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Empirical Evidence on Jumps in the Term Structure of the US Treasury Market.*

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Abstract

Sufficiently fast and large disruptions to the continuous price process are referred to as jumps. Cojumping arises when jumps occur contemporaneously across assets. This paper finds significant evidence of jumps and cojumps in the US term structure using the Cantor-Fitzgerald tick dataset sampled over the period 2002-2006. Cojumping frequently occurs in response to scheduled macroeconomic news announcements, however, around one-third of cojumps occur independently of any news announcements.

Keywords: US Treasuries, high frequency, realized variance, jumps, cojumping

JEL Classification: C22, G14.

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1 Introduction

Understanding the process by which bond prices evolve is fundamental to our knowledge of this market. In particular, the characterisation of disruptions to the underlying price process, or jumps, represents an important piece of the temporal dynamics puzzle. For example, Piazzesi (2003) and Johannes (2004) demonstrate the improvements in bond pricing, and Andersen, Bollerslev and Diebold (2007) the gains in forecasting, which result from taking into account jump behaviour. Despite its importance however, relatively little is known about the jump behaviour of bond prices. Das (2002) examines daily Federal Funds Rate data and finds that Federal Open Market Committee (FOMC) meetings are an important factor in explaining jumps. Johannes (2004) focuses on daily 3 month Treasury bill data and identifies 12 large rate changes (termed jumps) that coincide with economic and political news as well as Federal Reserve announcements. In the high frequency domain, Tauchen and Zhou (2006) estimate the jump intensity, mean and variance of 10 year US Treasury bond rates sampled at a 5 minute interval. They use this information to parameterise a jump risk measure, which they relate to movements in credit spreads.

The purpose of this paper is to identify and characterise jumps in the US Treasury bond market. To this end, we first aim to establish the presence of jumps by applying a test proposed by Barndorff-Neilsen and Shephard (2004a, 2006) and Andersen, Bollerslev and Diebold (2007) to individual bond maturities. A recent innovation in the literature is extending this univariate concept of jumping to the multivariate domain, whereby two or more assets simultaneously jump. For example, Bollerslev, Law and Tauchen (2007) consider the issue of cojumping in the context of an index and its constituent stocks, while Jacod and Todorov (2007) develop a test to distinguish common jumping in a two asset environment and Lahaye, Laurent and Neely (2007) consider the relationship between jumps and news across a range of asset types. The focus of this paper on the bond market presents an interesting and unique opportunity to extend this cojumping literature. Unlike other asset markets, the US Government Treasury markets trade a range of near identical assets, which are distinguished only by maturity and coupon. As such, it is interesting to consider the extent to which jumps occur simultaneously across the term structure. This distinction is potentially important as the detection of concurrent jumps across different maturities has very different implications for bond market dynamics compared to the situation where individual bond maturities jump in isolation.

Having established the presence (or otherwise) of jumps in the data, our second objective is to characterise these jumps. A well established literature exists, which shows that the unexpected component of scheduled macroeconomic news has a significant affect on the US Treasury market (see Ederington and Lee, 1993, Becker, Finnerty and Kopecky, 1996, Fleming and Remolona, 1997, 1999a,b, Jones, Lamont and Lumsdaine, 1998, Goldberg and Leonard, 2003, Green, 2004, Simpson, and Ramchander, 2004, and Pasquariello and Vega, 2006). Further, recent forays into the high frequency domain have shown the reaction times to news surprises are very short (see Balduzzi, Elton and Green, 2001, Gurkaynak and Wolfers, 2006 and Andersen, Bollerslev, Diebold and Vega, 2006). This literature suggests that macroeconomic news announcements may be responsible for generating jumps in high-frequency bond price dynamics. As such, our paper is related to that of Piazzesi (2003), who finds considerable improvements in pricing across the yield curve when the potential for jumps associated with FOMC decisions is included. Andersson (2007) also notes the effects of FOMC decisions on bond markets using high frequency data.

We focus on understanding jumps that disrupt the entire term structure, which we argue represent the most interesting jump events. To identify these term structure wide disruptions, we implement a measure of cojumping based on the coexceedances analysis of Bae, Karolyi and Stulz (2003), which was developed in the context of examining extreme events across stock markets. Once we have identified those cases where jumps occur across all maturities, we attempt to establish a relationship to news surprises in a wide range of macroeconomic variables.

The results of our study produce significant evidence of frequent jumps in bond prices for a given maturity. Further, cojumping across two or more maturities is also common, including a large number of cases where the entire term structure jumps. For the latter, jumps across the term structure typically occur in association with a scheduled news release, although not all news releases generate jumps. However, where a news release does generate a jump, the observed return is significantly larger than where news is released that does not generate a jump. Further, news related cojumping is usually associated with a shift in the term structure consistent with the sign of the news announcement surprise. This is not the entire story however, as a number of jumps in the term structure are observed where there is no news surprise and conversely, news surprises do not always generate a jump. These issues remain the subject of ongoing research.

The remainder of this paper proceeds as follows. Section 2 discusses the theoretical relationship between the term structure and the arrival of news to the market. Section 3 describes the price process and the econometric methods used in testing for univariate jumps. The empirical application of jump tests to US Treasury bonds is considered in Section 4, with formal univariate tests and the application of a coexceedance measure of jumping. The cojumps are related to news using intradaily analysis in Section 5. Section 6 concludes.

2 News and the Term Structure of the Yield Curve

The expectations theory of the term structure of interest rates attributes the shape of the yield curve to a consensus forecast of future interest rates. In this context, any macroeconomic news that impacts on bond prices should affect all maturities and simultaneous jumps should be observed. This pure expectations theory of the term structure assumes risk neutrality. The implausibility of this assumption means that this theory has long been discounted as a possible explanation for the term structure and alternatives have been sought. Most alternatives focus on some form of liquidity preference theory or preferred habitat behaviour based explanation for the term structure.

The liquidity preference theory of the term structure assumes that longer term rates are higher than the average of expected future rates by an amount equal to a liquidity risk premium. This premium reflects the relatively higher risk of long bonds, given their greater potential for capital loss before maturity. The liquidity premium hypothesis suggests that long bond prices should be more responsive to the arrival of sensitive news than shorter maturities, so that information driven jumps may be more frequent at the long end of the yield curve.

The liquidity preference theory implies a risk premium which rises uniformly with maturity, which is unrealistic (albeit technically possible). Market segmentation theory also augments the expectations theory with a risk premium, but in this model the premium is not linked to maturity. Instead, investors are assumed to operate solely within particular segments of the yield curve and local supply and demand ultimately determine the equilibrium price for a bond at any given maturity. Investor preference for a particular maturity range may be a function of market characteristics (investors may prefer short-term instruments for reasons of liquidity) or reflect asset-liability management constraints. For example, insurance companies and pension funds typically have predictable long term liabilities, which they hedge by matching to long dated bonds. Commercial banks however, have a portfolio of short and medium term loans which prudent banking practice dictates should be funded by liabilities of a similar maturity. Thus, the segmented market theory assumes that bonds are not substitutable and the supply and demand for short-term and long-term instruments are independent. Modigliani and Sutch (1966) extend this model by removing the assumption of rigid market segmentation. Their preferred habitat theory argues that investors may be induced to move out of their chosen segment of the yield curve, where a risk premium is paid that reflects the marginal investors aversion to reinvestment risk.

The market segmentation/preferred habitat model suggests that speculators may be more active at the short end of the yield curve (where liquidity is higher) compared to the long maturity markets, which are dominated by institutional investors hedging long dated liabilities. In this case, news may generate a relatively greater response in short maturity bond prices as speculators alter their portfolio holdings whereas fund managers do not (unless that news happens to impact on the liability position of their portfolio). Thus, under a preferred habitat theory, jumps may be more prevalent in short maturity bonds compared with longer maturities.

As discussed in the introduction, the empirical evidence on the importance of macroeconomic news announcements on bond pricing is well established; see inter alia Ederington and Lee (1993) Becker, Finnerty and Kopecky (1996), Fleming and Remolona, (1997, 1999a,b,c), Li and Engle (1998), Jones, Lamont and Lumsdaine (1998), Goldberg and Leonard (2003), Green (2004) and Simpson, and Ramchander (2004), Pérignon and Villa (2006) and Pasquariello and Vega (2006).

A relatively small number of papers have considered the responses of different bond maturities to the arrival of macroeconomic news. Barrett, Gosnell and Heuson (2004) found that the unexpected news component of four announcements had the same impact across the maturity spectrum using zero coupon yields. In contrast, de Goeij and Marquering (2006) find that macroeconomic announcements are more influential at the intermediate and long end of the yield curve, while monetary policy changes affect short-term bonds most. Both of these papers consider daily data which may mask intraday effects. Using high frequency data Campbell and Sharpe (2007) find relatively little difference in the news impact for 2 and 10 year bonds, while Balduzzi, Elton and Green (2001) and Gurkaynak, Sack and Swanson (2005) find that news impact is generally increasing with maturity for most macroeconomic announcements. This latter result is supported by Gurkayanak and Wolfers (2006) who use improved data on expectations, based on the relatively new options contracts on future data announcements, and also find that the news impact is broadly increasing from the short end to the longer end of the curve.

3 Identifying and Measuring Jumps

Analysis of high frequency asset market data focuses on measures of the underlying volatility of the data generating process. The price of the asset is assumed to evolve as a continuous process of the form

$$p_t = \int_0^t a_s ds + \int_0^t \sigma_s dW_s \tag{1}$$

where p_t represents the price of the bond at time t, and the right hand side terms represent a continuous, locally bounded variation process, a_s, a strictly positive stochastic volatility process with well defined limits, σ_s, and W_s is Brownian motion. Returns in this process are defined as $r_t = p_t - p_0$ and the associated quadratic variation is given by

$$[r, r]_t = \int_0^t \sigma_s^2 ds \tag{2}$$

where the notation $[r, r]_t$ is taken to denote the equivalent of variance at time t (and commensurately $[r, q]_t$ represents a covariance between r and q). It is well known that asymptotically the quadratic variation in equation (2) can be approximated by realized variance, that is the sum of n squared returns sampled at frequency δ. The subscript δ is used to identify the sampling frequency such that in expressing the realized variance,

$$RV_{t+1}(\delta) = \sum_{j=1}^{1/\delta} r_{t+j\delta,\delta}^2 \tag{3}$$

$r_{t+j\delta,\delta} = p_{t+j\delta} - p_{t+(j-1)\delta}$ are the δ period returns within the day.

Although realized variance has proven to be a useful concept in high frequency analysis, it is also apparent that there are sometimes spikes in the daily realized variance potentially due to underlying events affecting the markets. The search for a means of identifying these spikes led to a literature on jumps in realized variance; see particularly Barndorff-Neilsen and Shephard (2004a) and Andersen and Bollerslev, Diebold (2007). This consists of augmenting the continuous process given in equation (1) with a potentially discontinuous jump component as follows

$$p_t = \int_0^t a_u du + \int_0^t \sigma_u dW_u + \sum_{j=1}^{N} c_{jt} \tag{4}$$

where the final term is the jump process with c_{jt} a non-zero random number, and N is a count variable, representing the number of jumps.

The quadratic variation associated with this equation is given by

$$[r,r]_t = \int_0^t \sigma_s^2 ds + \sum_{j=1}^{N} c_j^2. \tag{5}$$

Barndorff-Nielsen and Shephard (2004a) show how to separate the jumps using bi-power variation.[1] This technique for separating jumps relies on the observation that forms other than realized variance also converge to the true quadratic variation given in equation (2). In particular the Barndorff-Neilsen and Shephard (2004a) test exploits realized bi-power variation, which consists of the standardized sum of the product of consecutive returns given by

$$BV_{t+1}(\delta) = \mu_1^{-2} \sum_{j=2}^{1/\delta} \left|r_{t+j\delta,\delta}\right| \left|r_{t+(j-1)\delta,\delta}\right|.$$

The coefficient of standardization is the mean of the absolute value of the standard normally distributed random variable, $\mu_1 = \sqrt{2/\pi}$. Bi-power variation has the property that

$$BV_{t+1}(\delta) \rightarrow \int_0^t \sigma_s^2 ds. \tag{6}$$

It follows that asymptotically as $\delta \rightarrow 0$

$$RV_{t+1}(\delta) - BV_{t+1}(\delta) \rightarrow \sum_{0<s\leq t} c_s^2$$

where the difference between realized variance and bi-power variation provides a consistent estimate of a jump. In a finite sample it is possible that the sample bi-power variation may be negative, so it is convenient to truncate the measure of jumps at zero and define the jumps $J_{t+1}(\delta)$ as

$$J_{t+1}(\delta) = \max\left[RV_{t+1}(\delta) - BV_{t+1}(\delta), 0\right].$$

In order to select statistically significant jumps the jumps test statistic under the null hypothesis of no jump is defined as

[1] This turns out to be a special case of the more general testing framework for jumps recently proposed by Ait-Sahalia and Jacod (2006), however, their new tests require extremely high numbers of observations to produce good sampling properties, the authors recommend less than one minute sampling, and are hence unsuited to the current data set.

$$JS_{t+1}(\delta) = \frac{RV_{t+1}(\delta) - BV_{t+1}(\delta)}{\sqrt{(\mu_1^{-4} + 2\mu_1^{-2} - 5)\delta \int_t^{t+1} \sigma^4(s)ds}} \to N(0,1). \quad (7)$$

An estimate of $\int_t^{t+1} \sigma^4(s)ds$ is provided by the realized tri-power quarticity, $TQ_{t+1}(\delta)$. For $\delta \to 0$

$$TQ_{t+1}(\delta) = \delta^{-1}\mu_{4/3}^{-3} \sum_{j=3}^{1/\Delta} |r_{t+j\delta,\delta}|^{4/3} |r_{t+(j-1)\delta,\delta}|^{4/3} |r_{t+(j-2)\delta,\delta}|^{4/3} \to \int_t^{t+1} \sigma^4(s)ds,$$

where $\mu_{4/3} = 2^{2/3}\Gamma(7/6)\Gamma(1/2)^{-1}$. Huang and Tauchen (2005) however, have shown that a statistic based on substituting $TQ_{t+1}(\delta)$ into equation (7) tends to over-reject the null. As such, the test statistic implemented in this paper contains a correction based on modifying the denominator of equation (7) (see also Andersen, Bollerslev and Diebold, 2007) as follows.

$$JS_{t+1}(\delta) = \frac{RV_{t+1}(\delta) - BV_{t+1}(\delta)}{\sqrt{(\mu_1^{-4} + 2\mu_1^{-2} - 5) \max\{1, TQ_{t+1}(\delta)BV_{t+1}(\delta)^{-2}\}}} \to N(0,1). \quad (8)$$

The test is then implemented for chosen significance levels. In practice, the significance level chosen has to be quite high as the test tends to find rather a lot of jumps - see Beine et al (2007). Pending the discovery of a formal solution to this problem, we limit the number of jumps by specifying a conservative significance level of 0.001.

4 Empirical Results

Previous research on US bond markets has typically focussed on the GovPX dataset, which brings with it a number of issues related to identifying trades, matching the actual bid-ask spread to trades, and correctly calculating the volume of trade. While one approach would be to ignore these problems, see Andersen and Benzoni (2006), most researchers have undertaken complicated sample manipulation, see Boni and Leach (2004), Brandt and Kavajecz (2004), and Dungey, Goodhart and Tambakis (2007).

Since 2000, the US Treasury market has undergone a significant number of changes (for details, see Mizrach and Neely, 2006). This resulted in a serious drop in the coverage of the GovPX database and the emergence of two new US bond data vendors: Cantor Fitzgerald who provides the eSpeed database and ICAP who provide the BrokerTec database. Mizrach and Neely (2006) report that on-the-run trading is now almost completely electronic, with eSpeed (BrokerTec) capturing 40% (60%) of trading volume. They compare the two databases and find there are qualitatively few differences, which suggests that any empirical results are unlikely to be source dependent.

In this paper, we sample data from the Cantor trades database beginning with the first available observation on January 2, 2002 to September 29, 2006. These 1166 trading days provide over 13.5 million trades in on-the-run bonds, an average of over 11.7 thousand trades each day. While the dataset covers the 2, 3, 5, 10 and 30 year maturities, the 3 year bond as data is only available from April 30, 2003 and so is excluded here. A trading day is defined as starting at 07:30 and finishing at 17:30 (all time references refer to New York trading time). The data have been filtered to remove all US public holidays.

Figure 1 presents average daily volumes and trade size for each maturity. The average daily trading volume is highest in the 5 and 10 year bonds. The 30 year bond however, has a much lower trading volume and averages around 1000 trades per day. The average trade size for the 2 year bond is highest (averaging $US12 million) and this falls progressively as the bond maturity increases to the 30 year bond which has an average trade size of just under $US2.5 million. We omit a more detailed discussion of the volume and trade flow properties of this data in the interests of brevity.

In order to apply the univariate jump testing procedures described in Section 3, the trade by trade data must be sampled at discrete and equal time intervals. There is a lively debate in the high frequency literature about the nature of this sampling interval, including the advantages and disadvantages of sampling at higher frequencies and resampling (see Aït-Sahalia, Mykland and Zhang 2005, Oomen, 2006, and Oomen and Griffin, 2007). In general, a trade-off exists between sampling as frequently as possible to obtain maximum information and sampling from a noisy price signal. Selecting a sampling frequency is further complicated by issues surrounding the choice of sampling method. The usual approach is to take the last trade price in the δ interval as indicative of the total volume traded in that interval. This potentially leads to the problem of scrambling, where information is assigned in a way that distorts the true time interval between the observations. Sheppard (2006) shows that scrambling problems can bias the covariance and may be used to justify lower sample frequencies.

While univariate tests of optimal sampling frequency do exist, the results are not consistent across different maturities.[2] As such, we choose to consider a range of different sampling intervals (5, 10, 15 and 30 minutes) to ensure the robustness of our results. By way of comparison, a wide range of intervals has been used in the previous literature. Fleming (1997) uses 30 minute samples in his study of the US bond spot market, Lahaye, Laurent and Neely (2007) settle for 15 minutes, while Andersen, Bollerslev, Diebold and Vega (2006), Mizrach and Neely (2005) and Bollerslev, Cai and Song (2000) sample at 5 minute intervals in their studies of bond futures data (although none of these authors apply an optimal sampling frequency test). Other asset markets currently used 5 minute intervals, see Andersen and Bollerslev (1998) for foreign exchange and Bandi and Russell (2006) for equities.

The daily realized variance for each of the four maturities sampled at a 5 minute frequency are presented in Figure **??**, other sampling frequencies are provided in Appendix A.1). Realized variance is lowest in the 30 year contract and highest in the 5 year maturity. As indicated in Section 3 the tests for jumps focuses upon comparisons of realized variance with bi-power variation and we proceed to investigate this issue in the next section.

4.1 Univariate Jumping

Table 1 shows the rejection frequency of the univariate jumps test given in equation (8) for the different maturities at the 0.1% significance level - that is the proportion of total observations which are jumps. Where the data is sampled at a 5 minute frequency, jumps are found in the 2 year bond price series on 914 days in a sample of 1166, or 78.4% of the time. The 30 year bond exhibits the second highest number of jumps (689), that is, a jump occurs on 59.1% of the days in the sample.[3] The intermediate 5 and 10 year bonds jump the least, generating a significant test score 42.7% and 44.8% of the time respectively. In other sampling intervals the results qualitatively mirror the 5 minute outcome. That is, the 2 year bond consistently generates the highest number of jumps, the 30 year bond provides the second highest number of jumps (except for the 30 minute interval), and the 5 and 10 year bond show the least number of jumps. The proportion of jumps identified in each maturity increases with the sampling frequency possibly reflecting increasing noise in the data (see Bandi and Russell, 2006).

[2] Zhang, Mykland and Aït-Sahalia (2005) and Bandi and Russell, (2006) develop a means of estimating the optimal sampling frequency. These methods applied to the data used in this paper produce a range of 2 to 19 minutes and vary across maturity and year.

[3] The high proportion of jumps is usual in the application of these jumps tests in the literature, but contrasts with Johannes (2004) method which identifies only 10 jumps in Treasury bills in the period 1991 to 1993.

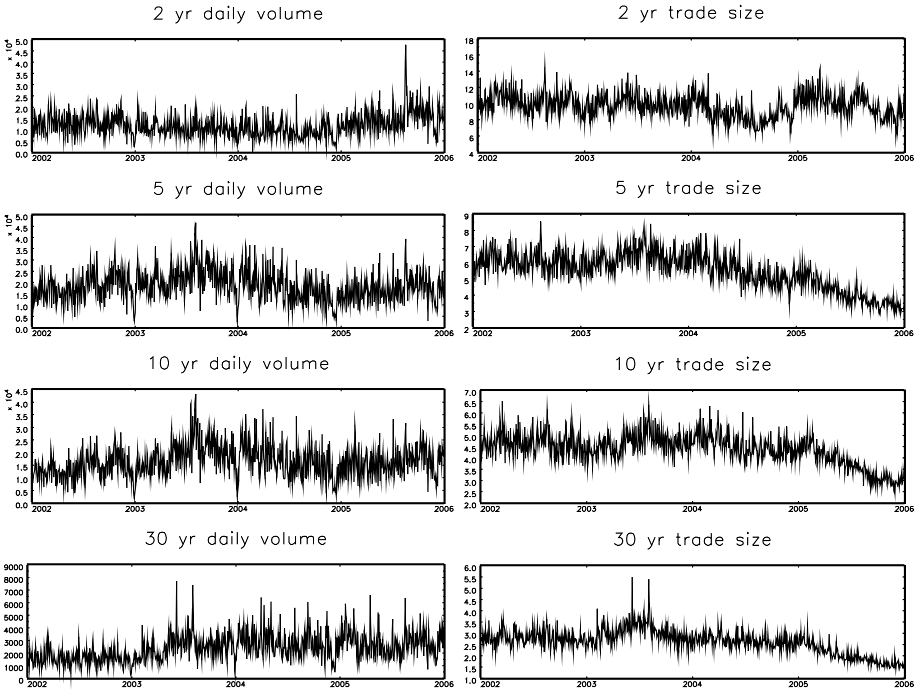

Figure 1: Average daily volume and trade size by maturity 2002-2006

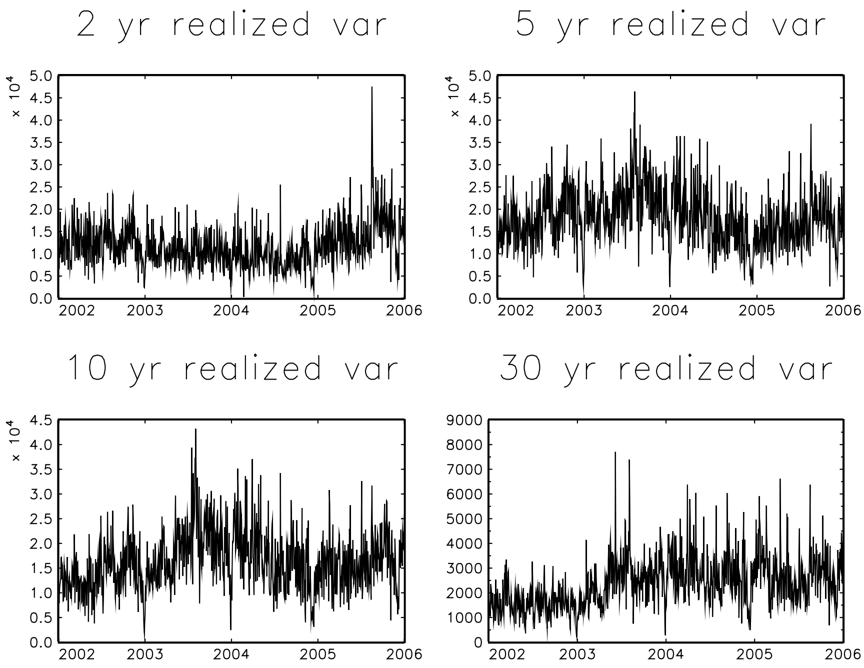

Figure 2: Realized variance calculated from 5 minute sampling frequency.

Table 1:
Rejection Frequency of Jumps Test for 7:30am to 5:30pm sample, number of jumps identified

Maturity	Total days	Rejection Frequency	No. of jump days	Rejection Frequency	No. of jump days
		30 minute sampling		*15 minute sampling*	
2 year	1166	0.279	325	0.389	453
5 year	1166	0.200	233	0.225	262
10 year	1166	0.204	238	0.241	281
30 year	1166	0.194	226	0.251	293
		10 minute sampling		*5 minute sampling*	
2 year	1166	0.521	607	0.784	914
5 year	1166	0.285	332	0.427	498
10 year	1166	0.272	317	0.448	522
30 year	1166	0.300	350	0.591	689

Figure 3 shows the jumps tests results for each of the maturities for the 5 minute sampling interval as the exceedance of the sample statistic over the critical value, and provides visual confirmation of the prevalence of jumps in the 2 year and 30 year maturities. Figure 3 suggests a degree of coincidence in observed jumps, as many of the large critical values appear contemporaneously across maturities and clustering in jump activity also appears common. In the next section, we consider this issue more formally and introduce a measure of cojumping.

4.2 Cojumping

In addition to identifying jumps in the prices of individual bonds through the application of univariate jumps tests, we may also consider whether bonds of differing maturity cojump. Unfortunately, the development of an effective multivariate jump test is an outstanding issue in the literature, although Barndorff-Neilsen and Shephard (2004b) have developed the main elements in the form of multivariate quadratic variation (denoted MQV) and multivariate bi-power covariation (BPCV).

In this paper, we develop an alternative approach to examining the degree of cojumping in the bond data. Our measure is based on the identification of co-exceedances, as introduced by Bae, Karolyi and Stulz (2003) in the context of financial market con-

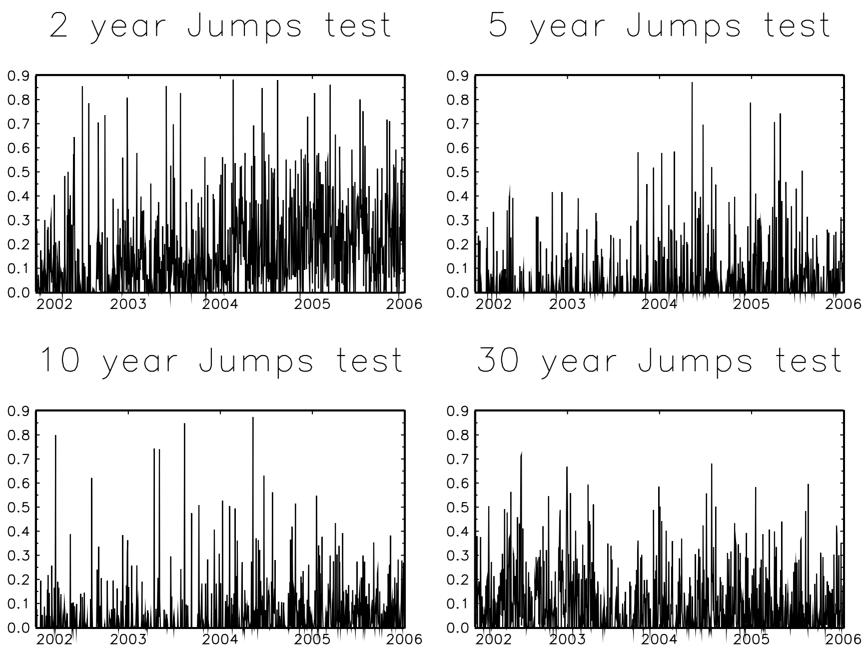

Figure 3: Barndorff-Neilsen and Shephard Univariate Jumps test by maturity at 0.1% significance using 5 minute sampling, presented as the excess of the sample Jump statistic over its critical value.

tagion and extreme events. This approach counts of the number of times the estimated jump test score exceeds a pre-determined threshold across different maturities. The threshold is given by the critical value of the jump statistic, $JS_{t+1}(\delta)$, which will be determined independently for each series under consideration. More formally, denote $d_{i,t,\delta}$ as a binary variable taking the value 1 when returns in bond of varying maturity subscripted i, $i = 1..n$, (sampled at frequency δ) contain a jump as indicated by the univariate jumps test,

$$d_{i,t} = \begin{cases} 1: & JS_{i,t}(\delta) > JS_{i,t}(\delta)_{critical} \\ 0: & \text{otherwise} \end{cases} . \tag{9}$$

The number of coexceedances for a jump in bond of maturity j recorded at time t can then be calculated as a simple sum of $d_{i,t}$ over all $i \neq j$,

$$E_{j,t|d_{j,t}=1} = \sum_{i=1, i\neq j}^{n} d_{i,t}$$

which in the current application of 4 maturities, $n = 4$, means that $E_{j,t}$ varies discretely between 0 and 3.

Table 2 presents the number of co-exceedances associated with an observed jump in

Table 2:
Number of coexceedances in jumps by maturity.

	Co-exceedances				Total number
Maturity	0	1	2	3	of jumps
30 minute sampling					
2 year	124	81	53	67	325
5 year	32	68	66	67	233
10 year	36	66	69	67	238
30 year	68	49	43	67	227
15 minute sampling					
2 year	176	105	73	99	453
5 year	21	66	76	99	262
10 year	34	69	79	99	281
30 year	75	68	51	99	293
10 minute sampling					
2 year	217	169	110	111	607
5 year	32	97	92	111	332
10 year	23	86	97	111	317
30 year	71	98	70	111	350
5 minute sampling					
2 year	186	241	230	257	914
5 year	10	61	170	257	498
10 year	13	79	173	257	522
30 year	84	177	171	257	689

the maturity shown in the first column. With 15 minute sampling, the 2 year bond is observed to jump uniquely (the number of co-exceedances is 0) on 176 occasions, and with one other bond of unspecified maturity 105 times, and contemporaneously with all the maturities in the sample 99 times (the column headed 3 coexceedances). The final column in the table gives the total number of jumps recorded in each maturity. The Table reveals that cojumping across all 4 maturities is clearly the most frequent event.

The results in Table 2 allow some characterisation of jumps by maturity structure. The 2 year maturity has more jumps than other maturities and a relatively high proportion that are unique jumps. The proportions of unique jumps in the 5 and 10 year maturities are relatively low, which means that they are more likely to jump in conjunction with other bonds. The 30 year bond exhibits fewer jumps than the 2 year bond, but at most sampling intervals more than the middle maturity bonds. It also exhibits a large number of unique jumps. The 15 minute sample data highlights these aspects of our results: 176 (38%) of the 2 year jumps are unique, only 21 (8%) and 34 (12%) of the 5 and 10 year jumps are unique, and 75 (75%) of the 30 year jumps are unique. In the 5 minute sample data the corresponding figures for the unique jumps in the 2, 5, 10 and 30 year bonds are 20%, 2%, 2% and 33%. Overall, these results tend to suggest a stylized representation of the yield curve jumping more at both ends than the middle, consistent with elements of both the liquidity preference and preferred habitat theory.

To explore further the term structure of these jumps we refine the co-exceedances reported in Table 2 by maturity structure. Table 3 reports the frequency of cojumping in combinations of bonds denoted as (2,5,10) for example, which gives the number of observations for which the 2, 5 and 10 year bonds record jumps on the same day. The numbers reported are mutually exclusive, meaning that the numbers of jumps recorded in the 2 year and 5 year pair, denoted (2,5), for example, is not a subset of the 2 year, 5 year and 10 year maturity triplet, denoted (2,5,10) in the Table. The results reveal that cojumping is most likely to occur in assets which are contiguous on the term structure.

The most frequent type of cojumping is where all assets jump on the same day. The next most frequent event is a jump involving three assets at the shorter end of the maturity structure (2,5,10) and the pair at the short end consisting of the 2 year and 5 year (2,5). The least frequent events are those which involve two assets which are not contiguous in the maturity structure - for example the 5 and 30 year pair (5,30), although one exception to this is the (2,30) pair in the 5 minute data.

4.3 Intraday Timing of Jumps

While the previous section has identified cojumping in terms of daily jump results, it is not clear that these jumps occur contemporaneously within a day.[4] To address this possibility, the precise timing of any given jump is determined using an approach motivated by Beine et al (2007). Specifically, on a day in which a jump is identified, the returns for each sampling interval in the day are ranked in terms of their absolute value for each maturity. This ranking is then compared across maturities to identify the time period during which the largest absolute return is observed. To limit the scope of the reported results, we only formally consider the case where all 4 maturities cojump

[4] Jacod and Todorov (2007) distinguish between disjointed jumps - which occur on the same day but at different times - and common jumps on a pairwise basis.

Table 3:
Maturity Structure of Multiple Jumps

	sampling frequency			
	30 minute	15 minute	10 minute	5 minute
maturity pairs				
(2,5)	38	41	71	46
(2,10)	21	28	38	25
(2,30)	22	17	60	143
(5,10)	24	17	18	4
(5,30)	6	8	8	11
(10,30)	21	24	30	23
maturity triples				
(2,5,10)	34	42	53	77
(2,5,30)	8	14	26	75
(2,10,30)	11	17	31	78
(5,10,30)	24	20	13	18
all jump	67	99	111	257

within the exact same interval of a given day.[5]

Table 4 provides a detailed breakdown of the intraday timings[6] and shows that the majority of the cojumps across all maturities (henceforth cojumps) occur in the interval beginning with 8:30am regardless of the sampling frequency. The left most column gives the start period for the interval under consideration, and the different columns represent the number of jump days on which the largest absolute movement in returns occurs in the period immediately following the start time for the different sampling frequencies. For example, all four maturities cojumped on 68 occasions in the interval 8:30 to 8:35 for the 5 minute data. The 10 minute column shows that on 53 occasions a cojump occurred in the interval 8:30-8:40 and so forth. Nesting the results across the different sampling frequencies is not straightforward, in part due to issues with selecting the representative price as the last recorded trade in the interval.

[5] We tested the sensitivity of these results to other options and found they are qualitatively unchanged. For example, where we consider the case where 3 maturities experienced their largest intradaily return in the same interval, and the remaining maturity experienced its second largest intradaily return in that interval.

[6] Recent work by Lee and Mykland (2007) suggests a new univariate test which identifies jump times within a day, a multivariate extension of this approach would provide a useful point of comparison here.

Table 4:
Jump Timings

period start time	sampling frequency			
	30 min	15 min	10 min	5 min
8:30	27	40	53	68
10:00	15	14	14	17
14:15	5^a	5	3^a	2
other	7	18	10	27
total	54	77	80	111
unallocated	13	22	81	146
total jump days	67	99	111	257
unallocated as propn of jump days (%)	19	22	29	67

a: There are no 10 or 30 minute intervals beginning at 14:15, the figures given represent jumps in the interval that contains the 14:15 observation - in the case of the 10 minute sample this begins at 14:10, for the 30 minute sample this begins at 14:00. These are provided simply as a point of comparison.

These results clearly show that most cojumping occurs in the periods immediately following 8:30 and 10:00, which are the two most common times for scheduled US news releases. The cojumps at 14:15 also coincide with news releases. In this case FOMC announcements, which have been found to be an important influence on the bond markets. For example, Piazzesi (2005) found that simply including potential jumps for FOMC decisions improves fitting of the yield curve. Our results show that FOMC decisions are less important compared with other news, which suggests that the results of Piazzesi (2005) may be further improved with the inclusion of other news events. Table 4 also contains a row labelled 'other' which records the number of times cojumps occur within a time interval that is not associated with the scheduled release of news. The row labelled 'unallocated' summarises the number of instances in which common jumps were recorded on a given day, but the intraday returns did not correspond across maturities to a particular time period.

5 Sources of Jumps

The evidence of section 4.3 suggests that macroeconomic news may be associated with jumps in the bond market. Existing work suggests that bond markets are strongly affected by the unanticipated component of scheduled news releases, or news surprises. To investigate this possibility further, we focus on CPI, PPI, retail sales, housing starts, GDP, durable goods and non-farm payrolls, which the literature suggests are the most important news items for bond markets.

The first row of Table 5 indicates the number of days in the sample on which news occurs (there are some days with multiple news events) and the sign of the surprise content of each announcement. The surprise content is defined as the difference between the actual announcement and its expected value, where the latter is the median forecast estimate taken from Bloomberg. The surprise in each series is described as 'positive' ('negative'), when the outcome is a greater (smaller) than expected number in the case of non-farm payrolls, retail sales and housing starts, and smaller (greater) than expected number for CPI and PPI. In cases where more than one news release occurred on the same day if the data were both in the same direction then that direction was recorded[7], if the news acted in opposite directions (one positive and one negative piece of news) this was classified as an 'offsetting' news day. A 'no surprise' result is recorded when expectations accord with the actual release. In our data, there were 361 days containing news announcements, 148 containing positive news and 169 containing negative news and 32 with no surprise. The full set of news releases and associated jumps are given in Appendix A.4.

The remaining rows of data in Table 5 record the number of jumps associated with news announcements for different sampling frequencies. The numbers recorded are slightly lower than those in Table 4 as there are a number of instances where cojumps occurred at 8:30 on a particular day, but no news announcement occurs in our data set.[8] The results show that the proportion of news days on which there are jumps is relatively low, under 10 percent of the total days recorded. Negative news was more likely to record a jump than positive news, even after controlling for the higher prevalence of negative news items in the sample data.

The direction of the jumps in the term structure should relate to the surprise content of the news release. For example, Figure 4 provides a snapshot of the shift in the term structure for a positive and a negative non-farm payroll news event drawn from the 5 minute data sample. The three lines describe the shift in the yield curve at time t, $t+1$ and $t+2$ (which are $5, 10$ and 15 minutes respectively) from the

[7] In some cases there were two announcements, one of which had no surprise and the other a positive (negative) surprise, in which case the news was classified as a positive (negative) surprise event.

[8] For example in the 15 minute data there were jumps across the term structure at 8:30am on 28 June 2004, 15 September 2004 and 31 March 2005 which do not seem to relate to any particular news release.

Table 5:
Positive and negative news concerning CPI, PPI, retail sales,GDP(prelim, advance and final), durable goods and non-farm payrolls, housing starts and relationship with jumps at 8:30am.

	total		type of news		
	news	positive	negative	offsetting	no surprise
type of surprise	361	148	169	12	32
with jumps by sampling frequency					
30 minutes	25	14	11	0	0
15 minutes	37	15	19	0	3
10 minutes	44	13	25	3	3
5 minutes	61	19	36	3	3

prevailing price at the time of the news event. Note that sensitivity analysis to the return as calculated from a starting point 5 minutes prior to the news release showed no discernible difference in the results.

The left hand panel in Figure 4 is for December 6, 2002 on which day non-farm payrolls were released with an expected figure of +35,500 and an actual figure of -40,000. In response to this news, bond prices rose which is consistent with a downward revision of the outlook for the economy. The right hand panel relates to May 11, 2004 when non-farm payrolls were expected to be +175,000, while the actual release was much stronger than expected at +337,000. Bond prices fell across the maturity structure consistent with stronger expectations for the economic growth (and higher inflation). In each case the analysis of the moves in term structure correspond to the direction of the news surprise, and this is generally the case for all the jumps associated with news surprise events. The exceptions to this pattern are relatively few. The complete sample of news events and shifts in the term structure are contained in Table A.5 in the Appendix where the news release, its expectation and realisation are given in table form, and the term structure shifts in graphical form. For any particular news event associated with a jump consult Table A.4 for the date of the release and the sign and extent of the surprise and cross match this with the graphs in Sections A.2 and A.3 for the 5 and 15 minute samples respectively for the corresponding day to see the response in the term structure.

Table 6 documents some descriptive statistics of the size of the surprises in each of the macroeconomic news announcements considered using the 5 minute sample (the

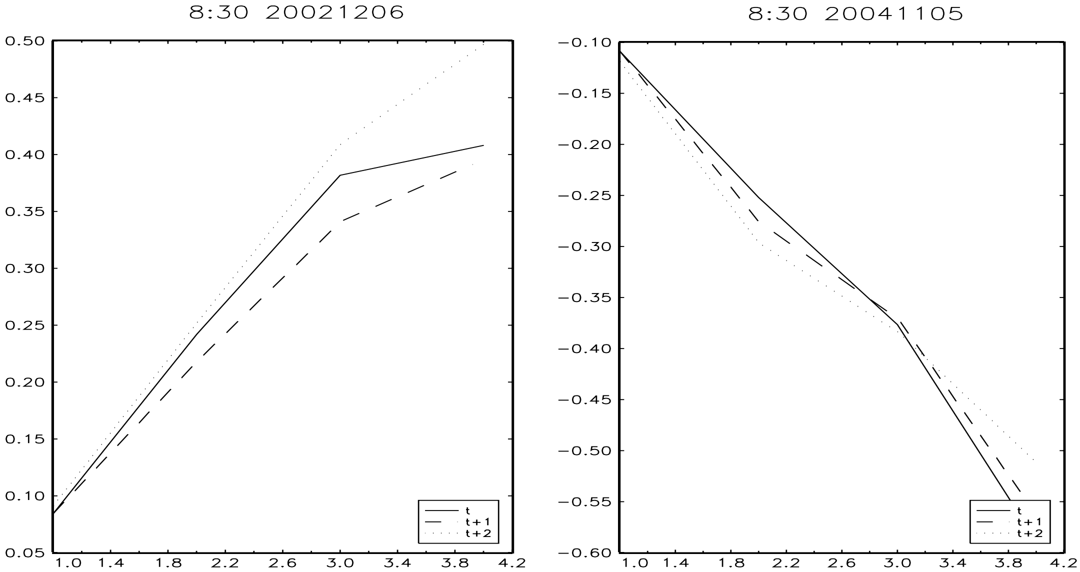

Figure 4: Shift in the term structure associated with a non-farm payrolls announcement. The left panel is the response to payrolls being -75,500 less than expected, the right panel is the response to payrolls being 162,000 more than expected. The release dates are given as YYYYMMDD.

corresponding results for the 10, 15 and 30 minute samples may be found in Table A.5 in the Appendix). The measures of surprise are in units appropriate to that release, so are not comparable across the columns. The top panel of the table gives the surprise characteristics for all the announcements in the sample period, so for example, non-farm payrolls had an average surprise component of 68,460 persons, with a maximum recorded surprise of 318,000 and minimum of 3,000. The bottom panel records the size of surprises associated with jumps in the sample. So for non-farm payrolls, the average surprise component in a jump situation was 93,313 with a maximum of 208,000 and minimum of 9,000.

Across the different announcements, the average surprise is larger in the cases where jumps occur, but the largest surprises are often not associated with jumps. For example, there are large surprises in the PPI, retail sales, GDP and durable goods announcements that are not associated with jumps. The exception is CPI and housing starts where jumps occur at the maximum surprise. On the other hand, at the minimum surprise, which is zero in most cases, jumps also occur. The size of the surprise component in the announcement does not necessarily relate to the likelihood of a jump.[9] In the

[9]The possibility that the expectations data are stale may account for some of the recorded discrepancies. Gurkaynak and Wolfers (2005) use options based estimates of major news release expectations

context of the existing literature, the current results extend the association between jumps and scheduled news (Piazzesi 2006) and jumps and surprise events (Johannes 2004), to include the existence of both large surprises without jumps and jumps with no surprise information.

To formalise the extent to which jumps may be related to news we adapt the methodology of Balduzzi, Elton and Green (2001) who regress the return from five minutes prior to the news announcement to 30 minutes afterwards on the size of the news surprise. In order to distinguish whether the relationship between returns and the surprise component of scheduled news differs significantly in the presence of jumps, we augment their model to include an interaction term for the presence of jumps, ie. we regress:

$$r_t = \alpha + \beta S_t + \gamma D_t S_t + \varepsilon_t, \tag{10}$$

where r_t is the return (log price difference of traded prices sampled immediately prior to the news release to the next sampling period), S_t is the standardized news surprise (where the surprise is the difference between the actual and expected news divided by the standard deviation of all surprises for that macroeconomic indicator), D_t is a one-zero dummy indicating whether the news event was associated with a jump in the term structure and ε_t is the error term.

Table 7 reports the estimation results for each maturity and sampling frequency. These results indicate that good news for the economy decreases bond prices, as indicated by the negative β coefficients. These results are consistent with the significant negative relationship between news surprises and returns found in the earlier literature. Surprises on jump days have a significantly greater price impact than on non-jump days, ie. γ is negative in all cases. Lahaye, Laurent and Neely (2007) show a significant impact of news surprises on jump days across a range of assets, although they do not distinguish the increment from non-jump surprise days. The estimation results also show that the effects of news surprises from scheduled releases are increasing across the maturity structure as found by Balduzzi, Elton and Green (2001), Gurkaynak, Sack and Swanson (2005) and Gurkayanak and Wolfers (2006). Additionally, here we find that the effect of news surprises, given by β, does not change much across different sampling frequencies. The impact of the interaction with jump identification, given by γ, decreases as the sampling frequency increases. This suggests that the effect of jumps at lower frequencies is substantially greater than those only detectable at high frequency (note that many jumps are detectable at multiple frequencies, as shown in

and find that they are slightly more accurate than survey based forecasts.

Table 6:
Surprises in scheduled news announcements and Jumps from 5 minute data sample,January 2002- September 2006 inclusive. Surprise units are: non-farm payrolls ('000s of persons), CPI, PPI, retail sales,durable goods (month on month growth), housing starts ('000s starts), GDP (quarter on quarter growth).

	non-farm payrolls	CPI	PPI	retail sales	house starts	GDP	durable goods
number of announcements	57	57	57	57	57	57	57
surprise characteristics							
max abs(surprise)	318.00	0.30	1.20	1.50	256.00	1.70	8.20
min abs(surprise)	3	0	0	0	7.5	0	0
average abs(surprise)	68.46	0.10	0.36	0.39	89.83	0.37	1.88
jumps matching announcements	19	12	12	12	11	5	11
positive surprise	5	7	4	5	5	1	7
negative surprise	14	2	6	6	6	4	4
zero surprise	0	3	2	1	0	0	0
surprises & jumps characteristics							
max abs(surprise)	208.00	0.30	1.10	0.80	256.00	0.80	7.20
min abs(surprise)	9.00	0.00	0.00	0.00	13.00	0.10	0.80
average abs(surprise)	93.13	0.11	0.30	0.36	93.23	0.42	2.81

Appendix A.4). This may tie directly to the persistence of the price effects from the news surprise and is an ongoing area of research.

The preceding analysis has focussed on the price impact of the surprise component of macroeconomic news announcements. From Table 4, it is evident that there are a number of jumps that occur in the absence of scheduled news events. For example, Figure 5 provides a summary of the shifts in the term structure for the 24 non-news jump events in the 5 minute data (the corresponding figures for 15 minute samples can be seen in Section A.3 in the Appendix). Casual observation suggest that there is nothing to distinguish these events from those shifts associated with news releases. One possible explanation would be that these jumps are in response to news events other than macroeconomic data announcement dates. For example, at all sampling frequencies a jump is detected on 20 April 2005, which is the date on which US Secretrary to Treasury McClellan held a press conference in which he commented on reissuance of

Table 7:
Returns, Surprises and Jumps, results of estimating equation (7) across maturities and different sampling frequencies, (standard errors), * indicates statistically significant at 5% level.

	2 year	5 year	10 year	30 year	2 year	5 year	10 year	30 year
	30 minute sampling				*15 minute sampling*			
α	0.001	0.005	0.007	0.016	0.002	0.009	0.016	0.032
	(0.005)	(0.007)	(0.011)	(0.014)	(0.005)	(0.007)	(0.011)	(0.015)
β	-0.030*	-0.075*	-0.116*	-0.150*	-0.030*	-0.069*	-0.106*	-0.126*
	(0.005)	(0.008)	(0.012)	(0.016)	(0.006)	(0.009)	(0.012)	(0.017)
γ	-0.098*	-0.238*	-0.320*	-0.424*	-0.070*	-0.184*	-0.249*	-0.370*
	(0.013)	(0.020)	(0.029)	(0.039)	(0.012)	(0.017)	(0.024)	(0.034)
	10 minute sampling				*5 minute sampling*			
α	0.002	0.008	0.012	0.025	0.002	0.014	0.014	0.016
	(0.005)	(0.007)	(0.010)	(0.015)	(0.005)	(0.010)	(0.010)	(0.014)
β	-0.031*	-0.070*	-0.104*	-0.128*	-0.033*	-0.073*	-0.117*	-0.147*
	(0.006)	(0.008)	(0.012)	(0.017)	(0.005)	(0.008)	(0.012)	(0.016)
γ	-0.062*	-0.172*	-0.234*	-0.365*	-0.055*	-0.159*	-0.204*	-0.276*
	(0.011)	(0.016)	(0.023)	(0.034)	(0.011)	(0.016)	(0.023)	(0.031)

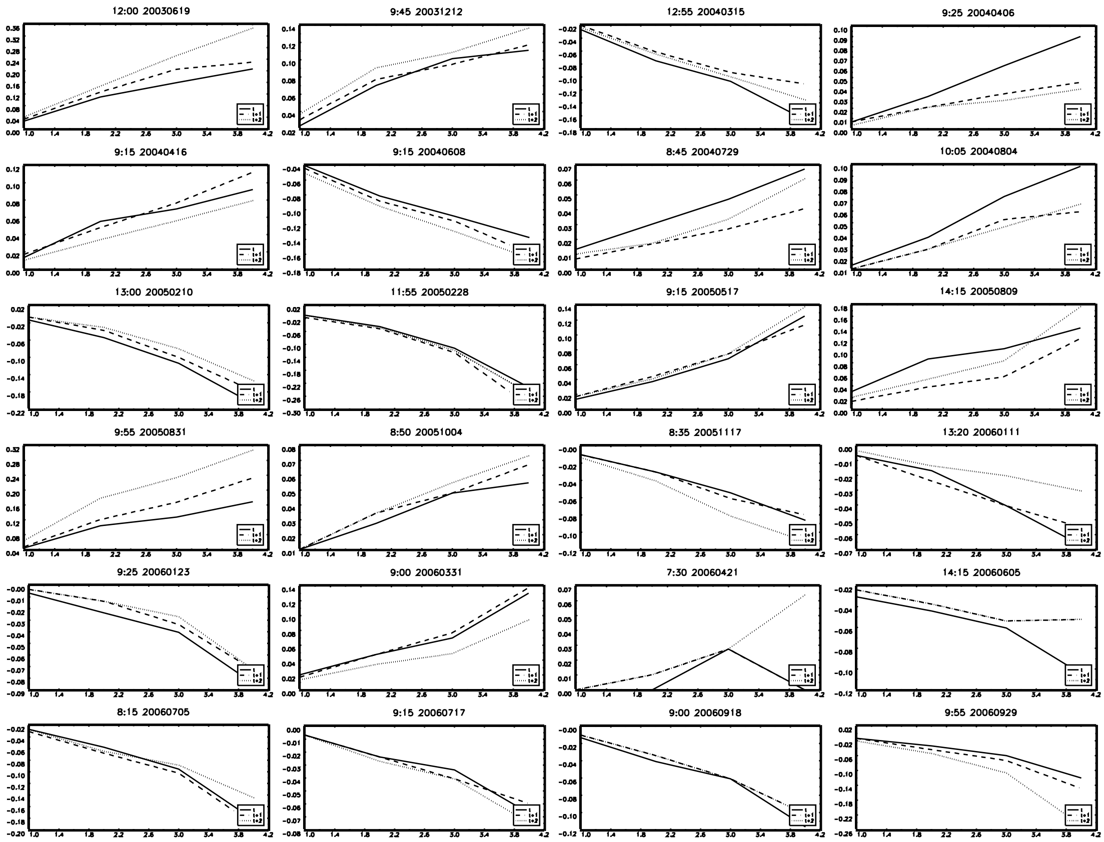

Figure 5: Shift in prices across the term structure associated with jumps but no scheduled news giving time and day for period January 2002 to September 2006. The date is given in the form YYYYMMDD.

30 year Treasury bonds. Jiang, Lo and Verdelhan (2007) have found evidence relating jumps to liquidity pressures captured in the order book. Another possibility is that the jumps in the bond market are in response to events in other asset markets. For example, Das (2002) finds that jumps are more likely to occur on Wednesdays, which he attributes to option expiry effects. Dungey and Martin (2007) provide evidence of spillovers from equity to bond markets. Explaining non-news related jumps and their causes is an area of ongoing investigation.

6 Conclusion

This paper builds on an emerging literature which attempts to understand the process by which bond prices evolve. We first identified significant disruptions to the price dynamics for US Treasury bonds using univariate jumps tests across a variety of sampling intervals using the newly available Cantor-Fitzgerald trades database. The concept of cojumping was introduced as a means of exploring whether jumps occurred together across the maturity structure, consistent with expectations theory of term structure, or were predominantly associated with short term assets, consistent with preferred habitat theory, or longer term assets, consistent with liquidity theory. The empirical results showed that the US Treasuries tended to cojump across maturities, but that there were also more unique jumps at both ends of the curve, providing some support for both liquidity and preferred habitat behaviour.

In around two-thirds of the sample, cojumping across the maturity structure coincided with a scheduled US news release, confirming earlier results that news has a significant impact on Treasury bonds. However, not all news was associated with a significant disruption in the price process, and the size of surprise in the news is not necessarily directly related to the existence of a jump. The direction of the shift in the term structure in response to news was consistent with expectations: news which added to inflationary pressures decreased bond prices. Additionally, the presence of jumps was associated with a stronger response to a news surprise than where no jump is observed. Jumps which occured without any identifiable news event were not readily distinguishable from the jumps associated with news, although they tended to be somewhat more likely to be associated with negative news. The evidence on jumps in bond prices explored in this paper indicates the complexity of the dynamics in this market, stimulating future research into the transmission of shocks into this market, the response of the term structure and interactions with other asset markets.

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A Appendix – All Jumps by Sampling Frequency

A.1 Realized Variance at alternative sampling frequencies

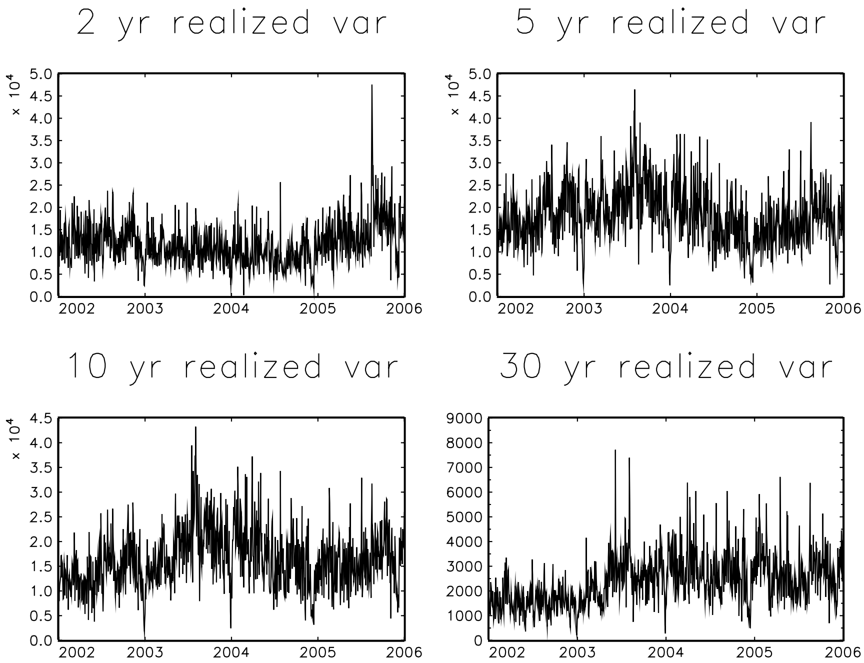


Figure 6: Realized variance calculated from 10 minute sampling frequency.

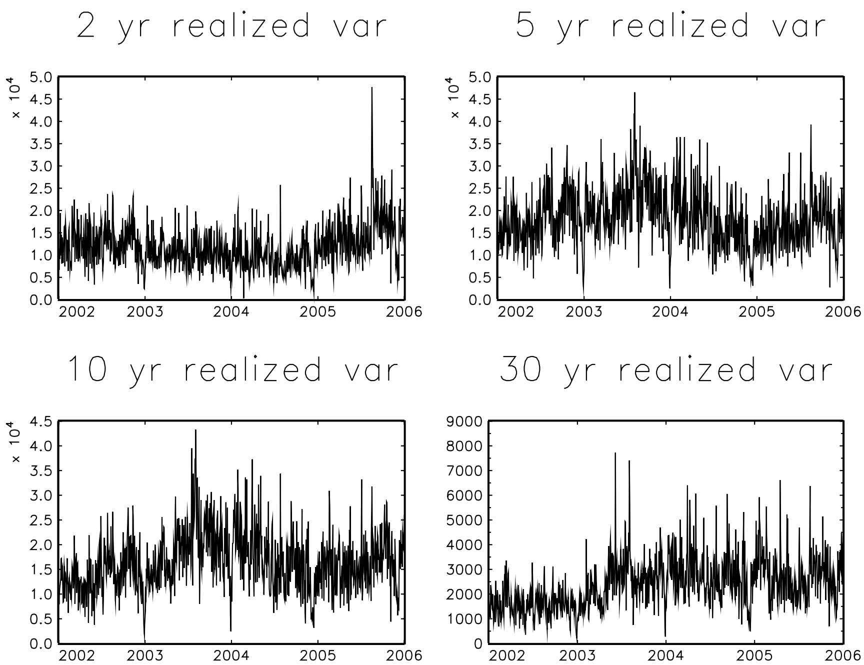


Figure 7: Realized variance calculated from 15 minute sampling frequency.

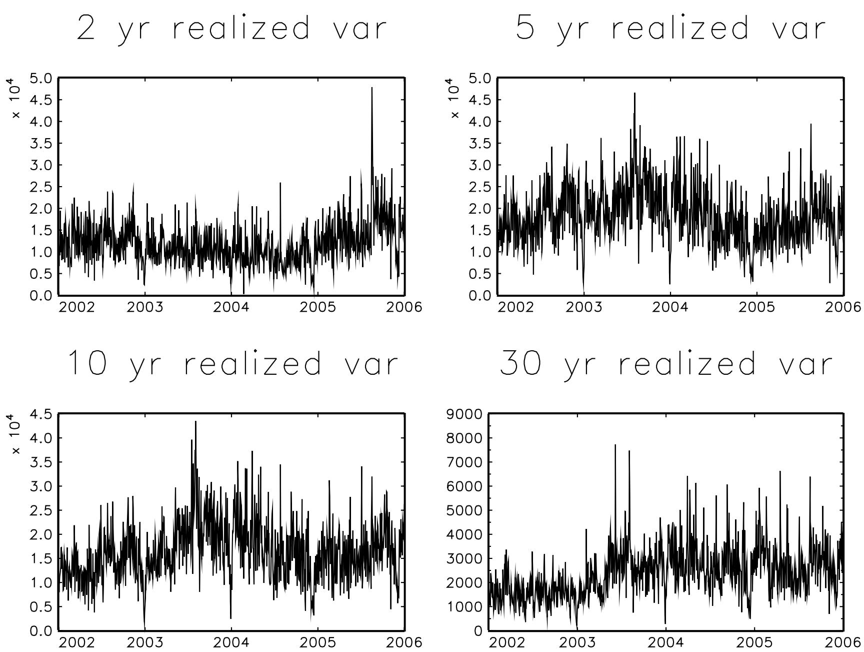
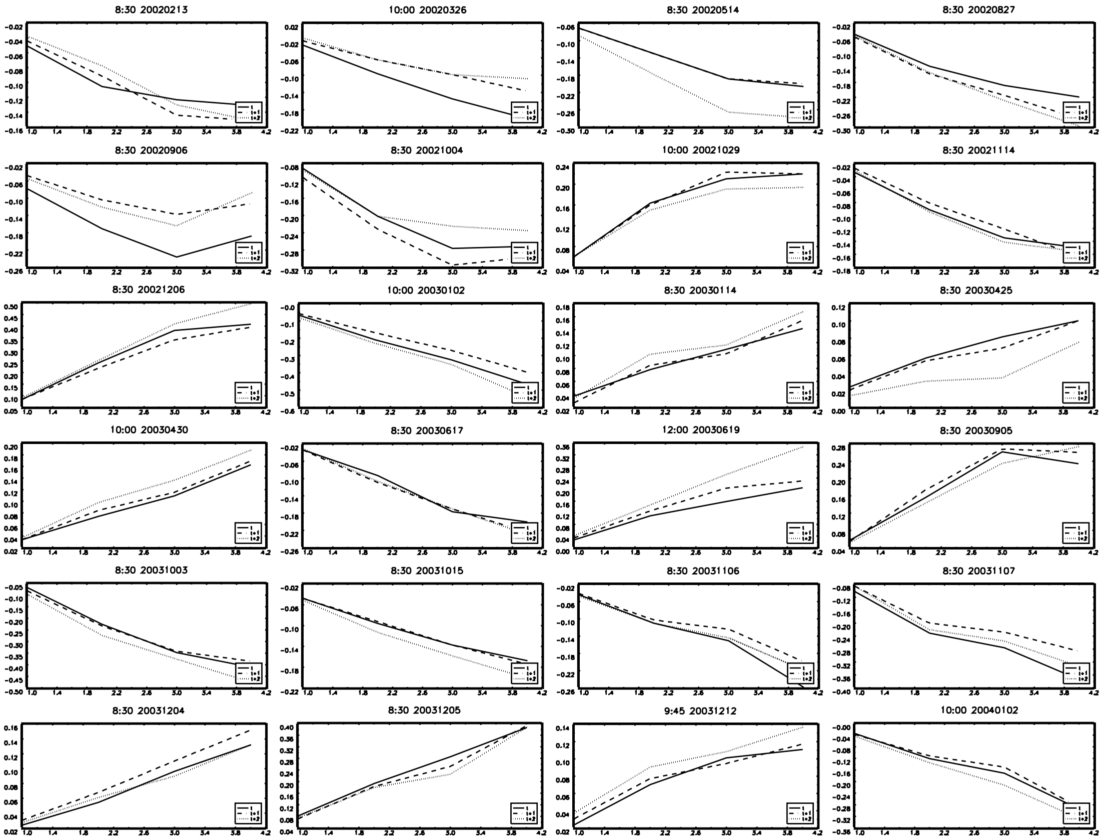
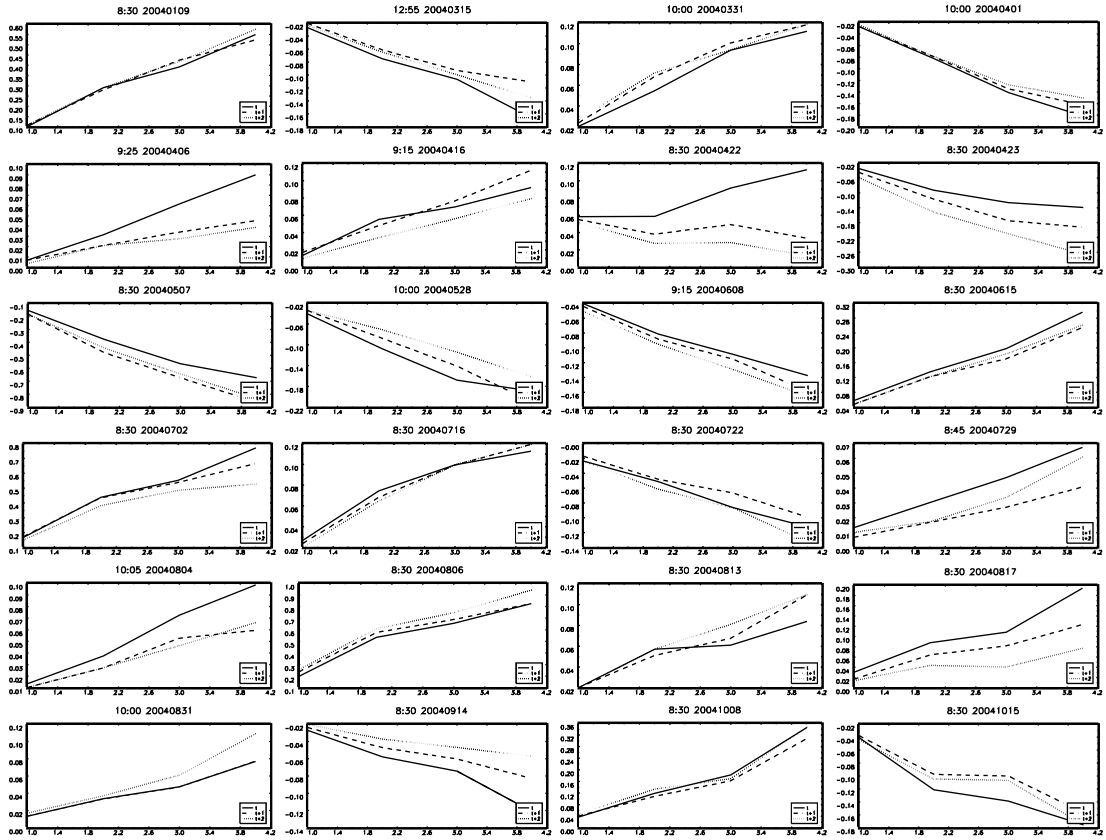


Figure 8: Realized variance calculated from 30 minute sampling frequency.

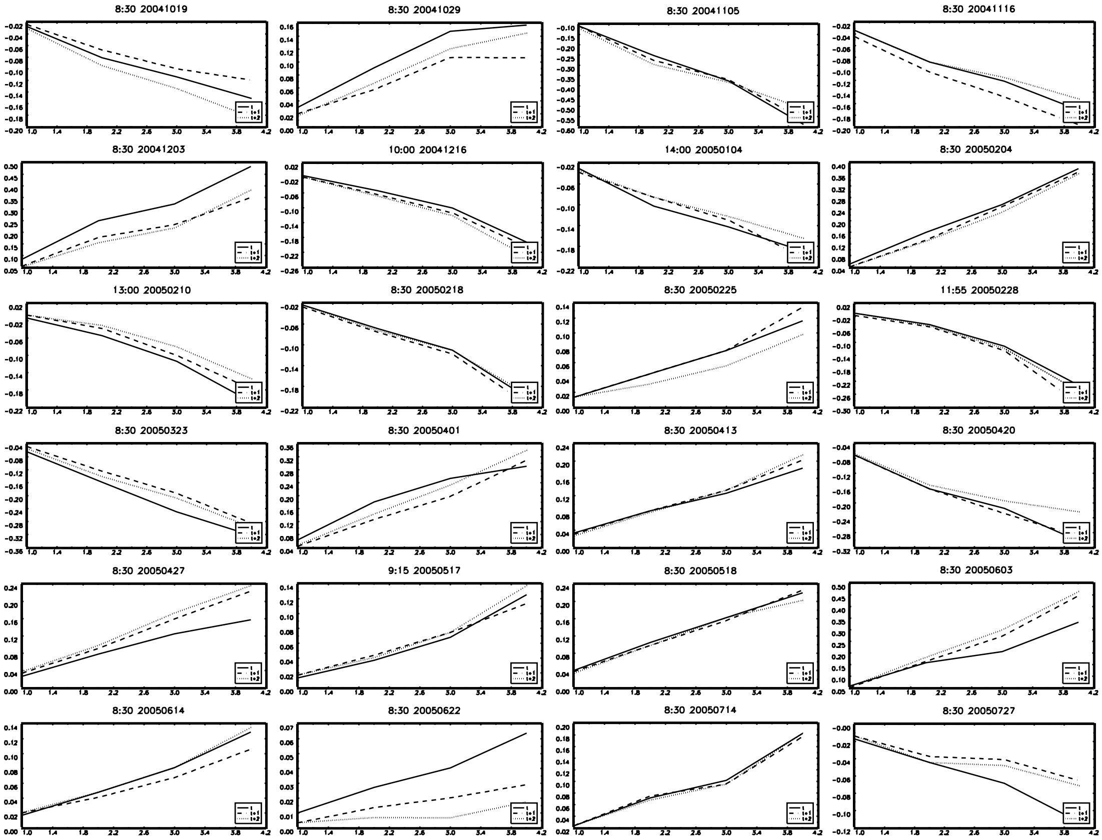
A.2 Term Structure Shifts Associated with a Jump in 5 Minute Sampling



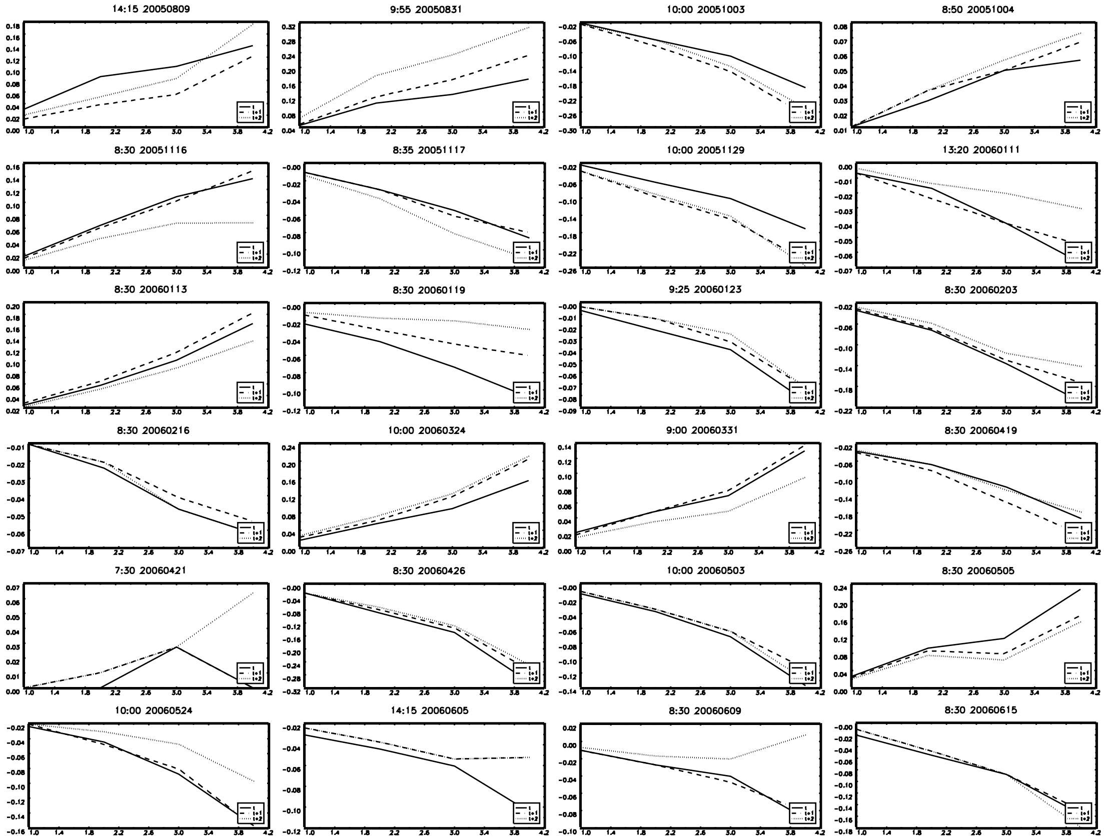
Shift in prices across the term structure when a jump is detected in 5 minute data by time and day for period January 2002 to January 2004. The date is given in the form YYYYMMDD.



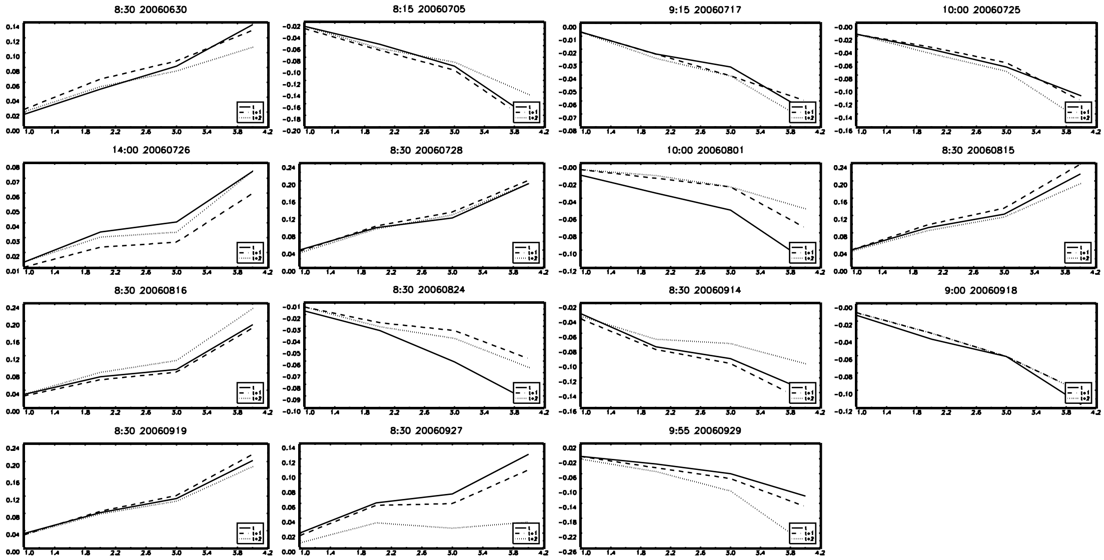
Shift in prices across the term structure when a jump is detected in 5 minute data by time and day for period January 2004 to October 2004. The date is given in the form YYYYMMDD.



Shift in prices across the term structure when a jump is detected in 5 minute data by time and day for period October 2004 to July 2005. The date is given in the form YYYYMMDD.

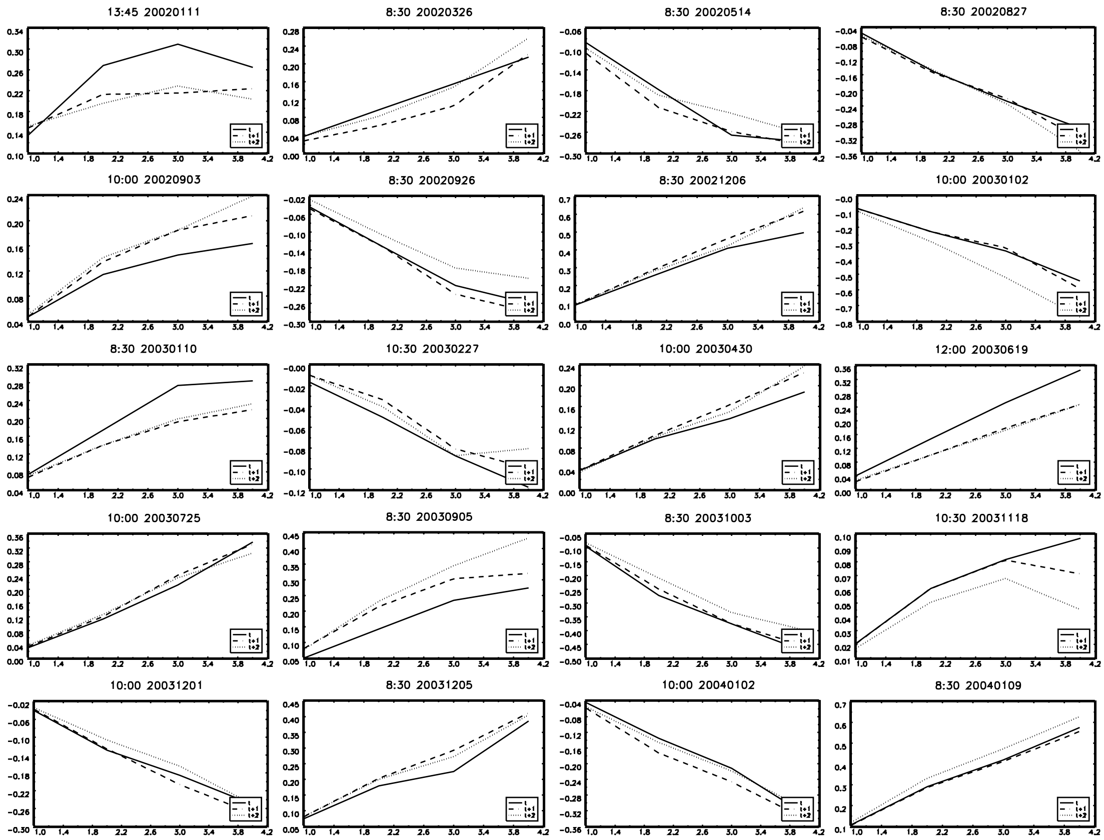


Shift in prices across the term structure when a jump is detected in 5 minute data by time and day for period August 2005 to June 2006. The date is given in the form YYYYMMDD.

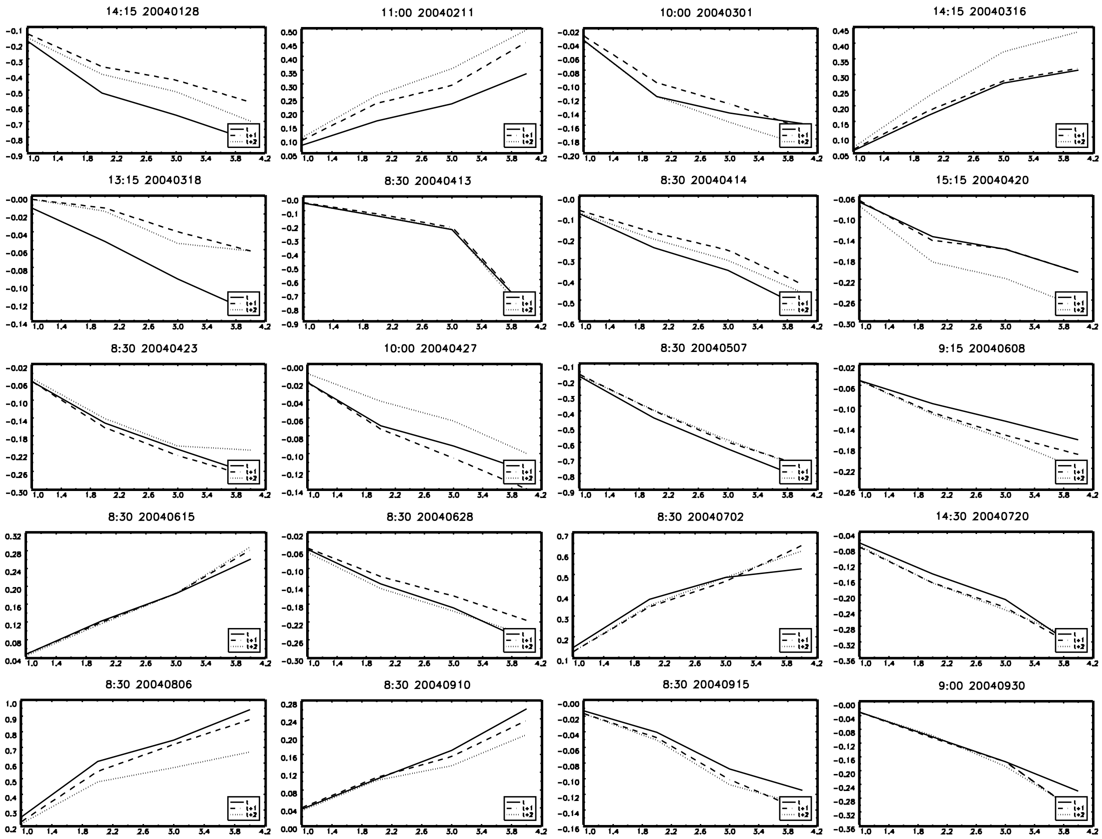


Shift in prices across the term structure when a jump is detected in 5 minute data by time and day for period June 2006 to September 2006. The date is given in the form YYYYMMDD.

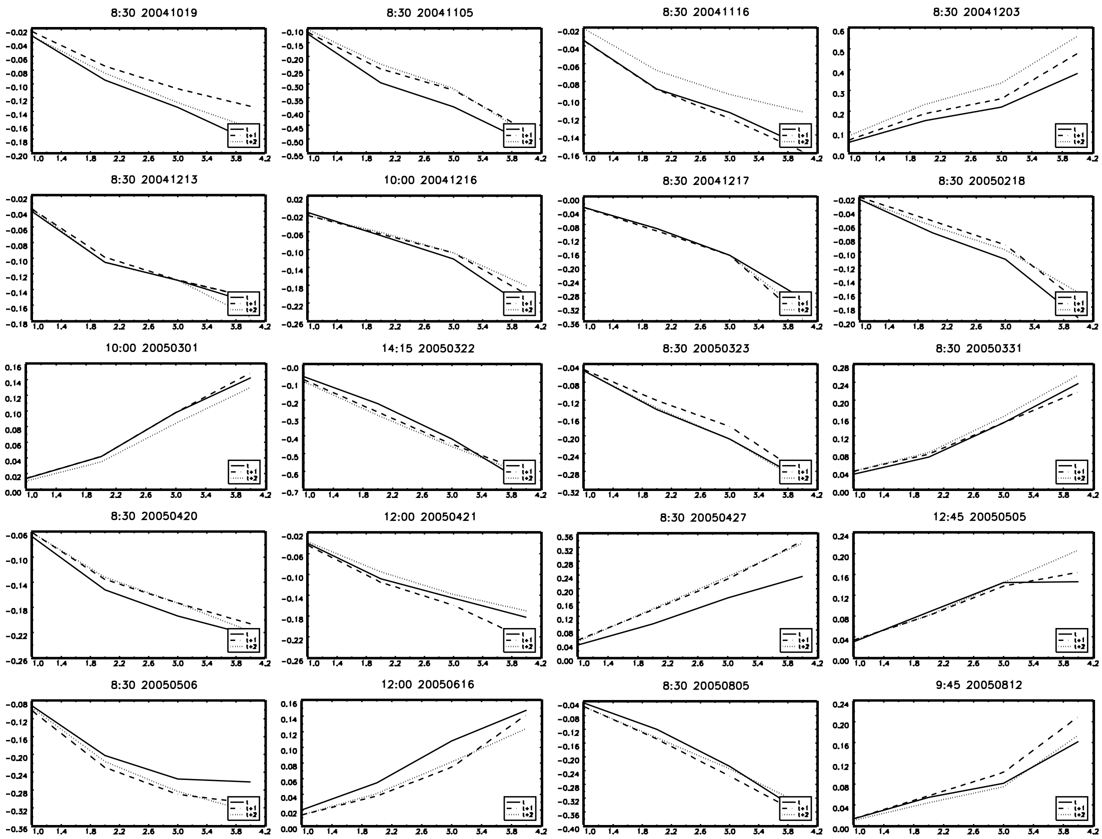
A.3 Term Structure Shifts Associated with a Jump in 15 Minute Sampling



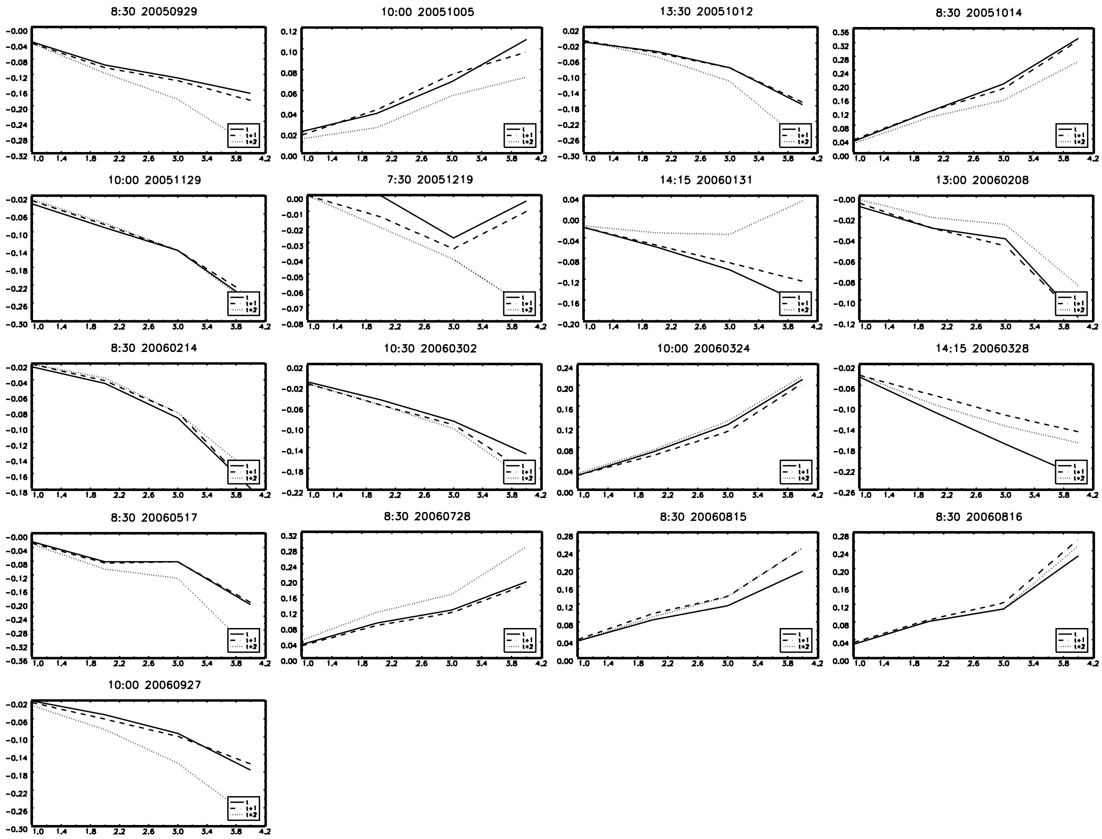
Shift in prices across the term structure when a jump is detected in 15 minute data by time and day for period January 2002 to January 2004. The date is given in the form YYYYMMDD.



Shift in prices across the term structure when a jump is detected in 15 minute data by time and day for period January 2004 to September 2004. The date is given in the form YYYYMMDD.



Shift in prices across the term structure when a jump is detected in 15 minute data by time and day for period October 2004 to August 2005. The date is given in the form YYYYMMDD.



Shift in prices across the term structure when a jump is detected in 15 minute data by time and day for period September 2005 to September 2006. The date is given in the form YYYYMMDD.

A.4 News surprises, dates and jumps

News Release Surprises and Jumps by sampling frequency: January 2002 to August 2004

Date	Release	News Actual	Expected	Surprise	Jump in sampling frequency (mins)			
					5	10	15	30
13/02/2002	Retail sales	-0.2	-0.2	0	X			
26/03/2002	Dur. Goods Orders	1.8	1	0.8			X	
14/05/2002	Retail sales	1.2	0.6	0.6	X		X	X
27/08/2002	Dur. Goods Orders	8.7	1.5	7.2	X	X	X	X
06/09/2002	NonFarm payrolls	39	30	9	X			
26/09/2002	Dur. Goods Orders	-0.6	-3	2.4		X	X	
04/10/2002	NonFarm payrolls	-43	6	-49	X			
14/11/2002	Retail sales	0	-0.2	0.2	X			
06/12/2002	NonFarm payrolls	-40	35.5	-75.5	X		X	
24/12/2002	Dur. Goods Orders	-1.4	0.8	-2.2		X		
10/01/2003	NonFarm payrolls	-101	20	-121		X	X	
14/01/2003	Retail sales	1.2	1.5	-0.3	X			
25/04/2003	GDP	1.6	2.4	-0.8	X			
06/06/2003	NonFarm payrolls	-17	-30	13				X
17/06/2003	CPI	0	-0.1	0.1	X	X		
17/06/2003	Housing starts	1732	1700	32	X	X		
03/07/2003	NonFarm payrolls	-30	0	-30		X		
05/09/2003	NonFarm payrolls	-93	20	-113	X	X	X	
03/10/2003	NonFarm payrolls	57	-25	82	X	X	X	X
15/10/2003	Retail sales	-0.2	-0.1	-0.1	X			
07/11/2003	NonFarm payrolls	126	65	61	X			
05/12/2003	NonFarm payrolls	57	150	-93	X	X	X	X
12/12/2003	PPI	-0.3	0.1	-0.4				X
09/01/2004	NonFarm payrolls	1	150	-149	X	X	X	X
06/02/2004	NonFarm payrolls	112	175	-63		X		
13/04/2004	Retail sales	1.8	0.7	1.1		X	X	
14/04/2004	CPI	0.5	0.3	0.2			X	X
22/04/2004	PPI	0.5	0.4	0.1	X			
23/04/2004	Dur. Goods Orders	3.4	0.7	2.7	X		X	

News Release Surprises and Jumps by sampling frequency: September 2004 to December 2005

Date	Release	News Actual	Expected	Surprise	Jump in sampling frequency (mins)			
					5	10	15	30
03/09/2004	NonFarm payrolls	144	150	-6		X		
10/09/2004	PPI	-0.1	0.2	-0.3			X	X
14/09/2004	Retail sales	-0.3	-0.1	-0.2	X			
08/10/2004	NonFarm payrolls	96	147.5	-51.5	X			X
15/10/2004	PPI	0.1	0.1	0	X	X		
15/10/2004	Retail sales	1.5	0.7	0.8	X	X		
19/10/2004	CPI	0.2	0.2	0	X		X	
19/10/2004	Housing starts	1898	1950	-52	X		X	
29/10/2004	GDP	3.7	4.3	-0.6	X			
05/11/2004	NonFarm payrolls	337	175	162	X	X	X	X
16/11/2004	PPI	1.7	0.6	1.1	X		X	
17/11/2004	CPI	0.6	0.4	0.2		X		
17/11/2004	Housing starts	2027	1960	67		X		
03/12/2004	NonFarm payrolls	112	200	-88	X	X	X	
13/12/2004	Retail sales	0.1	-0.1	0.2			X	X
17/12/2004	CPI	0.2	0.2	0			X	X
04/02/2005	NonFarm payrolls	146	200	-54	X			
18/02/2005	PPI	0.3	0.3	0	X	X	X	
25/02/2005	GDP	3.8	3.7	0.1	X			
23/03/2005	CPI	0.4	0.3	0.1	X	X	X	X
01/04/2005	NonFarm payrolls	110	212.5	-102.5	X			
13/04/2005	Retail sales	0.3	0.8	-0.5	X	X		
20/04/2005	CPI	0.6	0.5	0.1	X	X	X	X
27/04/2005	Dur. Goods Orders	-2.8	0.3	-3.1	X	X	X	X
06/05/2005	NonFarm payrolls	274	174	100			X	X
18/05/2005	CPI	0.5	0.4	0.1	X	X		X
03/06/2005	NonFarm payrolls	78	175	-97	X	X		
14/06/2005	PPI	-0.6	-0.2	-0.4	X			
14/06/2005	Retail sales	-0.5	-0.2	-0.3	X			
14/07/2005	CPI	0	0.2	-0.2	X			
14/07/2005	Retail sales	1.7	1	0.7	X			
27/07/2005	Dur. Goods Orders	1.4	-1	2.4	X			
05/08/2005	NonFarm payrolls	207	180	27		X	X	X
29/09/2005	GDP	3.3	3.3	0			X	
14/10/2005	CPI	1.2	0.9	0.3		X	X	
14/10/2005	Retail sales	0.2	0.5	-0.3		X	X	
16/11/2005	CPI	0.2	0	0.2	X	X		

News Release Surprises and Jumps by sampling frequency: January 2006 to September 2006

Date	Release	News Actual	Expected	Surprise	Jump in sampling frequency (mins)			
					5	10	15	30
13/01/2006	PPI	0.9	0.4	0.5	X	X		X
13/01/2006	Retail sales	0.7	0.9	-0.2	X	X		X
19/01/2006	Housing starts	1933	2035	-102	X			
26/01/2006	Dur. Goods Orders	1.3	1	0.3		X		
03/02/2006	NonFarm payrolls	193	250	-57	X	X		
14/02/2006	Retail sales	2.3	0.9	1.4		X	X	
16/02/2006	Housing starts	2276	2020	256	X			
22/02/2006	CPI	0.7	0.5	0.2		X		
21/03/2006	PPI	-1.4	-0.2	-1.2		X		
30/03/2006	GDP	1.7	1.7	0		X		
19/04/2006	CPI	0.4	0.4	0	X	X		
26/04/2006	Dur. Goods Orders	6.1	1.8	4.3	X	X		
05/05/2006	NonFarm payrolls	138	200	-62	X			
17/05/2006	CPI	0.6	0.5	0.1			X	
28/07/2006	GDP	2.5	3	-0.5	X	X	X	
15/08/2006	PPI	0.1	0.4	-0.3	X	X	X	X
16/08/2006	CPI	0.4	0.4	0	X		X	
16/08/2006	Housing starts	1795	1808	-13	X		X	
24/08/2006	Dur. Goods Orders	-2.4	-0.5	-1.9	X			
01/09/2006	NonFarm payrolls	128	125	3				X
14/09/2006	Retail sales	0.2	-0.2	0.4	X			
19/09/2006	PPI	0.1	0.3	-0.2	X	X		
19/09/2006	Housing starts	1665	1745.5	-80.5	X	X		
27/09/2006	Dur. Goods Orders	-0.5	0.5	-1	X			
28/09/2006	GDP	2.6	2.9	-0.3		X		

A.5 News surprises and jumps by sampling frequency

Surprises in scheduled news announcements and jumps from different sampling frequencies ,January 2002- September 2006 inclusive. Surprise units are: non-farm payrolls ('000s of persons), CPI, PPI, retail sales,durable goods (month on month growth), housing starts ('000s starts), GDP (quarter on quarter growth).

	non-farm payrolls	CPI	PPI	retail sales	house starts	GDP	durable goods
number of announcements	57	57	57	57	57	57	57
surprise characteristics							
max abs(surprise)	318	0.3	1.2	1.5	256	1.7	8.2
min abs(surprise)	3	0	0	0	7.5	0	0
average abs(surprise)	68.46	0.10	0.36	0.39	89.83	0.37	1.88
30 minute sample							
jumps matching announcements	14	6	6	5	3	0	5
positive surprise	8	4	1	4	0	0	3
negative surprise	6	0	4	1	3	0	2
zero surprise	0	2	1	0	0	0	0
surprises & jumps characteristics							
max abs(surprise)	205	0.2	0.5	0.8	188	-	7.2
min abs(surprise)	3	0	0	0.2	50	-	1.3
average abs(surprise)	90.57	0.08	0.28	0.40	104.33	-	3.1
15 minute sample							
jumps matching announcements	13	10	7	5	6	2	11
positive surprise	5	6	3	4	0	0	8
negative surprise	8	1	3	1	6	1	3
zero surprise	0	3	1	0	0	1	0
surprises & jumps characteristics							
max abs(surprise)	208	0.3	1.1	1.4	209	0.5	7.2
min abs(surprise)	27	0	0	0.2	13	0	0.8
average abs(surprise)	113.42	0.10	0.37	0.72	96.33	0.25	2.34
10 minute sample							
jumps matching announcements	16	10	8	7	5	5	9
positive surprise	4	9	2	3	3	1	7
negative surprise	12	0	4	4	2	3	2
zero surprise	0	1	2	0	0	1	0
surprises & jumps characteristics							
max abs(surprise)	208	0.3	1.2	1.4	80.5	1.7	7.2
min abs(surprise)	6	0	0	0.1	32	0	0.3
average abs(surprise)	97	0.14	0.33	0.63	58.5	0.54	2.54