qquad - \textit{expected average path of short rates over } n \textit{ periods}, \end{aligned}$$

we directly measure the expected path of short rates using a unique dataset that covers all surveys of professional forecasters in the U.S. Our identification relies on the common assumption of a 'representative market participant'; but instead of using a statistical model to infer expectations, we obtain the consensus market expectation directly from professional forecasters. This novel approach minimizes the impact of model-specific assumptions on identifying the components of the yield curve. It does not require choosing a particular stochastic discount factor, making distributional assumptions for yields, or making assumptions about the number and nature of the factors driving the term structure. An additional advantage of our approach is to provide real time measures of the expected path of future policy rates and term premiums which, by construction, are consistent with the perceived lower bound on policy rates.[1] Since we also observe forecasters' expectations about future inflation, we can directly measure the path of expected real short rates as well. Importantly, no assumptions are required about the rationality of survey-based short rate expectations, allowing us to evaluate the expectations hypothesis separately from the assumption of rational expectations.[2] Finally, it is important to emphasize that since 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.

Our analysis focuses on the sample 1983–2016 for which a wealth of survey information especially at longer forecast horizons is available. Specifically, we obtain measures of nominal and real short-rate expectations by combining all available surveys of professional forecasts of the 3-month Treasury bill rate, CPI inflation, and real GDP growth corresponding to over 600 survey-horizon pairs at a monthly frequency. Despite the comprehensive coverage of survey data, not all forecast horizons are observed in each month while in some months the same forecast horizon is available for different surveys. We show that a parsimonious monthly vector autoregression (VAR) with time-varying long-run means approximates the multivariate term structure of professional forecasts very well. It provides a simple and transparent method to extract the common information across surveys as well as consistent proxies for missing observations.[3] With the survey-implied expected short rates at hand, we document five key facts about the term structure of interest rates:

Fact 1. The term structure of short-rate expectations behaves in accordance with standard monetary theory.[4] Expected real short rates closely track expected nominal short rates, consistent with a strong degree of perceived nominal rigidities. 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 co-move with expected inflation, consistent

[1] Surveys do not get revised and reflect the information set available to investors at each point in time.

[2] This is not true for common regression-based tests of the expectations hypothesis, see Friedman (1979). Bacchetta et al. (2009) and Cieslak (2017) argue that some of the predictability of bond returns can be accounted for by predictable variation in return or short rate forecast errors.

[3] Our model can be thought of as a multivariate extension of the model of Kozicki and Tinsley (2012) who use it to fit the term structure of CPI inflation expectations obtained from a single survey.

[4] See, for example, Clarida et al. (2000) and Woodford (2003).

with the 'Taylor Principle', and with real rates multiple years out, in line with systematic monetary policy managing expectations.

Fact 2. Interest rate expectations display substantial volatility at all forecast horizons including the medium to long-term, suggesting market participants frequently revise their views about the long-run mean of inflation and the long-run equilibrium or 'natural rate' of interest. This finding challenges the assumption, often made in macroeconomics and finance, that interest rate expectations converge to a time-invariant mean.[5] Relative to the standard deviation of changes in nominal forward rates, changes in short-rate expectations are around 70% as volatile at the one-year horizon and remain about 40% as volatile at forward horizons beyond three years.

Fact 3. In terms of unconditional volatility, the expectations hypothesis fails dramatically at explaining the behavior of bond yields. Even though expected nominal and real short-term rates vary considerably over time, their contribution to the variation in bond yields *is close to negligible at all but short-term maturities.* Surprisingly, this is due to the fact that short rate expectations display low correlation with yields themselves at medium to longer maturities. While expected rates remain a key determinant of forward rates at the one year horizon, the relative importance of the term premium for interest rate variation rises rapidly along the maturity spectrum. Beyond the three year maturity, term premiums are the main driver of bond yields.

Fact 4. Term premiums 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 based on predictive regressions of excess bond returns on past forward rates.[6] This result is striking as we obtain term premiums solely from observed yields and observed short rate expectations and do not impose any distributional assumptions or data generating process.

Fact 5. The expectations hypothesis remains a poor representation of bond yields also in a conditional sense. We measure the on impact responses of the term structure of interest rates to different monetary, fiscal, "demand" and "supply" shocks that have been identified in

[5]This finding also contrasts with common macroeconomic models where agents have perfect information about a time-invariant steady state and are more in line with models that involve shifting-end points such as Kozicki and Tinsley (2001), or models with learning such as Eusepi and Preston (2016). See also Gürkaynak et al. (2005b).

[6]Cochrane (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.

the macroeconomic literature. With the exception of monetary shocks which strongly move expected rates out several years, the response of medium and longer maturity yields to any other macroeconomic shock is primarily driven by their term premium components.

Taken together, these facts give rise to two broad conclusions. On the one hand, the behavior of nominal and real short rate expectations is consistent with the predictions of standard macroeconomic models, in terms of both its unconditional behavior and its conditional response to monetary policy shocks. On the other hand, the prominent role of term premiums in explaining the dynamics of interest rates and their significant reaction to a host of structural economic shocks highlights the need to incorporate this commonly omitted component in macroeconomic models.

A few previous studies have used survey forecasts of nominal short rates or inflation in the estimation of no-arbitrage term structure models. While Kim and Wright (2005) and Kim and Orphanides (2012) employ survey forecasts of the nominal short rate at a few select horizons to discipline the estimates governing the physical dynamics of the state variables in small samples, Piazzesi et al. (2015) combine survey forecasts of the short rate, inflation, and of longer-term Treasuries with the aim of distinguishing between subjective (i.e. survey forecasters') beliefs and objective beliefs (i.e. those of a statistician endowed with full-sample information). Several important features distinguish our analysis from these studies. First, they use a small number of state variables to fit both short rate expectations and bond yields and give rise to substantial deviations of model-implied short rate expectations from observed short rate expectations. Second, these studies make distributional assumptions about yields and term premiums which we explicitly avoid. Third, they assume a stationary VAR to govern the dynamics of short rates and term premiums.[7]

The paper proceeds as follows. Section 2 presents the data while Section 3 introduces the model used to extract the consensus term structures of survey expectations and discusses the properties of these 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 studies the response of these components to macroeconomic shocks. Section 6 concludes. The Appendix includes further details about the survey data while a Supplementary Appendix provides additional results.

[7] In the Supplementary Appendix we show that the implications for the behavior of expected rates and term premiums are very different in these models. Moreover, specific parametric assumptions appear to induce implausibly tight correlations between the term premium and expectations components of yields in some models.

2 Data

To measure the term structure of expectations 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) Goldsmith-Nagan (GN); (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 the CPI over alternative inflation measures such as the GDP deflator because 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]

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. While we provide more details about each individual survey in the Appendix, we emphasize here that the survey data differ in frequency, forecast timing, target series, sample availability and forecast horizons.

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 consistency between model-implied and observed forecasts with respect to variable definition and forecast horizon. See the Appendix for further details.

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

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 (RGDP) 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.

	BCFF	**BCEI**	**CE**	**DMP**	**EF**	**GN**	**Liv.**	**SPD**	**SPF**
Survey Sample (full)									
Frequency	*Monthly*	*Monthly*	*Monthly*	*Irregular*	*Monthly*	*Quarterly*	*Biannually*	*8 per year*	*Quarterly*
RGDP:	1984–present	1978–present	1989–present	n/a	1984–1995	n/a	1971–present	2011–present	1968–present
CPI:	1984–present	1980–present	1989–present	1978-1987	n/a	n/a	1946–present	2011–present	1981–present
TBILL:	1982–present	1982–present	1989–present	n/a	1984–1995	1969-1986	1992–present	n/a	1981–present
Survey Sample (LT)									
Frequency	*Biannually*	*Biannually*	*Quarterly*	*n/a*	*n/a*	*n/a*	*n/a*	*8 per year*	*Quarterly*
RGDP:	1984–present	1979–present	1989–present	n/a	n/a	n/a	1990–present	2012–present	1992–present
CPI:	1984–present	1984–present	1989–present	1978-1987	n/a	n/a	1990–present	2011–present	1991–present
TBILL:	1983–present	1983–present	1998–present	n/a	n/a	n/a	n/a	n/a	1992–Present
Horizons (NT)									
RGDP:	Q0-Q6, Y2 Y1-5, Y2-6	Q0-Q7, Y2, Y0-4, Y1-5, Y2-6, Y1-10	Q0-Q8, Y1, Y2	n/a	Q1-Q4	n/a	Q1-2, Q3-4, Y2, Y0-9	Q0-Q2, Y1, Y2	Q0-Q4, Y2, Y0-9
CPI:	Q0-Q6, Y2 Y1-5, Y2-6	Q1-Q7, Y2 Y1-5, Y2-6	Q2-Q8, Y1, Y2	Y1-10	n/a	n/a	Q3-4, Y2, Y0-9	n/a	Q2-Q4, Y1, Y2 Y0-4, Y0-9
TBILL:	Q0-Q6, Y1, Y2 Y1-5, Y2-6	Q1-Q7, Y1, Y2, Y1-5, Y2-6	M3, M12, Y1, Y2	n/a	Q1-Q4 Y0, Y1	M3	Q0, Q2, Q4, Y1, Y2	n/a	Q1-Q4, Y1, Y2, Y0-9
Horizons (LT)									
RGDP:	Y3, Y4, Y5, Y6 Y6-10, Y7-11	Y3, Y4, Y5, Y6, Y5-9, Y6-10, Y7-11	Y3-Y10	n/a	n/a	n/a	Y0-9	Y3, LR	Y3, Y0-9
CPI:	Y3, Y4, Y5, Y6 Y6-10, Y7-11	Y3, Y4, Y5, Y6, Y5-9, Y6-10, Y7-11	Y3-Y10	Y1-10	n/a	n/a	Y0-9	Y5-10	Y0-4, Y0-9
TBILL:	Y3, Y4, Y5, Y6 Y6-10, Y7-11	Y3, Y4, Y5, Y6, Y6-10, Y7-11	Y3-Y10	n/a	n/a	n/a	n/a	n/a	Y3, Y0-9

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, covering 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. More details about each survey are provided in the Appendix.

3 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. 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 overweighing 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 are able to extract the common information across different surveys in a coherent way and can provide consistent proxies for missing survey observations. 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. It is important to reiterate that our primary aim is not to model the law of motion for expectations but rather to interpolate and harmonize the survey data in a transparent manner. Moreover, we again emphasize that we do not require any assumptions of rationality of the forecasts.[9]

[9] 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. Ang et al. (2007) and Faust and Wright (2013), among others, document that professional forecasters' inflation predictions outperform those implied by a range of time series models. Similarly, Cieslak (2017) argues that professional forecasts of short-term interest rates are superior to those

To this end, let the true state of the macroeconomy be captured by the random vector $z_t = (g_t, \pi_t, i_t)'$ representing real output growth, g_t, inflation, π_t, and the short-term interest rate i_t. z_t evolves according to,

$$z_t - \bar{z}_t = x_t \tag{3.1}$$

$$x_t = \Phi x_{t-1} + \nu_t, \tag{3.2}$$

or alternatively,

$$z_t - \bar{z}_t = \Phi\left(z_{t-1} - \bar{z}_{t-1}\right) + \nu_t, \tag{3.3}$$

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

$$\begin{pmatrix} \bar{g}_t \\ \bar{\pi}_t \end{pmatrix} = \begin{pmatrix} \bar{g}_{t-1} \\ \bar{\pi}_{t-1} \end{pmatrix} + \eta_t, \tag{3.4}$$

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

$$\bar{i}_t = \psi \cdot \bar{g}_t + \bar{\pi}_t + \bar{\zeta}_t, \tag{3.5}$$

where $\bar{\zeta}_t$ is an independent random walk with innovation variance σ^2 which captures changes in household preferences and other determinants of $\bar{i}_t$. The parameter ψ 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.

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.[10] 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

implied by different statistical models.

[10]See, for example, Stock and Watson (1989), Laubach and Williams (2003), Cogley and Sargent (2005), Kozicki and Tinsley (2001, 2005, 2012), Gürkaynak et al. (2005b), and van Dijk et al. (2014).

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 long-run forecasts show substantial time variation.[11]

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,

$$\begin{pmatrix} y_t^A \\ y_t^S \end{pmatrix} = \begin{bmatrix} H_t^A \\ H_t^S \end{bmatrix} Z_t + \begin{pmatrix} \varepsilon_t^{y,A} \\ \varepsilon_t^{y,S} \end{pmatrix}, \qquad Z_t = F Z_{t-1} + V \varkappa_t \tag{3.6}$$

where $Z_t = (z_t, z_{t-1}, z_{t-2}, z_{t-3}, z_{t-4}, x_t, \bar{z}_t)'$ is the 21×1 state vector, $F = F(\Phi, \psi)$ is the 21×21 transition matrix and $V = V(\psi)$ is a 21×6 matrix which maps the innovations to x_t, $\bar{g}_t$, $\bar{\pi}_t$, and $\bar{\zeta}_t$, stacked in $\varkappa_t$, to the appropriate elements of the state vector, and $(\varepsilon_t^{y,A\prime}, \varepsilon_t^{y,S\prime})'$ are the stacked measurement errors. The presence of four lags in the state vector are essential for mapping monthly growth rates to quarterly growth rates.[12]

The first set of variables, 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). We assume that the true state of real output growth and inflation are measured with error whereas the TBILL is perfectly observed. Specifically, we assume $\varepsilon_t^{y,A} = (\varepsilon_t^{g,A}, \varepsilon_t^{\pi,A}, 0)'$ where $\varepsilon_t^{g,A}$ and $\varepsilon_t^{\pi,A}$ are mean-zero, *i.i.d.*, mutually independent Gaussian innovations. 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. It further accounts for the notion that forecasters aim to filter the underlying, persistent factors from the noisy data. This is consistent with the observation that, forecasts, even at very short horizons, are considerably less volatile than realized variables.

The second set of observable variables includes all survey forecast data discussed in Section 2 corresponding to the 602×1 vector y_t^S. We assume individual observation errors for each survey, stacked in $\varepsilon_t^{y,S}$, to be mean-zero, *i.i.d.*, mutually independent Gaussian innovations. To ensure a parsimonious model we impose equal variances for each target

[11] Andrade et al. (2016) show that a multivariate forecasting model with shifting endpoints of this kind is consistent with the empirical properties of forecaster disagreement.

[12] 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. 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.

variable at similar forecast horizons (but not by the specific survey). 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 construct the matrix H_t^S we match each observed survey forecast with the corresponding model implied forecast respecting the specific transformation (e.g., annual average growth) and the forecast horizon. H_t^S is then a nonlinear function of the parameters Φ and ψ (see the Appendix for examples).

The model is estimated at the monthly frequency for the sample starting in January 1955 and ending in September 2016 using maximum likelihood and the Kalman filter. Recall that the observation equation (shown in equation (3.6)) has time-varying coefficients to account for missing observations in actual and survey data. We fix the value of σ, the volatility of the innovation to $\bar{\zeta}_t$, because longer-run forecasts of short-term interest rates are available only at irregular frequencies.[13] While the estimated parameter values are provided 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: $\bar{i}_t = \bar{\pi}_t + 0.92 \cdot \bar{g}_t + \bar{\zeta}_t$. The coefficient on the long-run mean of output growth, which equals the inverse of the intertemporal elasticity of substitution parameter in dynamic optimization models, is modestly below 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 more than 600 forecast series. We document the fit of the model series by series in the Supplementary Appendix.

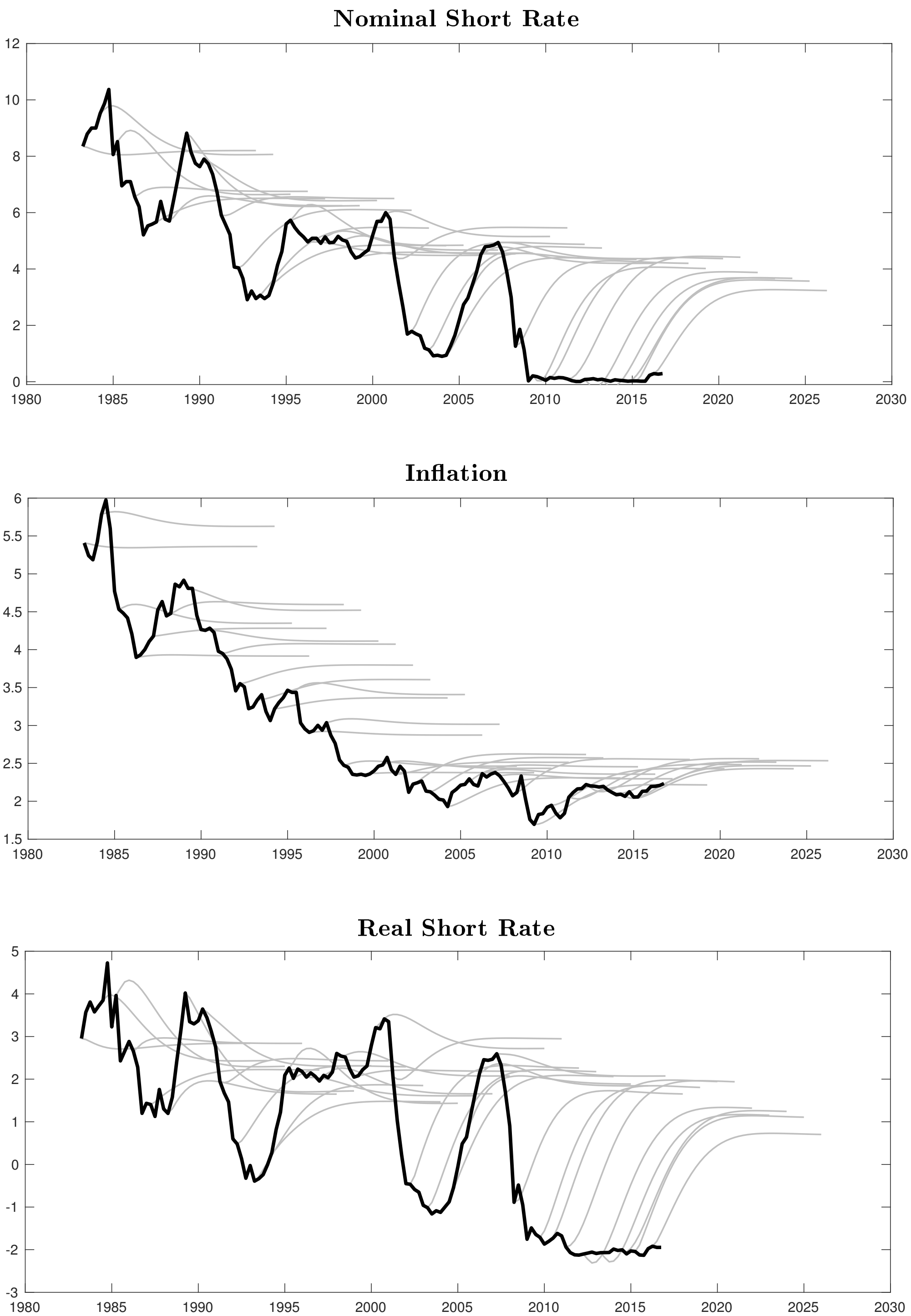
Properties of Expectations Our data allows us to study the expected paths of future nominal and real rates as well as inflation at any specific point in time.[14] Figure 1 displays a number of "hair charts" which are a convenient way to summarize the evolution of these expected paths over time. Specifically, in each chart the black solid lines show the actual nominal or real short-term rates and the persistent component of inflation, while the grey lines show the expected paths of the three variables over the next ten years once every twelve months.

[13] We set the value to $\sigma = 0.01$. This choice is motivated by two observations. First, the "longer-run" forecast for the Federal Funds Rate from the SPD, once first differenced, has a standard deviation of 0.05. Second, the bulk of the variation in $\bar{i}_t$ should come from long-run inflation and output. Note that our results are robust to other values of σ in this range.

[14] Since 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.

Figure 1: **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 π_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 $\mathbb{E}_t[\pi_{t+1}]$, 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.



The top panel of Figure 1 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 (and often inverting) at the end and steepening before the beginning of monetary tightening cycles, as professional forecasters respond to the predictable component of monetary policy.[15] For example, the term structure of short rate expectations inverts in the first quarter of 1989 when short rates reached their local peak leading into the 1990-91 recession. A flattening and slight inversion is also observed at the end of the 2004–2006 tightening cycle. After short rates reached the zero lower bound in 2008, the term structure steepened again as forecasters continued to expect an eventual lift-off. 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 therefore perceive the persistent component of inflation to approximately follow a random walk. An important implication is that movements in expected nominal short rates translate almost one to one to expected real short rates (bottom panel), consistent with nominal rigidities preventing prices from adjusting in the short term.

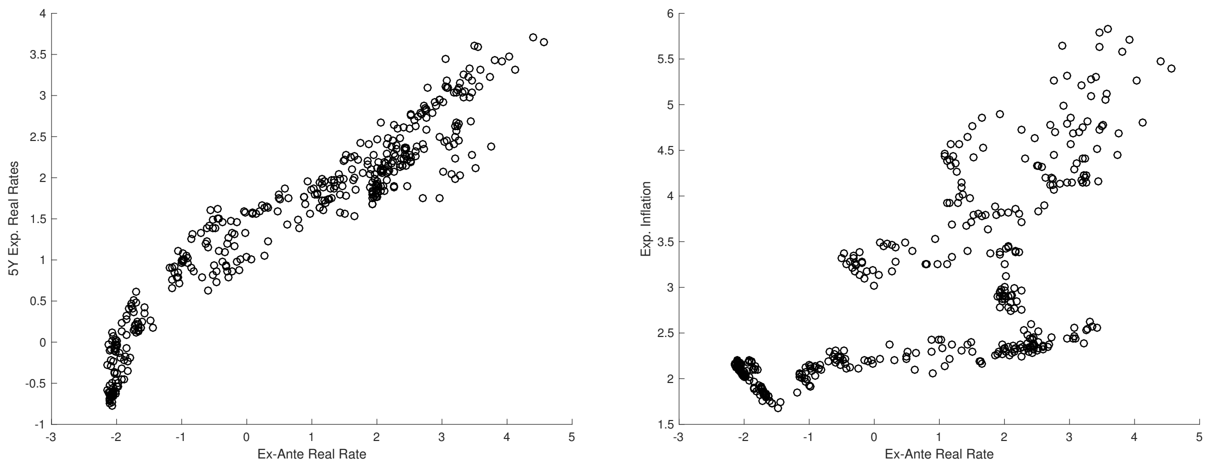
Monetary policy decisions, implemented through the nominal short rate, are transmitted through the entire term structure of expectations: as shown in the left column of Figure 2, there is substantial co-movement between the short term ex-ante real interest rate and the average expected real rate over the next five years. This is consistent with the standard monetary transmission mechanism, for example in the new Keynesian framework (Woodford (2003)). Central banks' commitment to a systematic monetary policy, often described by a policy rate or targeting rule, coupled with a high degree of transparency, is factored in market participants' expectations, providing the link between short-term interest rate changes and movements in medium-term rate 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 2, 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). In 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.

[15]As already noted before these measures of expectations based on survey forecasts, in contrast to many model-based expectations, are consistent with a (perceived) zero lower bound on nominal interest rates.

Figure 2: **Expected Real Rates and Expected Inflation**

These figures show the behavior of the ex-ante real short-term interest rate and expected inflation. Expected inflation is measured as the one-month ahead forecast, $\mathbb{E}_t[\pi_{t+1}]$, 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 corresponding time series plots are available in the Supplementary Appendix.



The expected ten-year paths of short rates and inflation shown in Figure 1 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 fallen from about eight percent in the mid 1980s to about 3.5 percent in 2016. Much of this decline is accounted for by a secular decline in the expected long-run level of inflation, which dropped from about six 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 2 percent over the thirty year period starting in 1983, but has begun to decline after 2011, falling below 1 percent by the end of 2014. This reduction of expected long-run real rates is consistent with recent evidence on the decline of the natural real rate of interest. In the Supplementary Appendix, we compare the survey-based long-run real rate expectations with those implied by the Laubach and Williams (2003) model.

4 What Drives Bond Yields?

Having studied the properties of forecasters' short rate expectations, we now analyze the quantitative importance of these expectations for the observed variation in Treasury yields. To this end, we decompose bond yields into two components: the consensus average expected short rate over the life of a bond, and a residual component which we label term premium. Let $y_t(n)$ be the continuously compounded yield on an n-month discount bond and i_t the risk-free nominal short rate at time t.[16] 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. For example, a 4Y1Y forward would set $n = 12$ and $m = 48$. We then define forward term premiums as the difference between $f_t(n,m)$ and the consensus expected short-term rate over the n months m months hence (i.e., a forward version of the identity introduced in the Introduction), which we can further decompose in the expected real short rate and expected inflation:

$$\begin{aligned} tp_t^{fwd}(n,m) &= f_t(n,m) - \frac{1}{n}\sum_{h=m+1}^{n+m} \mathbb{E}_t\left[i_{t+h}\right] \\ &= f_t(n,m) - \frac{1}{n}\sum_{h=m+1}^{n+m} \mathbb{E}_t\left[r_{t+h} + \pi_{t+h+1}\right]. \end{aligned}$$

In other words, the forward term premium is simply given by the difference between observed forwards and what would be the yield predicted by the (pure) expectations hypothesis, i.e. the average expected future short rate over the n months beginning in m months. 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.

[16] The Appendix provides further details on the relevant notation along with examples.

Figure 3: **The Components of Treasury Yields**

These figures show the decomposition of Treasury forwards into the expected short-term real interest rates, expected inflation and the nominal forward term premium as discussed in Section 4. Treasury forwards 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.

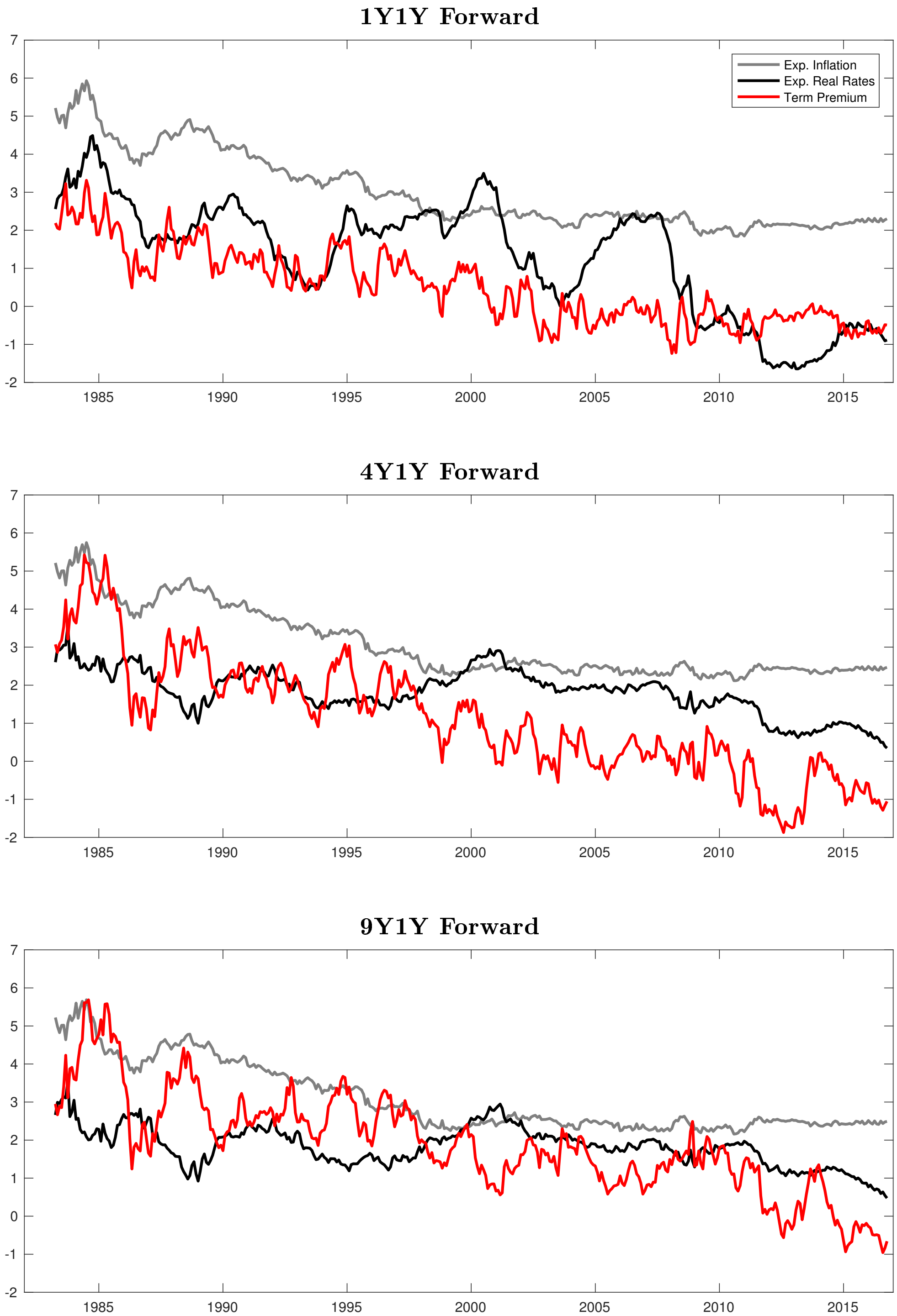


Figure 3 provides a decomposition of nominal Treasury forward rates into expected future real short rates, expected future inflation as well as the forward term premium for the sample from 1983 through 2016 for the 1Y1Y, 4Y1Y and 9Y1Y forward horizons (top, middle, and bottom panel, respectively). All three components of bond yields have contributed to the secular decline in Treasury yields observed over the past several decades, albeit with different timing. At the 1Y1Y horizon, the term premium declined from about 3 percent in the early 1980s and stabilized at about zero beginning in the early 2000s following a similar path as expected inflation. At longer maturities, forward term premiums display a similar pattern falling over the 1980s and 1990s and stabilizing in the 2000s. Since about 2010, however, longer-maturity forward term premiums again declined in parallel with a decline in the expected real short rate. Term premiums have remained at negative levels since 2010, except for a brief spike up around the "taper tantrum" episode of 2013. Overall, forward term premiums account for more than half of the secular decline in longer-maturity forwards. Our finding of a secular decline in term premiums is consistent with the evidence in Wright (2011) who uses an affine term structure model to show that term premiums in the U.S. and in other developed countries have experienced sizable and persistent declines between 1990 and mid-2009.[17]

Figure 3 shows that at higher frequencies, forward term premiums and expected real rates feature significant variability across all maturities. In contrast, expected inflation shows little variability beyond its underlying trend. We can make these informal observations more concrete via a variance decomposition of forward rates based on the following identity:

$$\mathcal{S}\left(n^{-1}\sum\nolimits_{h=m+1}^{n+m}\mathbb{E}_t\left[r_{t+h}\right]\right)+\mathcal{S}\left(n^{-1}\sum\nolimits_{h=m+1}^{n+m}\mathbb{E}_t\left[\pi_{t+h+1}\right]\right)+\mathcal{S}\left(tp_t^{fwd}(n,m)\right)=1$$

where

$$\mathcal{S}(x_t)=\frac{\mathbb{C}\left(f_t(n,m),x_t\right)}{\mathbb{V}(f_t(n,m))}$$

is defined as the ratio between the corresponding covariance ($\mathbb{C}$) and variance ($\mathbb{V}$). Table 2 provides variance decompositions for both the level (upper panel), as well as monthly (middle) and annual changes (lower panel) of the one-year yield and one-year forward rates from one through nine years out. These decompositions highlight the pivotal role of term premiums in accounting for yield variation. Expected real rates explain about 60% of the variance of the one-year yield while expected inflation and the term premium account for about 30% and 10%, respectively.

[17] While Bauer et al. (2014) argue that the model in Wright (2011) understates the persistence of expected short rates, Wright (2014) shows that the alternative estimates of Bauer et al. (2014) imply implausibly volatile short rate expectations.

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, the middle panel for the first difference of the forward rates, and the bottom panel for the twelve-month change in forward rates. The sample period is March 1983–September 2016.

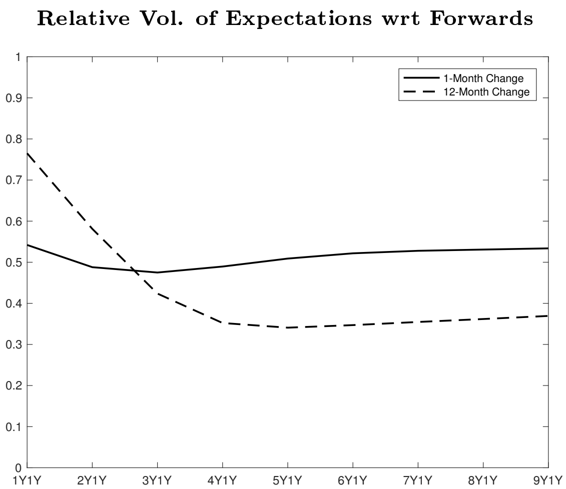
	Y1	1Y1Y	2Y1Y	3Y1Y	4Y1Y	5Y1Y	6Y1Y	7Y1Y	8Y1Y	9Y1Y
Levels										
Avg Exp Real Rate	0.58	0.43	0.29	0.20	0.15	0.12	0.11	0.11	0.12	0.12
Avg Exp Inflation	0.31	0.30	0.30	0.31	0.32	0.33	0.34	0.34	0.35	0.36
Fwd Term Premium	0.13	0.29	0.42	0.50	0.55	0.56	0.56	0.55	0.54	0.53
1-Month Changes										
Avg Exp Real Rate	0.49	0.18	0.07	0.03	0.01	0.01	0.01	0.00	0.00	-0.00
Avg Exp Inflation	0.11	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.06
Fwd Term Premium	0.41	0.75	0.88	0.92	0.94	0.94	0.94	0.94	0.94	0.94
12-Month Changes										
Avg Exp Real Rate	0.69	0.49	0.28	0.11	0.01	-0.04	-0.06	-0.08	-0.09	-0.10
Avg Exp Inflation	0.17	0.17	0.16	0.14	0.13	0.12	0.12	0.12	0.12	0.13
Fwd Term Premium	0.14	0.34	0.57	0.75	0.87	0.92	0.95	0.96	0.97	0.98

Expected real rates remain a meaningful driver of (the level of) forward rates up to three years out, 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 intermediate and 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 their 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% at the one-year forward horizon to over 90% at longer forward horizons. In contrast, expected real short rates only account for 18% 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.

Figure 4: **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 black solid line denotes 1-month changes whereas the dotted line denotes 12-month changes.



Given the considerable volatility of expected short rates, how can we explain the overwhelming role of term premiums in accounting for the variability of bond yields? Figure 4 sheds light on this question. The left-hand chart reiterates that nominal rate expectations are fairly volatile at all forecast horizons when compared to actual forward rates: their volatility ranges from 40% for 12-month changes to 50% for monthly changes at horizons beyond three years. However, the right-hand chart shows that changes in expectations co-move very little with changes in yields beyond short forecast horizons. Since the variance share of the yield components ($\mathcal{S}$) can be re-expressed in terms of variances and correlations

$$\mathcal{S}\left(x_t\right) = \text{Corr}\left(f_t(n,m), x_t\right) \cdot \left(\frac{\mathbb{V}(x_t)}{\mathbb{V}(f_t(n,m))}\right)^{1/2},$$

the low shares of variance explained by real rate and inflation expectations are thus due to the fact that expectations are only weakly correlated with forward yields. This is consistent with aggregate shocks affecting the components of the yield curve in different ways. Note that 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 the Supplementary Appendix, we repeat the variance decompositions ending the sample in 2007 and show that term premiums played an even larger role before the financial crisis.

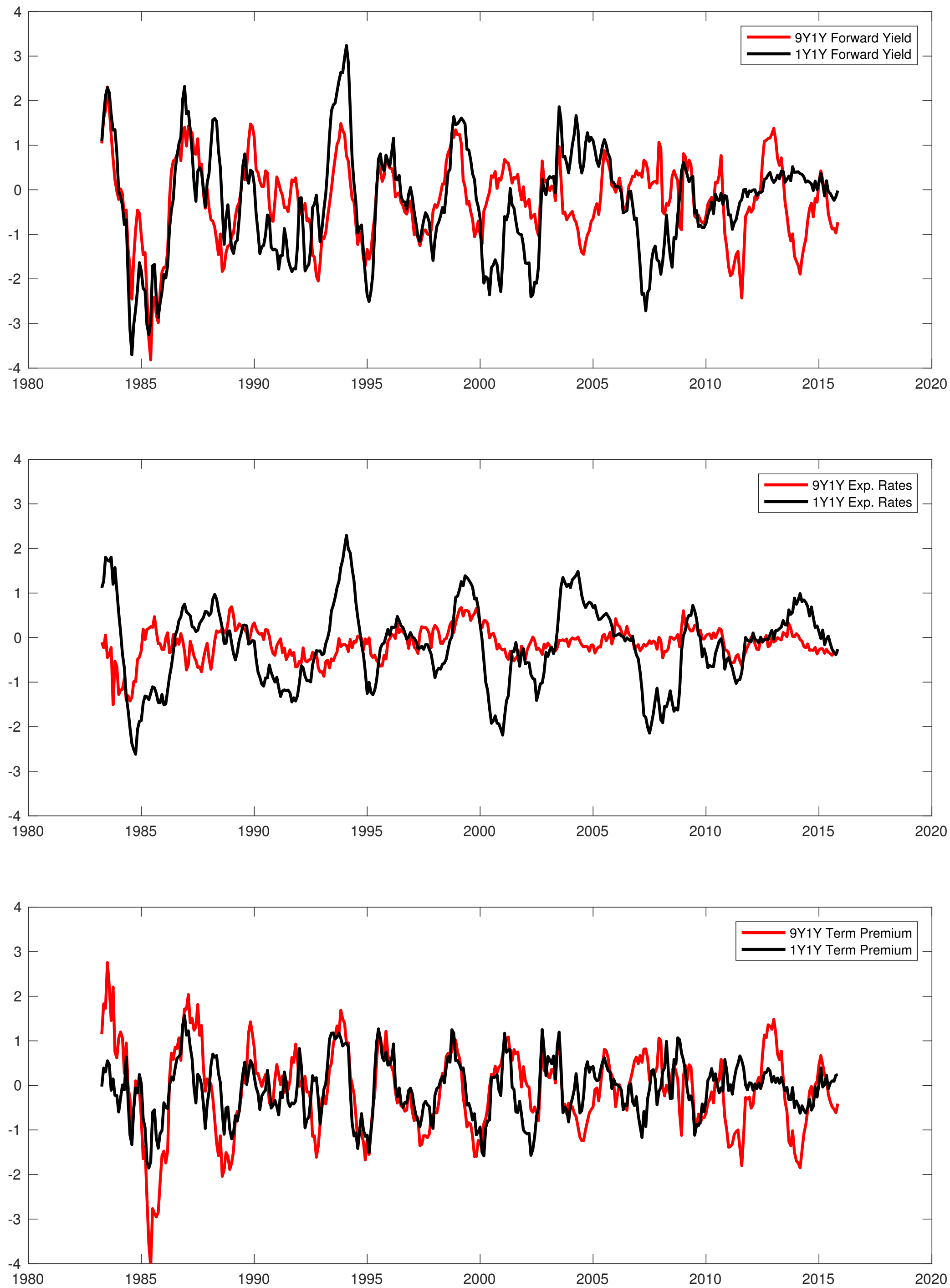
Why do Bond Yields Co-Move Across Maturities? A long literature in finance has documented that government bond yields feature substantial co-movement across maturities (e.g., Garbade 1996, Scheinkman and Litterman 1991). This is also true in the sample we consider: the first two principal components extracted from the ten maturities shown in Table 2 explain 97 and 3 percent of their joint variation. The loadings of these principal components confirm the common interpretation as level and slope of the yield curve. Based on our decomposition of forwards into expected short rate and term premium components, we can parse out the sources of the strong cross-sectional correlation. In line with the results in Table 2, almost half of the variance of the level factor is explained by term premiums, one third by expected inflation and the remaining 22 percent by expected real short rates. Also consistent with the variance decompositions for individual forwards, almost 90 percent of the month-to-month variation in the level factor and more than three quarters of the year-over-year variation are explained by term premiums. The expectations components are somewhat more important for the slope factor: 85 percent of its variation are accounted for by expected real short rates, about 10 percent by expected inflation and the remainder by term premiums. However, more than two thirds of the month-to-month variation of the slope factor are explained by term premiums, in line with the above finding that only a small share of the yield curve variation at higher frequencies is driven by expectations.

Figure 5 visualizes the importance of term premiums for the strong co-movement across maturities. It 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 1Y1Y and 9Y1Y forward 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. 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, at least until the mid to late 2000s.

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

Figure 5: **Co-Movement of Expected Rates and Term Premiums**

These figures show 12-month changes in forward rates (top chart), expected forward nominal short-term rates (middle chart) and the forward term premium (bottom chart) as discussed in Section 4. Treasury forwards 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.



In sum, the results of this section forcefully document that term premiums, not expected rates, explain the bulk of the time-series and cross-sectional variation of Treasury yields. Thus, the expectations hypothesis dramatically fails at explaining the behavior of interest rates.

5 Bond Yields and Macroeconomic Shocks

The results thus far demonstrate that in an *unconditional* sense, the expectations hypothesis is a poor description of the behavior of interest rates at most maturities. 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. These effects are not captured in most macroeconomic models assuming the expectations hypothesis as the prominent transmission mechanism of shocks through the term structure of interest rates.[18] While this result presents a challenge for these models, in certain circumstances the expectations hypothesis may hold at least approximately. In this section we utilize popular shocks from the macroeconomics literature to describe the *conditional* response of forward rates and their expectations and term premiums components. We measure the on impact effects of different shocks on interest rates by estimating a regression of the form,

$$\Delta x_t = a + b\epsilon_t + e_t, \tag{5.1}$$

where $x_t \in \left\{ f_t(n,m), n^{-1}\sum_{i=m+1}^{n+m} \mathbb{E}_t\left[r_{t+i}\right], tp_t^{fwd}(n,m)\right\}$: we fix $n = 12$ months, as we focus on yearly rates, and vary m to evaluate the response across forward maturities from one year to nine years.[19] The variable ϵ_t represents the different shock series that we consider. We group the shocks into three broad categories: monetary and fiscal shocks, "demand" shocks and "supply" shocks. In the second category, we consider both financial and uncertainty shocks which have "demand-like" features by inducing a positive co-movement between inflation and economic activity. In contrast, supply shocks are generally viewed as having opposite effects on inflation and output. Here we focus on oil price and TFP-news shocks.

Monetary Policy Shocks We utilize the monetary policy shocks of Nakamura and Steinsson (2017) who obtain monetary policy surprises at *scheduled* FOMC meetings as the 30-minute change in short-run market-based expectations measured by federal funds and eu-

[18] Given these models are log-linearized around their non-stochastic steady state, the expectations hypothesis is the only channel driving the yield curve.

[19] In the Supplementary Appendix we also show the response for the expected path of nominal short-rates, $x_t = \sum_{i=m+1}^{n+m} \mathbb{E}_t\left[i_{t+i+1}\right]$. These are generally almost identical to the ones for the expected real short rates.

rodollar futures up to a one year ahead horizon.[20] These shocks are similar in spirit to those presented in Gürkaynak et al. (2005a) who also use high-frequency changes in market-based expectations – see Nakamura and Steinsson (2017) for further discussion. As such, policy news measure both the surprise change in the federal funds target rate and shifts in short term policy expectations driven by FOMC statements. The shock is scaled so that the effect on a one-year Treasury yield is equal to one. Because our survey-based measure of interest rate expectations is monthly, in order to ensure that we cleanly capture the change in expectations before and after an FOMC meeting we define Δx_t as the difference between expectations from the month after the meeting relative to the month before the meeting. This larger interval has the drawback that it lowers the precision of the estimated impact of the shock, but it ensures that our results are not contaminated by the timing of the different survey responses.

The top row of Figure 6 shows the estimated regression coefficients from equation (5.1) across forward maturities along with their associated 90% confidence intervals. Our sample starts in January 1995 and ends in October 2007, in order to focus on monetary policy shocks during "normal times" when the policy rate is away from the zero lower bound. In unreported results, we find very similar responses when including the post-crisis sample. With the exception of the one year rate, forward rates do not respond significantly to monetary policy shocks within a three-month window. However, this masks differential responses of the rate expectations and term premium components of forwards, shown in the second and third column of the figure. Expectations about the path of short-term real rates display a strongly significant upward shift in response to a monetary surprise up to four years out, showing that central bank target rate decisions and communication are important drivers of medium term real short rate expectations.[21] Conversely, term premiums compress across the curve in response to a contractionary monetary policy shock. This accords with a shift in the price of risk as predicted by standard asset pricing models – see Rudebusch and Swanson (2012) and Piazzesi and Schneider (2007). While their response is comparable to that of the expectations component in magnitude, it is statistically significant only at the 1Y1Y maturity. In sum, monetary policy shocks have a strong impact on expected rates several years out, but do not elicit a significant reaction of term premiums over the quarterly interval at which we measure the shock impact.

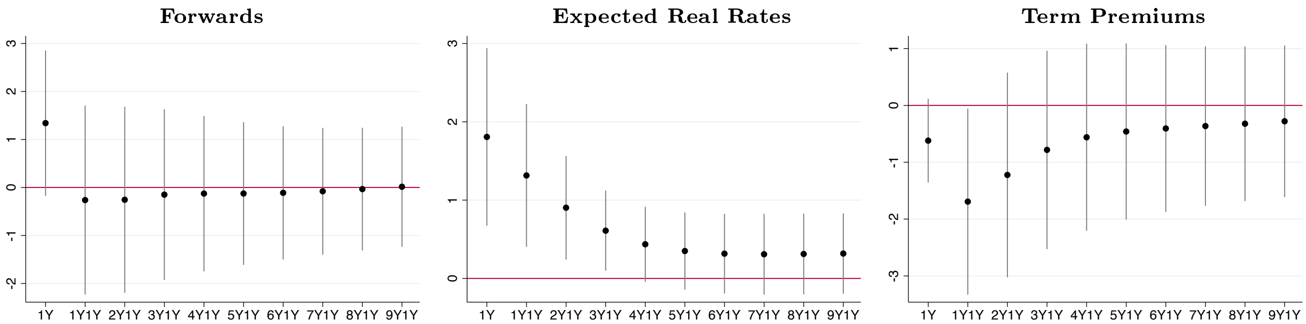
[20] The shocks are defined as the first principle component of the change in five interest rates: the price of fed funds futures contract for the months of the current and following month FOMC meeting and the price of eurodollar futures at horizons of two, three and four-quarters.

[21] We also produced the results based on the "target" and "path" shocks of Gürkaynak et al. (2005a) and found that the response to the path shock is closely aligned with the results using the Nakamura and Steinsson (2017) shock series whereas the response to the target shock is generally insignificant.

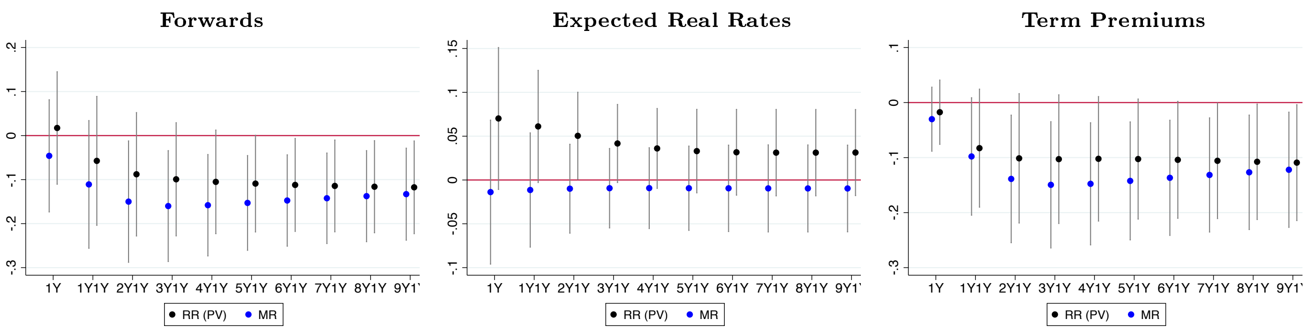
Figure 6: **Response of Yield Decompositions to Shocks Across Forward Maturities**

These figures show estimated coefficients (points) and 90% confidence intervals (grey bars) from regressions of changes in (the components of) yields on individual macroeconomic shocks as discussed in Section 5.

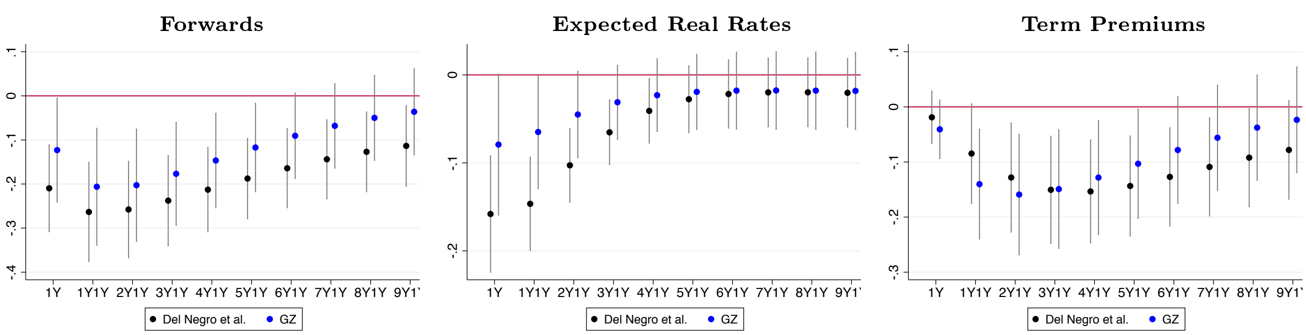
Nakamura and Steinsson (2017): 1995M1–2007M8



Romer and Romer (2010): 1983Q1–2006Q4; Mertens and Ravn (2012): 1983Q1–2006Q4



Del Negro et al. 2013: 1983Q1–2014Q4; Gilchrist and Zakrajšek (2012): 1983Q1–2010Q3



Nakamura and Steinsson (2017) also provide evidence in favor of a strong response of expectations to monetary policy surprises. They use consensus forecasts from the BCEI survey to show that these shocks have significant effects on real interest rate expectations for short-term forecasts up to a one-year horizon and partly attribute the response of macroeconomic aggregates to monetary policy surprises to their effect on agents' beliefs about macroeconomic fundamentals. In addition, Nakamura and Steinsson (2017) use daily changes in expected real rates and term premiums from the model of Abrahams et al. (2016) to show that risk premiums do not respond to monetary shocks instantaneously. The decline in term premiums following a contractionary monetary policy shock that we document is also in contrast to the VAR evidence in Gertler and Karadi (2015). These authors 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 and term premiums are based on a constant parameter VAR.[22] Interestingly, when adding a measure of short-term survey forecasts of the three-month Treasury bill rate to the VAR, they also find a stronger reaction of short-term expectations to the monetary shock.

In the remainder of this section we describe the response of the term structure of interest rates to fiscal policy, demand and supply shocks. These shocks share two key features. First, they are measured quarterly: consequently Δx_t in equation (5.1) is defined as the difference in forwards, expectations and term premiums between the quarter in which the shock occurs and the previous quarter. Second, we show that the expectations hypothesis is a poor representation of the responses of interest rates to these shocks since term premiums display large and statistically significant responses.

Fiscal Policy Shocks As fiscal shocks, we use the present value of exogenous tax changes from Romer and Romer (2010) and the unanticipated exogenous tax changes from Mertens and Ravn (2012) which are based on Romer and Romer (2009, 2010). Each shock, measured as tax changes as a fraction of annual GDP at the time of tax implementation, is constructed using a narrative analysis of U.S. fiscal policy. Our sample covers the period 1983Q1–2006Q4.[23]

The estimated responses in the middle row of Figure 6 show that a surprise increase in tax receipts induces a statistically significant decline in term premiums at all but the shortest maturities. While this could reflect a diminished risk to the fiscal outlook, to our knowledge no structural model discusses the implications of tax changes for term premiums.[24]

[22] For a discussion of the drawbacks of using stationary VARs when modeling interest rates see discussion in the Supplementary Appendix.

[23] See Romer and Romer (2009) and Mertens and Ravn (2012) for full details.

[24] That said, in line with our result, Dai and Philippon (2006) and Laubach (2009) find that higher fiscal

Conversely, tax shocks do not significantly affect the expected path of short-term real rates on impact, consistent with the VAR evidence in Mertens and Ravn (2012). In the case of the present value shock we observe a slight increase in the expected path of the short-term real interest rate. Upon closer inspection this is due to lower inflation expectations associated with the tax hike, while the expected nominal rate remains essentially unchanged.[25]

Demand Shocks A recent macroeconomic literature has emphasized the importance of financial shocks for 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) and is available for the sample period 1983Q3–2010Q3. The second is given by the spread shocks identified using the DSGE model in Del Negro et al. (2013) and is available for the sample period 1983Q1–2014Q4.[26]

As shown in the bottom row of Figure 6 both shocks trigger a decline in forward rates in the same quarter. At one and two year maturities expected short-term real rates explain the bulk of the decline, especially in the case of the Del Negro et al. (2013) shock. Beyond two years, however, term premiums become the main driving force of the decline in forwards. In response to the Del Negro et al. (2013) shock, forward term premiums display strongly significant declines up to eight years out. The negative response of the term premium may reflect a change in 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 an additional "demand" shock which is based on a measure of macroeconomic uncertainty. This shock is identified by Basu and Bundick (2017) in a structural VAR as the exogenous innovation to the implied volatility of future stock returns measured by the Chicago Board of Options' VXO index, in addition to selected macroeconomic variables.[27]

As the top row of Figure 7 shows, an unexpected increase in uncertainty implies a sharp decline in forward rates. Similarly to the corporate spread shocks described above, this

deficits raise term premiums using reduced form affine term structure models.

[25]The response in nominal rate expectations are provided in the Supplementary Appendix.

[26]The model uses 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.

[27]Specifically, they use real GDP, consumption, investment, hours worked, the GDP deflator, M2, 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 1987Q1-2014Q3. We thank Susanto Basu and Brent Bundick for providing this series.

decline is mostly explained by lower expected rates at shorter maturities, but is dominated by a decline in term premiums at maturities beyond three years which show a strongly statistically significant decline. One might worry that the response of forward rates and their components to shocks identified using other financial time series are unduly affected by the recent financial crisis. The responses in the pre-crisis sample ending in 2007Q3 are very similar albeit somewhat less precisely estimated particularly for the Basu and Bundick (2017) shock (see Supplementary Appendix).

Supply Shocks We first consider the yield curve reaction to an oil price shock. We use the oil *supply* shock series computed in Kilian (2008), which measures exogenous oil production disruptions across OPEC countries. This series is available at the quarterly frequency for the sample 1971Q1-2004Q3. The second row of Figure 7 provides the responses of forward rates and their components to a positive oil supply shock. The observed decline in forward rates is entirely explained by lower term premiums at all maturities, which however become significant only at longer horizons. As shown by the wide confidence bands, these responses are estimated relatively imprecisely, possibly due to the small number of oil supply shocks observed in this sample.

We also consider the yield curve reaction to a shock capturing news about future TFP as identified by 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 best explains future TFP at a ten year horizon and is orthogonal to current TFP shocks.[28] The shock series is available at a quarterly frequency for the sample period 1983Q1–2007Q3 which roughly spans the Great Moderation. As can be seen from the bottom row of Figure 7, a positive news shock produces a decline in both forward rates and term premiums at medium-to-long maturities, and no significant changes in expected short-term real rates. However, similar to the case of oil shocks the effect on forward rates and term premiums is only statistically significant at longer maturities.

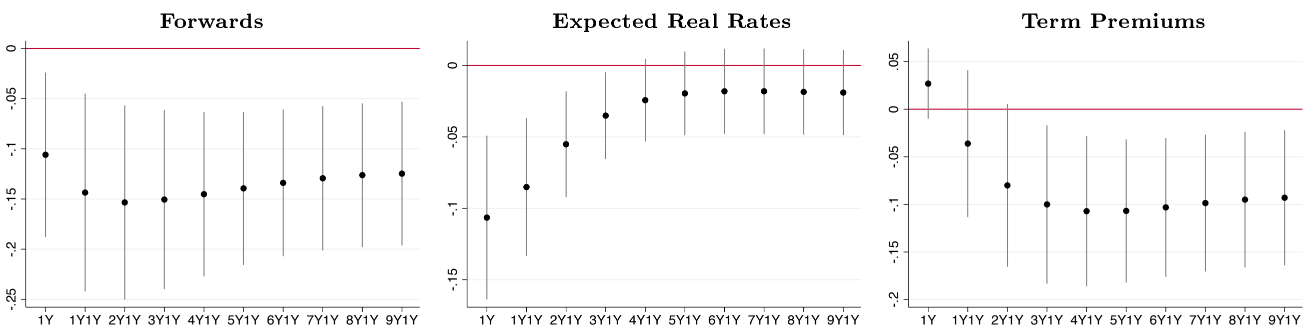
The decline in term premiums in response to positive supply shocks is again consistent with the models of e.g. Piazzesi and Schneider (2007) and Rudebusch and Swanson (2012). The lack of response in the expectations component is consistent with a (perceived) monetary policy that does not provide "accommodation" in response to the shock.

[28] We use the same shock series as in Coibion and Gorodnichenko (2012).

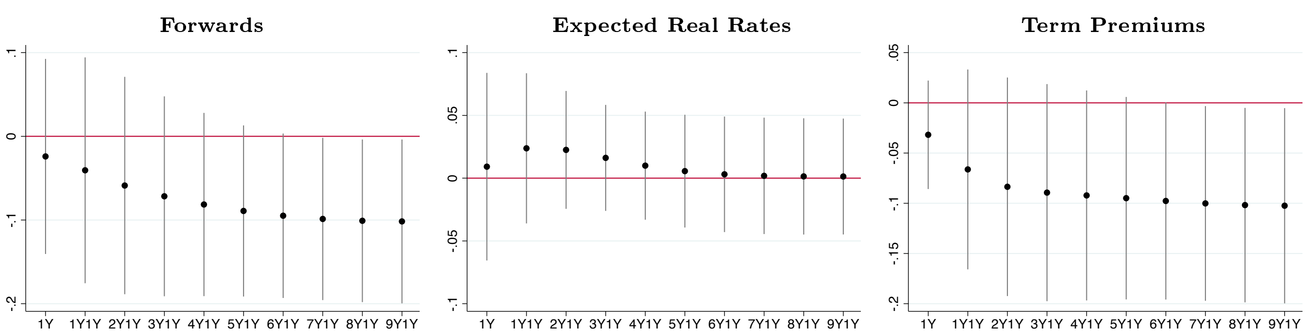
Figure 7: **Response of Yield Decompositions to Shocks Across Forward Maturities**

These figures show estimated coefficients (points) and 90% confidence intervals (grey bars) from regressions of changes in (the components of) yields on individual macroeconomic shocks as discussed in Section 5.

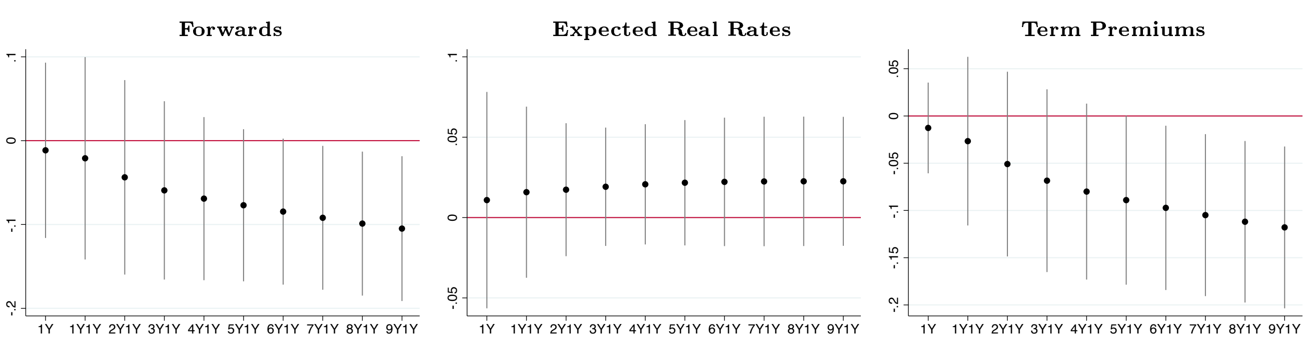
Basu and Bundick (2017): 1987Q1–2014Q3



Kilian (2008): 1983Q1–2004Q3



Barsky and Sims (2011): 1983Q1–2007Q3



In sum, the response of the components of forwards to macroeconomic shocks are fairly closely aligned with the unconditional results discussed in the previous section. Beyond short-term maturities, the expected rates component reacts strongly only to monetary policy surprises, while term premiums respond significantly to all other economic shocks. This suggests a broad failure of the expectations hypothesis in explaining yield curve variation also when conditioning on shocks that have been shown to be quantitatively important for economic activity. This stands in stark contrast to most macroeconomic models used to study business cycles and policy design, where transmission via interest rates is based solely on the expectations hypothesis.

6 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 components 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 main 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 forward yields across maturities. With the exception of monetary policy surprises which significantly affect the expected short rate component of yields, term premiums also account for most of the yield curve's response to a variety of macroeconomic shocks.

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 that the expectations hypothesis holds, at least to a first-order approximation. Our results instead suggest that incorporating time varying term premiums is necessary in order to account for the observed variation of long-term bond yields. Moreover, to the extent that our survey-implied term premiums capture required compensation for risk, finance models should feature stochastic discount factors which generate the quantitative importance of term premiums for yield variation that we observe in the data.

Appendix

A.1 Defining Term Premiums

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

$$y_t(n) = \frac{1}{n}\mathbb{E}_t\left[i_t + i_{t+1} + \cdots + i_{t+n-1}\right] + tp_t(n), \tag{A.1}$$

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-month bond maturing in $n+m$ months:

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

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 months m months hence (i.e., a forward version of equation (A.1)):

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

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:

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

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 $\mathbb{E}_t\left[i_t\right]$, $\mathbb{E}_t\left[i_{t+1}\right]$, $\mathbb{E}_t\left[i_{t+1}\right],\ldots$, whereas yields, $\{y_t(n) : n = 1,\ldots\}$ would be

$$\mathbb{E}_t\left[i_t\right], \frac{1}{2}\left(\mathbb{E}_t\left[i_t\right] + \mathbb{E}_t\left[i_{t+1}\right]\right), \frac{1}{3}\left(\mathbb{E}_t\left[i_t\right] + \mathbb{E}_t\left[i_{t+1}\right] + \mathbb{E}_t\left[i_{t+3}\right]\right), \ldots$$

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 nominal future short rates into expected real short rates and expected inflation,

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

where r_t is the *ex-ante* real short rate, i.e., $i_t = r_t + \mathbb{E}_t\left[\pi_{t+1}\right]$.

A.2 Data

In this section we provide additional details about the data we use in the paper. 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. Table 1 in the main text 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 Appendix. 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 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 known for 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 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 as far out 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 obtained the data available from 1978 to 1987 from Havrilesky (1988).

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 three-month Treasury bill are averages 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 Friedman (1979) 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.[29] 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 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.

Survey of Primary Dealers The Survey of Primary Dealers (SPD) is conducted by the Trading Desk of the New York Fed one to two weeks before each regularly scheduled Federal Open Market Committee meeting.[30] 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.[31] 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.[32] Annual GDP forecasts are requested for Q4/Q4 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.[33] 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 three 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 the SPF documentation.

[29] For more details on the survey see https://www.philadelphiafed.org/-/media/research-and-data/real-time-center/livingston-survey/livingston-documentation.pdf?la=en.

[30] For more details on this survey see Golay et al. (2013).

[31] See https://www.newyorkfed.org/markets/pridealers_current.html for more information.

[32] See http://www.newyorkfed.org/markets/primarydealer_survey_questions.html.

[33] For more details on the survey see https://www.philadelphiafed.org/-/media/research-and-data/real-time-center/survey-of-professional-forecasters/spf-documentation.pdf?la=en.

A.3 Approximation of Growth Rates

In this section we 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 follow Crump et al. (2014) and use

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

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,

$$\begin{aligned}100 \cdot (G_{2013}/G_{2012} - 1) \approx \frac{1}{24}\big(&g_{2012m2} + 2 \cdot g_{2012m3} + 3 \cdot g_{2012m4} + \cdots + 12 \cdot g_{2013m1} \\ &+11 \cdot g_{2013m2} + 10 \cdot g_{2013m3} + \cdots + 2 \cdot g_{2013m11} + g_{2013m12}\big).\end{aligned}$$

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

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

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 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 all three variables are observable, H_t^A is of the form

$$H_t^A = \begin{bmatrix} \frac{1}{9} & 0 & 0 & \frac{2}{9} & 0 & 0 & \frac{3}{9} & 0 & 0 & \frac{2}{9} & 0 & 0 & \frac{1}{9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

To illustrate how H_t^S is formed, consider the following two examples:

Example 1 Consider the case of a Y1 forecast in January 2012, 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 that month. This can be approximated by the linear combination,

$$\sum\nolimits_{j=1}^{23} w_j \hat{g}_{\tau+j}, \qquad \hat{g}_{\tau+j} = e_g' F^j Z_\tau$$

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_τ is the annualized monthly real GDP growth rate in January 2012 and $\hat{g}_{\tau+j}$ 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 $\sum\nolimits_{j=1}^{23} w_j e_g' F^j$.

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

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