Risk Is Not Symmetric: An Intraday Study of the Bond Market Term Premia Around Macroeconomic Announcements

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Abstract

This paper analyzes the impact from macroeconomic news announcements on risk premia on bond yields using high-frequency data. A new method is proposed for the identification of the fundamental part using risk adjusted money market futures. Consequently, we are able to identify the behaviour of both the fundamental part and the risk premia. Our results suggest that changes in risk premia react asymmetric to news while expectations of future short rates react symmetrically.

Keywords: Risk Premia, Bond Yields, Macroeconomic News, Asymmetric Response.

JEL classification: E43, E44, G15

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1 Introduction

Why do bond markets react differently to negative and positive macroeconomic news? Our answer is asymmetric responses in the term premia. We find that changes in the term premia reacts asymmetrically to information about the economy across various macroeconomic news announcements at longer maturities: Positive news leads to increases in the risk premia, where as negative news impacts the risk premia less or even causes it to increase. At the same time, positive (negative) news increases (decreases) the fundamental economic component of bond yields. The asymmetric reaction of the term premia result is contrasted by our finding that the reaction in the fundamental economic component of bond yields is symmetric. These two results taken together explain why bond yields overall react asymmetrically to positive and negative macroeconomic news as described in Andersen, Bollerslev, Diebold, and Vega (2003).

We believe to be the first to address the behavior of the intraday term premia in a high-frequency framework. To do so we propose a theoretically motivated approach of extracting the risk premia for longer-dated bonds based on changes in the monetary policy path, which in macroeconomic theory reflects changes to economic fundamentals. This allows the identification of the intraday risk premia.

Our results depend crucially on two identifying assumptions.

- The expectation hypothesis with a **time-varying risk premia** holds.
- All fundamental economic information impacts solely through changes in the monetary policy path.

In empirical research, the existence of a time-varying risk premia is often given the blame when explaining the overwhelming empirical evidence rejecting the expectation hypothesis. For instance Tzavalis and Wickens (1997) and Dai and Singleton (2002) - using different approaches - find support for 1), but others, such as Bekaert and Hodrick (2001) and Thornton (2006) note that such approaches requires a very large variability in the term premia. Whether one can claim that the expectation hypothesis holds when accounting for a time-varying risk premia is however an open question. We find no compelling evidence against this, quite the contrary, ample theoretical evidence, as documented later in the theoretical part of this paper, in support of the hypothesis. We consequently make use of the assumption in our identification procedure, but realize that this might be a controversial choice.

The second assumption is fairly standard in most macroeconomic models. For instance in DSGE models, where all available information is incorporated into the monetary policy path; the monetary path being the monetary policy interest rate set by the central bank from today and into the future. This directly implies that expected monetary policy path is an indicator for market participants view on the economy. Any incoming information about the economy will swiftly be incorporated into the expected monetary policy path. Therefore changes in the monetary policy path as a result of new macroeconomic information is very likely to be a good indicator for changes to fundamental macroeconomic expectations.

While previously neglected in macroeconomics, focus has lately moved away from fundamentals and on to the risk premia, see e.g. Alvarez, Atkeson, and Kehoe (2007), Alvarez, Atkeson, and Kehoe (2008), and Cochrane (2001), motivating the analysis in this paper. The provocative view of Alvarez, Atkeson, and Kehoe (2007), as an extreme example, is that moves in response to monetary policy shocks is neither inflation nor output but risk premia. This in turn implies a new modelling strategy for monetary models, namely a more thorough examination of the model properties of risk premia, for an example of the analysis of risk premia and macroeconomics, see Rudebusch, Sack, and Swanson (2007), Rudebusch and Swanson (2007), and Pedersen (2008). It also implies a need for a deeper empirical analysis of what affect risk and address the relative importance of fundamentals and risk premia. This paper address exactly these issues using bond market data.

Our paper is most similar to Beechey (2007). She decomposes the U.S. curve on daily data using an affine term structure approach with a fitted time-varying risk premia. With this approach, she finds that movements from macroeconomic announcements in the term premia, and not expected future short rates, account for most of the reaction of forward rates at long horizons. Term premia accounts for about 75 per cent of the reaction of nominal forward rates in the long end of the yield curve suggesting that the fundamental part in the U.S. yield curve are reasonably well anchored. Beechey (2007) finds that weaker-than-expected inflation and real-side news are associated with lower term premia.

In this paper we extend the analysis of Beechey (2007) in two ways. Firstly, we use high-frequency data from 1999 to March 2008[1], instead of daily data in order to measure the market reaction to macroeconomic announcements more precisely. The use of high-frequency data should allow a more precise measure of the market impact from macroeconomic fundamentals as it reduces the noisiness of the daily measure. Our findings does seem to indicate that Beechey (2007) underestimates the impact from macroeconomic fundamentals, as we find that term premia only account for around 25-40 per cent of the reaction around macroeconomic announcements. This does suggest, that the use of daily measures induces some noise.

Secondly, we depart from the affine term structure approach and use a theoretical derived decomposition, that is changes in the monetary policy path as a proxy for fundamentals, as suggested by standard macro models. The affine term structure approach is difficult to implement on intraday data, at least for the entire yield curve.[2]

[1] In order to separate our analysis from the financial crisis and especially the money market turmoil, we use data until the time of the Bear Stearns collapse.

[2] We tried to estimate an affine term structure for both bond yields with short maturities and longer maturies. However, this approach is extremely cumbersome for datasets with more than 200.000 observations. Further, the fit of our model where unsatisfactory. We

Piazzesi and Swanson (2008) document relatively large excess returns on federal funds futures and thereby indicate that also money market futures contracts contain a non-negliable term premia. In order to account for the risk in money market yields, a 1-factor affine term structure model with a time-varying risk premia is fitted on the money market data. This gives us a risk-adjusted money market curve and thereby the expected risk-free monetary policy path.

The remainder of the paper is structured as follows. Section 2 gives our theoretical motivation for our decomposition. Section 3 examine the issue empirically, specifically section 3.1 describes the data used in this study, section 3.2 describes our method for extracting risk premia from the short end of the yield curve. This gives us a risk-adjusted path of monetary policy and thereby a good approximation for the expectation of the fundamental economic information contained in the yield curve. Finally in section 4 we decompose the market reaction at 2-, 5- and 10-year maturities from macroeconomic releases into a fundamental and a risk premia component and regress the changes in the components against the most important macroeconomic announcements. In section 5 we discuss the implications for macroeconomic modelling. Finally section 6 concludes.

have therefore stuck to the methodology as presented in the text.

2 Theory

To derive the explicit theoretical decomposition of bond yields for our empirical analysis, we start with some notation. Let P_t^n denote the price at time t of a zero coupon bond with time-to-maturity n. Its log price is denoted by p_t^n, yields are defined from prices as $y_t^n = -\frac{1}{n} p_t^n$, and we denote the short rate of interest as $i_t = -p_t^1$. We denote the expected log-holding period return from holding an n-period bond for one period in excess of the risk free rate of interest as

$$E_t \left[hpr_{t+1}^n \right] \equiv E_t \left[p_{t+1}^{n-1} - p_t^n \right] - i_t \tag{1}$$

All variables as nominal unless stated otherwise. We assume all variables are jointly log-normal and complete markets such that a unique pricing kernel, M_{t+1}, prices all assets in the economy.

The short rate is set by a central bank according to an interest rule. The central bank rule aims to achieve the dual goals of keeping output, Y_t, at its natural level, Y_t^n, and inflation, π_t, at its target, $\bar{\pi}$

$$i_t = F \left(\pi_t - \bar{\pi}, Y_t - Y_t^n \right) \tag{2}$$

with $\partial F / \partial \left(\pi_t - \bar{\pi} \right) > 0$ and $\partial F / \partial \left(Y_t - Y_t^n \right) < 0$, see e.g., Gali (2008) or Woodford (2003). As short rates are dependent on inflation and the output gap, short rates therefore hinge on expectations of future macroeconomic variables in this framework.

In appendix A we derive the following bond yield decomposition:

$$y_t^n = \frac{1}{n}\sum_{i=0}^{n} E_t\left[i_{t+i}\right] + \frac{1}{n}\sum_{i=1}^{n-1} E_t\left[hpr_{t+i}^{n+1-i}\right] \equiv ES_t^n + TP_t^n. \quad (3)$$

The first term in (3), ES_t^n, captures expected future short rates. We therefore interpret the ES_t^n term as *fundamentals*, $\digamma_t$, by which we mean a term capturing current macroeconomic variables or expectations of future macroeconomic variables like the output gap, inflation and other considerations leading to the current the stance of monetary policy. The second term in (3), TP_t^n, is a sum of current and future *risk* premia denoted by hpr_{t+1}^{n+1}. Consequently, the second term captures movements in the risk premia.

The decomposition in equation (3) states that bond yields depend on expected future short rates.From (2) we know that this involves expectations of future macroeconomic variables, which in turn implies bond yields implicitly depend upon expected future macroeconomic variables and thus fundamentals. In addition, investors demand a time varying risk premia to compensate for the uncertainty related to the expected monetary policy path.

Decomposition (3) assumes the expectations hypothesis (EH) *holds once bond yields are adjusted for risk premia*. We thus assume that the empirical failure of the EH is due solely to non constant risk premia following both theory and the empirical analysis in Dai and Singleton (2002).

3 Empirical Analysis

We want to decompose bond yield spreads into fundamentals and a risk premium, and be able to say something about the relationships between these terms and macroeconomic announcements at the same time. The idea is to estimate the impact from a vector of *US news announcement surprises*, N_t, on y_t^n, TP, and ES. In order to detect any asymmetric effects stemming from positive and negative releases, the use of a dummy for negative surprises, D_t, is used as well in the following regressions:

The overall yield impact regression

$$\Delta y_t^n = \alpha + \beta N_t + \beta_{NEG} D_t N_t + \varepsilon_t, \tag{4}$$

the risk premia regression

$$\Delta TP_t^n = \alpha + \beta^{TP} N_t + \beta_{NEG} D_t N_t + \varepsilon_t, \tag{5}$$

and the fundamental regression

$$\Delta ES_t^n = \alpha + \beta^{ES} N_t + \beta_{NEG} D_t N_t + \varepsilon_t, \tag{6}$$

where the Δx operator denotes 20 minute changes in x.

The regression setup is similar to the setup used in other announcement studies, see for instance Faust, Rogers, Wang, and Wright (2007).[3] We consider the changes in yields, term premia and fundamentals around the announcement for three maturities, $n = 2, 5$ and 10 and for 8 of the most important US releases, CPI, Factory Orders, Industrial Production, Initial Jobless Claims, ISM Manufacturing, Non-farm Payroll, Philidelphia Fed and Retail Sales. Consequently we estimate 8 regressions for each bond maturity with differing macroeconomic announcements using both US bond yields - a total of 24 regressions.

In order to estimate the three regressions above, either the term premia or the fundamentals needs to be identified. As we saw in the previous section, the fundamental part, ES_t^n, can be identified as the sum of expected short rates. In practise this is however not easily accomplished. Two main obstacles prevent this.

Firstly, as noted earlier, Piazzesi and Swanson (2008) find that also short-term rates can contain substantial risk premia. To employ the decomposition for long rates, a decomposition for short rates is consequently also needed. To adjust for the risk premia on short rates, we estimate a affine term structure model with a time-varying risk premia. The method and results from this decomposition is given in section 3.2.

[3] Another class of macroeconomic announcement studies focus on the effects on volatility stemming from these announcements. These papers include among many others Andersen and Bollerslev (1997) and Andersen, Bollerslev, Diebold, and Vega (2003). This is not considered in this paper, however we did fit an asymmetric volatility equation. This did not change our results.

Secondly, and probably more importantly, the fundamental part, ES_t^n, consists of all short rates. For a 10-year bond, this would consist of all short rates for a 10-year period. However, as the main impact of changes to the monetary policy path is likely to be in the first part of the yield curve, we approximate the ES_t^n component with 12-month rates. This is only an approximation, albeit a plausible one, and has the consequence, that all changes beyond what is induced by changes at the 12-month rate becomes term premia.[4] This is where our two assumptions of i) the expectation hypothesis and ii) that fundamental economic information only impacts through the monetary policy comes into play.[5]

With the data and risk-adjusted money market rates at hand, the regressions (4), (5) and (6) can now be implemented. The results of the regressions is reported in section 4.

3.1 Data

To obtain accurate measures of the bond market response to macroeconomic announcements the use of high-frequency data is essential. All the bond- and money market data used in this study is therefore intraday data. All

[4]Data availability restricted us from looking at longer horizons, such as a 18 month horizon.

[5]It is important to note that our approach only gives the reponse or movements in the risk premia, but does not enable us to comment on the level of the risk premia. This is probably the largest drawback of using this method compared to the the affine term structure approach.

high-frequency data, i.e. money market interest rate and bond yields[6], are based on futures contract data from TickData Inc. We use US interest rates and bond yields at 3-, 6-, 9- and 12-month, 2-, 5- and 10-year horizons and announcements for 8 selected US announcements.

The sample period covers the period January 1999 to March 2008. The start period is determined by data availability for macroeconomic surprises and the end period coincides with collapse of Bear Stearns, which was the beginning of the money market turmoil under the financial crisis. To avoid any early releases or inaccuracies in time stamps, all changes in market data around the macroeconomic releases is collected in an event window from 5 minute before release to 15 minutes after release on days with the macroeconomic release. This is similar to the procedure by Faust, Rogers, Wang, and Wright (2007).

The announcement data is collected from Bloomberg. A noted previouly, a selection of the most important US macroeconomic announcements has been used, which includes CPI, Factory Orders, Industrial Production, Initial Jobless Claims, ISM Manufacturing[7], Non-farm Payroll, Philidelphia Fed and Retail Sales.[8] Both the survey, collected continuously up to the release date,

[6] Prices on the US 2-, 5- and 10-year government futures contracts are converted into yields. The conversion is based on the internal rate of return using an exact maturity of 2, 5 and 10 years and the coupon rate on the futures contract, typically 6%. This is contrary to the use of returns in most other papers. The use of yields has the advantage of allowing a more direct comparison across maturities, as the return impact is considerably different across maturities due to differences in duration.

[7] One observation was deleted as this was distorted by an external event, Hurricane Katrina. The markets did not react to this release due to this distortion.

[8] The GDP (Advance) release is not considered, as this is only released quarterly.

and the actual release is from Bloomberg. The data is similar to that used in Andersson, Overby, and Sebestyén (2009).

The selected indicators are those that tend to have the highest market impact in previous studies, as found in for instance Bartolini, Goldberg, and Sacarny (2008). They note that the non-farm payroll report and ISM manufacturing tend to have the strongest impact on US asset prices. This is also confirmed by our findings later on in the paper. The news vector N_t consists of the standardized surprises.[9]

The 3-month Eurodollar futures contract is used to determine the expected US monetary policy path, as this contract is based on the 3-month deposit rates (LIBOR) and thereby an excellent approximation for actual money market rates. From the Eurodollar futures contract, 12-month money market rates are constructed. [10]

3.2 Money Market Decomposition

The use of a affine term structure is relatively standard and is done among others by Rudebusch, Sack, and Swanson (2007), Kim and Wright (2005), and Cochrane and Piazzesi (2006). The identification of a fundamentals component is crucial to our analysis and in order to ensure robustness, a

[9] The standardised surprise is defined as $S = \frac{Actual - Survey}{St.dev(Actual - Survey)}$, where *Actual* and *Survey* is respectively the actual number released and the survey observed on Bloomberg. See Kuttner (2001) for a further description.

[10] A more thorough description of the method used for the calculation of money market yields is available upon request.

variety of term structure models is specified. The results are independent of the chosen specification and consequently we have adopted the simplest possible approach of fitting a one-factor affine term structure model.

We interpret short rates as expectations of fundamentals and we approximate these interest rates by the futures contract. These future contracts are a way to lock in a 3-month loan today starting in, say, 6 months. Two points are clear for these contracts. Three month interest rates are closely correlated with monetary policy rates, that is the Federal Fund Rate (FFR), making these futures contracts an instrument to identify the ES_t^n -part of (3). However, the money market futures contract contain a risk premium in part due to the uncertainty related to future monetary policy and we therefore need to adjust for these risk premia.

We obviously face another identification problem, as we only have futures prices to identify both the risk premia and the expectations part in the money market rate. We solve this problem by estimating an affine term structure model for a panel of the future contract consisting of the 3, 6, 9 and 12 month future. We decompose the estimated futures into an expectations part related to fundamentals, $ES_{mm,t}^n$, and a risk premia part reflecting risk premia in the futures contract, $TP_{mm,t}^n$, as in (3). We thus use $y_t^n - ES_t^n$ as *risk adjusted* futures contract which we henceforth denote *risk adjusted fundamentals*. The estimation follows Ang and Piazzesi (2003), Dai and Singleton (2002) and Duffie and Kan (1996). The technical details are available upon request.[11]

[11] For the referee: The information is available in the appendix submitted together with

The main results from the estimation of the affine term structure model are given below.

3.2.1 Estimates and results

The model has a relatively good fit with quite small mean fitting errors (around 0.2 basis points), see figure 1. This provides evidence in favour of our one-factor model. Figure 2 shows the panel of estimated term premia, $TP^n_{mm,t}$. These are both in absolute terms and relative to the money market rates small. The average risk premia is around 15 basis point at a 12-month horizon. This corresponds very well to the 'rule of thumb' used in the Federal Reserve, see Piazzesi and Swanson (2008), which states that the average risk premia is around 1 basis point pr. month + 3 basis points ~15 basis points for a 12-month horizon.

<Insert figure 1 and 2>

However, the time-variability is very large. Under the bursting of the dot-com bubble and the more recent sub-prime crisis, risk premia has increased considerably. Figure 3 and 4 shows that the term premia, $TP^n_{mm,t}$, contribute relatively little to the level of money market rates. They are, however, non-negliable and would, if not taken into account, give biased estimates in regressions (4), (5) and (6).

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4 Results

Using the risk adjusted monetary path derived in the previous section, the fundamental news reaction can now easily be derived - hence we have identified the ES_t^n term in (3). This allows us to estimate regressions (4), (5) and (6). The results of these regressions for respectively 2-, 5- and 10-year bond yields on US data are given in the below tables.[12]

< Insert table 1, 2 and 3>

The overall picture can be summarized as follows. Firstly, the impact on the yield curve is on average greater when positive news is released than for negative news, thus causing an asymmetric response at longer maturities. Secondly, this asymmetry is explained by the term premia part of the yield curve, again mainly at longer maturities. Thirdly, the size of risk premia response from news in the yield curve is non-negible. Finally, the risk premia appear anchored at longer maturies, causing term premia to fluctuate more at shorter maturities.

[12] In order to ensure robustness of the results, we considered a number of alternative specifications. Firstly, we considered a number of different model specifications on the extraction of money market risk premia. The overall results did not qualitatively differ with other specifications. Secondly, a volatility equation was added to the regressions, aimed at taking care of asymmetric effects in volatility. There were some signs of asymmetric volatility effects, but again it did not change our conclusions.

The quantitative impact from the announcements differ across maturities. Specifically, news moves the yield curve relatively more in the short end of the curve than in the long end, which again is linked to larger responses in the term premia. The uneven response to news suggests that term premia is more well-anchored at longer maturities.

Across the different announcements, a pattern of aymmetry does emerge. There is no statistical significant asymmetry at the 2-year maturity, but only at 5- and 10-year maturities. Retail Sales is the only release, at 5- and 10-year maturities, where there is the asymmetry is present in the overall yield response. However, for the risk component, the asymmetry effect is statistically significant at the 5-year maturity for Retail Sales and Philadelphia Fed, and at the 10-year maturity, CPI, Factory Orders, Non-Farm Payroll, Philadelphia Fed and Retails Sales is statistically significant. The fundamental component in all cases exhibit a symmetric reaction to positive and negative news.

Looking at the numbers from an economic perspective, the effect becomes even more pronounced. The coefficient capturing the asymmetry is negative for all releases at 5- and 10-year maturities, except for two announcements with the overall smallest news effects, Industrial Production and Initial Jobless Claims. The pattern of asymmetry is therefore consistent, both overall, but also at the risk level.

The magnitude of the risk premia response of overall response also deserves some attention. For positive surprises, about 25% to 40% of the overall response is risk premia for the 4 announcements with the highest overall impact (Non-farm Payroll, ISM Manufacturing, Retail Sales and Philadelphia Fed). This is somewhat lower than the share suggested by Beechey (2007), which probably is due to her use of daily measures.

The asymmetry of the reaction is relatively large. As an example consider the impact on 10-year yields following the release of the non-farm payroll number. A one standard deviation surprise in the non-farm payroll release, i.e. about 100.000 new workers above or below the consensus, causes the yield curve to decrease around 3.1 basis points on a negative surprise and increase around 4.7 basis points on a positive surprise. The response in the money market rates, i.e. the fundamental component, is a symmetric response of around 3.4 basis points on both negative and positive news. The asymmetry in the overall reaction comes from the risk premia. The risk premia increases with the 0.2 basis point on negative news and increases 1.3 basis point on positive news. The risk premia consequently does not move in response to a negative surprise, but only to a positive surprise.

Our results clearly link the information content of macroeconomic variables to responses in the term premia and note that risk premia on average play a non-negible part in the yield curve.

5 Implications for macroeconomic modelling

Our results suggest that up to 40% of the response in the yield curve to macroeconomic announcements is risk. Hence there is an endogenously *wedge* - in terms of a risk premia - between the bond market response predicted by macroeconomic models and the realized values. This may in part explain the so called *excess volatility puzzle*, see e.g., den Haan (1995) and Gurkaynak, Sack, and Swanson (2005); long term interest rates vary more to macroeconomic variables than what DSGE models predict it should for economies with quite stable inflation and small movements in output.

The excess volatility puzzle implies the models do not get the end points in the economy correct, and as expectations are everything in modern macroeconomics, this implies DSGE models do not get short-run behavior correct as indicated in the discussion in Gurkaynak, Sack, and Swanson (2005). The fundamental stance of the economy feeds back to the economy both through their direct determination of the long interest rate and its effect upon the macroeconomy, but also through the impact of future fundamentals upon expectations of future macroeconomic variables today. The excess volatility observed in the long end of the yield curve can be attributed to the term premia, which breaks both the interrelationships between yields and relationship between long yields, the end points of the macroeconomic variables and expectations about them today. The long end of the yield curve is simply an unreliable source of information about the stance of the economy.

The standard paradigm in macroeconomics has so far been to simply to ignore risk premia, but both theory and our results points to that this ignorance of modelling risk premia is not innocuous, as also pointed out in Alvarez, Atkeson, and Kehoe (2007). Furthermore it certainly warrants the approach to central banking advocated in Blinder (1998): *'Estimate how much you need to tighten or loosen monetary policy to "get it right". Then do less'.* Ignoring the risk premia is certainly not the way to go, the risk premia has an important role to play in future macroeconomic modelling.

Another implication of the results presented in this paper is that time variation in risk premia on financial assets can generate empirically plausible responses in bond yields to movements in macroeconomic variables. Furthermore, as shown in this paper, we are confident that term premia movements are significantly influenced by movements in macroeconomic variables. These insights together suggest, firstly, that risk premia should be incorporated into macroeconomic models, and, secondly, risk premia derived from first principles is the road ahead as risk premia do depend on key macroeconomic variables in a meaningful way. Also it would be preferable, that preferences allow for asymmetric movements in risk premia in response to movements in macroeconomic variables. This may hopefully also help solve other puzzles than the excess volatility puzzle. We leave a deeper analysis and modelling of risk premia in macroeconomic models to future research.

6 Concluding Remarks

The decomposition clearly shows the asymmetry stemming from the term premia. Furthermore, the effects are particularly pronounced at longer maturities. Our decomposition method is crucial for obtaining this result. This clearly warrants some consideration, although it is remarkable that the assumptions behind the decomposition are standard in macroeconomic modelling.

The alternative of our approach is to estimate an affine term structure model for the entire yield curve. This however also has drawbacks. Firstly the method is clearly parametric and not based on any economic intuition. Secondly, the estimation becomes very cumbersome for large datasets. Finally, and probably most importantly, there are a number of parametric choices to be made, which all can be crucial for the actual outcome of the estimation. Therefore this approach is also not perfect.

We have intentionally not touched upon the drivers behind this asymmetry, as this appears very difficult without a concrete modelling framework. We however hope that our paper provides some inspiration for theoretical macro models, that may explain the asymmetric response in the bond risk premia.

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A Theoretical bond yield decomposition

We start from the fundamental pricing relation for zero coupon bonds, see for instance Cambell, Lo, and MacKinlay (1997),

$$P_t^n = E_t\left[M_{t+1}P_{t+1}^{n-1}\right].$$

We then take logs of the expression, assume joint log-normality, and obtain

$$\begin{aligned} p_t^n &= E_t\left[m_{t+1}\right] + E_t\left[p_{t+1}^{n-1}\right] \\ &\quad + \frac{1}{2}V_t\left(m_{t+1}\right) + \frac{1}{2}V_t\left(p_{t+1}^{n-1}\right) + cov_t\left(m_{t+1}, p_{t+1}^{n-1}\right), \end{aligned} \tag{7}$$

where $m_{t+1} \equiv \log(M_{t+1})$. Note, from this expression an explicit expression for the time-varying risk premia ϕ_t^n can be obtained as $\phi_t^n \equiv \frac{1}{2}V_t\left(m_{t+1}\right) + \frac{1}{2}V_t\left(p_{t+1}^{n-1}\right) + cov_t\left(m_{t+1}, p_{t+1}^{n-1}\right)$.

By iterating (7) and by the use of the law of iterated expectations we get

$$p_t^n = \sum_{i=1}^{n}\left[E_t\left[m_{t+j}\right] + \frac{1}{2}V_t\left(m_{t+j}\right)\right] - \sum_{i=1}^{n-1} E_t\left[hpr_{t+j}^{n-j+1}\right].$$

The joint log-normality assumption implies that the (log) short rate of interest, i_t, can be written as:

$$i_t = -E_t\left[m_{t+1}\right] - \frac{1}{2}V_t\left(m_{t+1}\right).$$

We define risk premia as the premium part of realized excess returns; the difference between the price of an asset, p_t, and its payoff discounted with the risk free rate, or, equivalently

$$hpr_{t+1}^{n+1} = -\frac{1}{2}V_t\left(x_{t+1}\right) - cov_t\left[\beta u^{'}\left(c_{t+1}\right), x_{t+1}\right]/u^{'}\left(c_t\right), \qquad (8)$$

which reduces $\phi_t^n \equiv \frac{1}{2}V_t\left(m_{t+1}\right) + \frac{1}{2}V_t\left(p_{t+1}^{n-1}\right) + cov_t\left(m_{t+1}, p_{t+1}^{n-1}\right)$ derived above if the payoff, x_{t+1}, is the future price asset price, p_{t+1}. We have further introduced a consumption based discount factor, m_{t+1}, see e.g., Cochrane (2001).

B Figures

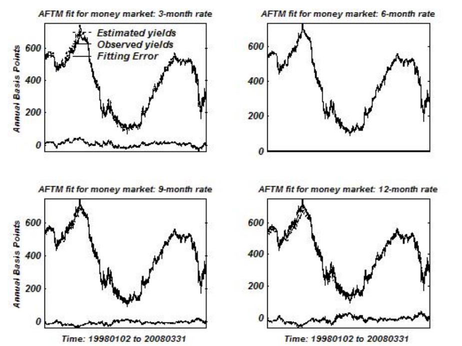


Figure 1: Fit of the affine term structure model for money market yields. This figure shows the fit of the affine term structure model estimated on the money market for the 3, 6-, 9 and the 12-month horizon together with the model implied fitting errors defined as the difference between data and estimated yields. Details regarding affine term structure estimation is available upon request.

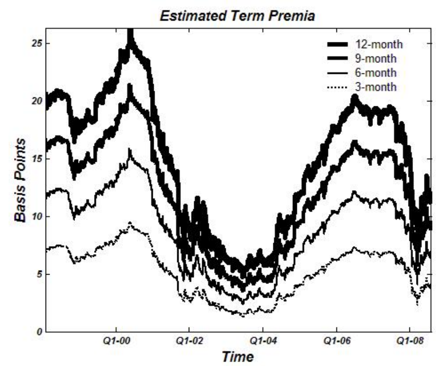
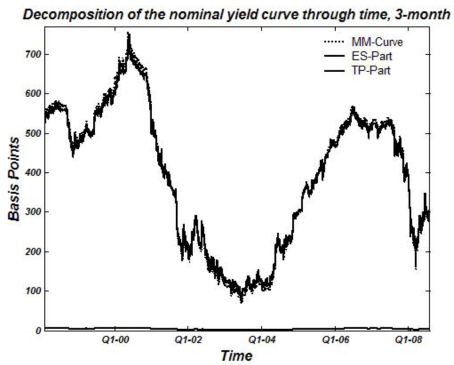
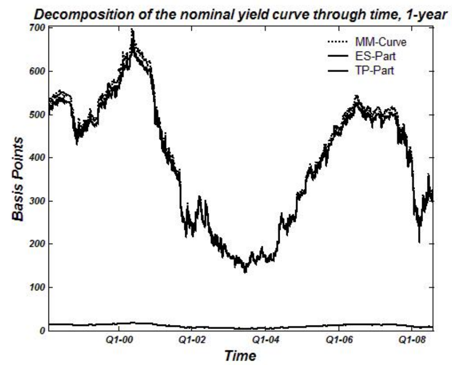


Figure 2: Estimated term premia for money market yields. This figure shows the estimated term premia from the affine term structure model. Details regarding the affine term structure estimation is available upon request.



(a) 3-month maturity



(b) 12-month maturity

Figure 3: Example of the money-market decomposition. This figure shows model implied money market decomposition, see section (3.2), for the money market future through time.

C Tables

Decomposition regressions					
	R^2	α	β	β_{NEG}	No. Obs
CPI	0.0555	-1.4185 (1.4582)	1.9846 (2.0852)	-2.5525 (3.0286)	66
- Fundamentals	0.0450	-0.0097 (0.6902)	0.3319 (0.9272)	0.1847 (1.3671)	
- Risk	0.1080	-1.4088 (0.8467)	1.6527 (1.2140)	-2.7373 (1.7782)	
Factory Orders	0.0454	-0.0068 (0.3119)	0.3114 (0.2566)	0.1242 (0.5592)	73
- Fundamentals	0.0383	0.1516 (0.2166)	-0.0021 (0.1441)	0.3836 (0.3491)	
- Risk	0.0452	-0.1584 (0.1581)	0.3135** (0.1467)	-0.2593 (0.3015)	
Industrial Production	0.2628	-0.0659 (0.2861)	0.9843*** (0.3304)	-0.4016 (0.6499)	68
- Fundamentals	0.2916	-0.2270 (0.2330)	0.9358*** (0.3242)	-0.5907 (0.5623)	
- Risk	0.0318	0.1610 (0.1477)	0.0484 (0.1801)	0.1892 (0.3199)	
Initial Jobless Claims	0.1163	0.2928 (0.1818)	-0.8131*** (0.2386)	0.1436 (0.4447)	395
- Fundamentals	0.1452	0.0323 (0.1095)	-0.5317*** (0.1494)	0.0318 (0.2847)	
- Risk	0.0324	0.2606*** (0.1039)	-0.2814** (0.1304)	0.1118 (0.2080)	
ISM Manufacturing	0.4403	0.5542 (0.4645)	2.0455*** (0.5233)	0.7943 (0.9182)	74
- Fundamentals	0.4299	0.2961 (0.3298)	1.3989** (0.5862)	0.6556 (0.8550)	
- Risk	0.2022	0.2581 (0.2284)	0.6466*** (0.1831)	0.1387 (0.3968)	
Non-farm Payroll	0.4306	0.7163 (1.0283)	6.0380*** (2.0602)	-1.2732 (2.5873)	109
- Fundamentals	0.4155	0.2475 (0.7447)	3.2590*** (1.1256)	0.1546 (1.5484)	
- Risk	0.2722	0.4687 (0.4541)	2.7790*** (1.0454)	-1.4278 (1.2989)	
Philadelphia Fed	0.4407	0.4051 (0.7054)	0.4290 (0.7202)	1.0253 (1.1951)	17
- Fundamentals	0.4429	0.8673 (0.4991)	-0.1485 (0.4287)	1.4778* (0.8022)	
- Risk	0.1428	-0.4623 (0.4705)	0.5774 (0.4287)	-0.4525 (0.5785)	
Retail Sales	0.2114	-0.0310 (0.4903)	2.0453*** (0.5317)	-1.3317 (1.0163)	93
- Fundamentals	0.2107	-0.0870 (0.3072)	1.2171*** (0.3343)	-0.5807 (0.6273)	
- Risk	0.1121	0.0560 (0.2598)	0.8282*** (0.3006)	-0.7510 (0.5038)	

Table 1: US yield decomposition regressions for the 2-year T-note futures contract. The table shows the estimates from regression equations (4), (5) and (6) with Newey-West robust standard errors in parenthesis. ***,**, and * denotes statistical significance at the 1%, 5% and 10% level.

Decomposition regressions					
	R^2	α	β	β_{NEG}	No. Obs
CPI	0.0467	-0.6982	1.3394	-1.3908	78
		(1.1174)	(1.7397)	(2.4582)	
- Fundamentals	0.0424	0.2786	-0.0013	0.6912	
		(0.5574)	(0.7689)	(1.1123)	
- Risk	0.1029	-0.9768	1.3407	-2.0820	
		(0.6262)	(0.9967)	(1.4388)	
Factory Orders	0.0847	-0.1956	0.6096**	-0.2760	85
		(0.2386)	(0.2514)	(0.5103)	
- Fundamentals	0.0421	0.0674	0.0977	0.2380	
		(0.1775)	(0.1660)	(0.3182)	
- Risk	0.0996	-0.2630	0.5120***	-0.5140	
		(0.1518)	(0.1594)	(0.3240)	
Industrial Production	0.1576	-0.0528	0.6374*	0.0860	81
		(0.3279)	(0.3899)	(0.7733)	
- Fundamentals	0.1986	-0.2394	0.6959***	-0.3628	
		(0.2417)	(0.2744)	(0.5295)	
- Risk	0.0372	0.1865	-0.0585	0.4488	
		(0.2216)	(0.3218)	(0.5067)	
Initial Jobless Claims	0.0730	0.1247	-0.5559***	-0.0811	451
		(0.1733)	(0.1983)	(0.3732)	
- Fundamentals	0.1215	-0.0006	-0.4658***	-0.0278	
		(0.1069)	(0.1420)	(0.2728)	
- Risk	0.0078	0.1252	-0.0901	-0.0534	
		(0.1043)	(0.1128)	(0.1775)	
ISM Manufacturing	0.4826	0.3168	2.8684***	-0.4517	94
		(0.4694)	(0.3745)	(0.8045)	
- Fundamentals	0.4196	0.1477	1.6113***	0.2982	
		(0.2954)	(0.4272)	(0.7315)	
- Risk	0.2248	0.1691	1.2571***	-0.7499	
		(0.3176)	(0.4071)	(0.6606)	
Non-farm Payroll	0.3771	-0.1020	5.8721***	-1.5680	118
		(1.0326)	(1.9853)	(2.4942)	
- Fundamentals	0.3859	-0.0387	3.3264***	0.0029	
		(0.7756)	(1.1208)	(1.5890)	
- Risk	0.2073	-0.0633	2.5457***	-1.5709	
		(0.3928)	(0.9791)	(1.0880)	
Philadelphia Fed	0.2418	-0.7885*	1.8109***	-1.1712	97
		(0.4028)	(0.6231)	(0.9006)	
- Fundamentals	0.2815	-0.2038	0.8359***	0.0620	
		(0.2543)	(0.3329)	(0.5721)	
- Risk	0.1338	-0.5847***	0.9750***	-1.2332***	
		(0.2257)	(0.3585)	(0.4819)	
Retail Sales	0.1971	-0.2774	2.0421***	-1.7232**	106
		(0.3969)	(0.4543)	(0.8244)	
- Fundamentals	0.1867	-0.2035	1.2555***	-0.8915	
		(0.2768)	(0.3138)	(0.5607)	
- Risk	0.0943	-0.0739	0.7865***	-0.8316**	
		(0.2038)	(0.2716)	(0.3998)	

Table 2: US yield decomposition regressions for the 5-year T-note futures contract. The table shows the estimates from regression equations (4), (5) and (6) with Newey-West robust standard errors in parenthesis. ***,**, and * denotes statistical significance at the 1%, 5% and 10% level.

Decomposition regressions					
	R^2	α	β	β_{NEG}	No. Obs
CPI	0.0557	-0.5386	1.0711	-1.0087	79
		(0.8485)	(1.3266)	(1.8641)	
- Fundamentals	0.0423	0.2859	-0.0075	0.7001	
		(0.5495)	(0.7619)	(1.1042)	
- Risk	0.1228	-0.8246**	1.0786*	-1.7088*	
		(0.3817)	(0.6095)	(0.8839)	
Factory Orders	0.1177	-0.2700	0.7126***	-0.4960	87
		(0.2090)	(0.2497)	(0.4704)	
- Fundamentals	0.0407	0.0194	0.1288	0.1838	
		(0.1725)	(0.1672)	(0.3207)	
- Risk	0.1405	-0.2894**	0.5838***	-0.6798**	
		(0.1394)	(0.1697)	(0.3032)	
Industrial Production	0.1768	-0.1774	0.6881**	-0.2666	82
		(0.2646)	(0.2968)	(0.5969)	
- Fundamentals	0.2238	-0.3039	0.7721***	-0.4937	
		(0.2337)	(0.2463)	(0.4911)	
- Risk	0.0071	0.1265	-0.0841	0.2271	
		(0.1689)	(0.2225)	(0.3354)	
Initial Jobless Claims	0.0672	0.1195	-0.4588***	0.0253	458
		(0.1343)	(0.1565)	(0.2966)	
- Fundamentals	0.1179	-0.0005	-0.4547***	-0.0303	
		(0.1046)	(0.1391)	(0.2660)	
- Risk	0.0009	0.1200	-0.0040	0.0555	
		(0.0739)	(0.0801)	(0.1294)	
ISM Manufacturing	0.4418	0.1263	2.3967***	-0.6644	95
		(0.3995)	(0.2935)	(0.6485)	
- Fundamentals	0.4157	0.0853	1.6537***	0.2484	
		(0.2998)	(0.4305)	(0.7300)	
- Risk	0.0606	0.0410	0.7430*	-0.9128	
		(0.2978)	(0.4434)	(0.7437)	
Non-farm Payroll	0.3692	-0.3278	4.6657***	-1.5556	118
		(0.7949)	(1.5976)	(1.9498)	
- Fundamentals	0.3859	-0.0387	3.3264***	0.0029	
		(0.7756)	(1.1208)	(1.5890)	
- Risk	0.0591	-0.2892	1.3394**	-1.5585**	
		(0.2841)	(0.6587)	(0.6829)	
Philadelphia Fed	0.2155	-0.6582*	1.4315***	-0.9933	99
		(0.3400)	(0.5197)	(0.7438)	
- Fundamentals	0.2935	-0.1992	0.8317***	0.0951	
		(0.2525)	(0.3318)	(0.5643)	
- Risk	0.1036	-0.4590**	0.5997**	-1.0884***	
		(0.1907)	(0.2757)	(0.4190)	
Retail Sales	0.2043	-0.2154	1.6357***	-1.4218**	106
		(0.2987)	(0.3556)	(0.5788)	
- Fundamentals	0.1867	-0.2035	1.2555***	-0.8915	
		(0.2768)	(0.3138)	(0.5607)	
- Risk	0.0342	-0.0118	0.3802*	-0.5303*	
		(0.1787)	(0.2248)	(0.3280)	

Table 3: US yield decomposition regressions for the 10-year T-note futures contract. The table shows the estimates from regression equations (4), (5) and (6) with Newey-West robust standard errors in parenthesis. ***,**, and * denotes statistical significance at the 1%, 5% and 10% level.