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R. Ben-Abdallah
M. Breton

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GERAD HEC Montréal
3000, chemin de la Côte-Sainte-Catherine
Montréal (Québec) Canada H3T 2A7

Tél. : 514 340-6053
Téléc. : 514 340-5665
info@gerad.ca
www.gerad.ca

Time is money: An empirical investigation of delivery behavior in the U.S. T-bond futures market

Ramzi Ben-Abdallah [a]
Michèle Breton [b]

[a] *Université du Québec à Montréal, Montréal (Québec) Canada, H2X 3X2*

[b] *GERAD & HEC Montréal, Montréal (Québec) Canada, H3T 2A7*

ben_abdallah.ramzi@uqam.ca
michele.breton@hec.ca

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Abstract: One of the most complex early-exercise decisions faced by traders in the financial derivatives markets is with T-Bond futures, due to the combination of multiple timing options embedded in the contract in combination with a quality option. The aim of this paper is to provide a broad empirical investigation of short traders' delivery behavior observed in the CBOT T-Bond futures market over the period spanning 1985 to 2015. More precisely, we analyze the main factors driving the selection of the delivery time, the choice of the security delivered, as well as the number of futures contracts fulfilled by delivery. Our findings show that short traders generally preferred to defer delivery to the last possible moment. However, the last three decades were also regularly punctuated by early-delivery episodes, largely motivated by substantial profits for immediate exercise, but also by bond market liquidity and volatility. Finally, we assess *a posteriori* the optimality of the observed delivery strategies and conclude that, not only was the rule of thumb for early delivery generally not used by traders, it would not have performed better than a naive strategy of systematically choosing to deliver at the end of the delivery month.

Key Words: Futures, treasury bonds, early exercise, cheapest-to-deliver, basis.

Résumé : L'une des décisions d'exercice les plus complexes dans le marché des produits dérivés concerne celle des contrats à terme portant sur des bons du Trésor, du fait de la combinaison d'une option de qualité avec plusieurs options de livraison qui sont implicites dans ces contrats. Cet article présente une analyse empirique du comportement des opérateurs du Chicago Board of Trade (CBOT) observé sur le marché des contrats à terme de 1985 à 2015. Plus précisément, nous analysons les facteurs principaux ayant un effet sur le choix du moment de livraison et de l'obligation livrée, ainsi que le nombre de contrats donnant lieu à une livraison. Nos résultats montrent que les opérateurs ont généralement choisi de livrer au tout dernier moment. Cependant, on observe régulièrement au cours des derniers trente ans des épisodes où des livraisons ont été effectuées plus tôt, le plus souvent du fait d'opportunités immédiatement profitables, mais aussi pour des raisons de liquidité ou de volatilité sur le marché des bons du Trésor. Finalement, nous évaluons *a posteriori* l'optimalité des stratégies de livraison observées historiquement et concluons que la règle empirique proposée pour le choix du moment de livraison n'est généralement pas utilisée par les opérateurs; de plus, nous constatons que cette règle n'aurait pas été plus performante que le choix de toujours effectuer la livraison au dernier moment possible.

Acknowledgments: Research supported by NSERC Canada.

1 Introduction

The Treasury Bond futures contract traded on the Chicago Board of Trade (CBOT T-Bond futures hereafter) is one of the most liquid, transparent and actively traded futures contracts in the world, making it an instrument of choice for hedging long-term interest-rate-risk exposure. This contract calls for the delivery of the $100,000 face value of a reference government bond with a term to maturity of 20 years and bearing a 6% coupon rate.[1] Because this underlying notional bond does not generally trade in the marketplace, the short trader is offered the option to choose which bond to deliver among a deliverable set fixed by the exchange (the *deliverable basket*). This delivery privilege is called the *quality option.* However, since the characteristics of the deliverable issues may differ substantially from those of the notional bond, and in order to make the delivery fair for both parties, the futures price received by the short trader is adjusted according to the quality of the T-Bond actually delivered. To do so, the CBOT uses a set of *conversion factors,* defined as the prices of the eligible T-Bonds computed on the first possible delivery day, under the assumption that the yield curve is flat at a level fixed at 6% per annum with semiannual compounding. This assumption is generally not realistic, resulting in a conversion-factor-system bias that intensifies as the discrepancy widens between the assumed yield curve (flat at 6%) and the one currently observed. The conversion factor system thus fails to make eligible T-Bonds equal for delivery; the Treasury security that maximizes the short trader's economic profit is commonly known as the *cheapest-to-deliver* bond (CTD).[2] In the U.S. Treasury bond futures market, in addition to the quality option, short traders enjoy so-called *timing options,* which allow them to deliver on any business day during a delivery month.[3] The quality and timing options offered to the short trader aim to alleviate the demand that would be triggered by the futures market on a single issue or on a single delivery day, thereby reducing the likelihood of liquidity problems (e.g., short squeezes) and ensuring the smooth functioning of the futures market.

There is not much literature on the exercise of the strategic timing options embedded in the U.S. T-Bond futures, and most of it is concerned with their pricing in conjunction with the quality option (see, for instance, Kane & Marcus 1986 [23], Hedge 1988 [20], Boyle 1989 [6], Cohen 1995 [12], Peck & William 1990 [28], Biagini & Björk 2007 [5], Chen et al. 2009 [9], and Chen & Yeh 2012 [10]). However, because of the complexity arising from taking all the embedded delivery options into account simultaneously, not much has been said about the optimal timing strategy, apart from rules of thumb that have been suggested for early delivery (see Burghardt et al. 2005 [7] and Choudhry 2010 [11]).

The aim of this paper is to provide a broad empirical investigation of the short traders' delivery behavior observed in the CBOT T-Bond futures market over the last three decades (1985–2015). To do so, we track the history of the actually observed deliveries, using a data set that includes, for each delivery month, the number of futures contracts settled, the securities actually delivered, and their delivery dates. This allows us to analyze the main factors driving the selection of the delivery time during the contract delivery month and to assess the optimality of the observed delivery strategies.

We observe that short traders generally preferred to defer delivery to the last two possible delivery days over our period of study. However, this period was also occasionally punctuated by early deliveries, which were largely motivated by substantial immediate-exercise profits. Our findings show that short traders were generally monitoring both the bond cash and futures markets over the delivery month in an attempt to fully take advantage of bond market volatility and to maximize the outcomes in satisfying the futures contract. Nevertheless, in some instances, short traders missed valuable early-exercise opportunities and even incurred sizeable delivery losses. Finally, our analysis shows that bond market liquidity plays an important role in the observed delivery strategies.

The organization of this paper is as follows. Section 2 presents the strategic delivery options implicit in the U.S. T-Bond futures and discusses the main drivers of the T-Bond cash-futures basis as well as the resulting rules that help short traders pick the best time to make delivery. Section 3 is devoted to describing

[1] Prior to March 2000, the coupon rate of the notional bond was equal to 8%, and has since then been reduced to 6%.

[2] For an in-depth discussion of the imperfections of the CBOT conversion-factor system, and the risk of and possible mitigations for conversion-factor risk, we refer refer to Kane & Marcus 1984 [22], Jones 1985 [21], Grieves & Mann 2004 [18], Oviedo 2006 [27], and Ben-Abdallah et al. 2009 [4].

[3] Delivery months are March, June, September, and December.

the data we use in this paper. In Section 4, we provide an empirical investigation of the short traders' delivery behavior, as well as an assessment of the optimality of their timing decisions. Section 5 concludes.

2 Choosing the time to deliver a T-Bond: Theory, outcomes and market rules

In this section, we first provide a comprehensive description of the strategic delivery options implicit in U.S. T-Bond futures. We then present the bond cash-futures relationship defining the T-Bond basis and analyze its main drivers. Finally, we present and discuss rules of thumb that are used as guides to choose the best time to fulfill the T-Bond futures contract.

2.1 The strategic delivery options embedded in U.S. T-Bond futures

In addition to enjoying the quality option, consisting of choosing the most profitable bond for delivery, short traders in .S. T-Bond futures are afforded privileges that give them the possibility to deliver earlier rather than later during the contract expiry month.

The futures contract specifications stipulate that, during the delivery month, deliveries must take place according to a *delivery sequence* (or *delivery process*) that involves three consecutive business days:

- The *position day* (or *tender day*), where the short trader officially declares his intention to deliver;
- The *notice day*, where the short trader indicates the T-Bond that will be delivered;
- The *delivery day*, where delivery takes place against a payment based on the settlement price of the position day, adjusted using the conversion factor (the *futures invoice price*).

It is significant to stress that, according to the delivery sequence, the delivery date is actually decided on the position day. Note that, during the last seven business days before the end of the delivery month, trading on the T-Bond futures contracts stops while delivery—based on the last futures settlement price—remains possible according to the delivery sequence.

These special delivery features thus offers the short trader multiple valuable privileges over the delivery month:[4]

- The *timing options*: These options refer to the possibility of delivering on any business day during the contract delivery month.
- The *end-of-day option* (or *wild card play* or *six-hours option*): This option refers to the possibility of deciding to deliver up to six hours after the futures market is closed for the day, while trading in the bond cash market continues. A large move in bond prices may result in a valuable early-exercise opportunity.
- The *end-of-month (EOM) option*: This option refers to the opportunity to take advantage of bond price changes during the last seven business days of the delivery month. Bond price fluctuations during the EOM period may result either in a decline in the price of the CTD or in shifts from one CTD to a cheaper one.
- The *switch option*: This option stems from the opportunities resulting from the potential price moves that may occur during the period before trading in the futures market expires for the contract month (i.e., before the end-of-month option comes into play). In fact, unlike the EOM period, both futures and bond prices vary according to market forces during the switch period. Short traders can then take advantage of these price changes or even swap out of one CTD and into another.[5]

[4] For a broad discussion of these multiple delivery options, we refer to Burghardt et al. 2005 [7].

[5] See, for example, Barnhill & Seale 1988 [3], Barnhill 1990 [2], and Grieves & Marcus 2005 [19] for the valuation of the switch option embedded in the U.S. T-Bond futures.

2.2 The T-Bond cash-futures basis and its main drivers

In U.S. T-Bond futures, the difference between the cash price of a T-Bond and the futures invoice price is defined as the T-Bond *gross basis*. The interest earned from holding the bond until the last possible delivery day, that is, the difference between the coupon income and the financing cost of the bond, is called the *bond carry*. The *basis net of carry* of a bond can therefore be interpreted as the cost resulting from engaging in a cash-and-carry trade.

Since the gross basis represents the immediate cost of delivering a T-Bond into the futures contract at a given date, the T-Bond maximizing the short trader's profit (that is, the CTD) is the one with the lowest gross basis amongst deliverable grades. For futures short traders, the immediate cost of delivering the CTD bond rather than waiting until the last possible delivery day mainly stems from two drivers, namely, the CTD bond carry and the market value of the embedded delivery options. These futures-cash bond relationships are summarized as follows:

$$\begin{aligned} \text{Bond gross basis} &= \text{Bond cash price} - \text{Futures price} * \text{Conversion factor} \\ \text{CTD gross basis} &= \text{CTD bond carry} + \text{Value of the delivery options.} \end{aligned}$$

The main determinants of the evolution of the CTD gross basis during the delivery month are then changes in the yield curve and bond market volatility. Bond carry depends on the coupon rate of the CTD, as well as on its financing cost over the holding period, generally through the repo markets at the repo rate associated with this specific bond. On the other hand, the value of the various implicit delivery options (including the switch option, the end-of-month option, and the other timing options) over the delivery month greatly depends on the expected bond market volatility as well as on the composition of the deliverable basket. In fact, substantial changes in the yield curve could result in multiple changes in the CTD or in its price during the delivery month, thus conferring much value to the switch and end-of-month options. The impact of these yield-curve changes is even more sizeable as the discrepancy between the characteristics of the bonds making up the set of deliverable grades increases. Indeed, the advantage of swapping from one CTD to another not only depends on the volatility of interest rates (impacting their prices individually), but also on the difference between the market prices of the old and new CTDs (i.e., the spread in their yields to maturity), which is essentially driven by the differences in their features.

2.3 Gross basis, delivery outcome and exercise strategy

Simply observing the sign of the gross basis allows us to relate the outcome of immediate delivery to the shape of the yield curve. A positive gross basis leads to a loss on immediate delivery. A delivery profit is only possible when the bond carry is negative (financing cost is higher than the coupon income), and when the option value is small. This observation is the rationale for what is known among practitioners as the rule of thumb for early delivery (see Burghardt et al. 2005 [7]). When the term structure of interest rates is upward sloping, the carry of the CTD, a long-maturity bond, should be positive. By postponing delivery, the short trader simultaneously enjoys positive bond carry and keeps possession of the remaining embedded delivery options. On the other hand, a negatively sloped yield curve results in negative bond carry, implying that early delivery would avert the losses related to holding the bond, but would forfeit the positive value of the implicit delivery options. In that case, the short trader should deliver early when bond market volatility is low, so that the value of the delivery options does not exceed a whole month of negative carry. This rule of thumb for early delivery makes it fairly simple for short traders to choose the time of delivery, without requiring daily monitoring of the sign and the magnitude of the basis.

Another rule of thumb (see Choudhry 2010 [11]) relates delivery time to the yield of a cash-and-carry strategy (also known as the Implied Repo Rate). In a negative-yield-curve environment, the short should deliver early if the yield of carrying the bond to the last possible delivery day is much lower than the financing rate.

As the shape of the yield curve is conventionally and more generally positively loped (see Figure 3), these rules of thumb imply that early delivery would only be optimal under extreme circumstances (i.e., under a

negative gross basis resulting from a negative carry and under a low volatility setting or relatively high repo rates). Short traders are therefore generally better off delaying delivery to the last possible day.

It is important to point out that the basis only indicates the profit or loss related to immediate exercise, and gives no indication of whether or not delaying delivery is advisable. In addition to the importance of the current sign and magnitude of the basis, its future evolution—known as *basis risk*—is a key factor that needs to be taken into account in order to make an optimal timing decision. In fact, it could be worth the short's while to deliver early when the basis is positive if it is anticipated to increase during the delivery month. On the other hand, even when the gross basis is negative, the short trader could be better off postponing delivery if this gross basis is expected to decrease further over the delivery month. Note however that negative-gross-basis situations consist of riskless profit opportunities (sell the futures, buy the CTD and deliver it immediately) that should rapidly vanish, as arbitrage forces would put downward pressure on futures prices. On the other hand, since the bond market is also involved, it may happen that distortions in the cash market prevent these arbitrage forces from instantaneously bringing the basis back to positive levels.

The next section presents the data that will be used to investigate how short traders actually chose to exercise their timing options during the last three decades.

3 Data

3.1 Futures data

In this paper, we consider 124 futures contracts traded in the period between March 1, 1985, and December 31, 2015, representing the quarterly delivery cycles of the nearby futures contracts. The data we use for these futures contracts is obtained from Bloomberg and includes prices, open interest, and trading volumes observed on the first day of the delivery month. We present summary statistics for these futures contracts in Table 1. This data is also depicted in Figures 1 and 2.

Table 1: Descriptive statistices for futures contracts.

	Quoted Prices	Open Interest	Trading Volume
Count	124	124	124
Mean	112.61	128678	66689
Median	111.94	120295	56703
Standard Deviation	17.78	56847	51544
Kurtosis	0.13	−0.24	11.72
Skewness	0.44	0.51	2.95
Minimum	69.28	30785	1890
Maximum	157.22	292341	327777
First Quartile	100.29	83337	38536
Third Quartile	120.10	169753	77252

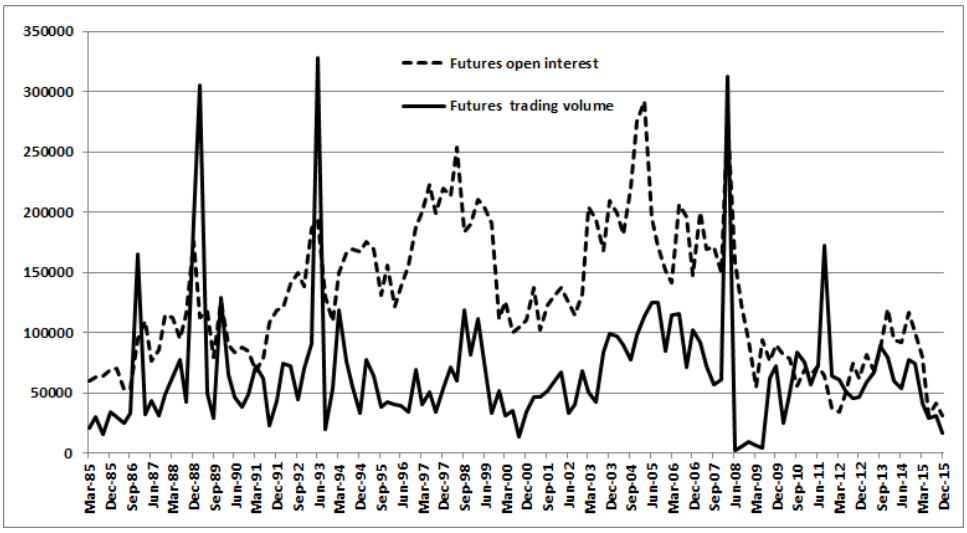
This table presents summary descriptive statistics for the U.S. T-Bond futures contracts over the period spanning March 1985 to December 2015 (124 contracts). The data on observed futures prices, open interest and trading volume is obtained from Bloomberg and reported on the first day of the delivery month of the nearest-expiring futures contract.

3.2 Interest rate data

The observed term structure of interest rates consists of Treasury yield curves for maturities ranging between three months and 30 years for the period spanning March 1, 1985, to December 31, 2015. We also use the Fed funds rate observed on the first day of the delivery months over our period of study. Interest rate data is obtained from the Federal Reserve Statistical Release.

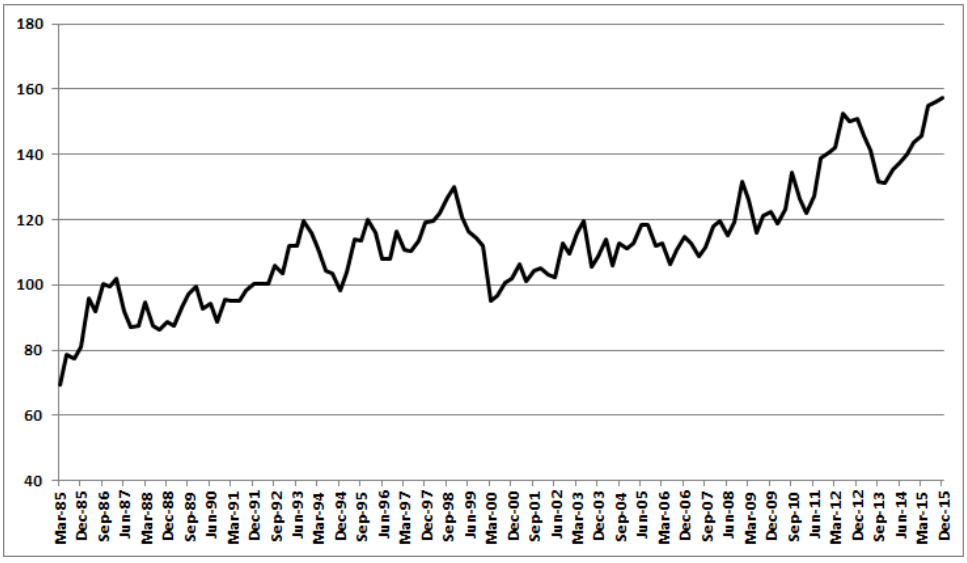
Figure 3 depicts the U.S. spot-yield surface computed on the first day of the delivery month of the nearest-expiring futures contract during our period of study. Notice that this surface is generally upward sloping.

Figure 1: U.S. T-Bond futures contracts' open interest and trading volume.



This figure presents the open interest and trading volume of the U.S. T-Bond futures contracts over the period spanning March 1, 1985, to December 31, 2015. The data is obtained from Bloomberg.

Figure 2: U.S. T-Bond futures prices on the first day of the delivery month.

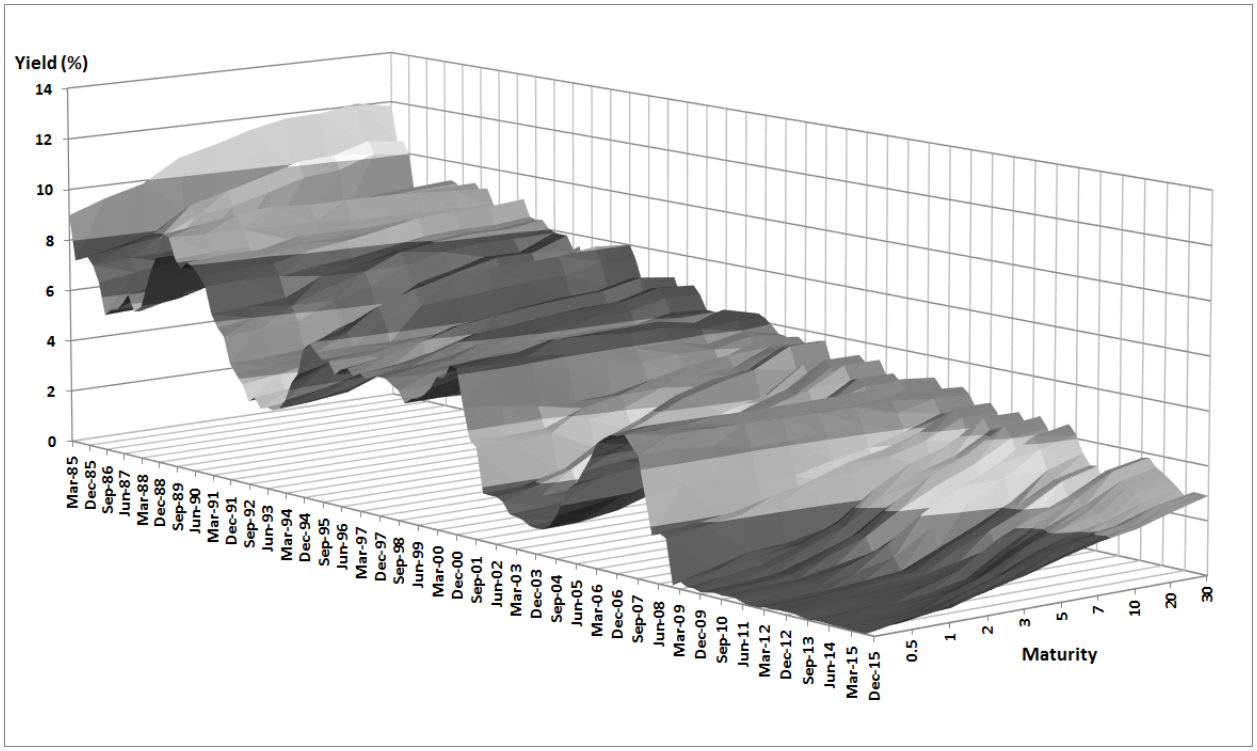


This figure presents the quoted prices of the nearby U.S. T-Bond futures contracts on the first day of the delivery month over the period spanning March 1, 1985, to December 31, 2015 (124 futures contracts), obtained from Bloomberg.

The rules of thumb for early delivery rely on the *slope* of the yield curve, computed as the difference between the 30-year Treasury yield and the Fed funds rate. Figures 4 and 5 report the evolution of these two rates and the slope of the yield curve on the first day of the delivery months over our period of study.

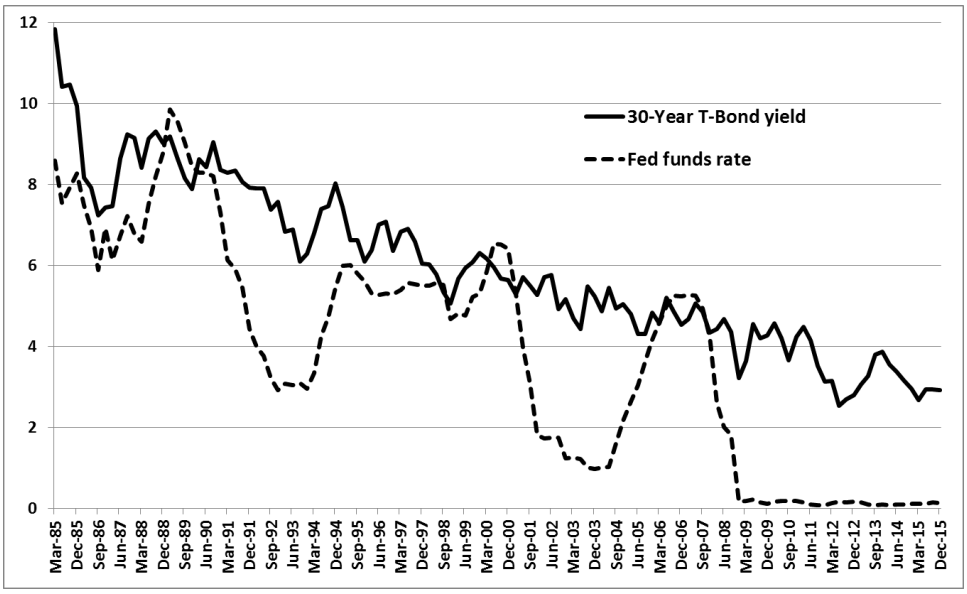
From March 1985 to December 2015, the computation of the slope of the yield curve on the first day of the delivery months gives a negative value for only 15 of the 124 contracts. The observation of Figure 5 shows three distinct episodes of a negatively sloped yield curve over the considered period: March 1989 to December 1989 (four contracts), June 2000 to March 2001 (four contracts), and March 2006 to September 2007 (six contracts). Notice that the slope was never lower than -1% during these episodes.

Figure 3: U.S. spot-yield surface (1985–2015).



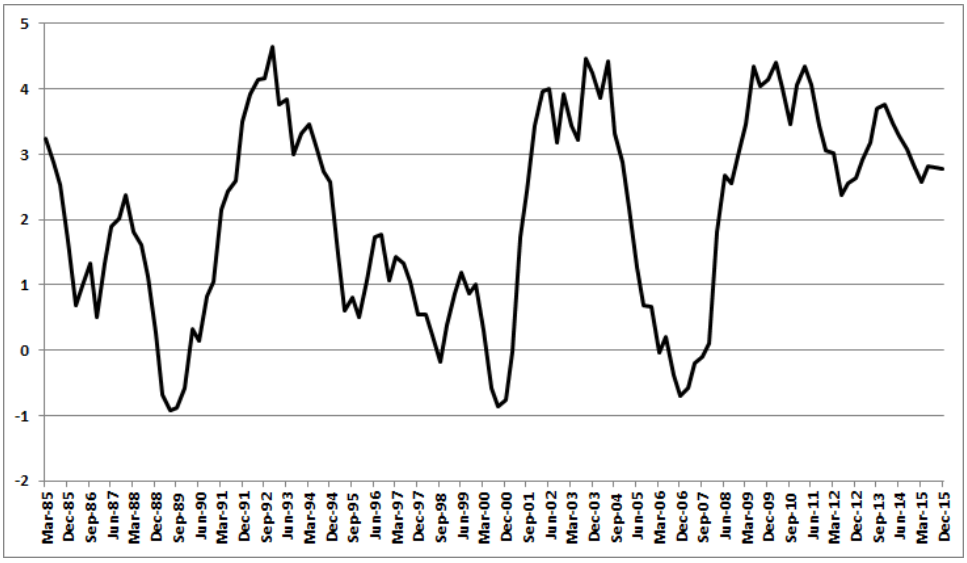
This figure presents the U.S. spot-yield surface computed on the first day of the delivery month of the nearest-expiring futures contract from March 1985 to December 2015.

Figure 4: 30-year Treasury rate vs. Fed funds rate (1985–2015).



This figure plots the evolution of the yield on 30-year Treasury bonds (%) and the Fed funds rate (%) over the period spanning March 1, 1985, to December 31, 2015. Data is obtained from the Federal Reserve Statistical Release.

Figure 5: U.S. yield-curve slope (%) (1985–2015).



This figure presents the evolution of the slope of the Treasury yield curve, defined as the difference between the yield on 30-year Treasury bonds and the Fed funds rate, over the period spanning March 1, 1985, to December 31, 2015. This slope definition is generally interpreted as a proxy for T-Bond carry. Rates used for yield-curve slope computation are obtained from the Federal Reserve Statistical Release.

3.3 Deliverable basket data

The basket of T-Bonds deliverable into the futures contract is based on the information about the issue dates of the 30-year U.S. Treasury bonds—which is available on the TreasuryDirect web site. Until December 2010, any government bond with at least 15 years to maturity or earliest call was eligible for delivery according to the futures contract specifications; as of the March 2011 expiry, the set of securities deliverable into the classic futures contract only includes T-Bonds with remaining terms to maturity of between 15 to 25 years. A total of 68 T-Bonds—issued between 1975 and 2010—could then be delivered into the 124 futures contracts considered in this study.[6] Table 2 presents summary statistics of the T-Bonds making up the baskets eligible for delivery between March 1985 and December 2015.

We also use the carry of the CTD observed on the first day of the delivery month, and the gross basis of the CTD (denoted by GBC thereafter) observed on the first day of the delivery month and on the last futures trading day. This data, presented in Figures 6 and 7, is available from June 1987 (115 contracts) and provided by Bloomberg.

Figure 6 shows that the CTD only had a negative carry on the first day of the delivery month five times over our period of study, that is, from March 1989 to December 1989 (4 contracts) and in December 2000. Meanwhile, Figure 7 shows that the GBC was negative on the first day of the delivery month on only six occasions: September 1987, March and September 1989, March 2001, September 2005, and December 2006. Finally, Figure 8 shows that the GBC generally decreased between the first day of the delivery month and the last futures trading day (recall that the GBC is the immediate cost of delivering the CTD). An increase in the GBC between these two dates is observed 32 times over the 115 delivery months.

3.4 Data on actual deliveries

We now describe the data set used in this paper to investigate the strategies that were actually applied by short traders to settle the U.S. T-Bond futures through physical delivery over the period spanning March 1, 1985,

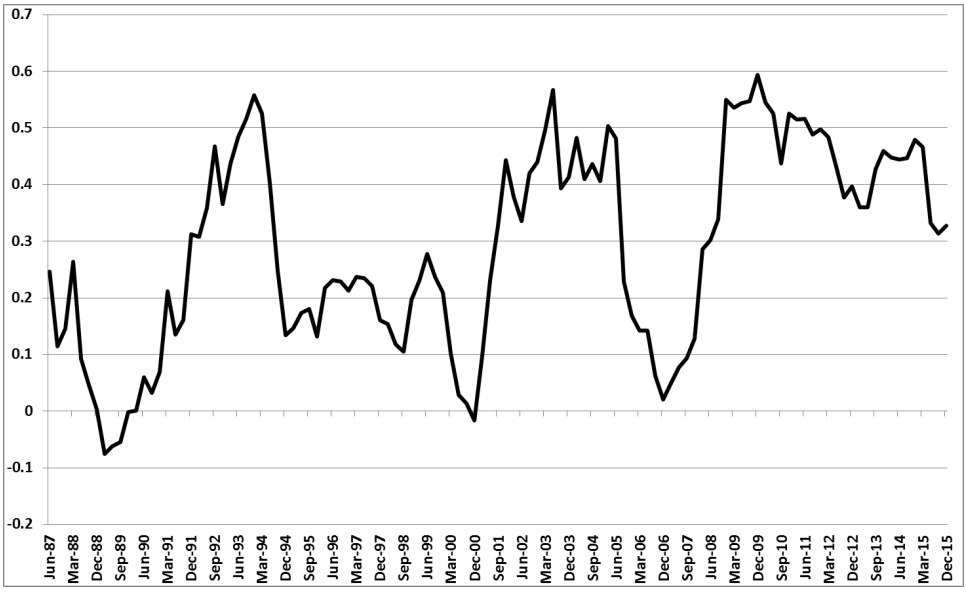
[6] The U.S. Department of the Treasury suspended the issuance of 30-year bonds for a five-year period starting in early 2001.

Table 2: Descriptive statistics on deliverable baskets.

	T-Bond		
	Coupon Rate (%)	Basket Size	Amount Eligible
Count	68	124	124
Mean	7.77	23.19	273.89
Median	7.63	23	283.78
Standard Deviation	2.61	7.05	100.30
Kurtosis	−0.29	−0.32	−0.77
Skewness	0.51	−0.35	0.03
Minimum	3.50	9	85.29
Maximum	14.00	36	533.71
First Quartile	5.87	21	185.60
Third Quartile	9.03	27	350.49

This table presents summary descriptive statistics for the T-Bonds making up the baskets deliverable into the U.S. T-Bond futures contracts over the period spanning March 1985 to December 2015 (124 contracts). The data includes bond coupon rate, delivrable basket size, as well as the total dollar amount eligible for delivery per futures contract (millions). Data is obtained from the CBOT.

Figure 6: Carry of the CTD ($) (1987–2015).

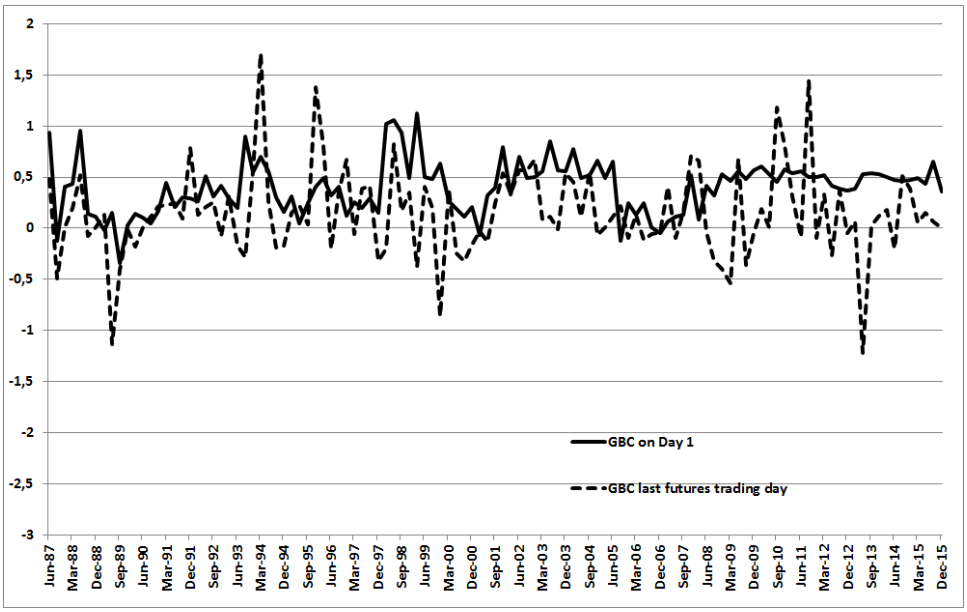


This figure depicts the market carry of the CTD reported on the first day of the leading delivery month for the period spanning June 1, 1987, to December 31, 2015. Data is obtained from Bloomberg.

to December 31, 2015. This data set is provided by the CBOT and includes the dates on which deliveries took place during the delivery month, the corresponding number of futures contracts settled, as well as the T-Bond chosen by short traders to fulfill the delivery requirements. This data thus represents the distribution of the timing of actual deliveries throughout the delivery months. Note that the CBOT updates this set of data quarterly following each expiration of a futures contract. Figure 9 presents the monthly number of futures contracts settled by delivery over our period of study, while Figures 10 and 11 illustrate the distribution of the observed timing of deliveries.

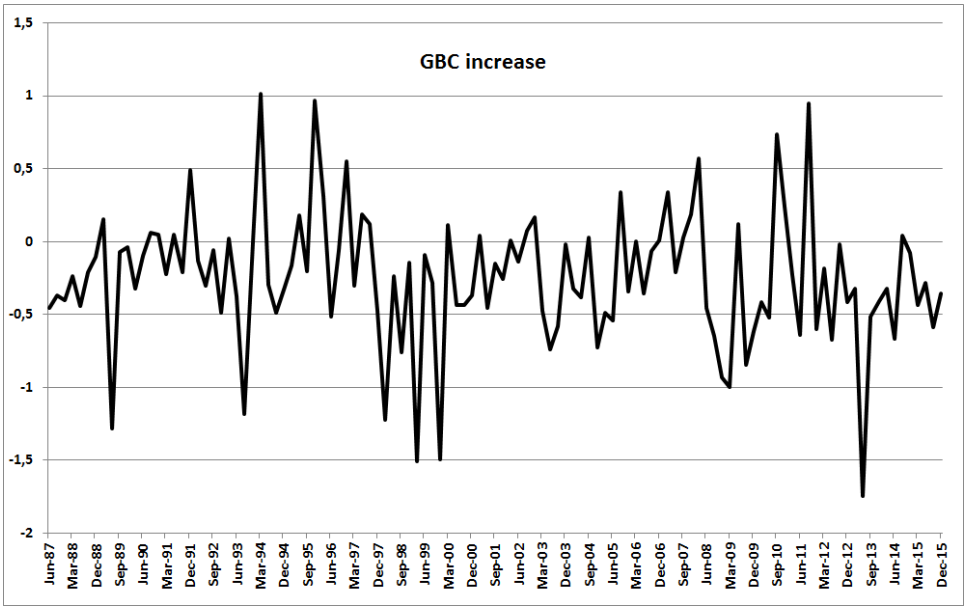
A first observation of Figures 10 and 11 shows that, over the last three decades, short traders generally elected to postpone delivery toward the end of the month (we observe only 20 instances where less than 90% of the deliveries were made during the last two business days of the delivery month). These figures also show several distinct episodes where early delivery took place regularly during the delivery period; we observe 12

Figure 7: CTD gross basis on Day 1 of the delivery month and on last futures trading day.



This figure is a comparison between the gross basis of the CTD on the first day of the delivery month and on the last futures trading day. Data is obtained from Bloomberg and spans the period from June 1, 1987, to December 31, 2015.

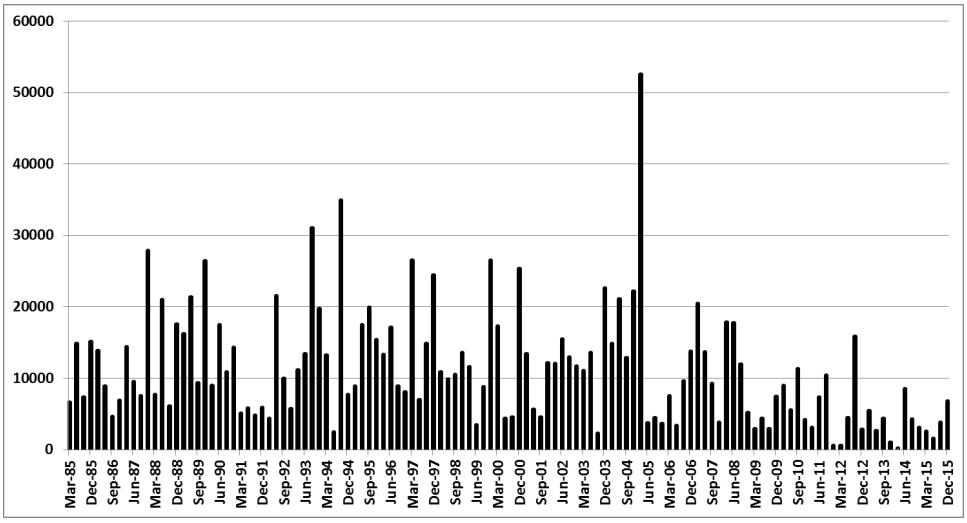
Figure 8: Increase in the value of the GBC between Day 1 of the delivery month and the last futures trading day.



This figure represents the difference between the gross basis of the CTD on the last trading day and Day 1 of the delivery month. Data is obtained from Bloomberg and spans the period from June 1, 1987, to December 31, 2015.

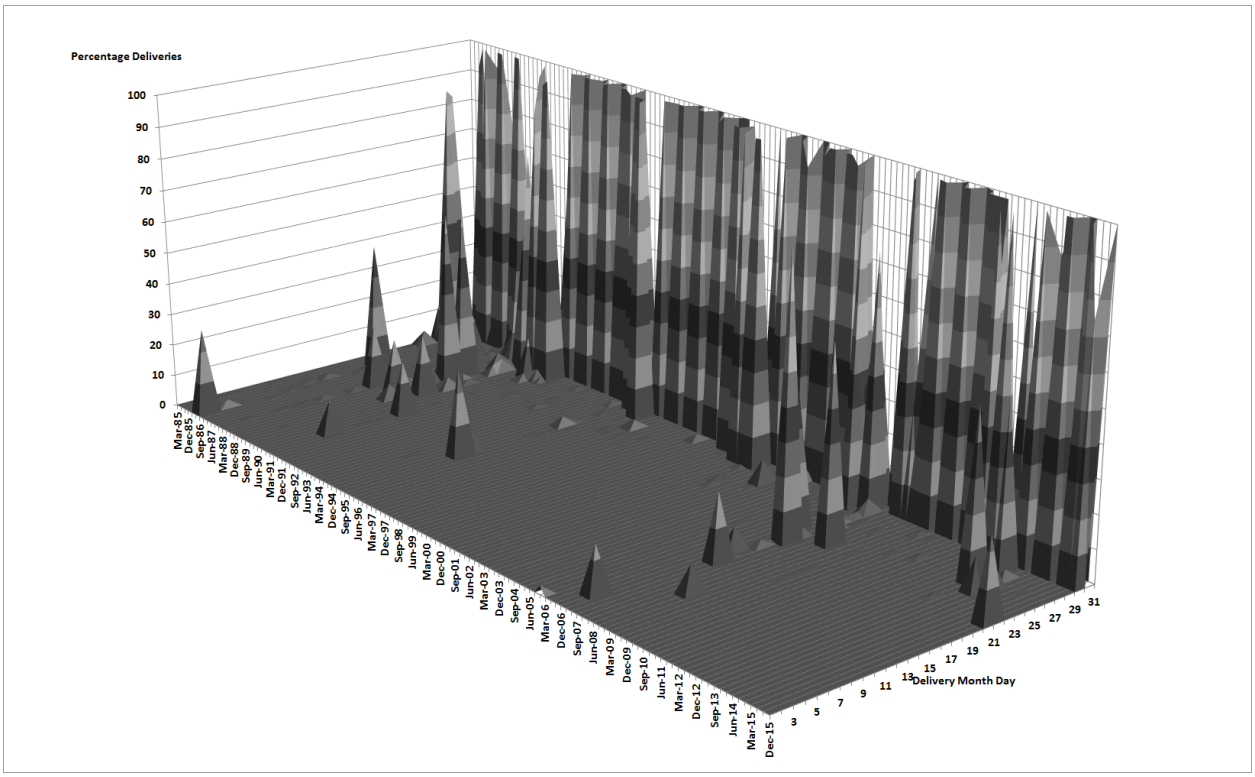
instances where more than 10% of the deliveries occurred during the switch period. Early-delivery episodes include for instance the late 1980s, the period corresponding to the last 2007–2008 global financial crisis, as well as some more recent episodes in 2013 and 2015.

Figure 9: Total number of deliveries into the U.S. T-Bond futures (1985–2015).



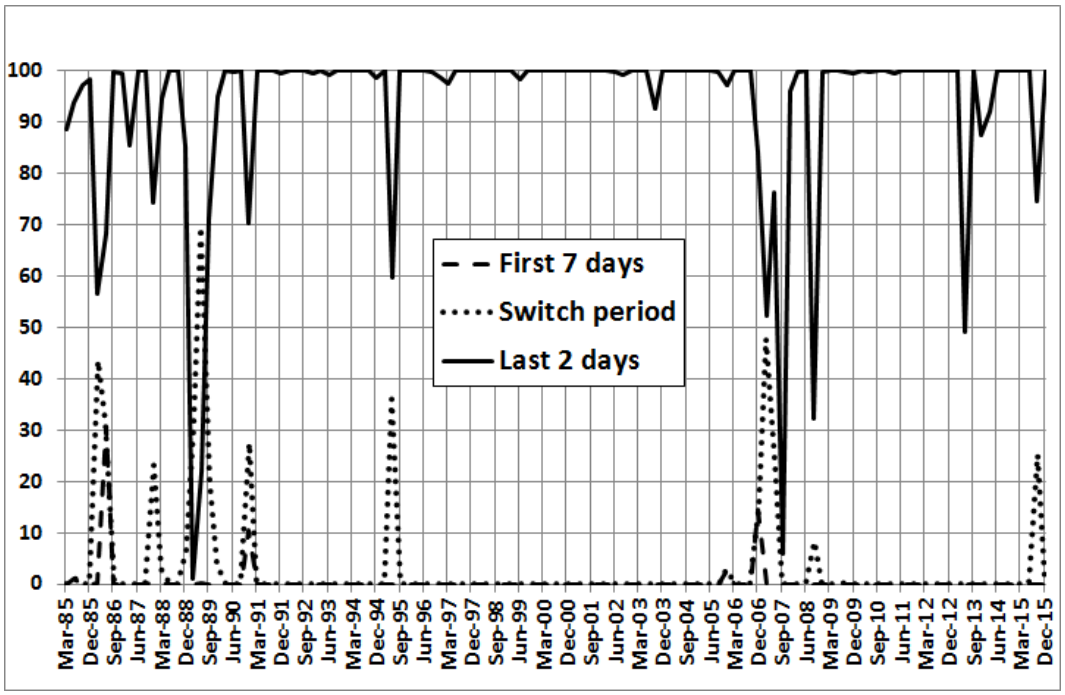
This figure presents the number of U.S. T-Bond futures contracts fulfilled by delivery for each futures contract over the period spanning March 1, 1985, to December 31, 2015. Data is obtained from the CBOT.

Figure 10: Distribution of actual deliveries into the U.S. T-Bond futures throughout the delivery month (1985–2015).



This figure presents the distribution of actual deliveries into the U.S. T-Bond futures as a percentage of the month's total deliveries for each futures contract over the period spanning March 1, 1985, to December 31, 2015. Data is obtained from the CBOT.

Figure 11: Distribution of the timing of actual deliveries into the U.S. T-Bond futures throughout the delivery month (1985–2015).



This figure presents the distribution of the timing of actual deliveries into the U.S. T-Bond futures, that is, the percentages of contracts fulfilled by delivery during the first seven days, during the switch period, and during the last two days of the delivey month, for each contract over the period spanning March 1, 1985, to December 31, 2015 Data is obtained from the CBOT.

4 Empirical investigation

We now provide an in-depth analysis of the short traders' delivery behavior observed in the U.S. T-Bond futures market over the last three decades, in order to examine the main factors driving the selection of a delivery time. As early delivery is supposed to occur under very special circumstances, we focus our analysis on episodes where early delivery was observed; we will investigate whether or not the rule of thumb was applied by short traders and assess whether bond carry and bond market volatility were the only forces driving the observed exercise decisions.

4.1 March and June 1986: The end of a squeeze

For the March 1986 futures contract, 44% of the month's total deliveries (6,041 contracts) occurred during the switch period. Moreover, a total of 17 different issues were delivered during this month, representing the widest variety of T-Bonds ever used within a delivery month to fulfill the contract's requirement in our period of study. For the June 1986 contract, ten different grades were delivered, and 32% of the month's total deliveries (2,798 contracts) took place during the switch period. In fact, the June 1986 contract is the only one in our data set for which there was a substantial delivery on the first day of the delivery month (27% of the month's total deliveries).

It is important to note that this early-delivery episode took place concurrently with the end of the most dramatic short squeeze ever to hit the U.S. T-Bond futures market. This infamous squeeze developed due to Japanese investment strategies in the U.S. fixed-income market and resulted in the dearth of T-Bonds over the period spanning March 1985 to June 1986 (see, e.g., Seeman 1986 [29], Burstein 1987 [8] and Cornell & Shapiro 1989 [13]). Although we lack the information to analyze the usual expected drivers of early delivery

decisions,[7] most probably the early deliveries as well as the unusually large number of issues involved were motivated by the lack of liquidity in the T-Bond market during this episode. On the other hand, notice that long-term yields (8.16% and 7.91% on the first days of March 1986 and June 1986 respectively) were at that time very close to the reference coupon rate of 8%, making deliverable grades roughly equal for delivery and considerably reducing losses related to the delivery of non-CTD issues.

4.2 December 1987: Cash market liquidity

The CTD during December 1987 was the 7.25% of May 2016, and most of the deliveries of this bond were made at the end of the delivery month. However, 20% of the month's total deliveries (5,500 contracts) took place on December 16, 1987, when the grade that was delivered, the 10.375% of November 2012, was not even among the three cheapest bonds. Examination of the data suggests that this early delivery episode had little to do with the futures market and the short traders' delivery behavior, since, most likely, the opportunity to take a selling position on the futures market during the delivery month was used by holders of the 10.375% because of liquidity problems in the cash market. Indeed, a crash in the dollar market on December 10, 1987, triggered a marked decrease in bond prices. As reported in the press on December 11, 1987, (see Maidenberg 1987 [25]), the position day for a delivery on December 16, 1987, "The losses were most pronounced among the longer-term Treasury maturities as institutions struggled to sell bonds to uninterested buyers."

4.3 The year 1989: Monitoring the basis

Table 3 reports the early delivery figures observed in 1989.

Table 3: Early delivery pattern during the period spanning March 1989 to December 1990. Source: CBOT.

Delivery Month	Mar-89	Jun-89	Sep-89
Month Dates	16–23	15–22	18–19
Percentage of Month's Total Deliveries	85%	71%	20%
Number of Contracts Settled by Delivery	13,708	15,298	1,867
Number of Issues Used for Delivery	1	5	7

During the year 1989, the Fed funds rate exceeded the 30-year T-Bond yield, and the yield curve generally exhibited a slightly inverted slope. An examination of interest-rate and basket data shows that the year 1989 presents distinct characteristics that make it stand out in our period of study. Indeed, four out of the five instances where we report negative CTD carry on the first day of the delivery month in our entire period of study correspond to the four 1989 contracts, while these four contracts also include two of the six instances of negative GBC and four of the 15 instances of negative slope on the first day of the delivery month. We analyze the delivery patterns for each of these four contracts in the following paragraphs.

During March 1989, the average level of the yield curve was 9.5%, considerably above the level of the reference coupon rate (8% at the time), favoring the delivery of the highest-duration bond. The CTD in the March 1989 set of eligible-for-delivery bonds was the issue $7\frac{1}{4}$% of May 2016. With a Fed funds rate at 9.85% on the first day of the delivery month, the carry of the CTD was substantially negative (amounting to −\$0.076, the lowest CTD carry recorded over our whole period of study). This negative carry resulted in the negative gross basis observed for this bond on the first day of the delivery month, which would in turn result in an immediate profit should the futures short trader decide to deliver on that day. It is worth noting that short traders elected to deliver early, but not on the first day of the delivery month, and that the $7\frac{1}{4}$% of May 2016 was the only bond delivered into this futures contract. The fact that the bulk of the deliveries took place during the last week of the switch period is an indication that the short traders were expecting the GBC to decrease further during the delivery month. The GBC became briefly positive on March 14, 1989, the position day of a first sizable early delivery on March 16, 1989, (18% of the contracts), and then decreased again to negative values. However, the GBC was in fact positive on the last futures trading day, where 54% of the contracts were settled by delivery.

[7] Bloomberg data on the identity of CTD bonds is only available from June 1987.

Following March 1989, yields dropped further, and the yield curve consistently presented a nearly flat shape at a level neighboring 8% (the futures contract standard), which made deliverable grades roughly equal for delivery and explains the variety of bonds delivered during this episode.

For the remaining three delivery months of 1989, the carry of the CTD was negative on the first day of the delivery month, but increasing toward zero. For the June 1989 contract, the GBC was positive on the first delivery day, but decreased during the month. While 56% of the month's total deliveries took place on June 21, 1989, we find that the GBC on June 19, 1989 (the position day) was negative at −\$0.058. For the September 1989 contract, the GBC was negative on the first delivery day, but decreased further during the month, reaching −\$0.411 on the last futures trading day. Finally, in December 1989, no early deliveries were recorded. In fact, the carry was approximately nil and the gross basis was positive on the first day of the delivery month, and then the GBC decreased to attain a negative value on the last futures trading day of December 1989.

These observations strongly suggest that short traders monitored the gross basis of the CTD to choose their delivery time and that they took into account not only its sign but also its expected evolution during the delivery month.

4.4 December 1990: CTD shift

Early deliveries took place in December 1990 despite the observed positive CTD carry, GBC, and yield curve slope on the first day of the delivery month. Deliveries took place on December 7, 1990 (10%), and on December 14, 1990 (17%), for a total of 3,928 contracts, and involved seven different issues. The observation of the evolution of the 30-year T-Bond yield during the year 1990 shows a humped shape that greatly impacted the corresponding evolution of the CTD throughout the year. In fact, long-term rates exceeded 9% in the middle of the year 1990 and then started falling until they hit 8%—the reference coupon rate. As a result, the bond with the highest duration (the issue $7\frac{1}{2}$% of November 2016) that had long retained CTD status lost this status on December 5, 1990, when it was overtaken by lowest-duration bonds bearing substantially higher coupon rates and thus trading at a premium. This drastic shift and the corresponding jump in the CTD price probably triggered the early-delivery process that began two days later on December 7, 1990.

4.5 June 1995: Immediate profit opportunity

At the beginning of June 1995, all the evidence (positive CTD carry, GBC, and slope) was indicating that it was better to postpone delivery. The GBC became negative during the first week of the delivery month, reaching −\$0.29 on June 9, 1995, and triggering a sizable early delivery of 36% of the month's total deliveries (4,819 and 1,476 contracts) on June 12, 1995, and June 13, 1995, respectively.

4.6 June 2000–March 2001: Negative slope

It is worthwhile examining this episode because it corresponds to the second of only three periods over the last three decades, in which the yield curve observed on the first day of the front delivery month was slightly inverted, a condition that, combined with a low-volatility setting, favors early delivery according to the rule of thumb. Observation of the bond and basis data shows that the carry of the CTD was rather positive during this episode, underlining possible discrepancies between slope and carry, and that the GBC was also generally positive. The delivery pattern for this episode shows that all deliveries occurred on the last possible day, even for the only exception where the GBC was negative and would have thus produced an immediate delivery profit, on the first day of the March 2001 contract.

Recall that the reference coupon rate was reduced to 6% as of March 2000 to reflect the levels of long-term yields prevailing at the time. As a result, short traders were indifferent between T-Bonds and therefore delivered multiple issues presenting very different characteristics and durations. These observations show that the value of the delivery options was relatively low, and therefore, that the traders did not deliver early as the rule of thumb would have suggested. It is possible that short traders were less inclined to monitor the market of the CTD because of the low value of the delivery option, and could thus have missed valuable early-exercise opportunities.

4.7 September 2006–September 2007: Failure of the rule of thumb

This period is the third one where the slope of the yield curve is negative on the first day of the front delivery month. Starting in 2004, the Fed implemented an interest-rate policy that consisted of raising short-term interest rates and that resulted in a flattening of the yield curve, which can be observed as of 2006. This nearly flat (or even slightly downward-sloping) interest rate term structure favored delivery of the issue with the lowest duration because long-term rates were below the reference coupon rate of 6%. As yields were falling, the new issues entering the deliverable baskets were bearing lower coupon rates, preventing them from being plausible contenders for CTD status. The grade positioned at the top of the basket was therefore secured CTD status, making it highly predictable and known well in advance. This points to a small value of the switch option. According to the rule of thumb, the combination of a negative slope with the small value of the delivery options should have led traders to deliver during the first days of the delivery month. Examination of Table 4, reporting on the pattern of early deliveries observed during this period, shows that the rule of thumb was not applied by the traders. In fact, no early deliveries were recorded in September 2006, and there is only one instance in December 2006 of a significant delivery at the beginning of the month.

Table 4: Early delivery pattern during the period spanning December 2006 to September 2007. Source: CBOT and Bloomberg.

Delivery Month	Dec-06	Mar-07	Jun-07	Sep-07
Month Dates	4	16 and 22	14	20
Percentage of the Month's Total Deliveries	14.5%	7% and 41%	20%	87%
Number of Contracts Settled by Delivery	2000	9745	2825	8008
Number of Issues Used for Delivery	2	2	1	1
GBC on Position Day	−0.0156	−0.1387 and −0.0491	−0.5252	−0.0286

Actually, despite the negative slope of the yield curve, the carry of the CTD was generally positive during this period because it was bearing a coupon rate significantly higher than the financing rate (7.25% and 7.625% compared with 5% on average). Note also that this period was characterized by substantial cash and futures pricing distortions, as multiple illiquidity episodes hit the market of the well-known CTDs. As a consequence, negative values for the GBC are observed, indicating a negative market value for the delivery options.

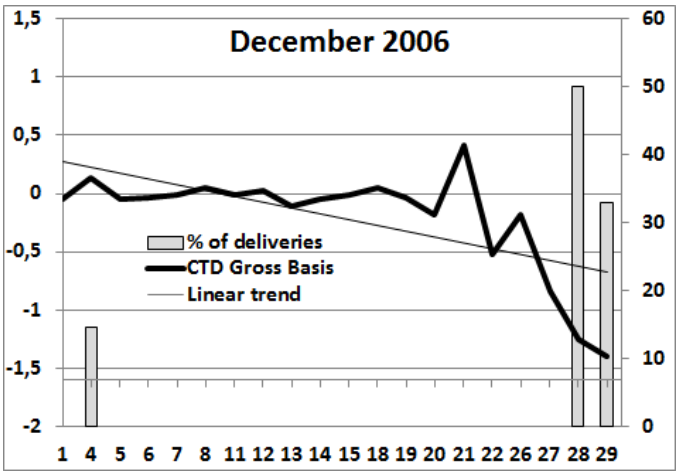
We report in Figures 12, 13, 14 and 15 the evolution of the GBC along with the delivery patterns over the months of December 2006, March 2007, June 2007 and September 2007, respectively. These figures show that the GBC was generally negative and decreasing during this episode, except for the June 2007 contract, where the GBC generally increased during the delivery month. It is worth noting that all the early deliveries recorded during this episode were preceded by a negative gross basis observed on the position day. It seems that taking advantage of observed negative GBC occurrences was the main driver of the short traders' decisions to make early deliveries during this episode.

4.8 September 2008: Flight to quality

On September 22, 2008, 7,133 contracts were settled by delivery, representing 60% of the total deliveries for the September 2008 contract. This early delivery took place despite the substantial value of carrying the bonds to the end of the month. In fact, the bonds that were competing for CTD status were the $7\frac{1}{2}\%$ of November 2024 and the $7\frac{5}{8}\%$ of February 2025, while the Fed funds rate prevailing at the time was 1.91%.

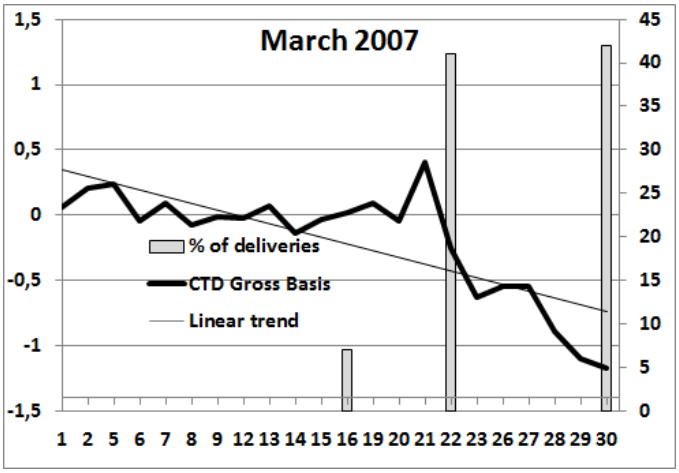
We believe that short traders preferred to deliver early because of the short supply of Treasuries and the flight to quality observed following the collapse of Lehman Brothers on September 15, 2008. As the likelihood of being short-squeezed had risen dramatically during the month, short traders settled their positions by early delivery in order to avoid the increased losses that would be incurred because of higher bond and futures prices reflecting the lack of the underlying CTD.

Figure 12: Evolution of the gross basis of the CTD during December 2006.



This figure depicts the evolution of the GBC and the distribution of deliveries (right axis) during the December 2006 delivery month. Data is obtained from Bloomberg.

Figure 13: Evolution of the gross basis of the CTD during March 2007.



This figure depicts the evolution of the GBC and the distribution of deliveries (right axis) during the March 2007 delivery month. Data is obtained from Bloomberg.

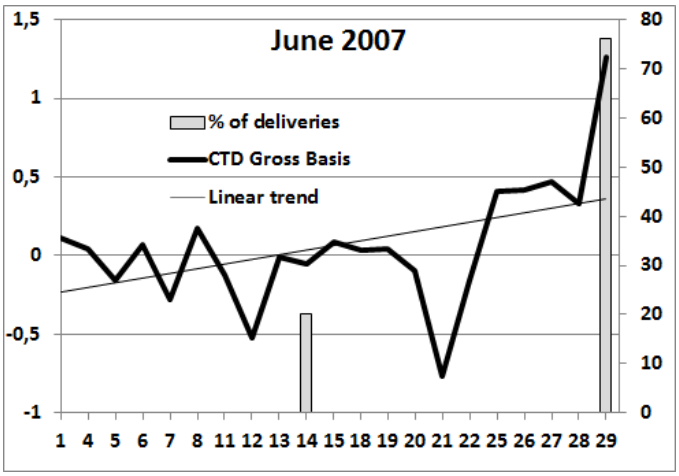
Note that, for this specific episode, it would have been advisable to delay delivery to the last possible day under both the basis rule and the rules of thumb; however, the GBC was negative on September 22, 2008, indicating that early delivery did result in an immediate profit.

4.9 Recent episodes: Monitoring the CTD cash price

In the aftermath of the last 2007–2008 global financial crisis, interest rates in the U.S. reached their record low. These low interest rate levels along with the resulting steeper, positively sloped yield curves made postponing delivery until the last possible day an obvious delivery strategy, allowing short traders to take advantage of high positive carry.

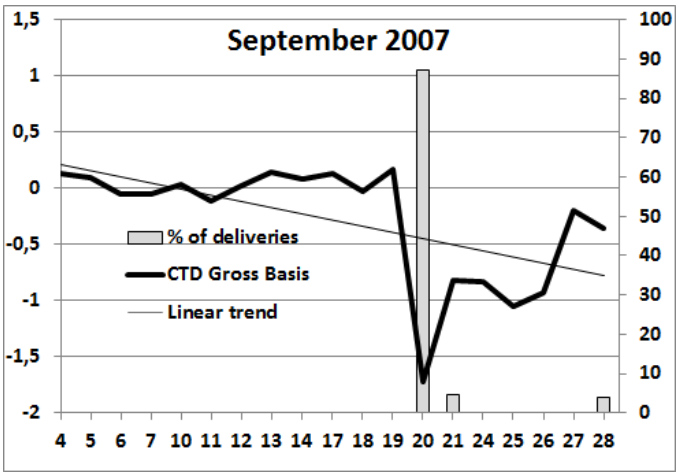
Moreover, under the prevailing environment of historic low interest rate levels, the bond market was intrinsically more volatile, with frequent and sizeable changes in the level and slope of the yield curve. This

Figure 14: Evolution of the gross basis of the CTD during June 2007.



This figure depicts the evolution of the GBC and the distribution of deliveries (right axis) during the June 2007 delivery month. Data is obtained from Bloomberg.

Figure 15: Evolution of the gross basis of the CTD during September 2007.



This figure depicts the evolution of the GBC and the distribution of deliveries (right axis) during the September 2007 delivery month. Data is obtained from Bloomberg.

high interest rate volatility, combined with increased deliverable basket heterogeneity,[8] translated into an expected high value for the delivery options during this last period. Although a low interest rate environment reduces the probability of CTD crossovers and favors the delivery of the lowest-duration bond, the history of the CTD over the last decade shows that two to three issues could still seriously compete for CTD status, and that interest rate volatility could make them substantially cheaper as the time to delivery diminished, conveying a high value to the delivery options.

However, despite these considerations, the recent period was punctuated by early deliveries that took place on rare occasions, as summarized in Table 5.

[8] These deliverable baskets include both T-Bonds issued before and after the 2001–2006 issuance suspension period, as well as after the substantial drop in yields in the aftereffects of the 2007–2008 financial crisis. As a result, the eligible grades have since shown significant differences in terms of their coupons rates and maturities.

Table 5: Early delivery pattern during the period spanning June 2013 to September 2015. Source: CBOT.

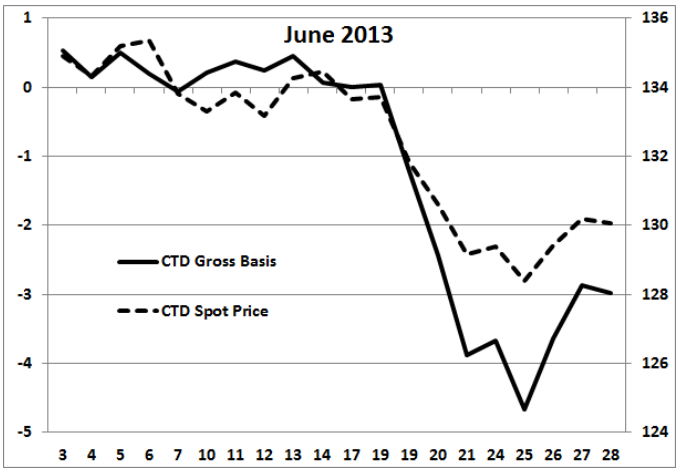
Delivery Month	Jun-13	Dec-13	Mar-14	Sep-15
Month Dates	25	24	25	21
Percentage of the Month's Total Deliveries	51%	10%	8%	25%
Number of Contracts Settled by Delivery	1351	101	18	959
Number of Issues Used for Delivery	1	1	1	1

In order to better understand the drivers of these early deliveries, we also depict, in Figures 16, 17, 18 and 19, the evolution of both the spot price and the gross basis of the CTD over the delivery months of June 2013, December 2013, March 2014, and September 2015, respectively.

It is particularly important to notice that, unlike in the previously discussed episodes, all the early deliveries recorded here took place during the end-of-month period. Recall that the particularity of the EOM period resides in the fact that the gross basis is then only driven by the evolution of the CTD and its market cash price, since the futures price is fixed, while the price of the CTD is allowed to vary with market forces. Because of the historic low-interest-rate environment, these four delivery months are also characterized by the fact that one single bond (the lowest-duration grade) retained CTD status with certainty during the whole month (the issue $5\frac{1}{2}\%$ of August 2028 for June 2013, the issue $6\frac{1}{8}\%$ of August 2029 for December 2014 and March 2014, and the issue $4\frac{1}{2}\%$ of February 2036 for September 2015). Under these circumstances, it is easier for short traders to take advantage of potential price moves by tracking the evolution of the cash price of one single bond. Indeed, any substantial drop in the price of the CTD necessarily results in a decline of the gross basis. Such situations create opportunities that could thus trigger early delivery events.

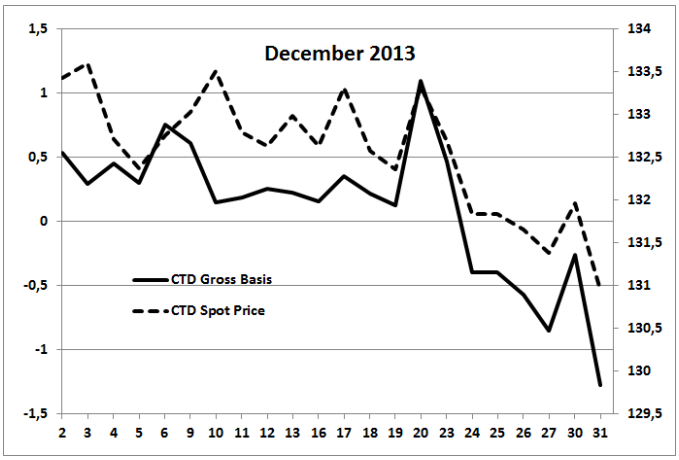
Figure 16 shows that the price of the CTD for the June 2013 futures contract experienced a dramatic drop as of June 19, 2013. This price move started immediately following the press conference made by Fed Chairman Ben Bernanke on June 19, 2013, during which he announced the upcoming slowing and then discontinuing of the Fed's Quantitative Easing program. This announcement engendered a selling panic and the biggest outflow of bonds from bond funds since 1992, resulting in the so-called Great Bond Market Massacre of 2013 (see, e.g., Eavis & Popper 2013 [14] and Nyaradi 2013 [26]). Observation of the U.S. T-Bond yield curve shows a 30-year yield jump of 26 basis points in the four days following Mr. Bernanke's announcement. The change in the CTD price resulted in a substantially negative gross basis and in valuable exercise opportunities that were used by 51% of short positions on June 25, 2013.

Figure 16: Evolution of the spot price and gross basis of the CTD during June 2013.



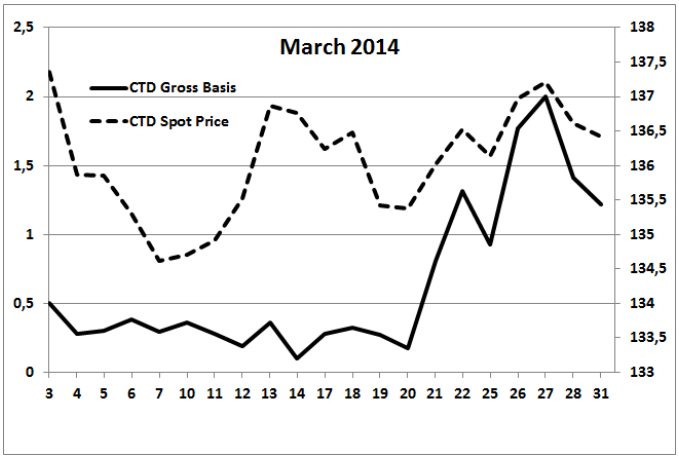
This figure depicts the evolution of the gross basis (left axis) and the spot price (right axis) of the CTD during the June 2013 delivery month. Data is obtained from Bloomberg.

Figure 17: Evolution of the spot price and gross basis of the CTD during December 2013.



This figure depicts the evolution of the gross basis (left axis) and the spot price (right axis) of the CTD during the December 2013 delivery month. Data is obtained from Bloomberg.

Figure 18: Evolution of the spot price and gross basis of the CTD during March 2014.

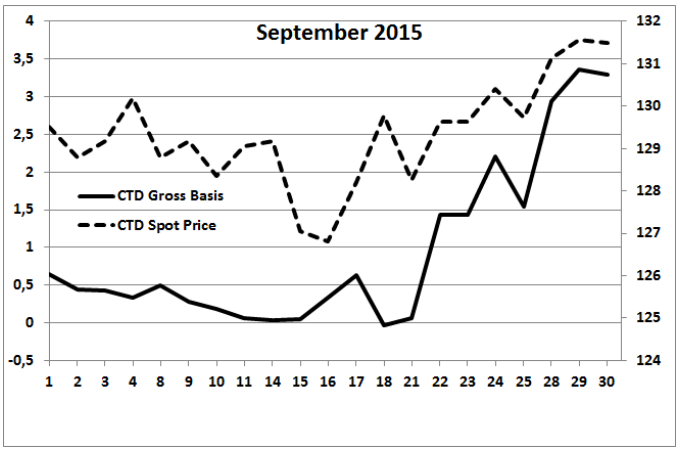


This figure depicts the evolution of the gross basis (left axis) and the spot price (right axis) of the CTD during the March 2014 delivery month. Data is obtained from Bloomberg.

Figure 17 also shows a significant decline in the spot price of the CTD corresponding to the EOM period of the December 2013 futures expiry month. In fact, in addition to the Fed's taper announcement, investors continued their massive bond-fund withdrawal in December 2013 as a result of disappointing economic data. This record-high bond sell-off made 2013 one of the worst years in the history of bond funds (see, e.g., Eisen 2013 [15] and Yousuf 2013 [30]). The 30-year T-Bond yield spiked in December 2013, reaching nearly 4% (see Figure 4), and the CTD price as well as the gross basis declined during the EOM period, during which 12% of the deliveries were early.

Unlike the two previously described episodes, which were motivated by a negative CTD basis resulting from a decline in bond prices, the early-delivery figures observed on March 25, 2014, and September 21, 2015, were clearly triggered by the fear that the then-observed positive gross basis would further increase in the future. In fact, in the beginning of both of these EOM periods, bond prices started to rise substantially (see Figures 18 and 19) because of unexpected bond rallies and the resulting short squeezes that hit the

Figure 19: Evolution of the spot price and gross basis of the CTD during September 2015.



This figure depicts the evolution of the gross basis (left axis) and the spot price (right axis) of the CTD during the September 2015 delivery month. Data is obtained from Bloomberg.

bond markets.[9] These bond rallies took place while the market was short-selling bonds because of a strong conviction that interest rates would rise in the future. As a result, squeezes developed as T-Bonds went in short supply and traded at abnormally high prices (see, for instance, Eisen (2014a [16], 2014b [17]) and Karunakar 2015 [24]).

4.10 Determinants of timing

Following the analysis of the short traders' delivery behavior observed in the U.S. T-Bond futures market over the last three decades, we find that, apart from isolated incidents where delivery is triggered by special circumstances or liquidity problems, the main determinant of delivery decisions is immediate delivery profit, as indicated by the gross basis of the CTD. We observe that delivery is in general postponed until the last possible delivery day, while some traders take advantage of jumps in the GBC during the switch or the EOM period. The rule of thumb, indicating that delivery should be made whenever the slope of the yield curve is negative and either the volatility of bond yields and yield spreads is low or the financing rate is relatively high, does not seem to drive the early delivery decisions of short traders.

On the other hand, it is interesting to point out that a negative gross basis indicates an immediate arbitrage profit.

To conclude on the observed delivery behavior, recall that, before 2009, no penalties were charged to traders failing to deliver. As of May 1, 2009, the Treasury Market Practices Group began charging a penalty that amounts to three percentage points on each uncompleted trade, which is usually higher than the costs incurred to meet the contract obligations, thus reducing a short's incentives to intentionally fail to deliver. Examination of Figure 9 shows a substantial relative decline in the total number of contracts settled by delivery during periods of short squeezes or financial crises, due to the greater illiquidity of the underlying Treasury issue and the higher risk of delivery failures, especially after the penalty was implemented.

4.11 Do good things come to those who wait?

We conclude this section by revisiting the observed delivery decisions and examining whether the outcomes for short traders would have been better if they had selected a different delivery time over the contract expiration month. We therefore investigate the existence of potential situations where, depending on the

[9] Note that the March 2014 early-delivery event was observed following the Fed's 18–19 March meeting that triggered a limited-time bond sell-off, after which prices resumed their increasing pace.

evolution of the market gross basis, an earlier - or later-than-observed delivery could have made the short traders better off.

Note that, as of September 2004, Bloomberg provides detailed data about the historical daily evolution of the CTD, including its gross basis. However, this data is available during the delivery month up to the last futures trading day, which allows for the analysis of the outcome of early deliveries only during the switch period. On the other hand, in circumstances where a single eligible-for-delivery Treasury security was ensured CTD status—because long-term interest rates were substantially below the reference coupon rate—it is also possible to compute the GBC during the EOM period based on the evolution of its cash price, thus allowing for an assessment of the outcomes of all deliveries for the month. Accordingly, we examine here the optimality of the observed early deliveries summarized in Tables 4 and 5.

December 2006

In December 2006, Figure 12 shows that the gross basis on the last day was substantially lower than the one that triggered early delivery at the beginning of the month (December 4, 2006).[10] This implies that short traders who settled early (14.5% of the month's total deliveries)—although at a profit—missed the much more valuable exercise outcome secured by the remaining 84% on December 28 and 29, 2006 (the GBC reached as low as −\$0.8365 on December 27, 2006).

March 2007

Figure 13 shows that, in March 2007, early deliveries that occurred on March 16, 2007, were more profitable than those that took place six days later. These profits were however substantially lower than those earned by postponing delivery until the last possible day (the GBC attained −\$0.8931 on March 28). It is worth noting that short traders, motivated by these large profits, delivered on the same day both the first CTD and sizeable amounts of the second-cheapest-to-deliver issue. In fact, on March 22, the issue $7\frac{1}{4}\%$ of August 2022 and the issue $7\frac{5}{8}\%$ of November 2022 were used to satisfy $6,300$ and $2,000$ futures contracts, respectively. The same was observed on March 30, where the issue $7\frac{1}{4}\%$ of August 2022 and the issue $7\frac{5}{8}\%$ of November 2022 were also used to fulfill $4,132$ and $6,509$ futures contracts, respectively. Short traders were able to take advantage of the fact that these two issues presented roughly the same features, in order to fully profit from these very valuable negative-gross-basis opportunities.

June 2007

For the June 2007 contract, we notice from Figure 14 that the GBC was substantially negative two days prior to June 14, 2007, thus explaining that 20% of the month's total deliveries occurred on that day. However, the lowest negative gross basis, observed on June 21, 2007, did not trigger any early deliveries; most probably, the short traders that had elected to wait were expecting that the CTD spot price would continue its decreasing pace, translating into a further widening of the negative basis. As the CTD spot price rose instead, short traders were compelled to satisfy 76% of total deliveries on June 29, 2007, at substantial losses (a large positive CTD gross basis amounting to \$0.4664).

September 2007

Of the total September deliveries, 87% and 4.5% took place on September 20 and 21, respectively. Figure 15 shows that this early delivery behavior followed a dramatic drop in the CTD bond price and its gross basis, the value of which reached −\$1.7283 on September 20, 2007. Note also that 4% of deliveries occurred on September 28, 2007, at a lower profit. In that case, a large majority of short traders exercised their options optimally during the month.

[10] Note that the position day for this early delivery was November 30, 2006, two business days before the beginning of the delivery month.

June 2013

In June 2013, 51% of the month's total deliveries occurred on June 25 in order to take advantage of the observed dramatic drop in the negative GBC, as depicted in Figure 16. The remaining 49% of total deliveries took place on the last possible day (June 28, 2013). On both of these delivery days, short traders had appropriately used their exercise opportunities by taking advantage of the substantial negative GBC consistently observed during the EOM period.

December 2013

Observation of Figure 17 shows that the GBC peaked on December 20, 2013. We believe that the early deliveries observed on December 24 (101 contracts), at a significant loss, were precipitated by fear of a further increase in the GBC. Instead, bond prices fell substantially following the unexpected bond sell-off, and 87% of the month's total deliveries took place on December 31, at a profit stemming from a considerably low negative GBC.

March 2014

The observed delivery strategies during March 2014 are particularly interesting. This contract was characterized by a consistently positive GBC that increased substantially during the EOM period to attain its highest value on the last possible position day ($1.9973 on March 27) (see Figure 18). Some short traders decided to deliver on March 25, as they—rightly—expected the GBC to widen. These short traders avoided the substantial loss that was incurred by those who delayed delivery to March 31 (92%). We deem that this explains the fact that a total of only 226 futures contracts were satisfied by delivery in March 2014, the lowest figure recorded over our entire period of study. Figure 18 also shows that opting to deliver on any day during the switch period would have represented a better exercise opportunity for short traders because of the subsequent dramatic increase in the positive gross basis observed during the EOM period.

September 2015

Figure 19 shows that the 25% of the month's total deliveries that took place on September 21, 2015, were settled at a significantly lower positive GBC compared to the remaining 75% delivered on the last day, for which the gross basis had experienced a substantial widening. By correctly assessing the expected evolution of bond prices, short traders who delivered early avoided the large losses that hit those who decided to postpone delivery to the last possible day.

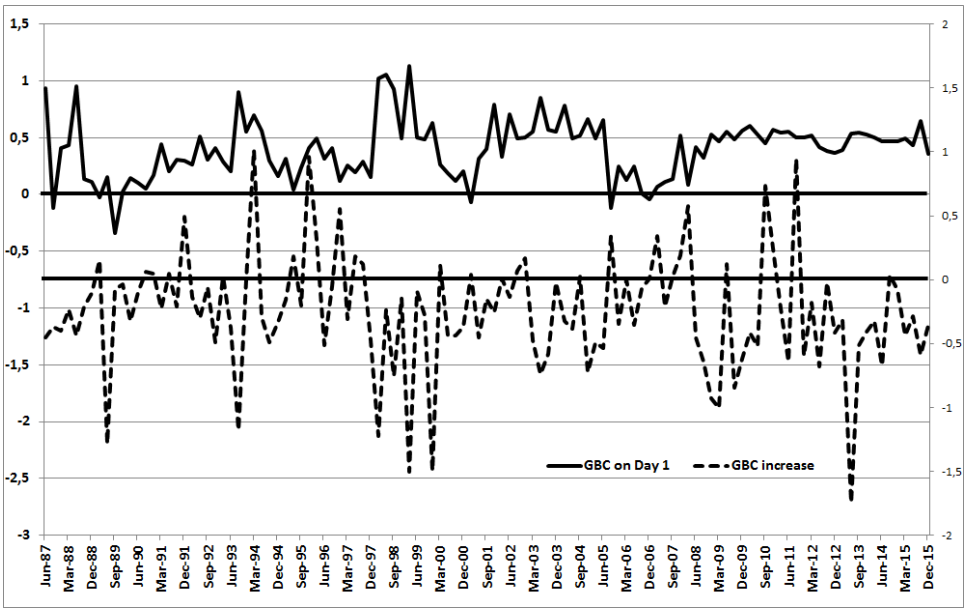
These observations seem to indicate that postponing delivery was more often than not the best choice during these periods, even when profits from immediate delivery were available. We now examine the advisability of delivering on the first day of the delivery month rather than on the last futures trading day, by comparing the GBC at these two dates, as depicted in Figure 20.

Figure 20 shows that, for the 115 contracts between June 1987 and December 2015, only 32 times was an increase in the value of the GBC observed between the first day of the delivery month and the last futures trading day. In these 32 cases, short traders would have been better off delivering on the first of these two dates.

On the other hand, only six times was the GBC negative on the first day of the delivery month. An examination of the history of actual deliveries shows that short traders did not apply the rule of the basis on the first day of the delivery month in these six instances, but instead, decided to delay delivery. On these six occasions, four saw an increase in the value of the GBC over the switch period.

This shows that the simple rule of delivering on the first day of the month when the GBC is negative would have yielded sub-optimal outcomes for 30 futures contracts, while the even simpler rule of always postponing delivery would have been sub-optimal for 32 contracts.

Figure 20: CTD gross basis on Day 1 of the delivery month vs. increase during the switch period.



This figure plots the gross basis of the CTD on Day 1 of the delivery month (left axis) and the increase in the GBC between Day 1 of the delivery month and the last futures trading day (right axis). Data is obtained from Bloomberg and spans the period from June 1, 1987, to December 31, 2015.

5 Concluding remarks

In this paper, we provide a broad empirical investigation of the short traders' delivery strategies observed in the CBOT T-Bond futures market over the last three decades (1985–2015). Our investigation shows that short traders were generally tracking the gross basis and monitoring both the bond cash and futures markets over the delivery month in an attempt to fully take advantage of bond market volatility and maximize the outcomes related to settling the futures contract by delivery. Our findings show that short traders generally preferred to defer delivery to the last two possible delivery days (nearly 88% of the total 124 futures contracts considered in this study), largely motivated by a positive bond carry and the valuable implicit delivery options available to them throughout the expiration month.

This late-delivery behavior was even observed despite immediate-profit opportunities, in anticipation of a better evolution of the gross basis. However, we also observe that short traders occasionally decided to deliver early during the switch and EOM periods. We observe that such early-delivery behavior was mainly driven by substantial negative-gross-basis exercise opportunities. Some early deliveries also took place in order to avoid the rising costs related to an expected widening of a positive gross basis. Nevertheless, we show that—by generally opting to delay delivery to the last two possible delivery days—short traders were also missing valuable early-exercise opportunities and even incurred sizeable late-delivery losses. These losses were mainly due to an incorrect assessment of basis risk and to the unexpected future evolution of interest rates. Finally, our analysis shows that, in addition to bond carry and the embedded delivery options, bond market liquidity plays an important role in the observed delivery strategies. In fact, we find that the short traders' decisions to accelerate or postpone delivery are largely influenced by the liquidity of the CTD, as it directly impacts the market value of the gross basis.

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