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MARKET STRESS AND STRUCTURAL DISTORTION: THE CASE OF THE 10-YEAR U.S. TREASURY NOTE FUTURES MARKET

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Abstract

During the spring and summer of 2005, a significant and persistent misvaluation was observed for the pricing of cash market 10-year U.S. Treasury notes and their associated 10-year U.S. Treasury note futures contracts. Based on long-standing concerns regarding the potential for manipulation in the Treasury market, regulators focussed their attention on trading irregularities in the cash market February 2012 10-year Treasury note, and eventually imposed new restraints on trading practices in the Treasury futures markets. Based on a detailed study of this episode, we find that the source of the market disruption was not linked to market manipulation, but instead was driven by structural shifts in the Treasury futures market, along with several related, but coincidental factors. This study provides additional evidence that financial derivatives markets relying on physical delivery for settlement are prone to episodes of market instability and distortion.

Keywords

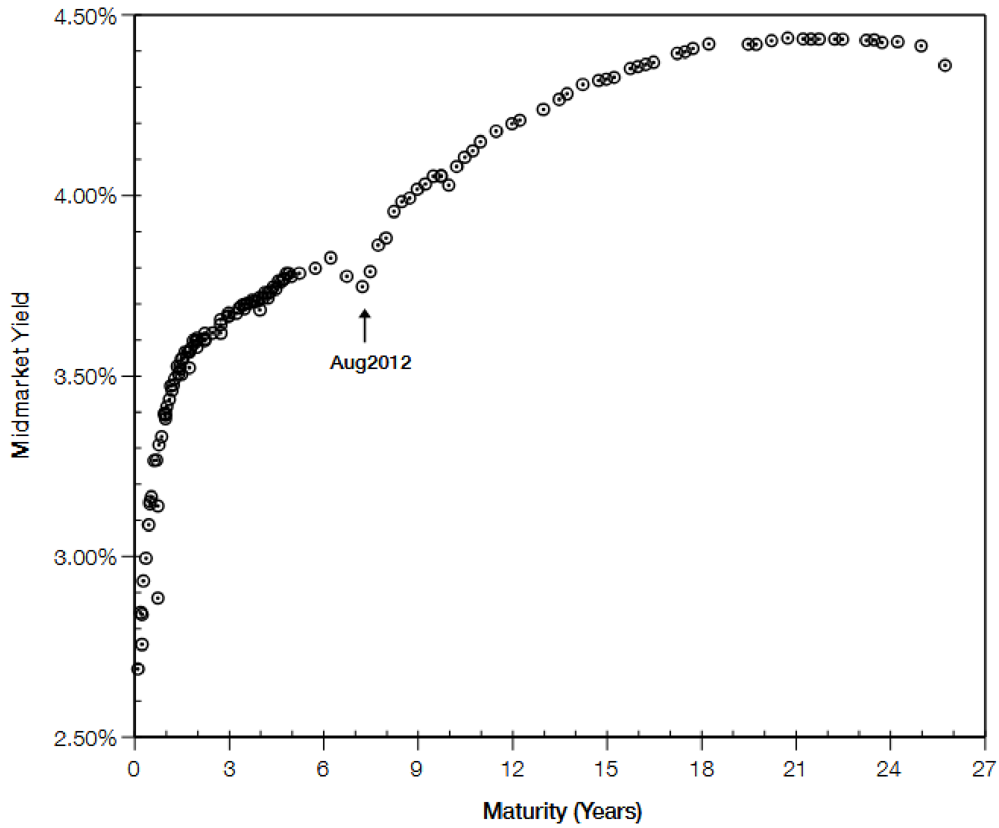
Treasury Note, Market Stress, Distortion

JEL classification: G12, G13, G14, G18

1. Introduction

This article examines a recent episode in the U.S. Treasury market where structural distortions in related markets led to a particularly severe instance of institutional disruption, with broad implications for market stability on a going-forward basis. We study the events surrounding an alleged squeeze in the cash and futures markets during the spring and summer of 2005 for particular 10-year U.S. Treasury notes, based on their attractiveness as delivery instruments in the associated 10-year U.S. Treasury note futures market. The incident was extensively covered in the financial press amid conjecture that a coordinated manipulation effort was undertaken to extract rents from market participants, based on concentrated holdings of the notes in question by specific private market actors.[i] Even casual market observers recognized that a disruption of some sort was clearly in effect during this time period; for example, Figure 1 depicts the U.S. Treasury coupon yield curve on May 24, 2005, which, *ex post*, was the day with the most severe market mispricing. As shown, there are several Treasury securities with roughly 7 years remaining maturity on that date that are clearly priced off the underlying yield curve, with the August 2012 10-year Treasury note exhibiting the most extreme price premium (yield discount). This specific note turns out to be central to the likely explanation for the events observed in 2005.

FIGURE 1 U.S. Treasury Coupon Yield Curve, May 24, 2005



The figure depicts the yield-to-maturity curve for coupon notes and bonds in the Treasury market on May 24, 2005. Yields are based on the average of the observed bid and ask (i.e., midmarket) flat price quote, with accrued interest calculated using normal next-day settlement conventions [Source: Federal Reserve Bank of New York]

As evidence of the serious disruptive nature of this market mispricing, together with persistent rumors of a corresponding manipulative squeeze (addressed by Deputy Director Clouse in the quote capture above), each of the U.S. Treasury Department, the Federal Reserve, the Commodities Futures Trading Commission, and the Chicago Board of Trade scrutinized the circumstances surrounding the market breakdown, both contemporaneously and *ex post*. While any characterization of the apparent squeeze as manipulative, rather than merely inadvertent or coincidental, is ultimately a legal matter, the unprecedented nature of regulatory activity associated with this event is notable. In direct response to this episode, the Chicago Board of Trade imposed position limits on large traders in the Treasury futures market during contract expiration months; the Treasury issued, for the first time, a formal call to reportable entities to document large positions in one of the affected notes; and the Federal Reserve, at the request of the Treasury department, asked foreign central banks to release their holdings of the affected notes for lending in the repurchase market to ease the price congestion.[ii]

Based on a detailed study of the price behavior of deliverable 10-year Treasury notes and 10-year Treasury note futures contracts during 2005, we find little empirical evidence consistent with outright market manipulation. However, we also find that the circumstances precipitating the event were not due to chance. We identify the explosion in financial derivatives market trading after Y2K, via the extensive participation of hedge fund entities, and facilitated by the advent and growth of electronic Treasury futures trading, as the most likely explanation (Garbade and Keane, 2017). Taken together with coincidental supply shortages of cost-effective, deliverable notes, we find that the market disruptions observed in 2005 were rational pricing responses to the structural mismatch between the potential demand for deliverable Treasury notes compared to their available supply. We conclude by providing evidence in an event study context showing that the market mispricing and associated market congestion was exacerbated or eventually relieved in direct response to traders' changing expectations regarding the cost of delivery in the futures market, along with related initiatives regarding market trading constraints. This episode provides additional evidence that financial derivatives markets employing physical delivery requirements rather than cash settlement are prone to episodes of market instability.

This study provides three distinct contributions to the literature on Treasury market efficiency and asset pricing. First, the case study approach here, for examining episodes of mispricing in the U.S. Treasury market, is closest in spirit to Cornell and Shapiro (1989), Jegadeesh (1993), Jordan and Jordan (1996), Jordan and Kuipers (1997) and, in the case of British governement securities, Merrick, Naik and Yadav (2006). The empirical design in this study uses similar methodology to identify and quantify the degree of mispricing in a specific market disruption episode, and provide evidence regarding the source of the mispricing and implications for future market stability.

Second, this paper adds to the growing body of evidence regarding the idiosyncratic component of Treasury security prices.[iii] In a perfect market, Treasury securities are homogeneous and, after allowing for observational noise, their market trade prices simply reflect the vector product of the contractual cash flows and the underlying term structure of interest rates. However, if Treasury securities are not homogenous and perfect substitutes for one another, then inferring the term structure from observed market data becomes difficult due to an unobserved variables problem. This study provides evidence that an additional idiosyncratic price factor for Treasury securities concerns the squeeze potential for deliverable instruments in the Treasury futures market.

Finally, the potential for market corners and manipulation resulting in corresponding market breakdown scenarios is a long-standing concern in derivatives markets in general, and derivatives markets utilizing physical delivery in particular.[iv] Any evidence regarding unfair trading practices in a market as large and far-reaching as the trade in U.S. Treasury securities has broad and unsettling implications for market efficiency and stability—and evidence to that effect will prompt a swift response from regulatory authorities. Such episodes are not without precedent in the Treasury market; e.g., the Salomon Brothers corner on the 2-year Treasury note auction during 1991 (Jegadeesh 1993), and the Fenchurch squeeze in the 10-year U.S. Treasury note futures market during 1993 (CFTC, 1996). This study alleviates such concerns, at least with respect to the specific episode studied here during 2005.

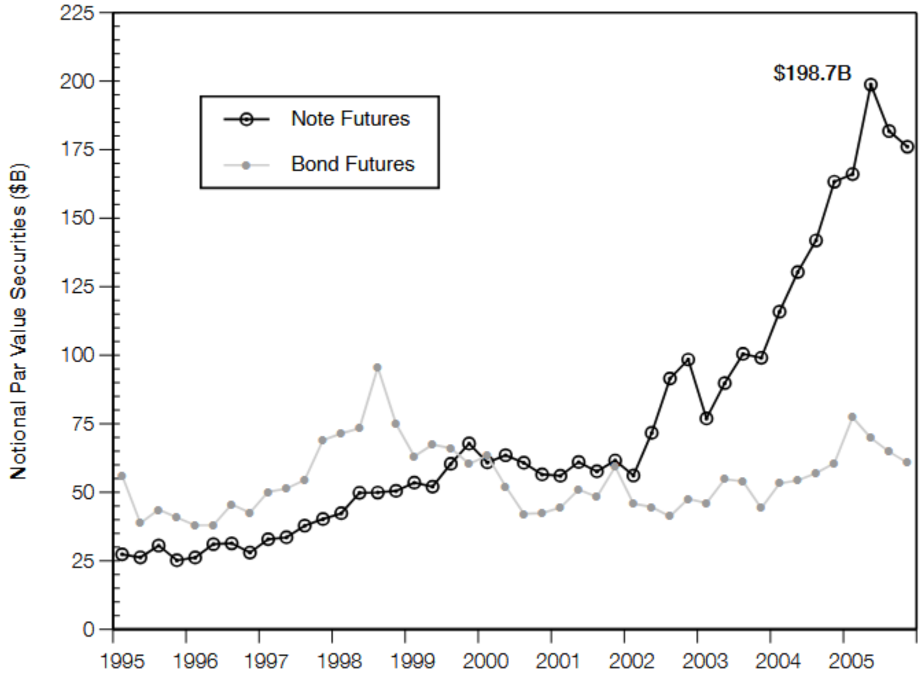
The remainder of the paper is organized as follows. Section 2 provides background on the 10-year U.S. Treasury note cash and futures markets during 2005, and outlines the research design for this study. Section 3 describes the data, and Section 4 reports our empirical findings. We provide some concluding remarks in Section 5.

2. Background

2.1 The 10-year U.S. Treasury note futures market in 2005.

The seeds of the disruption in the U.S. Treasury 10-year note futures market in the summer of 2005 were planted throughout the previous decade. Traditionally, from the onset of trading in public Treasury futures contracts in the late 1970s and early 1980s, the 30-year Treasury bond futures market (henceforth “TBF”) captured the most trading interest from market participants, consistently exhibiting open interest contracts of roughly double the notional principal for corresponding 10-year Treasury note futures contracts (henceforth “TNF”). This dynamic changed dramatically beginning in 2000. In an era of temporary U.S. budget surpluses, the Treasury reduced its issuance of 30-year bonds beginning in 2000, and ceased issuance entirely beginning in 2001 (Han, Longstaff and Merrill, 2007). Without an active, “on-the-run” bond to use as a compass, market participants seeking both liquidity and coordination between the spot and futures Treasury yield curve gravitated to the TNF market as a viable alternative. Open interest for TNF exceeded TBF for the first time during the Y2K event, and has been greater than TBF on a permanent basis beginning in early 2002.

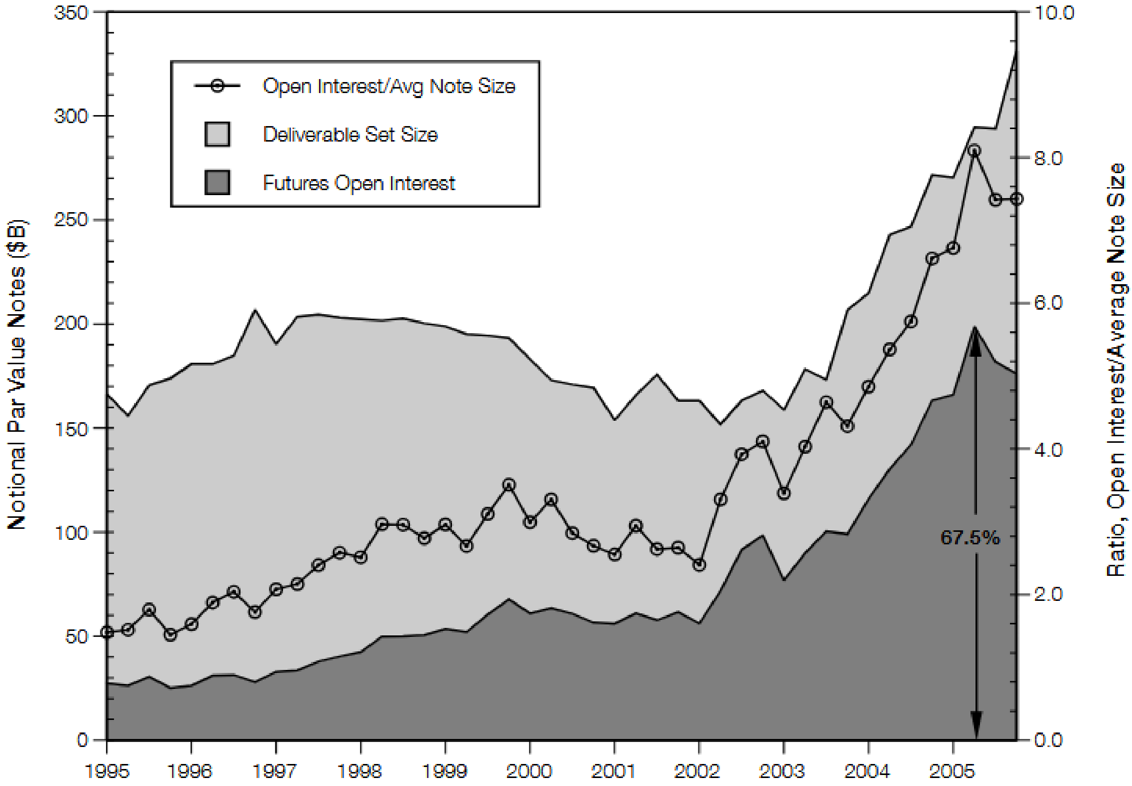
FIGURE 2 Open Interest in the U.S. Treasury Futures Market, 1995–2005



The figure depicts the maximum daily open interest at the Chicago Board of Trade for the front contract in the U.S. Treasury bond and 10-year U.S. Treasury note futures market during the period 1995–2005, expressed in terms of the notional par value of underlying deliverable instruments per contract. During this time period, open interest peaked at 1,987,361 on March 23, 2005 for the June 2005 expiry 10-year note futures contract.

Figure 2 depicts open interest for the front TNF and TBF contracts for the ten year time frame up through and including the market disruption episode in summer 2005.[v] While the move towards TNF trading noted above can be seen in the 2000–2002 time frame, the figure clearly shows the explosive growth in TNF trading beginning in late 2002. A number of market developments combined to drive this increase in TNF trading beyond the cessation of 30-year bond issuance alone. For example, the TNF contract provides a better hedging match than TBF for the coincident increase in agency and private-label mortgage-backed securities trading (e.g. Koutmos and Pericli, 2003). The cash market on-the-run 10-year note itself is the most liquid coupon Treasury security in the market (Fleming, 2003), and provides significant utility for trades involving other government securities markets (e.g., UK, France, Germany and Japan) where the 10-year instrument is the market bellweather. The most significant factor was likely the onset of electronic trading in U.S. Treasury futures markets, which began in late 2000 and transitioned to full electronic trading by fall 2003 (Orlowski, 2015). Taken together, these factors contribute to an exponential growth rate of 12.5% annually in TNF open interest beginning in 2000, peaking (during the sample period) with just under 2 million front contracts outstanding on March 23, 2005—which immediately precedes the event period of interest in this study. The corresponding TBF front contract exhibits open interest less than one-fourth that of TNF by this date, with a growth rate post-2000 of essentially zero (0.15%).

FIGURE 3 Relative Open Interest in the 10-Year U.S. Treasury Note Futures Market, 1995–2005



The figure depicts the maximum daily open interest in the front 10-year CBT Treasury note futures contract, expressed in terms of the notional par value of underlying deliverable instruments per contract, during the time period 1995–2005. By way of comparison, the aggregate par value outstanding in the Treasury market for all deliverable notes is also shown, along with the ratio of open interest (in terms of notional principal) to the average par value outstanding of an individual deliverable note. During this time period, open interest relative to the size of the deliverable 10-year note market reached a maximum of 67.5% for trading in the June 2005 expiry contract, amounting to 8.10 times the size of the total par value outstanding of an average deliverable note.

Figure 3 depicts the TNF front contract open interest from Figure 2, with additional information overlaid on the graph to demonstrate the elements of the structural distortion in the TNF market during summer 2005, leading to the subsequent natural squeeze documented in the results section of the paper. Specifically, the figure displays the open interest in TNF as notional principal of notes underlying the contracts (dark-shaded area), compared to the total size outstanding of all deliverable, cash market Treasury notes in combination (light-shaded area), on a coincident basis. As shown, in March 2005 open interest in the front TNF contract amounted to over two-thirds the notional principal of the entire deliverable U.S. Treasury note cash market. The true impact of this distortion is more pronounced than the figure suggests, as the effective float of available, tradeable U.S. Treasury securities at any one time is significantly less than the total size outstanding for any number of reasons.

For example, a nontrivial fraction of deliverable Treasury securities are held by the Federal Reserve in its portfolio for both monetary policy and market stability purposes. The supply held by the Fed is "sticky" in that the Fed typically does not alter its portfolio composition in response to events transpiring in the secondary or derivatives markets (Ihrig, Mize and Weinbach, 2017). Further, foreign central banks and foreign institutional investors own significant Treasury investments at any one time, and generally these securities are held as long-term holdings and do not actively trade.[vi] Even for U.S.-based investors, Treasury securities are gradually taken out of effective circulation as they age (Sarig and Warga, 1989), and in low interest rate environments, these seasoned securities are usually the most attractive delivery instruments.[vii] If any of the deliverable notes are held by investors in stripped form, the reduction in effective float is further exacerbated (Jordan, Jorgensen and Kuipers, 2000).

Thus, while it is impossible to directly measure the effective float of Treasury securities, it is reasonable to infer based on the discussion above that potential delivery demands in the futures market could, in theory at least, completely consume the entire supply of physical deliverables. At a bare minimum, it is a conceptual structural friction in the market. If all long positions chose to stand for delivery, as it is their contractual right to do so, then hypothetically, infinite price premia could be observed in the cash market; short futures positions need to acquire deliverable securities to complete their delivery obligations in an environment with inadequate supply. Of course, in this breakdown market scenario, short positions would simply choose to fail, so the potential costs are bounded rather than infinite, but such costs are certainly not trivial.[viii]

Regardless of the degree of potential delivery fails and supply shortages in a scenario like the above, the potential for market disruption becomes more tenable if there are concentrated ownership positions on one side of the market, or several large traders colluding to affect the same outcome.[ix] Whether due to inadvertent or coincidental trading activities, or outright market manipulation, the breakdown in market order would have enormous negative consequences for the smooth functioning of the financial markets. Manipulation in this scenario is aggressively enforced by U.S. regulators, and has been studied at length in several seminal academic papers including Kumar and Seppi (1992) and Pirrong (2001). Notably, most of the theoretical literature addressing market corners and price manipulation in derivative markets utilizing physical delivery assume either an infinite supply of deliverables, or at least, available supply that exceeds potential delivery sizes via contractual open interest. As noted above, these conditions likely did not apply in the TNF market during 2005.

One final observation about the structural distortions in the TNF market during this time period is depicted in Figure 3. The line graph in the figure relates (via the right-hand axis scale) the ratio between the TNF front contract open interest and the total size outstanding of an average deliverable Treasury note during the sample period; during 2005, this ratio exceeds 8x in value. If the note in question is the cheapest-to-deliver (CTD) note for the contract on that day, the implication is that, in principle at least, more than 7 of every 8 short futures positions, if forced to make physical delivery, would not be able to acquire and deliver the most cost-effective Treasury note. This natural "squeeze value" in the contract is a necessary, but not sufficient condition for subsequent price pressure effects in the cash market, and is studied at length (albeit during different time periods) in Jordan and Kuipers (1997), Clark and Kuipers (2025), and, in the case of British government securities, Merrick, Naik and Yadav (2005).

2.2 Research design.

To measure the impact, if any, on the cash market price of Treasury notes deliverable in the TNF market during 2005, we require three different pricing metrics for fair value. First, we need an estimate of a deliverable note's price with the same coupon rate and maturity, but whose market price is determined solely by the term structure of interest rates. Since such notes generally do not exist, we synthesize them using the term structure estimation model of cubic spline interpolation, as in Litzenberger and Rolfo (1984b), Jordan and Kuipers (1997) and many others; similar approaches are used throughout the Treasury richness/cheapness literature.[x]

Second, we need to identify the CTD instrument for the front TNF contract on a daily basis, and construct a rank-ordering of the deliverable notes each day in terms of their market cost if used as an alternate delivery instrument to the CTD note. The method for doing so is well-known and involves calculating an implied repo rate for deliverable notes each day; see for example, Burghardt and Belton (1994), or Clark and Kuipers (2025) for a summary of the approach.

Finally, we also want to measure and access via statistical inference any changes in the estimates of price richness or cheapness in event time, on a daily basis, in response to market events and announcements during 2005. In the absence of any direct guidance for an "event study" methodology applied to the U.S. Treasury market, we adopt a bootstrap-*t* methodology similar to the one used in Jordan and Jordan (1996); the specific approach is outlined in detail in the results section of the paper. Under repeated sampling, the *ad hoc* approach here works well with minimal Type I or Type II errors.

3. Data

The data for this study are comprised from two distinct sources. First, we obtain daily bid and ask quotes for all outstanding U.S. Treasury bills, notes and bonds during the time period 1995–2005. The data is sourced directly from the Federal Reserve Bank of New York (FRBNY); the same data underlies the prices reported in *The Wall Street Journal* and contained in the *CRSP Daily Treasury Database* maintained by the University of Chicago. The raw data quotes are used to calculate corresponding cash market prices using standard industry practice for next-day settlement.[xi]

The second set of data consist of daily settlement prices for the front TNF contract traded at the Chicago Board of Trade (CBT) over the 1995–2005 sample period. The futures prices are from Tick Data, Inc., a data vendor specializing in futures and options markets. We also obtained the CBT's quarterly Market Summary publications, which reports the delivery history of notes for expired futures contracts and the conversion factors for outstanding notes against current contracts, over the complete sample period. We reviewed the Market Summary reports as a cross-check on the conversion factors we require for calculating the delivery cost of eligible notes.

TABLE 1 Descriptive Data for Deliverable 10-Year U.S. Treasury Notes, March 2005

CUSIP	Coupon	Maturity	Reopening	Issue Size	Publicly Held	Last Futures
9128277L0	4.875	Feb 2012	May 2002	24.780	21.815	Jun 2005
912828AJ9	4.375	Aug 2012	—	19.468	16.781	Dec 2005
912828AP5	4.000	Nov 2012	—	18.113	17.877	Mar 2006
912828AU4	3.875	Feb 2013	—	19.498	18.002	Jun 2006
912828BA7	3.625	May 2013	—	18.254	18.002	Sep 2006
912828BH2	4.250	Aug 2013	Sep 2003	33.521	29.610	Dec 2006
912828BR0	4.250	Nov 2013	Dec 2003	30.637	28.601	Mar 2007
912828CA6	4.000	Feb 2014	Mar 2004	28.081	27.009	Jun 2007
912828CJ7	4.750	May 2014	Jun 2004	27.303	25.010	Sep 2007
912828CT5	4.250	Aug 2014	Sep 2004	24.722	23.004	Dec 2007
912828DC1	4.250	Nov 2014	Dec 2004	25.473	23.002	Mar 2008
912828DM9	4.000	Feb 2015	Mar 2005	24.215	23.003	Jun 2008

The table identifies each of the twelve nominal (non-TIPS) 10-year original-issue U.S. Treasury notes eligible for delivery for the front 10-year note futures contract at the Chicago Board of Trade (CBT) in March 2005. Notes cease to be of delivery grade when the remaining note maturity is less than 6.5 years as of the first day of the futures contract expiration month. The last futures contract for which the note is an eligible delivery instrument is shown, along with the note size in par value outstanding (billions of dollars) on March 31, 2005; the reopening date of the note (if applicable); and the estimated issue size held by the public (Source: Treasury Bulletin, June 2005).

Table 1 reports the descriptive data for the Treasury notes eligible for delivery in March 2005 for the June 2005 TNF contract; the primary event period of interest in this paper begins in late March, and the futures contracts that drew the most attention were the June and September 2005 expiries. As shown, the notes span the remaining-maturity range specified by the CBT for TNF contracts (6.5 to 10 years), and the specific Treasury note at the center of some market controversy (February 2012) later in the spring of 2005 is also the shortest maturity deliverable note available for the June 2005 contract. For the September and December 2005 contracts, the August 2012 note is the shortest maturity deliverable instrument. While most of the notes in the deliverable set have similar coupons and total issuance size, four stand out as unusual in this regard: All four of the deliverable notes with maturities between August 2012 and May 2013 were issued once, but not reopened on a later date. As a result, the issue size for these notes is significantly smaller than the alternatives in the market; as we show in the results below, these four notes play a central role in the TNF market disruption during the late spring and summer of 2005.

4. Results

4.1 Pricing errors for TNF-deliverable notes during 2005.

Panel A of Table 2 reports the descriptive statistics for daily estimated cash market price residuals for all deliverable Treasury notes with less than 8.25 years remaining maturity during the complete 1995–2005 sample period, as well as the subsample of observations during the event period of interest from February 25, 2005 through September 30, 2005.[xii] As shown for the full sample statistics, and consistent with existing research (e.g., Sarig and Warga, 1989), seasoned notes in this maturity range typically sell at a modest discount to fair value at 3.1 cents per $100 face value, reflecting their reduced liquidity. While statistically significant given the large sample size, this mean pricing error is not materially significant; 3.1 cents amounts to roughly 1/32nd of one percent of par value, which is the minimum tick size for market trading in off-the-run Treasury instruments (Fleming, 2003). As a result, the mean error cannot be resolved from the resolution of the data itself.[xiii]

TABLE 2 Cash Market Pricing Errors for Deliverable Treasury Notes, 1995–2005

Panel A.

Descriptive Statistic	All Notes, 1995–2005		2/25/2005–9/30/2005
N	12,747		815
Mean	–0.031		0.206
t-statistic		26.17	
Median	–0.026		0.151
Z-statistic		33.58	
Standard Deviation	0.176		0.199
Minimum	–0.787		–0.073
Maximum	0.902		0.902
Skewness	0.055		0.968
Kurtosis	1.709		0.129

Panel B. Regression Analysis of Pricing Errors for Specific Notes, 2/25/2005– 9/30/2005

$$\Delta P = -0.011 + 0.001 \cdot FEB12 + 0.223 \cdot AUG12\_MAY13 \qquad R^2 = 0.293$$
$$(2.17) \quad (0.04) \qquad (16.37) \qquad N = 1{,}064$$

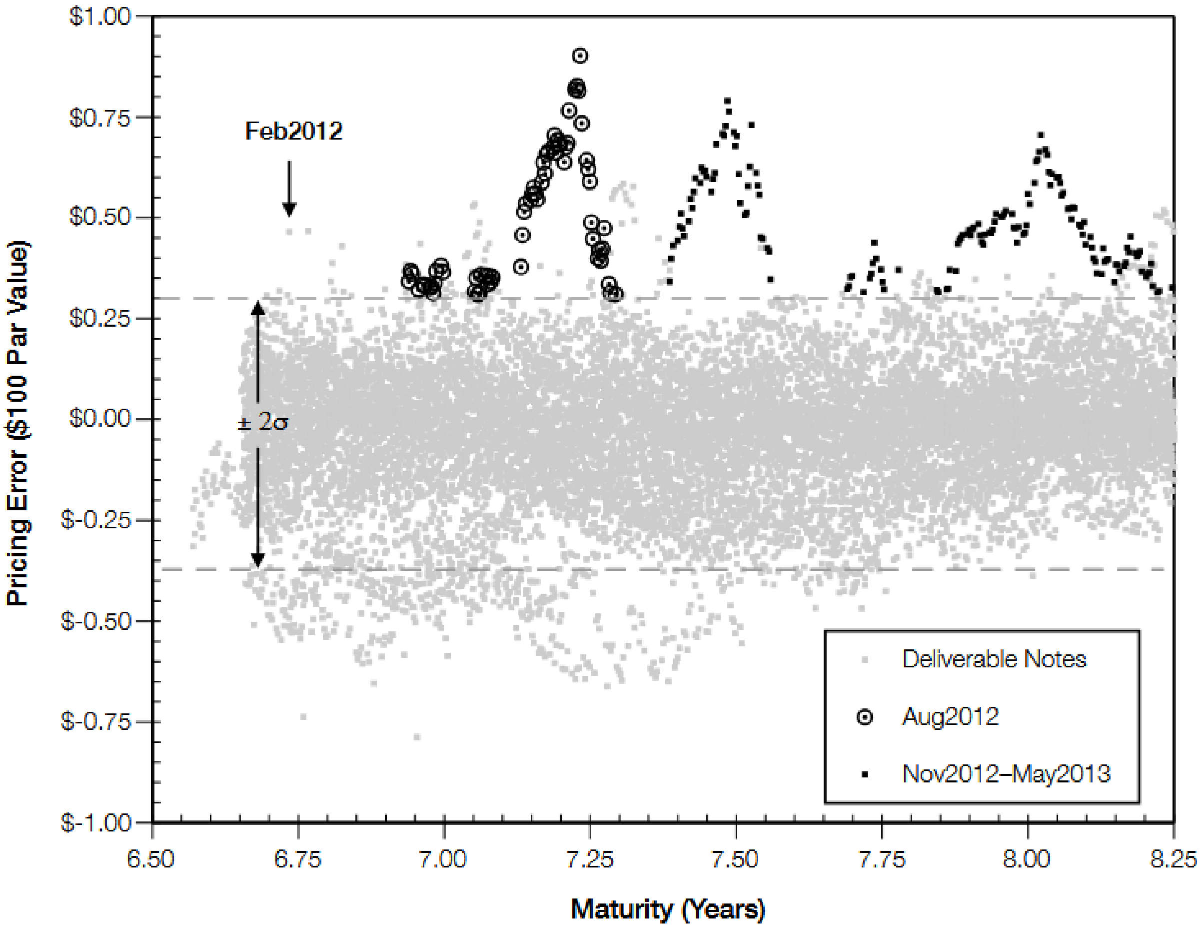
The table reports descriptive statistics for the estimated richness/cheapness of deliverable 10-year U.S. Treasury notes, as measured by the pricing error from daily fitted term structures, during the period 1995–2005. Pricing errors are in units of dollars per $100 face value of notes. Summary results for all deliverable notes during this time period with less than 8.25 years remaining maturity are shown in Panel A, contrasted with the subsample of notes in the same maturity range during the time period February 25, 2005 through September 30, 2005. Statistical significance for the difference in means and medians (Wilcoxon signed ranks test) are based on the 11,932 observations outside the subsample time period compared to the subsample observations; the parametric test is based on a heteroskedasticity and autocorrelation-consistent (HAC) covariance matrix (Newey and West, 1987). In Panel B, the pricing errors during the subsample period are examined separately for the first five deliverable notes shown in Table 1 and summarized in Panel A, compared to the two 10-year notes immediately preceding (August 2011) and following (August 2013) them by way of contrast. The two reference notes are contained in the regression intercept; dummy variables are used for observations involving the February 2012 note, and the four deliverable notes shown in Table 1 that were not reopened. The t-statistics (shown in parentheses) are again based on the Newey and West (1987) HAC covariance matrix estimator.

In contrast to the full sample, the average pricing error for TNF-deliverable notes in the 2005 subsample time period is large and materially significant. On average, mispricing for deliverable notes in this maturity range during this subsample period exhibit mean value of 20 cents per $100 par value of notes, with median value somewhat lower at 15 cents; as we show later, this skew in the measures of central tendency reflect the impact of some significant data outliers.[xiv]

Panel B of Table 2 uses a pooled time series-cross sectional dummy variable regression to examine more closely the price residuals, during the subsample period, for the deliverable notes in panel A. In the regression, the four notes that are central to the natural squeeze explanation of the market disruption event—namely, the four notes in Table 1 that were not reopened—are identified as the group dummy variable *AUG12_MAY13*. The February 2012 note identified by regulators and litigants as the potentially-manipulated instrument is identified by its own dummy variable *FEB12*. To control for potential localized term structure effects during this time period, the next-shortest (August 2011) and next-longest (August 2013) 10-year Treasury notes other than the previous five are also included in the regression analysis, their effect being contained in the regression intercept. Note that the sample size is slightly different in panel B compared to the panel A subsample because in A, observations are limited to deliverable notes, whereas some of the reference maturity observations in panel B are for notes that have exited the deliverable set (Kuipers, 2008).

The results from this simple analysis are surprising. Despite the low discriminatory power of dummy variable regressions, the panel B results clearly show that the group of four notes were rich in the cash market during the subsample period, and significantly so, whereas other notes of similar maturity were fairly priced. Specifically, the regression intercept is essentially zero, eliminating any potential term structure bias for pricing errors amongst similar-maturity instruments during this time period. However, the group dummy *AUG12_MAY13* is a positive and highly significant 22.3 cents in the regression, consistent with the natural squeeze explanation of the market disruption. Even more interesting is that, by way of comparison, the coefficient for *FEB12* in panel B is essentially zero; the specific note investigated by the press, regulators, and eventually, private party litigants did not exhibit any idiosyncratic cash market pricing behavior during the subsample period.[xv]

FIGURE 4 Daily Pricing Errors for Deliverable U.S. Treasury Notes, 1995–2005



The figure depicts each of the 12,747 daily pricing errors summarized in Table 2 for deliverable U.S. Treasury notes during the period 1995–2005. Pricing errors are the residual from daily fitted term structures via the method of cubic spline interpolation, and are measured in dollars relative to $100 face value. Two standard deviation error bounds about the global sample average price difference of –3.1¢ are shown; every pricing error for an observation greater than the upper bound and associated with one of the deliverable notes of interest during 2005 is explicitly noted in the figure with a unique symbol.

Figure 4 presents an alternate way of viewing the unusual price behavior in 2005 for the four notes first identified in Table 1. The figure depicts the scatter plot of spline-derived pricing residuals for all TNF-eligible notes during the full 1995–2005 sample period; i.e., the data sample described in panel A of Table 2. For visual convenience, the 95% confidence interval for the price residuals is shown on the figure, once again constructed using the Newey and West (1987) covariance matrix. All residuals that are both statistically significant and central to the market disruption event of 2005 are explicitly labelled.

As shown, for all practical purposes, the only statistically-significant, positive price premia for deliverable notes during this 11-year time period in this maturity range are the four specific notes originally identified in Table 1. Because the x-axis in the figure measures remaining maturity, the passage of time can be tracked in the figure by following the residuals right-to-left. Doing so, there are four distinct patterns that can be seen for the four affected notes; in each case, the residuals first become significant in late March 2005, they become more pronounced until peaking in late May 2005, and remain rich, albeit to a gradually-declining degree, until market order is restored in September 2005.

Further, the February 2012 note, by way of contrast, is decidedly not rich during this 11-year period. As noted in the figure, this note trades with a significant positive residual for one day alone in the sample period; namely, the day of maximum market price distortion shown in Figure 1. For all other days, the pricing residuals are buried in the noise and, as shown in panel B of Table 2, essentially mean-zero.

One final note of interest in the figure concerns the scale of the market mispricing episode as well as its duration. Informally at least, market participants often access the materiality of a presumed mispricing event by contextualizing it within scope and scale parameters. For example, in Cornell and Shapiro (1989), the mispricing event lasts for just over a month and amounts to a 20 basis point yield discount, on average. In Daskin and Kulkarni (1993), the mispricing is nearly a 100 basis point yield discount, albeit with duration of just one week. For the Salomon Brothers bid scandal of 1991, Jegadeesh (1993) and later, Jordan and Jordan (1996) find mispricing of roughly 15 to 25 cents on average, and persisting for nearly six weeks. In Jordan and Kuipers (1997), the mispricing is roughly 40 cents on average and lasts for eight months. In this case study, we find average mispricing of approximately 22 cents, persisting for seven months, with peak mispricing approaching one dollar per $100 face value. Similar to prior studies, it must be the case in a market as large, liquid and sophisticated as the Treasury market, that a rational explanation underlies the observation of such apparent anomalous price behavior. We address this question next with our final set of results.[xvi]

4.2 Measuring abnormal returns in the cash U.S. Treasury market.

Regardless of whether the mispricing of deliverable notes documented earlier is an outcome due to unintended structural factors or outright predatory behavior, the market price of the affected notes should react in a significant fashion to news developments or regulatory initiatives that impact rational expectations. In this case, we are not necessarily interested in whether the price residuals for one of the notes is large and positive, but instead, we are interested in measuring the *change* in perceived richness (or cheapness) in response to market stimuli. For example, if a market event has no valued information content, the price residual for an instrument (after allowing for measurement error) should not change; a rich note remains rich as before, and similarly for cheap and fairly-valued securities. If an event affects multiple instruments, or an entire subsector of the market, there again should be no impact on the *change* in the estimate for richness/cheapness of a particular security; the underlying zero curve would simply adjust, leaving the individual security's richness/cheapness value unchanged.

To quantify these effects and provide tests for statistical significance and inference, a method analagous to the event study literature is required. To date, no such method has been devised for the Treasury market specifically, presumably because the null hypothesis discussed earlier is that Treasury securities are homogeneous and, by extension, the only price residuals in the market should be from observational and estimation noise alone.[xvii]

For guidance, we choose to use an approach similar in design to Jordan and Jordan (1996), by utilizing a bootstrap-*t* statistic described in any number of statistics textbooks (e.g., Ebson and Tibshirani, 1994). Specifically, for all deliverable 10-year Treasury notes that comprise the full sample for this study (Table 2, panel A), we construct a measure for the two-day abnormal change in measured richness/cheapness of the note via:

$$\tilde{R}_{j,t} = \Delta\tilde{P}_{j,t+1} - \Delta\tilde{P}_{j,t-1} \quad , \qquad (1)$$

where $\tilde{R}_{j,t}$ is the measured abnormal return for the *j*th note and day *t*, and the $\Delta\tilde{P}_{j,t}$ are the corresponding price residuals for the *j*th note on days *t*+1 and *t*–1; these are the same price residuals derived from spline estimations studied earlier in the article and summarized in Table 2 and Figure 4. We construct two-day abnormal returns in the spirit of existing event study methodology to increase power (compared to single day returns). Significance for the abnormal returns is assessed via a bootstrap univariate *t*-test:

$$T = \sqrt{50} \cdot \tilde{R}_{j,t} \Big/ \tilde{\sigma}_e \quad . \tag{2}$$

The standard error $\tilde{\sigma}_e$ in equation (2) is estimated in two steps. First, the complete set of abnormal returns $\tilde{R}_{j,t}$ for the data sample over the period 1995–2004 (preceding the 2005 event period) are collected over all possible 100-day, non-overlapping test intervals. We then randomly select (with replacement) 1000 note/test interval combinations from the complete data, and run a regression of the returns $\tilde{R}_{j,t}$ on a constant, using Newey and West (1987) covariance matrices for robustness control as before. We collect the standard error from each regression run and use the sample average as our measure for $\tilde{\sigma}_e$ in (2).[xviii]

4.3 Chronology of events related to TNF market, March 2005–September 2005.

Table 3 provides a chronology of important developments and regulatory initiatives in the Treasury cash and futures markets during the subsample period of interest in spring and summer 2005. Figure 5 depicts the information contained in the table in graphical form as an alternative. We report abnormal returns for the August 2012 note alone in the table in part to save space, but also because it was the instrument with the largest observed market mispricing during this time period. The other three notes from Table 1 that were not reopened exhibit similar behavior, just not to the same magnitude as the August 2012 note. Further, the August 2012 note was the linchpin of the natural squeeze distortion alluded to earlier in the paper. Throughout the subsample period, the August note was the CTD instrument for the September 2005 TNF contract, and, as noted in Table 1, it was both the shortest maturity and smallest issue size deliverable instrument for that contract. As a result, this specific note was particularly sensitive to the type of price pressure effects documented in Jordan and Kuipers (1997) and Clark and Kuipers (2025).[xix]

TABLE 3 Chronology of Significant Events in the 10-Year U.S. Treasury Note Futures Market, 2005

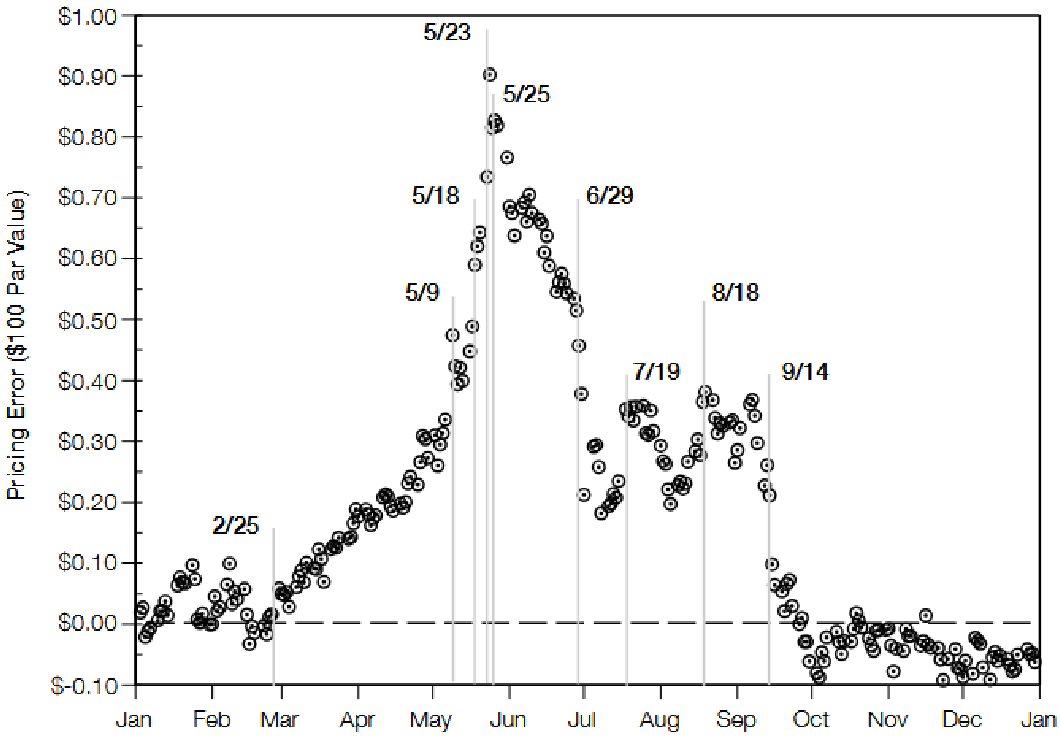
		Abnormal Price	
Date	Event	Change (–1,+1)	t-statistic
25-Feb	First Intention Day, March 2005 10-year Treasury note futures contract	$0.04	0.626
31-Mar	Record physical delivery in the Treasury futures market; $11.57 billion par value Feb 2012 note	$0.05	0.823
4-May	Treasury may reintroduce the 30-year bond, with reduced issuance size for 10-year notes; Standard & Poor's downgrades General Motors and Ford corporate debt to junk status	$0.05	0.963
9-May	Large cash market purchase of the Aug 2012 and Nov 2012 notes; hedge traders begin rolling out of the June 2005 futures contract	$0.16	2.882***
18-May	PIMCO forecasts 10-year note yield target of 3–4.5% for next 3–5 years	$0.13	2.369**
23-May	FOMC minutes released; Fitch downgrades General Motors debt to junk status; PIMCO believes Federal Reserve "virtually certain" to halt further interest rate increases	$0.26	4.641***
25-May	Foreign central banks release $5 billion par value of the Feb 2012 and Aug 2012 notes for lending in the Treasury repurchase market	–$0.075	1.331
27-May	First Intention Day, June 2005 10-year Treasury note futures contract	–$0.134	2.382**
29-Jun	CBT introduces position limits during delivery month for Treasury futures contracts	–$0.137	2.440**
30-Jun	Record physical delivery in the Treasury futures market; $14.21 billion par value Feb 2012 note	–$0.245	4.370***
19-Jul	CBT revises position limit announcement of 6/29 for 5-year and 10-year note futures	$0.11	1.916*
8-Aug	PIMCO identified as the largest holder of the Feb 2012 note during May and June, 2005	$0.04	0.672

18-Aug	Lawsuit filed alleging market squeeze in June 10-year Treasury note futures; Citadel identified as a large owner of the Feb 2012 note in late May, 2005	$0.10	1.871*
14-Sep	Federal Reserve announces call for dealer positions in the Aug 2012 10-year note	–$0.163	2.897***
30-Sep	$4.90 billion par value Aug 2012 notes delivered into the September 2005 note futures contract	–$0.051	0.904

The table reports the chronology of events pertaining to trading in the 10-year U.S. Treasury note futures contract at the Chicago Board of Trade (CBT) during calendar year 2005. Events are variously drawn from public news releases by the major wire services (via Lexis/Nexis), articles published in the New York Times and The Wall Street Journal, and public pronouncements from market regulators. Associated with each reported event is the two-day abnormal price change for the August 2012 10-year U.S. Treasury note, relative to $100 par value. For statistical inference, a bootstrap t-statistic is constructed based on estimates derived from deliverable 10-year notes during the period 1995–2004 and utilizing the HAC covariance matrix of Newey and West (1987); significance at the 10%, 5% and 1% levels are noted by an appropriate number of asterisks.

An examination of the individual news items in Table 3 quickly reveals an explanation for the market mispricing episode of 2005, one consistent with the natural squeeze argument. Specifically, items providing new information to traders regarding the likelihood that the (relatively scarce) August 2012 note would remain CTD for the September 2005 futures contract lead to statistically significant, positive abnormal returns. For example, the revelation on May 9 that a large quantity of the August 2012 was purchased led to a significant positive return at the 1% level—if the note was purchased and held in quantity by one trader or entity, it would be less readily available for purchase and delivery into the futures contract by an entity with a short futures position. As a second example, PIMCO, the largest and arguably most widely-followed bond mutual fund in the world, announces expectations on May 18 and May 23 that market interest rates will decline in the future. When interest rates decline, short duration delivery instruments have an advantage in CTD status with the CBT's conversion factor system, and as noted above, the August 2012 note was CTD during this time period largely due to the market interest rate environment.

FIGURE 5 Relative Value of the August 2012 10-Year U.S. Treasury Note during 2005



The figure depicts the relative value for the August 2012 note during 2005, estimated as the pricing error (relative to $100 par value) derived from daily fitted term structures via the method of cubic spline interpolation. Event dates from Table 3 with significant two-day price changes are noted in the figure for convenience. Based on the derived pricing errors, the August note is estimated to trade rich on every day during the period February 24 through September 28. The maximum pricing error of 90 cents occurs on May 24 and represents the largest estimated pricing error for any deliverable Treasury note of similar maturity during the period 1995 through 2005.

Conversely, news items relating to reduced incentives for capitalizing on issue scarcity, or initiatives addressing flaws in market structure, led to significant negative abnormal returns. For example, on first intention day for the June 2005 TFN contract (May 27), there were no abnormalities observed in the futures market regarding contract rolls as was noted with the March 2005 contract on February 25. If contracts are being closed out and rolled over to the next maturity in an orderly fashion, the risk that longs would demand physical delivery is reduced dramatically; and as a result, corresponding short positions will not need to acquire the CTD instrument in the cash market. Even more interesting is the single largest abnormal return in the table (June 30), which corresponds to a 24.5¢ abnormal price reduction for the August note. On this day, a record amount of physical delivery occurred in the TNF market for the expiring June 2005 contract, amounting to more than $14 billion of cash market notes. When observers and traders realized that even record amounts of actual, physical deliverables could be accommodated, concerns that delivery complications would occur for the August 2012 note were reduced dramatically.

Finally, it was likely that some traders still perceived a risk that market manipulation or predatory price behavior could still be an issue, and rationally priced that risk into the four notes identified earlier. When regulators imposed new restrictions on trading activity in this market that structurally lessened such risks, the market price responded in a significant fashion, consistent with market efficiency and rational expectations. For example, on June 29 the CBT announces new position limit requirements on traders, and the abnormal price change for the August 2012 note is significantly negative (at the 5% level). When the Federal Reserve announces an unprecedented call for dealer positions in the August 2012 note on September 14, the corresponding transparency results in a significantly negative abnormal return for the August 2012 note at the 1% level. Shortly after this announcement, the richness in the August note is completely eliminated and the instrument is fairly valued in the market (based on our estimation methodology) from that point forward.

5. Conclusions

This study examines an episode of market disruption and mispricing in the Treasury cash and futures markets during the spring and summer of 2005. Certain original-issue 10-year Treasury notes traded at price premia for an extended period of time that were both economically and materially significant. The episode involved pricing irregularities that were similar to previous episodes of Treasury market disruption, each of which drew the attention of market regulators and the financial press.

While investors and regulatory authorities were most concerned with the potential for manipulation and predatory behavior by market actors, the mispricing on its own represented a serious concern for those that rely on the smooth functioning of the Treasury markets for accurate market benchmarking, the implementation of monetary policy, and economic forecasting models. We provide evidence that the observed mispricing was the result of coincidental factors in the market during this time period largely unrelated to the trading practices of specific market actors. Instead, the market disruption was linked to issues concerning the expectations for physical delivery of the underlying cash market instruments, together with unprecedented growth in the use of these contracts. While cash settlement, if implemented in this market, may alleviate some of these concerns in the future (Oviedo, 2006), this study provides strong evidence that financial derivatives markets that continue to rely on physical delivery for settlement are prone to episodes of market instability and distortion.

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[i] The earliest rumors and stories appear to be "US Credit Mkt:June-Sept 10Yr Spread Collapses on Squeeze Talk," *Market News International/LexisNexis*, May 10, 2005; and "US Debt Futures: Dealers See Calendar Plays, 10Y Squeeze," *Market News International/LexisNexis*, May 24, 2005. Later stories in the mainstream press include: "Treasury Department Scrutinizes Trading of a Futures Contract," *Dow Jones Newswire*, August 9, 2005; "Imbalance in 10-Year Treasurys (sic) May Have Cost Investors Millions; September Futures Contract Looms," *The Wall Street Journal*, August 11, 2005, page C1; "Hedge Fund's Role Dents Market Theory On Treasury Shortage," *The Wall Street Journal*, August 18, 2005; Page C1. In these articles, the 10-year 4.875% February 2012 Treasury note was identified as the cash market instrument held in large quantities by the hedge fund Citadel Investment Group LLC. The world's largest bond mutual fund, Pacific Investment Management Co. (PIMCO), was identified as the largest open interest trader in the 10-year U.S. Treasury note futures market during this episode.

[ii] E.g., "Notice Regarding Position Limits in Treasury Futures During Last Ten Trading Days," *Commodity Futures Trading Commission*, Ruling Announcement, June 29, 2005.

[iii] A partial list of these studies includes Garbade and Silber (1976), Constantinides and Ingersoll (1984), Litzenberger and Rolfo (1984a), Ronn (1987), Cornell and Shapiro (1989), Sarig and Warga (1989), Amihud and Mendelson (1991), Kamara (1994), Jordan and Jordan (1997), Green and Ødegaard (1997), Elton and Green (1998), Jordan, Jorgensen and Kuipers (2000), Krishnamurthy (2002), Longstaff (2004), Vayanos and Weil (2008), Kuipers (2008), Fleckenstein, Longstaff and Lustig (2014), Livingston, Wu and Zhou (2019), and Clark and Kuipers (2025).

[iv] e.g., Figlewski (1981), Easterbrook (1986), Kumar and Seppi (1992), Pirrong (1993), Kyle (1984), Barnhart, Kahl and Barnhart, (1996), Cornell (1997), Cooper and Donaldson (1998), Chatterjea and Jarrow (1998), Pirrong (2001), Lien and Tse (2002), and Ben-Abdallah and Breton (2016).

[v] We track the front futures contract until the first calendar day of the contract expiration month, at which time we switch into the subsequent maturity contract. By doing so, we avoid potential contamination problems associated with the contract's quality option during the delivery month (e.g., Chance and Hemler, 1993). Our switching approach to the next contract is commonly used in note and bond futures research.

[vi] This is the scenario that prompted the market mispricing episode studied in Cornell and Shapiro (1989). Foreign investors held a significant fraction of the size outstanding for the affected Treasury securities.

[vii] Yield levels below the contract's 6% notional coupon tend to make shorter duration deliverable instruments cheaper to deliver after accounting for the exchange's conversion factor system, while positively-sloped yield curves favor the delivery of longer duration securities. This conversion factor bias is well-known and discussed in, for example, Kane and Marcus (1987), Livingston (1987) and Burghardt and Belton (1994).

[viii] The penalty imposed on traders at the Chicago Board of Trade/Chicago Mercantile Exchange for delivery fails in Treasury futures contracts is penurious, but the exact amount is unspecified, as no party has ever failed at meaningful scale. Nonetheless, it is likely that a failing party would suffer enormous indirect costs, including loss of reputational capital as well as loss of trading access at the exchange itself.

[ix] Rumors in the market regarding a single hedge fund or institutional trader controlling the majority of the deliverables or one side of the futures contract is what prompted attention and concern from regulators in the first place; in all likelihood, their interest would have been muted at best if the event were simply a matter of mispriced Treasury notes in the cash market. While these rumors were eventually confirmed, the evidence that these traders could leverage their position unfairly seems strained at best, at least relative to historical patterns. For example, in unreported analysis for this study, we examined the CFTC's "Commitment of Traders" (COT) reports throughout the 1995–2005 time period. These reports are compiled on a weekly basis from daily positions reported to the exchanges, and amongst other items, report "concentration ratios", which measure the fraction of open interest controlled by the 4 and 8 largest accounts in the market on both a gross and net basis. While this is an imperfect measure of market power, it does capture to some degree the potential for leverage and ultimately, market manipulation. While the concentration ratios for TNF contracts in 2005 were higher than average for this 11-year time period, they were not unprecedented in size or scope. On multiple occasions, including time periods of relative tranquil trading in the Treasury market, larger concentration ratios were observed than for TNF contracts in 2005.

We note in passing that in legal filings, plaintiffs litigation was settled out of court via summary judgement in 2010 ("Pimco to Pay $92 Million to Settle Market Manipulation Lawsuit," *Bloomberg Financial News*, December 30, 2010).

[x] Most studies in this literature use in-sample interpolation methods and smoothing splines to infer the underlying term structure discount function from the observed price of coupon-bearing Treasury securities; some version of cubic or exponential splines are the most common choice (Bliss, 1996). An alternative approach uses Treasury STRIPS as an independent measure of the term structure; however, for pricing of deliverable 10-year U.S. Treasury notes, Carayannopoulous (1994) shows that STRIPS systematically underprice cash market notes, which defeats the purpose of identifying unusually rich notes in the present study. Conveniently, the mean pricing error for in-sample spline methods is unbiased and zero, by construction.

[xi] We are grateful to Jordan and Kuipers (2005) for making this dataset available for the present study. All downstream calculations follow the market pricing practices outlined in that article.

[xii] The subsample begins on February 25, 2005 rather than March 1, 2005 because in the futures market, a short can indicate their intent to deliver two business days prior to the beginning of the contract expiration month, which in this case, is February 25. For both the full sample and the subsample, we bisect the maturity range of interest to 6.5 to 8.25 years remaining maturity alone for analysis, instead of 6.5 to 10 years as specified in the CBT's TNF contract, for two reasons. First, the shorter maturity range spans the affected notes subject to alleged squeeze activity and mispricing during 2005, and we want to limit the potential for maturity-specific term structure effects and/or contamination factors by examining instruments with maturities too distant from this maturity range. Relatedly, it is well-known that on-the-run and lightly-seasoned 10-year Treasury notes trade at significant price premiums in the Treasury market due to their transient liquidity enhancement; by limiting our attention to the shorter maturity range, we avoid notes trading with these premiums (Carayannoupoulos, 1994).

[xiii] The data used in this study are often highly autocorrelated and, in places, consist of pooled cross-sections and time series. Consequently, all *t*-statistics reported in the paper utilize heteroskedasticity and autocorrelation-consistent (HAC) standard errors (Newey and West, 1987). In general, these HAC standard errors are substantially larger than their univariate or ordinary least squares counterparts, so the reported *t*-statistics throughout the paper are conservative in that regard.

[xiv] The 20¢ (15¢) mispricing is well-outside the normal trading cost range, even for lightly traded instruments like seasoned notes (Fleming, 2003). Given the enormous leverage used by professional traders and firms, even small price discrepancies in the market are noticed by active traders, and can be levered into enormous trading profits in the right situation with timely trades. This is exactly the gaming scenario referred to by James Clouse in his speech to the Bond Market Association in 2006: "Remarks of Deputy Assistant Secretary for Federal Finance James Clouse, U.S. Department of the Treasury, Before the Bond Market Association, Government Securities and Funding Division," *U. S. Department of the Treasury Press Center*, September 27, 2006.

[xv] Of course, cash market price premia alone are not the only avenue for extracting rents from participants in the Treasury market. If a trading party controls an instrument that trades on special in the Treasury repo market, the same leveraged gains that can be captured in the cash market itself can, in principle at least, be monetized in the repo market as an alternative (Jordan and Jordan, 1997). Notably, this is the exact strategy pursued in the Fenchurch manipulation squeeze of 1993 as well as the Salomon Brothers Treasury auction scandal of 1991. We do not have access to special repo rates data for the notes of interest in this study, nor is it clear that such data even exists during this time period, at least for off-the-run, seasoned instruments (Fleming, Hrung and Keane, 2010). Anecdotally, market chatter during the event period was that the notes in question in panel B were on special in the repo market, but not to the extreme degrees as observed during the Salomon Brothers and Fenchurch episodes ("US Debt Futures: Dealers See Calendar Plays, 10Y Squeeze," *Market News International/LexisNexis*, May 24, 2005), during which the affected securities often traded at negative special repo rates.

[xvi] An interesting additional data point for comparison concerns the findings of government regulators in the Fenchurch scandal. The venue for trading in that instance was the same 10-year U.S. Treasury note cash and futures market we study in this article, albeit in an earlier time period (1993). In its findings for cause, the CFTC estimated a price pressure effect due to the actions of Fenchurch in the amount of 5/32 of one percent of par value notes, or roughly 16 cents, on average, which regulators deemed to constitute "an economically significant distortion of fair market pricing" (CFTC, 1996). This is in turn was used as justification for the assessment of damages and penalties. Notably, the price residuals in Table 2 and Figure 4 are larger than those in the Fenchurch affair and persist for a longer period of time.

[xvii] One would hope the maturing literature on idiosyncratic pricing within the Treasury market (fn. 3) would motivate the development of such an event study statistic specifically applied to the Treasury market.

Existing test statistics in this area are designed for tests involving corporate bond returns (e.g., Bessembinder et al., 2009; Ederington, Guan and Yang, 2015).

[xviii] The test statistic constructed in (2) seems well behaved for our purposes in this study; the rejection rate at the 5% level for the 1000 sample runs is 5.76%.

[xix] The two-day abnormal returns tested in Table 3 are converted into their equivalent $ price change for ease of comparison with results reported earlier in the paper. The *t*-statistic in the last column of the table tests the null hypothesis that the abnormal return in equation (1) is zero.