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Abstract: In early 2001, the U.S. Department of the Treasury suspended the issuance of 30-year bonds, and then resumed issuing its long paper in early 2006. As a result, there is a five-year gap in the baskets deliverable into U.S. T-Bond futures contracts expiring before 2016. The CME Group recently raised the issue that grades contending for cheapest-to-deliver status are becoming significantly isolated from the rest of the basket because of this maturity gap. The aim of this paper is to provide an ex-post assessment of the approach chosen by the CME Group to address this so-called "five-year-gap issue." We first analyze the chosen solution and show that it has succeeded in substantially decreasing the anticipated problems due to the 5-year-gap issue. We then show that alternative solutions involving a reduction in the reference coupon rate would have fared better than the solution that was actually implemented by the CME Group, in both the short and the long run. We conclude that, under the prevailing environment of historic low interest rates, the real issue is not a maturity gap but rather an interest rate gap related to the conversion factor system presently experiencing its poorest performance ever, which has been exacerbated by the five-year-maturity gap in the set of deliverable bonds.

Key Words: Futures, treasury bonds, maturity gap, short squeeze, basis.

Résumé : En 2001, le Trésor Américain interrompait l'émission de bons du trésor de longue maturité (trente ans), pour la reprendre en 2006. Par conséquent, il existe un écart de cinq ans dans le panier des obligations livrables pour les contrats à terme sur les bons du Trésor Américain expirant avant 2016. Le CME Group, la principale entreprise de bourse d'échange de marché à terme, a récemment soulevé la question de l'isolement, par rapport au reste du panier, des obligations les moins chères à livrer du fait de cet écart de maturité. L'objectif de cet article est de fournir une évaluation ex-post de l'approche choisie par le CME Group pour aborder cette question. Nous analysons d'abord la solution choisie et montrons qu'elle a réussi à réduire de façon importante les problèmes anticipés dus à l'écart de maturité. Nous montrons ensuite qu'une solution alternative consistant à réduire le taux du coupon de référence de ces contrats à terme aurait été encore plus efficace, aussi bien à court qu'à long terme. Nous concluons qu'étant donné le niveau actuel très bas des taux d'intérêt, la vraie question n'en est pas une d'écart de maturité, mais plutôt d'écart de taux, du fait des imperfections du système de conversion utilisé pour ces contrats à terme, qui enregistre actuellement la pire performance de son histoire, encore amplifiée par l'écart de maturité présent dans le panier d'obligations livrables.

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1 Introduction

Treasury bonds (T-Bonds) are financial instruments that are fundamental to the smooth and proper functioning of the interest-rate-derivatives markets. The Chicago Board of Trade (CBOT) T-Bond futures contract, which calls for the delivery of a U.S. T-Bond bearing a 6% coupon rate and with a remaining maturity of 20 years, is one of the most traded and liquid interest-rate derivatives in the world. Since the notional T-Bond underlying this futures contract is generally not available for trading in the financial marketplace, and to ensure that deliverable bonds are not in short supply, the CBOT affords the short trader the option to choose the bond to be delivered among a set of eligible issues predefined by the Exchange (the *deliverable basket*). In fact, all T-Bonds with remaining maturities ranging between 15 and 25 years as of the first day of the delivery month qualify for delivery into the U.S. T-Bond futures. The CBOT uses a system of conversion factors in order to adjust for the quality of the deliverable grades with respect to the notional T-Bond and to make short traders indifferent between the delivery of any eligible issue.

Between 2001 and 2006, the U.S. Department of the Treasury suspended the issuance of 30-year bonds. This decision was made in anticipation of budget surpluses, as well as because of the higher borrowing costs over the long term compared to shorter-term debt. The Treasury resumed its long-term financing program by reissuing the 30-year paper in February 2006. As a result, a five-year gap in the maturities of these T-Bonds arose, more precisely between the 5-3/8% issue maturing in February 2031 and the 4-1/2% issue maturing in February 2036.

Discontinuing the issuance of the long T-Bonds for a five-year period has obviously impacted all bond sectors, and the T-Bond market has been particularly affected in various ways, most notably by the reduction in the size of the deliverable basket. In addition, the evolution of the level of long-term yields over the last two decades also had an important impact on the T-Bond futures market, by increasing the heterogeneity of the deliverable basket in terms of coupon rates. It is well documented in the financial literature that the conversion factor system for CBOT T-Bond futures is not perfect (see, for instance, Ben-Abdallah *el al.* 2009 and Oviedo 2006), so that there usually exists a so-called cheapest-to-deliver (CTD) bond that short traders will choose to deliver whenever available. The current low-interest-rate environment favors delivery of the lowest-duration bonds (largest coupon rate combined with the nearest maturity). Because of the five-year gap in the issuance of 30-year bonds, CTD candidates are then a very small number of isolated aged bonds presenting great differences in price and characteristics with respect to the rest of the basket. This is precisely the five-year-gap issue that was raised and addressed by the CME Group in 2013.

As a response to this five-year-gap issue in the T-Bond futures market, the CME Group launched in July 2013 a worldwide consultation with market practitioners in which three potential options were presented. The solution reached by the CME Group was announced in December 2013: to exclude the T-Bond 5-3/8% of February 2031 from delivery into three futures contracts, namely, those of June 2015, September 2015 and December 2015.

The aim of this paper is twofold. We first provide an ex-post empirical assessment of the solution implemented by the CME Group with respect to other options that were considered in the June 2013 consultation. We then propose an alternative measure and analyze its efficiency in the short and long run, with respect to the solution that was actually implemented by the CME Group. We find that the CME Group's solution has succeeded in dramatically reducing the negative impact of the five-year gap on the deliverable bond supply and on the potential for manipulating the market of the CTD for the June 2015 and September 2015 futures contracts. However, by not excluding lowest-duration bonds from the preceding contracts, as considered in one of the options, the CME Group failed to attenuate this risk before June 2015. On the other hand, as the CME Group's solution concerns three contracts only, we find that an alternative measure, such as lowering the reference rate to 4% or 3%, would have produced better outcomes during the years 2014 and 2015 and would have proven efficient and sustainable in the longer term. We conclude that the real issue is the current conversion factor system's imperfections, intensified by the large gap between long-term T-Bond yields and the reference coupon rate, which accentuated basket heterogeneity in the presence of the five-year-maturity gap between the plausible contenders for CTD status.

We believe that these results are of interest to both academics and practitioners. To our knowledge, this paper is the first to analyze the five-year-gap issue and its potential solutions from an academic perspective. Our findings contribute significantly to the existing literature dealing with pricing, hedging, trading the basis, or trading the calendar spread of T-Bond futures or exchange-traded interest-rate options. In addition, our broad ex-post empirical assessment allows practitioners, and more specifically the futures market participants who took part in the consultation process leading to the CME Group's solution, to evaluate the path chosen by the CME Group as well as its relative effectiveness with respect to other options that were considered at the time. Finally, since the incentives to manipulate the market of the CTD bond are presently relatively high and are expected to continue to increase in the future, our finding that an alternative solution would have fared better in the past and would significantly contribute to reducing the risk of short squeezes and market manipulation in the future should be highly interesting for the CME Group and market participants.

The remainder of this paper is organized as follows. In Section 2, we present a detailed description of the five-year-gap issue and the potential options suggested by the CME Group to address it. A comprehensive analysis of the CME Group's chosen solution in terms of its impacts on futures prices, market manipulation incentives and trading activity is then provided in Section 3, where this solution is compared to the other options that were considered. Section 4 proposes new alternative measures to address the issues raised in this paper and analyzes their short- and long-term outcomes with respect to the solution that was implemented. Section 5 concludes.

2 The five-year-gap issue in the T-Bond futures market

In this section, after a brief chronological summary of the relevant events leading to the adjustment in the June 2015, September 2015 and December 2015 futures contracts, we provide an overview of the so-called five-year-gap issue in the T-Bond futures market, the potential options proposed in order to address it and the solution reached by the CME Group.

2.1 The chronology

October 2001 The U.S. Department of the Treasury announces that it will no longer issue 30-year bonds. The issue of T-Bonds will resume in February 2006, creating a five-year gap in the maturities of T-Bonds.

August 2007 The global markets are hit by one of the most severe financial crises in history. Interest rates in the U.S. reach all-time lows and long-term yields have remained low to date. Under these circumstances, bonds with the lowest duration are the most plausible contenders for CTD status.

March 2011 Launch of the Ultra T-Bond futures contract. T-Bonds with a maturity of more than 25 years are no longer eligible for delivery into what will then begin to be known as "classic" T-Bond futures.

July 18, 2013 The CME Group organizes a webinar introducing the "five-year-gap issue" and proposing three potential options to address it. The CME Group then starts worldwide consultations and asks for feedback from market practitioners. The webinar presentation slides are updated and released in November 2013.

December 13, 2013 The CME Group announces the approach taken to address the five-year-gap issue: the T-Bond 5-3/8% of February 2031 is preemptively excluded from delivery into the June 2015, September 2015 and December 2015 futures contracts.

September 17, 2014 The CME Group releases a special executive report to announce the solution reached in December 2013.

September 22, 2014 The June 2015 futures contract (the first delivery month affected by the basket composition change) is listed for trading. The CME Group decides to do so in order to allow enough time for market participants to adjust their trading systems.

October 22, 2014 The first open interest is reported for the June 2015 futures contract.

January 16, 2015 The CME Group releases a document on how to manage the March-June 2015 roll because of the significant jump in the calendar spread.

2.2 The problem

Following the suspension of the issuance of T-Bonds, the size of the deliverable basket dropped sharply from 34 bonds eligible for delivery into the March 2001 contract to 23 grades for the December 2005 contract. The dollar amount eligible for delivery consequently fell from $421 billion to $277 billion during the period of the issuance suspension. The maximum maturity inside the basket also decreased gradually from 30 years to 25 years, thus limiting the contract's efficiency in hedging longer-term interest-rate-risk exposures. The size of the deliverable basket was further reduced following the launch of the Ultra T-Bond futures contract, dropping dramatically from an average of more than 25 bonds (104 contracts from March 1985 to December 2010) to about 10 bonds (20 contracts over the period of March 2011 to December 2015). Figure 1 summarizes the evolution of the size of the basket deliverable into the U.S. T-Bond futures as well as the corresponding dollar amount eligible for delivery over the period spanning March 1985 to September 2015 (123 futures contracts).

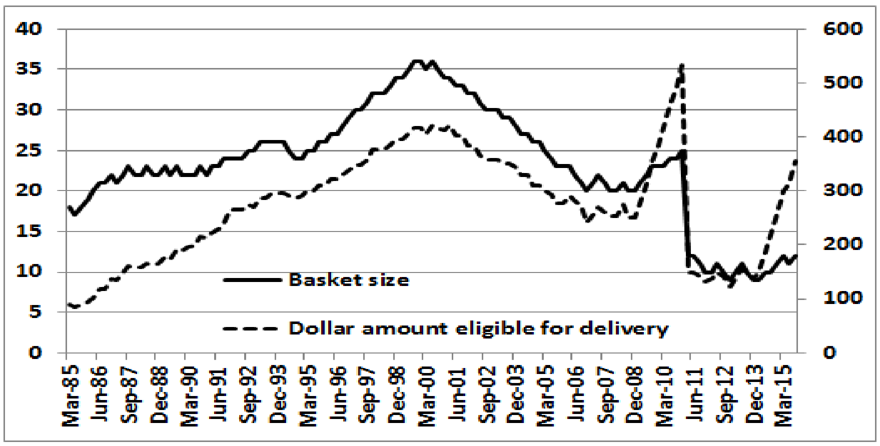

Figure 1: Number and dollar amount of U.S. T-Bonds eligible for delivery.

This figure plots the number of bonds eligible for delivery per contract (left axis) and the corresponding total dollar amount eligible for delivery in billion USD (right axis) into the U.S. T-Bond futures contract for the period covering March 1985 to September 2015 (123 contracts). Data is obtained from the CBOT.

In the aftermath of the 2007-2008 financial crisis, one of the most severe to ever hit the global markets, interest rates in the U.S. reached record low levels as a result of the FED's easing monetary policy and its multiple stimulus programs. The issuance of long-term bonds then reflected these low yields as the Treasury was able to lock in very low coupon rates at the time of the auction. As a consequence, in addition to the reduction in the number of eligible bonds, high discrepancies in coupon rates and maturities arose inside deliverable baskets, thus contributing to an increasing basket heterogeneity thereafter.

In a low-interest-rate environment, the CTD is the bond with the lowest duration (largest coupon rate combined with the shortest maturity). Accordingly, following the 2007-2008 global financial crisis, T-Bonds with the shortest terms to maturity were competing for CTD status. As time passed, the T-Bonds issued before the suspension period (presenting the lowest durations) were exiting the futures' deliverable baskets. Therefore, the number of bonds contending for CTD status (certainly among the set issued before the suspension period) gradually decreased, down to three bonds for March 2014 and June 2014; two bonds for September 2014, December 2014 and March 2015; and only one bond for the three remaining 2015 contracts.

When the CME Group raised the issue in 2013, the CTD bond was assured to be in the front of the basket among the isolated and aged Treasury securities issued before 2001. The CME Group argued that these aged bonds showed significant differences with the rest of the eligible grades in terms of their futures equivalent prices. Moreover, these isolated T-Bonds presented a relatively limited outstanding supply. As an illustration, the 5-3/8% T-Bond maturing in February 2031 was the only bond issued before the suspension period in the deliverable baskets of the June 2015, September 2015 and December 2015 futures contracts, and secured the CTD status for these three contracts. Consequently, significant differences in terms of equivalent futures prices would arise between the first and second CTDs for these three contracts.

According to the CME Group, if not addressed appropriately, this gap in the deliverable basket would result in higher basis volatility as well as an increased duration uncertainty. The CME Group was also concerned about the possibility that an unintended short squeeze might develop in the U.S. T-Bond futures market under such particular circumstances.

Note that from September 2014 to March 2015, differences in equivalent futures prices were also expected to arise between the second and third CTDs. Also recall that the last bond issued before the 2001–2006 suspension period, namely the 5-3/8% issue of February 2031, will no longer be eligible for delivery starting with the March 2016 contract, thus putting an end to the five-year-gap issue in the ensuing deliverable baskets.

2.3 The suggested options

In order to address the above-mentioned issues, the CME Group organized a webinar presented by Jonathan Kronstein, Senior Director – Interest Rate Products, and James Boudreault, Senior Director – Research and Product Development, on July 18, 2013 (see CME 2013a). The aim of this webinar was to present an overview of the five-year-gap issue as well as a detailed step-by-step description of the three potential solutions proposed by the CME Group. These suggested solutions included maintaining the status quo (Option A), preemptively excluding bonds with the shortest terms to maturity from the deliverable basket (Option B) and redefining the deliverable terms to maturity (Option C) (see CME 2013b). It is worth noting that this webinar also aimed to consult the worldwide audience by asking market practitioners and bond futures specialists for their feedback and recommendations, in order to decide on the best way to solve the problem.

The following paragraphs detail the risks and benefits related to each possible solution, as put forward by the CME Group.

Option A: Maintain the status quo Making no changes at all would maintain continuity in the futures contract, according to its predefined specifications. The difference in maturities between the shortest T-Bonds deliverable into the classic and into the Ultra T-Bond futures would also be maintained for the longest possible period. The problem and concerns described above could be addressed through a reinforcement of market surveillance, including the verification of position limits on expiring futures.

Option B: Exclude the shortest bonds This second option consisted in excluding some bonds with the shortest terms to maturity from delivery eligibility into some futures contracts. More precisely, the 5-3/8% issue of February 2031 would be excluded from the baskets of June 2015, September 2015 and December 2015 futures contracts. The CME Group was also considering the possibility of excluding two T-Bonds from the September 2014, December 2014 and March 2015 contracts. This option could significantly affect (in either direction) the trading volume and open interest of the futures contracts impacted by these changes. Furthermore, by accelerating the jump in the minimum maturity of deliverable bonds, less than four years would separate the maturities of shortest issues deliverable into the September 2014 classic and corresponding Ultra T-Bond futures, which could possibly lead to the development of a liquidity pool due to the increase in the correlation between these two contracts.

Option C: Redefine the terms to maturity This third option consisted in redefining the contract's specifications by operating a shift in the terms to maturity of deliverable grades. More specifically, the shortest terms to maturity of bonds deliverable into the classic futures contracts could be shifted to some value between 10 and 14 years, whereas the longest terms to maturity could be shifted to some value between 20 and 24 years (e.g. a 12- to 22-year range for the remaining maturities of eligible deliverable issues). This option would entail the most considerable changes and would obviously impact its neighboring T-Note and Ultra T-Bond futures. Under this option, since the classic futures would become closer to the T-Note futures, the Ultra contract would become the main instrument for hedging the long end of the market. However, this option would only postpone the problem, as the maturity gap would still need to be addressed at a later date, as determined by the extent of the shift.

2.4 The chosen solution

On December 13, 2013, after extensive consultations with participants in the bond futures market, the CME Group reached the decision to exclude the 5-3/8% issue of 15 February 2031 from delivery eligibility into three futures contracts, namely, the June 2015, September 2015 and December 2015 contracts (see CME 2013c and CME 2014). It was argued that this solution would prevent the excluded bond from being a CTD isolated from the rest of the basket, that the impact of this exclusion on the overall basket size would be insignificant and, finally, that the classic bond futures would continue to represent the 15-20-year-maturity sector, as preferred by market users (see CME 2013d for an overview of the expected benefits of this solution). Note that the CME Group therefore ruled out the possibility of excluding two T-Bonds from the September 2014, December 2014 and March 2015 futures contracts, as initially suggested under Option B.

Table 1 presents the resulting composition of the deliverable baskets for the T-Bond futures contracts over the period spanning March 2014 to December 2015.

Table 1: Deliverable basket characteristics for the 2014 and 2015 U.S. T-Bond futures contracts.

T-Bond CUSIP	Issuance ($ billion)	Coupon (%)	Issue Date	Maturity Date	2014				2015			
					Mar	Jun	Sep	Dec	Mar	Jun	Sep	Dec
912810FJ2	10.001	$6\frac{1}{8}$	08/16/99	08/15/29	x	x						
912810FM5	15.001	$6\frac{1}{4}$	02/15/00	05/15/30	x	x	x	x	x			
912810FP8	15	$5\frac{3}{8}$	02/15/01	02/15/31	x	x	x	x	x	Excl.	Excl.	Excl.
2001–2006 T-Bond issuance suspension period												
912810FT0	24	$4\frac{1}{2}$	02/15/06	02/15/36	x	x	x	x	x	x	x	x
912810PT9	14	$4\frac{3}{4}$	02/15/07	02/15/37	x	x	x	x	x	x	x	x
912810PU6	14	5	08/15/07	05/15/37	x	x	x	x	x	x	x	x
912810PW2	15	$4\frac{3}{8}$	02/15/08	02/15/38	x	x	x	x	x	x	x	x
912810PX0	20	$4\frac{1}{2}$	08/15/08	05/15/38	x	x	x	x	x	x	x	x
912810QA9	25	$3\frac{1}{2}$	02/17/09	02/15/39	x	x	x	x	x	x	x	x
912810QB7	36	$4\frac{1}{4}$	05/15/09	05/15/39		x	x	x	x	x	x	x
912810QC5	39	$4\frac{1}{2}$	08/17/09	08/15/39			x	x	x	x	x	x
912810QD3	42	$4\frac{3}{8}$	11/16/09	11/15/39				x	x	x	x	x
912810QE1	42	$4\frac{5}{8}$	02/16/10	02/15/40					x	x	x	x
912810QH4	42	$4\frac{3}{8}$	05/17/10	05/15/40						x	x	x
912810QK7	42	$3\frac{7}{8}$	08/16/10	08/15/40							x	x
912810QL5	42	$4\frac{1}{4}$	11/15/10	11/15/40								x
			Deliverable Basket Size		9	10	10	11	12	11	12	13

This table presents the composition of the basket deliverable into the 2014 and 2015 T-Bond futures contracts. The CUSIP, the amount issued in billion USD, the coupon rate, the issue date and the maturity date are listed for each grade eligible for delivery. Although the bond 5-3/8% of February 2031 should have been eligible for delivery into the June 2015, September 2015 and December 2015 contracts according to their specifications, the CME Group decided to exclude it from their deliverable baskets in order to address the five-year-maturity-gap issue caused by the suspension of the T-Bond issuance between 2001 and 2006. Data is obtained from the CBOT.

3 Analysis of the CME Group's solution to the five-year-gap issue

In this section, we provide an empirical assessment of the efficiency of the approach taken by the CME Group. Recall that the repercussions of the five-year-maturity gap in the deliverable supply included the following:

- The difference in prices and risk exposures of the March 2015 and June 2015 futures;
- The relatively low outstanding supply of the CTD for the June 2015 contract;
- The heterogeneity of the characteristics of bonds in the deliverable basket.

These repercussions translated into concerns about the calendar spread and its impact on roll management, the risk of higher basis volatility and increased duration uncertainty, trading activity and the possibility of a short squeeze in the market of the CTD. Note that the CME Group never explicitly mentioned this last risk until the solution overview was released, where it was argued that the chosen solution would prevent a short squeeze from developing inadvertently (see CME 2013d). We will however give this last possibility closer attention, as it obviously results from the CTD being isolated at the front end of the basket, and as many studies have shown that a short squeeze can result in severe price distortions and serious repercussions in the cash, repo and futures markets (see, e.g., Kumar and Seppi (1992), Cooper and Donaldson (1998), Järvinen and Käppi (2004), and Merrick et al. (2005)).

Accordingly, we analyze the impact of the solution that was adopted in terms of calendar spread, trading activity, short-squeeze propensity and basket composition. For all the analyses conducted in this paper, we include contracts starting from March 2014 (following the decision of the CME Group in December 2013) until September 2015. Note that the last two contracts in this series are the ones that have been affected by the T-Bond exclusion so far. All indicators are computed on the first day of each delivery month.

3.1 Calendar spread and roll strategy

The difference between the prices of the front-month futures contract and the first-deferred one is known as the calendar spread. Calendar spreads are listed on the Globex electronic trading platform and traded in the open outcry market. A calendar spread of $(-13.875) for a nominal $100 contract is recorded on the first day of the delivery month of the March 2015 contract, and represents a significant jump with respect to usually observed values (see Table 3).

Assuming that the CTD remains in the front of the basket in the near future, under the original futures contract specifications, as the issue 5-3/8% of 15 February 2031 (CTD for December 2015) loses delivery eligibility, the CTD for the March 2016 contract would have been the 4-1/2% of February 2036 and would have inevitably resulted in a significant jump in the calendar spread.

The path chosen by the CME Group has accelerated this price jump, which occurred instead between the March 2015 and the June 2015 futures contracts. Moreover, since the CTD bond for the March 2015 contract is the issue 6-1/4% of May 2030, while the CTD for the June 2015 contract is the issue 4-1/2% of February 2036 (as a replacement for the excluded T-Bond 5-3/8% of February 2031), the resulting jump in the calendar spread is higher than would have been expected between December 2015 and March 2016 if the status quo had been maintained, or at a later date if the maturity gap had been postponed (Option C), due to the considerably higher discrepancy between the first and second CTDs.

The solution retained thus results in an earlier and higher jump in the calendar spread compared to the other options considered. In order to address this calendar-spread jump, the CME Group proposed new measures allowing traders to more easily manage the roll of open Treasury bond positions from March 2015 to June 2015 (see CME 2015).

3.2 Futures trading activity

Although the June 2015 futures contract (the first delivery month affected by the CME Group's solution) was listed for trading as of September 22, 2014, in order to allow enough time for market participants to adjust their trading systems, its first open interest was reported one month later, on October 22, 2014. Table 2 reports the trading activity for the June 2015 contract at that date. It shows an unusually sizable intra-day price jump as well as a very light trading volume and open interest. According to Leong (2014), traders needed some time to gain awareness of the price spike before trading volume picked up during the afternoon, and some traders made the decision to position themselves ahead of increased trading of the June 2015 contract.

Figure 2 shows the evolution since 1985 of the open interest for the front-month U.S. T-Bond futures contract on the first day of the delivery month. Examination of Figure 2 shows that the open interest for the June 2015 contract reached a three-decade low, with 30,785 open contracts, which may be attributable to the significant upward jump in its price.

Table 2: Trading activity for the June 2015 futures contract on October 22, 2014.

June 2015	Open	High	Low	Change	Settlement	Trading Volume	Open Interest
22/10/2014	141.78	152.13	141.72	10.28	151.47	1,639	389

This table presents the trading activity for the June 2015 futures contract on the day its first open interest was reported (October 22, 2014). Data is obtained from Bloomberg.

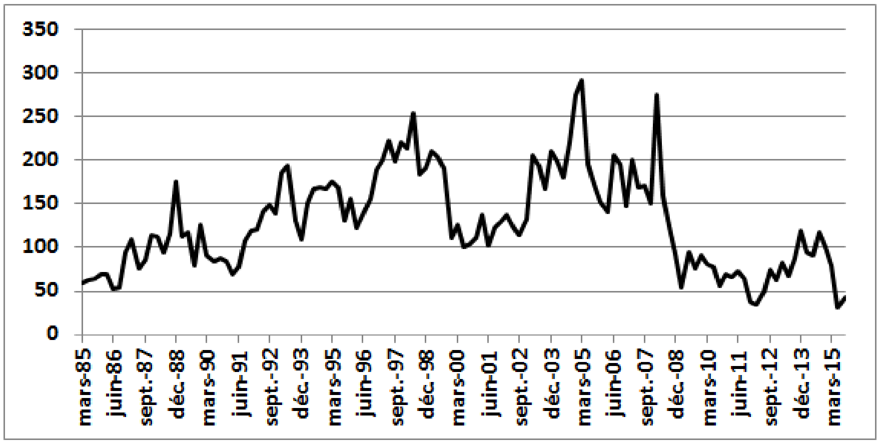

Figure 2: U.S. T-Bond futures open interest (in thousands).

This figure plots the open interest (in thousands) of 123 U.S. T-Bond futures contracts for the period spanning March 1985 to September 2015. This open interest is reported on the first day of the delivery month and is obtained from Bloomberg.

3.3 Short squeezes

A short squeeze develops when the CTD issue becomes in short supply in the cash and repo markets, forcing some short traders to deliver more expensive issues to fulfill the futures contract requirements. CTD short squeeze episodes are generally accompanied by severe price distortions in both the cash and futures markets (see Ben-Abdallah and Breton (2015) for a broad discussion of short squeeze episodes recorded in the U.S. and the Eurozone for futures written on government securities). When the CTD is highly predictable long in advance, its market manipulation can significantly reduce its supply and result in a short squeeze.

In this section, we examine the impact of the solution retained by the CME Group on the risk of short squeeze occurrences and on the incentive to manipulate the market of the CTD. In order to do so, we use three different indicators of the likelihood of short squeeze or manipulation occurrences, which we call the *squeeze propensity*. All three indicators can be broadly interpreted as the cost of delivering the second-cheapest-to-deliver issue (CTD2) if the first one (CTD1) is not available, for a par value of $100.

The first indicator is the difference in gross basis (GB) between the CTD2 and the CTD1. The gross basis of a bond is the difference between its cash price and the quoted futures price adjusted by its conversion factor. Accordingly, the CTD is the bond with the lowest gross basis.

The second indicator is the difference in futures equivalent prices (FEP) between the CTD2 and the CTD1, where the FEP of a bond is its cash price divided by its conversion factor. The FEP provides an approximate ranking of bonds that are candidates for CTD status, but it does not include the futures price.[1]

The third indicator is the squeeze potential (SP) proposed in Ben-Abdallah and Breton (2015). In the spirit of Merrick et al. (2005), the squeeze potential is defined as the difference between two theoretical futures prices, the first one under the assumption that all eligible bonds are available and priced at their

[1]Note that, in 2013, the CME Group ranked the bonds based on a forecast of their FEP in order to highlight the futures price discrepancies that would arise between the contenders for CTD status, due to the five-year-gap issue.

intrinsic value, and the second one under the assumption that the CTD is not available and that the short trader has to deliver the next-cheapest grade. The theoretical futures prices and the bond intrinsic values are obtained under the Hull and White (1990) stochastic interest-rate dynamics, calibrated to the observed term structure of interest rates, using the methodology of Svensson (1994) and Björk and Christensen (1999) and the estimation of Gürkaynak et al. (2007). The futures pricing model is described in Ben-Abdallah et al. (2012); it accounts for the composition of the delivery basket as well as all the strategic delivery options embedded in the T-Bond futures contracts.

Figure 3 shows the evolution of these three squeeze propensity indicators from June 1987 to September 2015. We observe that the three indicators behave consistently and have attained record values recently.

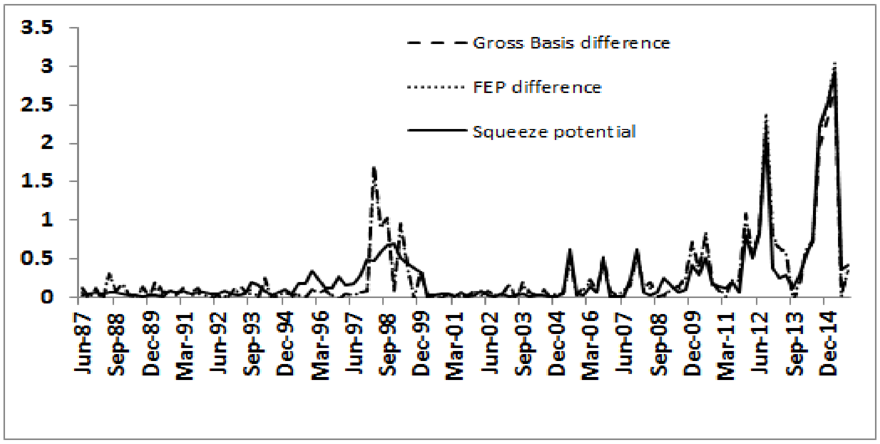

Figure 3: Squeeze propensity indicators in the U.S. T-Bond futures market.

This figure plots the evolution of three squeeze propensity indicators on the first day of the delivery month over the period spanning June 1987 to September 2015 (114 contracts). The first indicator is the difference in the gross basis of the second and first CTDs. The second indicator is the difference between the futures equivalent prices of the second and first CTDs.The third indicator is the squeeze potential and is computed as the difference between two theoretical futures prices obtained by either assuming that the first CTD or the second CTD is delivered to fulfill the contract, using the futures pricing model proposed in Ben-Abdallah et al. (2012). Data about the bonds, their cash prices and their gross basis are obtained from Bloomberg. Interest rate data is obtained from the Federal Reserve.

3.3.1 The CME Group's solution

Figure 4 reports on the values of the three squeeze propensity indicators for the contracts from March 2014 to September 2015, under the scenario implemented by the CME Group. Details of the computations are presented in Table 3.

Examination of Figure 4 shows that the three indicators of squeeze propensity experienced a substantial upward jump for the September 2014 futures, roughly tripling in value compared to the preceding contract. This is mainly due to the fact that the T-Bond 6-1/8% of August 2029 lost its delivery eligibility for September 2014, thus creating higher discrepancies between the first and second CTDs for this particular contract. From September 2014 to March 2015, no change was observed in the first and second CTDs, but long-term yields kept decreasing consistently (see Table 3), reaching as low as 2.68% on the first day of March 2015, where the three squeeze propensity indicators reached an all-time peak.[2] Notice that the high value of the squeeze propensity in March 2015 is not attributable to the five-year-gap issue, since the maturities of the first two CTDs are one year apart. As shown in Figure 4, the CME Group's solution resulted in a dramatic drop in all three squeeze propensity indicators as of June 2015, due to the elimination of the five-year gap, which lead to a more homogeneous basket, particularly between the first and second CTDs.

[2]This is consistent with the findings of Ben-Abdallah and Breton (2015), who show that the main determinant of squeeze potential is the discrepancy between the notional coupon rate and the 30-year T-Bond yield.

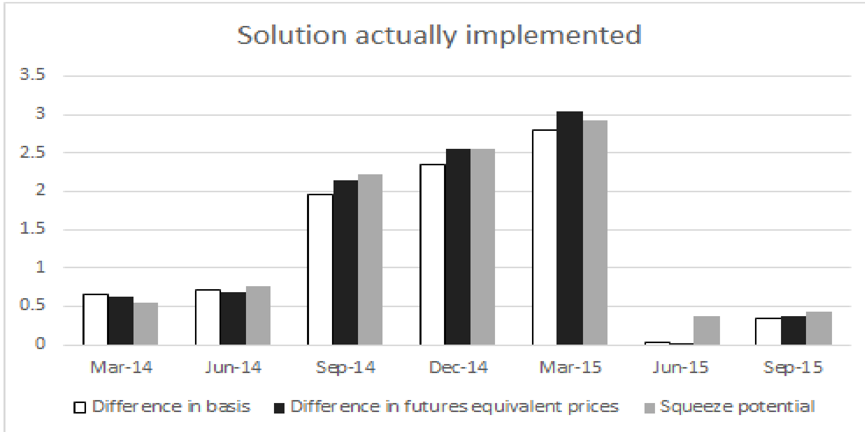

Figure 4: Evolution of squeeze propensity indicators for the solution that was implemented.

This figure illustrates the evolution of the three squeeze propensity indicators for the period covering March 2014 to September 2015 (7 contracts) under the scenario that was actually implemented by the CME Group. Data is taken from Table 3.

Table 3: Evolution of squeeze propensity indicators under the scenario that was actually implemented.

Futures Contract	Mar-14	Jun-14	Sep-14	Dec-14	Mar-15	Jun-15	Sep-15
CTD1	$6\frac{1}{8}$-08/29	$6\frac{1}{8}$-08/29	$6\frac{1}{4}$-05/30	$6\frac{1}{4}$-05/30	$6\frac{1}{4}$-05/30	$4\frac{1}{2}$-02/36	$4\frac{1}{2}$-02/36
CTD2	$6\frac{1}{4}$-05/30	$6\frac{1}{4}$-05/30	$5\frac{3}{8}$-02/31	$5\frac{3}{8}$-02/31	$5\frac{3}{8}$-02/31	5 -05/37	5 -05/37
GB CTD1	0.4778	0.4688	0.4656	0.4691	0.4901	0.4313	0.3844
GB CTD2	1.1308	1.1816	2.4303	2.8148	3.2935	0.4704	0.735
FEP CTD1	135.6594	137.6509	140.5795	143.9889	146.2909	155.4925	156.5907
FEP CTD2	136.2906	138.3406	144.7223	146.5374	149.3286	155.5032	156.9606
Differences (CTD2-CTD1)							
Gross Basis	0.6530	0.7128	1.9647	2.3457	2.8034	0.0391	0.3506
FEP	0.6312	0.6898	2.1428	2.5486	3.0377	0.0108	0.3698
Squeeze Potential	0.5517	0.7572	2.2299	2.5457	2.9310	0.3633	0.4225
Calendar Spread ($)	1.5312	0.8125	1.4375	1.46875	-13.875	1.56	
30-Year T-Bond Yield (%)	3.55	3.38	3.17	2.95	2.68	2.94	2.93

This table presents the evolution of the first and second CTDs as well as corresponding squeeze propensity indicators on the first day of the delivery month for seven T-Bond futures contracts over the period spanning March 2014 to September 2015. The gross basis is computed using the following formula: Deliverable bond cash price – bond conversion factor × futures price. The futures equivalent prices (FEP) are obtained by dividing bond cash prices by their conversion factors. The squeeze potential is computed as the difference between two theoretical futures prices obtained by either assuming that the first CTD or the second CTD is delivered to fulfill the contract, using the futures pricing model of Ben-Abdallah et al. (2012). We finally report the U.S. 30-year T-Bond yield as well as the calendar spread, defined as the difference between the price of the current futures contract and the next-expiring one. Data about the bonds, their cash prices and their gross basis are obtained from Bloomberg. Interest rate data is obtained from the Federal Reserve.

3.3.2 The status quo

We now analyze what would have been the behavior of the squeeze propensity indicators if the issue 5-3/8% of February 2031 had been kept inside the deliverable baskets of the June 2015 and September 2015 futures contracts. In order to do so, we compute a theoretical futures price under the assumption that the basket of deliverable securities is not altered, using the futures pricing model of Ben-Abdallah et al. (2012), and compute the corresponding indicators from the observed market prices of the CTD1 and CTD2 bonds. Table 4 presents the results for the June 2015 and September 2015 futures contracts, and Figure 5 shows the corresponding hypothetical evolution of the squeeze propensity indicators from March 2014 to September 2015.

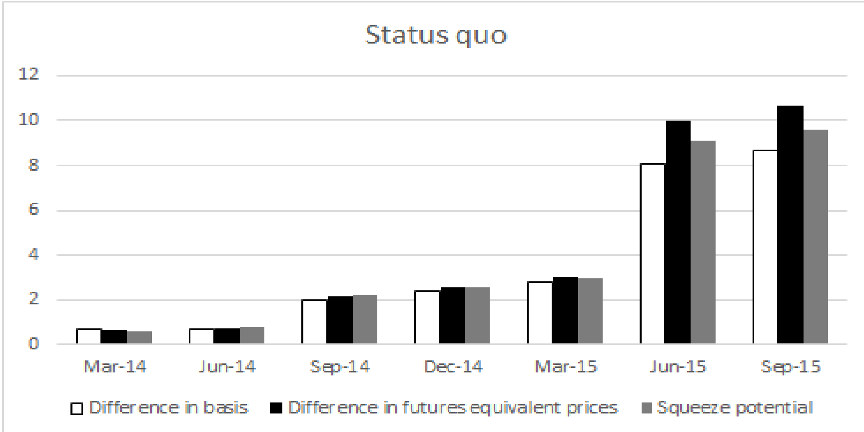

Figure 5: Evolution of squeeze propensity indicators under the status-quo assumption.

This figure illustrates the evolution of three squeeze propensity indicators for the period covering March 2014 to September 2015 (7 contracts), for the status quo scenario (T-Bond 5-3/8% of February 2031 not excluded from the deliverable basket). Data is taken from Tables 3 and 4.

Table 4: Squeeze propensity indicators under the status quo scenario.

Futures Contract	Jun-15	Sep-15
Theoretical Futures Price	144.1222	145.3024
CTD1	$5\frac{3}{8}$-02/31	$5\frac{3}{8}$-02/31
CTD2	$4\frac{1}{2}$-02/36	$4\frac{1}{2}$-02/36
GB CTD1	1.5339	0.8860
GB CTD2	9.3737	9.3174
FEP CTD1	145.7583	146.2470
FEP CTD2	155.4925	156.5907
Differences (CTD2-CTD1)		
Gross Basis	7.8398	8.4314
FEP	9.7342	10.3437
Squeeze Potential	9.1387	9.6116

This table presents the first and second CTDs as well as their corresponding gross basis and futures equivalent prices on the first day of the delivery month for the T-Bond futures contracts of June 2015 and September 2015, assuming that the T-Bond 5-3/8% of February 2031 is among the deliverable grades for these two contracts. The futures prices for the two contracts are theoretical and are computed on the first day of the delivery month, using the futures pricing model of Ben-Abdallah et al. (2012). The gross basis and futures equivalent prices of the first and second CTDs are computed using their observed cash prices, which are obtained from Bloomberg. This table also presents the squeeze potential computed as the difference between two theoretical futures prices obtained by either assuming that the first CTD or the second CTD is delivered to fulfill the contract.

Examination of Figure 5 shows that our three indicators for the risk of a CTD short squeeze or market manipulation for the June 2015 contract would have jumped dramatically to unprecedented levels, as their value would have been more than ten times higher than in June 2014.

Under these very special circumstances, if a shortage in the CTD, namely, the issue 5-3/8% of 15 February 2031, had occurred, short traders would have been forced to assume the highest losses ever recorded in relation to delivering alternative bonds, amounting to more than 6% of the CTD's cash price. Note that conditions would have been very favorable for such a short squeeze scenario to develop for the June 2015 and September 2015 contracts, as the CTD was highly predictable and its outstanding amount relatively low ($15 billion). We can conclude that the CME Group, by choosing to adopt an alternative solution to Option A, prevented what could possibly have been the worst short-squeeze scenario ever to hit the market of the CTD.

3.3.3 Preemptive exclusion of two bonds

Recall that, under Option B, the CME Group had considered the possibility of also excluding the two shortest T-Bonds from the September 2014, December 2014 and March 2015 contracts. We now analyze what would have been the behavior of the squeeze propensity indicators if the issues 5-3/8% of February 2031 and 6-1/4% of May 2030 had been excluded from the deliverable baskets from September 2014 onwards. We compute theoretical futures prices accordingly for the September 2014, December 2014 and March 2015 contracts, and compute the corresponding indicators using the observed market prices of the CTD1 and CTD2 bonds. Results are presented in Table 5 and Figure 6.

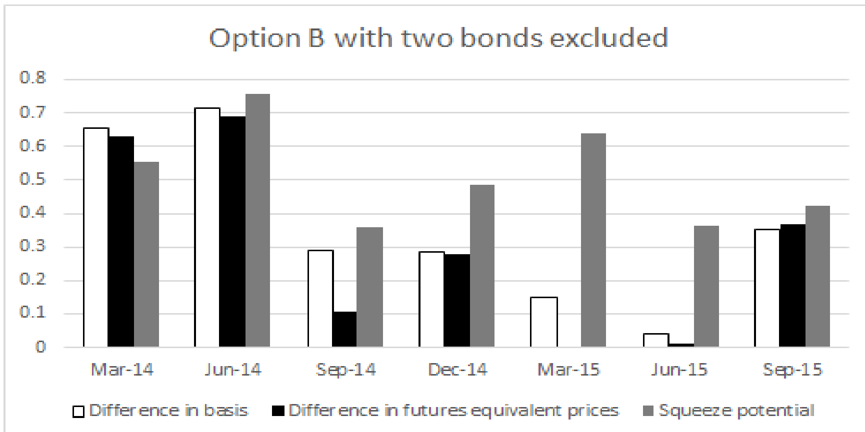

Figure 6: Evolution of squeeze propensity indicators under the scenario excluding two bonds.

This figure illustrates the evolution of three squeeze propensity indicators for the period covering March 2014 to September 2015 (7 contracts) assuming that two T-Bonds (5-3/8% of February 2031 and 6-1/4% of May 2030) are excluded from the deliverable basket from September 2014 onwards. Data is taken from Tables 3 and 5.

Table 5: Squeeze propensity indicators under the scenario excluding two bonds.

Futures Contract	Sep-14	Dec-14	Mar-15
Theoretical Futures Price	150.1458	154.9141	158.7936
CTD1	$4\frac{1}{2}$-02/36	$4\frac{1}{2}$-02/36	$4\frac{1}{2}$-02/36
CTD2	5 -05/37	$4\frac{3}{4}$-02/37	5 -05/37
GB CTD1	2.8637	1.5515	2.4218
GB CTD2	3.1527	1.8365	2.5697
FEP CTD1	153.6335	156.8011	161.7355
FEP CTD2	153.7390	157.0788	161.7179
Differences (CTD2-CTD1)			
Gross Basis	0.2890	0.2850	0.1479
FEP	0.1056	0.2777	-0.0175
Squeeze Potential	0.3587	0.4860	0.6380

This table presents the first and second CTDs as well as their corresponding gross basis and futures equivalent prices on the first day of the delivery month for the T-Bond futures contracts of September 2014, December 2014 and March 2015, assuming that the T-Bonds 5-3/8% of February 2031 and 6-1/4% of May 2030 are excluded from the deliverable baskets of the September 2014 to December 2015 futures contracts. The futures prices for the three contracts are theoretical and are computed on the first day of the delivery month, using the futures pricing model of Ben-Abdallah et al. (2012). The gross basis and futures equivalent prices of the first and second CTDs are computed using their observed cash prices, which are obtained from Bloomberg. This table also presents the squeeze potential computed as the difference between two theoretical futures prices obtained by either assuming that the first CTD or the second CTD is delivered to fulfill the contract.

Examination of Figure 6 shows that the exclusion of the two shortest bonds from September 2014 onwards would have considerably decreased the short-squeeze propensity from September 2014 onwards with respect to the solution that was adopted.

Figure 7 compares the "rise and fall" of the squeeze propensity, as indicated by the difference in gross basis, over the period from March 2014 to September 2015, under three scenarios that were considered to address the five-year-gap issue. Option C is not represented as it consists of shifting the gap and its possible impact on squeeze propensity to a later date. The behavior of the two other indicators of squeeze propensity is similar. We observe that the original Option B would have been the best one to reduce the overall possibility of short squeezes or manipulation, but that the solution retained by the CME Group did succeed in reducing the squeeze propensity for the June 2015 and September 2015 contracts by nearly 90%.

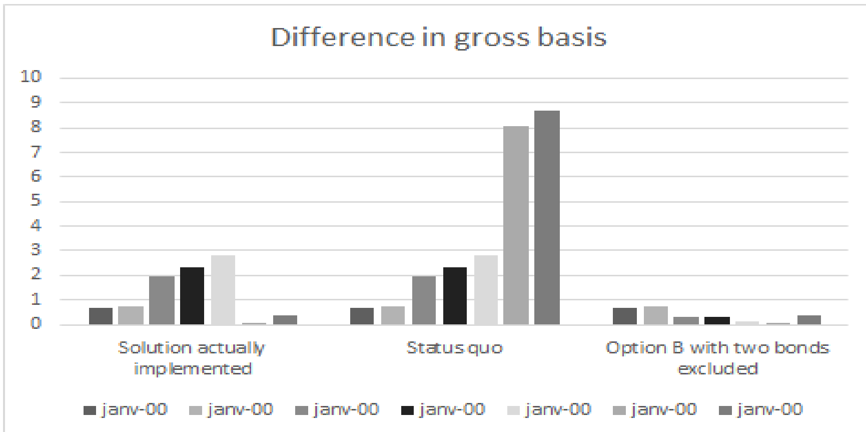

Figure 7: Comparison of the gross basis differences according to three possible scenarios.

This figure illustrates the evolution of the gross basis difference between the second and the first CTDs under three scenarios: The first scenario is the solution actually implemented by the CME Group (exclusion of the T-bond 5-3/8% of February 2031 from the deliverable basket from June 2015 onwards). The second scenario is the status quo (no bond excluded from the deliverable basket). The third scenario is Option B with two bonds excluded (the T-Bonds 5-3/8% of February 2031 and 6-1/4% of May 2030 are excluded from the deliverable basket from September 2014 onwards).

3.4 Basket composition

The CME Group decided to partially adopt Option B, excluding a single bond from delivery eligibility, in order to prevent the CTD from being a grade isolated from the rest of the basket (more specifically from the second-cheapest-to-deliver issue). This decision affects only three futures contracts (June 2015, September 2015 and December 2015). By ruling out the second part of Option B, which consisted in excluding the two shortest and isolated T-Bonds from the September 2014, December 2014 and March 2015 contracts, the CME Group implicitly considered that the maturity-gap issue has a negligible impact when it arises between the second and third CTDs. A scenario where both the first and second CTDs were in short supply was therefore considered very unlikely, in spite of their small combined outstanding supply (see Table 1). Moreover, this solution has maintained the difference in minimal maturities between the classic and Ultra T-Bond futures markets for a longer period. Indeed, because of the five-year gap, the deliverable basket no longer contains intermediate-maturity (15 to 20 years) bonds, which would have happened as early as September 2014 under Option B with two bonds excluded.

4 An alternative solution to the five-year-gap issue

In this section, we propose an alternative solution, not considered by the CME Group, that would have performed even better than the path that was taken to address the five-year-gap issue. This alternative solution is motivated by the following observations:

- The rationale behind the use of the CBOT system of conversion factors is to make all eligible bonds equivalent for delivery, regardless of any discrepancies that could exist between their characteristics, including those that arose from the five-year-maturity gap.

- When bonds are not equal for delivery, and more specifically when there is a significant difference between the delivery cost of the most desirable grades, there is a risk of experiencing a short squeeze, either because the outstanding amount of the CTD is insufficient to meet all the delivery requirements, or as a result of market manipulation, consisting of acquiring a substantial long position in the futures contract along with a sizeable fraction of its CTD bond issue.
- In a recent empirical study, Ben-Abdallah and Breton (2015) show that the main and most important factor in explaining squeeze potential is the difference between the long-term yield and the reference coupon rate.
- The discrepancy between long-term yields and the reference coupon rate of 6% has been increasing in the recent decade (see Figure 8), accentuating the imperfections of the conversion factor system, especially when it comes to adjusting for the highest heterogeneity ever recorded between the first and second CTDs, due to the five-year-maturity gap.

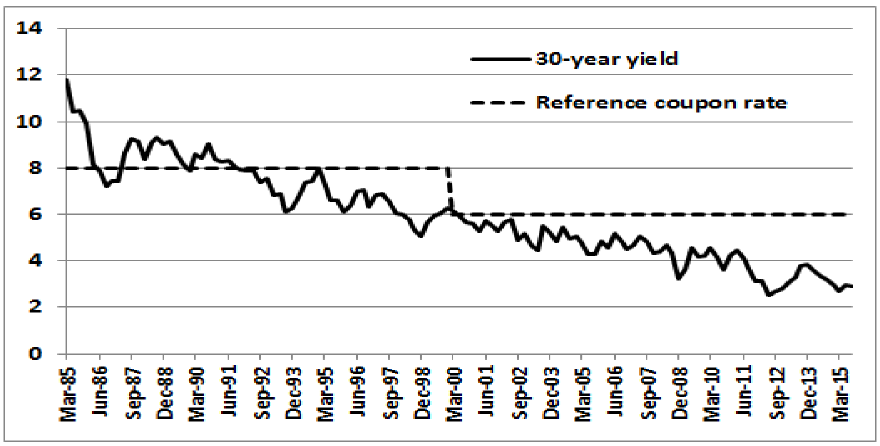

Figure 8: U.S. 30-year T-Bond yield vs. reference coupon rate.

This figure plots the 30-year T-Bond yield in the U.S. and the coupon rate of the T-Bond futures' notional bond over the period spanning March 1985 to September 2015. Interest-rate data is obtained from the Federal Reserve.

We contend that the real issue in 2014-2015 was not a maturity gap, but rather a reference-rate gap, and that the heterogeneity in the basket due to the maturity gap only amplified the impact of the prevailing discrepancy between the long-term yield and the reference coupon rate. We argue that lowering the notional bond's coupon rate would have performed better than the option chosen in the current situation. It is worth noting that a solution involving lowering the level of the reference coupon rate has not been among the options considered and discussed by the CME Group since the issue was raised in July 2013.

To assess this alternative solution, we perform a scenario analysis, where we assume that the notional bond's coupon rate is not the current 6%, but rather 4% or 3%. We analyze the relative efficiency of lowering the reference rate in terms of addressing the five-year-gap issue and reducing the incentives to manipulate the CTD market, compared to the solution that was actually implemented.

4.1 Description of the scenario analysis

This scenario analysis is conducted for the seven T-Bond futures considered in Section 3, namely, those covering the period from March 2014 to September 2015, where we do not exclude the T-Bond 5-3/8% of 15 February 2031 from the deliverable sets of June 2015 and September 2015.

We analyze two alternative values for the level of the reference coupon rate. We first obtain the conversion factors corresponding to notional coupon rates of 4% and 3%, using the CBOT conversion system,[3] for all

[3]The formula is available at www.cmegroup.com/trading/interest-rates/calculating-us-treasury-futures-conversion-factors.html

the bonds in the eligible basket. We then use the pricing model of Ben-Abdallah et al. (2012) to obtain theoretical futures prices of CBOT T-Bond futures contracts on the first day of the delivery month, where the stochastic interest-rate dynamics are calibrated to the observed term structure of interest rates at that date. We finally use the observed cash prices of the deliverable grades to compute their gross basis, which allows us to obtain their new ranking and determine the CTD on the first day of the delivery month of each contract. We also obtain, under each scenario, the value of the three squeeze propensity indicators defined in Section 3.3.

4.2 Impact on bond ranking

Tables 6 and 7 summarize our results about the ranking of the eligible bonds based on their gross basis, under the assumption that the reference coupon rate equals 4% and 3%, respectively. A first examination of Tables 6 and 7 shows that the ranking of bonds differs significantly according to the level of the reference coupon rate. More specifically, the first and second CTDs are not necessarily the neighboring issues positioned at the front of the basket, as was the case under the 6% level (see Table 3).

Table 6: Gross basis of deliverable T-Bonds under the scenario of a 4% reference coupon rate.

Fut. price	Mar-14 106.9738		Jun-14 111.8298		Sep-14 113.7351		Dec-14 116.4619		Mar-15 118.0970		Jun-15 116.4796		Sep-15 117.6987	
T-Bond	GB	#	GB	#	GB	#	GB	#	GB	#	GB	#	GB	#
$6\frac{1}{8}$ 08/29	4.62	9	0.94	7										
$6\frac{1}{4}$ 05/30	4.58	8	0.84	5	2.42	CTD	1.05	CTD	2.01	CTD				
$5\frac{3}{8}$ 02/31	3.96	7	0.77	CTD	2.60	2	1.62	2	2.95	2	1.80	CTD	1.15	CTD
$4\frac{1}{2}$ 02/36	3.15	6	1.21	10	4.33	8	4.24	10	6.78	8	3.85	12	3.71	12
$4\frac{3}{4}$ 02/37	3.10	4	1.08	9	4.35	9	4.10	9	6.56	5	3.55	10	3.64	11
5 05/37	3.13	5	0.97	8	4.39	10	4.34	11	6.83	10	3.72	11	3.86	13
$4\frac{3}{8}$ 02/38	2.60	2	0.79	2	3.96	4	3.49	4	6.34	3	3.10	9	3.07	10
$4\frac{1}{2}$ 05/38	2.65	3	0.85	6	4.07	5	3.55	6	6.36	4	2.97	6	3.05	9
$3\frac{1}{2}$ 02/39	1.99	CTD	0.79	3	3.92	3	3.39	3	6.60	6	2.93	4	2.81	8
$4\frac{1}{4}$ 05/39			0.82	4	4.18	6	3.50	5	6.63	7	2.85	2	2.54	6
$4\frac{1}{2}$ 08/39					4.29	7	3.59	7	6.79	9	2.92	3	2.50	3
$4\frac{3}{8}$ 11/39							3.652	8	6.870	11	2.957	5	2.532	5
$4\frac{5}{8}$ 02/40									7.029	12	3.053	7	2.471	2
$4\frac{3}{8}$ 05/40											3.086	8	2.518	4
$3\frac{7}{8}$ 08/40													2.675	7

This table reports the theoretical gross basis (GB) and the ranking (#) of T-Bonds composing the deliverable baskets of U.S. T-Bond futures from March 2014 to September 2015, assuming a reference coupon rate of 4% and that the T-Bond 5-3/8% of February 2031 is not excluded from the deliverable baskets of June 2015 and September 2015. The conversion factor of eligible grades is computed using the CBOT methodology. The futures prices are obtained on the first day of the delivery month, using the pricing model of Ben-Abdallah et al. (2012). The gross basis is computed on the first day of the delivery month, and the CTD is identified as the bond with the lowest gross basis. Cash bond prices are obtained from Bloomberg.

When the reference rate is set to 4%, the CTD for the March 2014 and June 2014 contracts is not the lowest-duration bond. Furthermore, the CTD for the March 2014 contract is not only a grade issued after the 2001–2006 suspension period, it is the bond with the highest duration (smallest coupon, longest maturity). This drastic shift in the CTD, from the top to the bottom of the basket, for the March 2014 contract is mainly due to long-term yields being, at that time, very close to the assumed reference rate of 4% (see Figure 8). As 30-year yields decrease thereafter, bonds with the lowest durations become CTDs under this scenario. Accordingly, if the reference rate were set to 4%, the CTD for June 2015 and September 2015 would remain unchanged compared to the status quo option (the isolated issue 5-3/8% of 15 February 2031). The five-year-gap issue would still have to be addressed under this scenario.

When the reference rate is set to 3%, we notice from Table 7 a more pronounced shift of the CTDs from the front to the back and middle of all deliverable baskets. For instance, the bond with the longest duration, namely, the issue 3-1/2% of February 2039, is the CTD until June 2015, but then is dethroned by a higher-duration bond in September 2015. Notice that this shift has consequently moved the contenders for CTD

Table 7: Gross basis of deliverable T-Bonds under the scenario of a 3% reference coupon rate.

Fut. price	Mar-14 90.6476		Jun-14 94.9970		Sep-14 98.1267		Dec-14 102.0724		Mar-15 105.5373		Jun-15 101.1116		Sep-15 102.3262	
T-Bond	GB	#	GB	#	GB	#	GB	#	GB	#	GB	#	GB	#
$6\frac{1}{8}$ 08/29	12.3	9	8.74	10										
$6\frac{1}{4}$ 05/30	11.9	8	8.33	9	8.07	10	4.78	11	3.14	11				
$5\frac{3}{8}$ 02/31	9.92	7	6.85	8	6.96	9	4.18	10	3.06	10	5.94	12	5.29	13
$4\frac{1}{2}$ 02/36	5.59	6	3.60	7	5.02	8	3.12	9	3.29	12	4.22	11	4.03	12
$4\frac{3}{4}$ 02/37	5.31	4	3.23	5	4.72	6	2.58	7	2.56	8	3.55	9	3.58	10
5 05/37	5.48	5	3.23	6	4.82	7	2.82	8	2.75	9	3.77	10	3.85	11
$4\frac{3}{8}$ 02/38	3.97	2	2.06	3	3.51	4	1.21	6	1.67	7	2.28	8	2.18	9
$4\frac{1}{2}$ 05/38	4.04	3	2.12	4	3.59	5	1.20	5	1.58	6	2.10	7	2.11	8
$3\frac{1}{2}$ 02/39	2.09	CTD	0.74	CTD	2.34	CTD	0.16	CTD	1.24	CTD	1.00	CTD	0.81	5
$4\frac{1}{4}$ 05/39			1.38	2	3.03	2	0.51	3	1.27	3	1.29	4	0.91	7
$4\frac{1}{2}$ 08/39					3.19	3	0.59	4	1.32	5	1.41	6	0.90	6
$4\frac{3}{8}$ 11/39							0.47	2	1.26	2	1.23	3	0.73	4
$4\frac{5}{8}$ 02/40									1.31	4	1.36	5	0.69	3
$4\frac{3}{8}$ 05/40											1.11	2	0.46	2
$3\frac{7}{8}$ 08/40													0.19	CTD

This table reports the theoretical gross basis (GB) and the ranking (#) of T-Bonds composing the deliverable baskets of U.S. T-Bond futures from March 2014 to September 2015, assuming a reference coupon rate of 3% and that the T-Bond 5-3/8% of February 2031 is not excluded from the deliverable baskets of June 2015 and September 2015. The conversion factor of eligible grades is computed using the CBOT methodology. The futures prices are obtained on the first day of the delivery month, using the pricing model of Ben-Abdallah et al. (2012). The gross basis is computed on the first day of the delivery month, and the CTD is identified as the bond with the lowest gross basis. Cash bond prices are obtained from Bloomberg.

status far away from the bonds concerned by the five-year-maturity gap: these are consistently ranked last throughout the period of study. The results reported in Table 7 show that the CTD shift, which occurred through the lowering of the reference rate to 3%, has completely eliminated the issue of the CTD being isolated from the rest of the basket. Therefore the disruptive exclusion of grades from delivery eligibility would have not been needed under this scenario.

4.3 Impact on squeeze propensity

We now assess the impact of the two alternative scenarios for the reference coupon rate on the short-squeeze risk and on incentives to manipulate the market of the CTD. Figure 9 and Table 8 compare the squeeze potential, the difference in gross basis and the difference in futures equivalent prices from March 2014 to September 2015, under the two alternative solutions, namely, where the reference coupon rate is assumed to be either equal to 4% or 3% while the issue 5-3/8% of February 2031 is not excluded from these baskets. These results are to be compared with the squeeze propensity indicators obtained under the solution that was actually implemented, as represented in Figure 4 and Table 3. Figure 10, for instance, compares the differences in gross basis under these three scenarios.

Observation of Figures 9 and 4 shows that all indicators of the squeeze propensity are minimal for the March 2014 and June 2014 delivery months under the 4% scenario. This can be explained by the fact that the long-term yields prevailing at that time were very close to 4%, and bonds eligible for delivery for these two contracts were thus exhibiting very small divergences after adjusting for their quality with respect to the notional bond. From September 2014 to March 2015, Figures 9 and 4 also show that both scenarios involving lower reference rates significantly outperform the actual case, in terms of reducing the squeeze propensity.

We now examine more closely the June 2015 and September 2015 futures contracts, as they were the first affected by the CME Group's solution. As discussed above, excluding the T-Bond 5-3/8% of February 2031 from delivery eligibility into these two contracts has succeeded in dramatically reducing the incentives to manipulate the market of the CTD. However, and despite this dramatic drop, the CME Group's solution is outperformed by the 3% scenario, which does not involve a disruptive resorting to bond exclusion, and

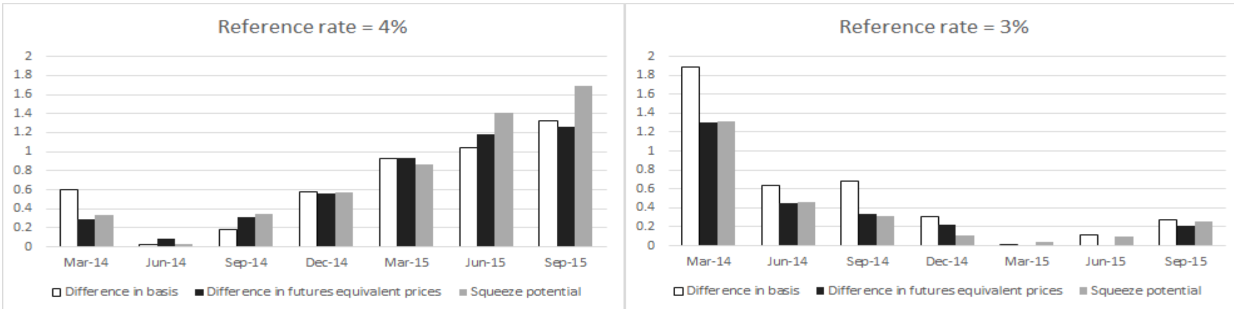

Figure 9: Evolution of the squeeze propensity, assuming the reference coupon rate is lowered.

This figure illustrates the evolution of three squeeze propensity indicators for the period covering March 2014 to September 2015 (7 contracts) under two alternative scenarios, where the reference coupon rate is 4% and 3%, respectively, and where the T-Bond 5-3/8% of February 2031 is not excluded from the deliverable basket. Data is taken from Table 8.

Table 8: Comparison of squeeze propensity indicators under the implemented and alternative solutions.

Futures Contract	Mar-14	Jun-14	Sep-14	Dec-14	Mar-15	Jun-15	Sep-15	Average
	Squeeze Potential							
Implemented solution	0.5517	0.7572	2.2299	2.5457	2.9310	0.3632	0.4225	1.4002
4% reference rate	**0.3356**	**0.0327**	0.3449	0.5701	0.8656	1.4093	1.6881	0.7495
3% reference rate	1.3120	0.4594	**0.3092**	**0.1055**	**0.0447**	**0.0955**	**0.2508**	**0.3682**
	Gross Basis Difference							
Implemented solution	0.6530	0.7128	1.9647	2.3457	2.8034	**0.0391**	0.3506	1.2670
4% reference rate	**0.6034**	**0.0222**	**0.1846**	0.5724	0.9314	1.0459	1.3257	0.6694
3% reference rate	1.8855	0.6335	0.6867	**0.3040**	**0.0125**	0.1094	**0.2710**	**0.5575**
	Futures Equivalent Prices Difference							
Implemented solution	0.6380	0.6890	2.2159	2.5182	3.0282	0.0289	0.3760	1.3563
4% reference rate	**0.2940**	**0.0884**	**0.3155**	0.5603	0.9316	1.1869	1.2629	0.6623
3% reference rate	1.3035	0.4470	0.3341	**0.2268**	**-0.1316**	**-0.0272**	**0.2079**	**0.3373**

This table compares the squeeze potential and the difference in gross basis and futures equivalent prices between the first two CTDs for the U.S. T-Bond futures contracts from March 2014 to September 2015 under three different scenarios. Implemented solution: reference coupon rate = 6% and T-Bond 5-3/8% of February 2031 is excluded from the deliverable baskets of the June 2015 and September 2015 contracts; Scenario 2: reference coupon rate = 4% and no bond is excluded from the deliverable basket; Scenario 3: reference coupon rate = 3% and no bond is excluded from the deliverable basket. The smallest values for each contract are shown in bold. Conversion factors under the new reference coupon rates of 4% and 3% are computed using the CBOT formula. Theoretical futures prices are computed on the first day of the delivery month, using the futures pricing model proposed in Ben-Abdallah et al. (2012). Data about the bonds and their cash prices are obtained from Bloomberg. Interest-rate data is obtained from the Federal Reserve.

therefore, would have been a better alternative. On the other hand, while the 4% scenario does not reduce the squeeze propensity as much as the CME Group's solution for these two contracts, it still fares substantially better for all preceding contracts (March 2014 to March 2015) and with respect to the status quo situation (see Figure 5), while again avoiding excluding bonds from the deliverable basket.

On the average, as shown in Table 8, lowering the reference coupon rate would have been efficient in reducing the basis volatility and short-squeeze propensity. Finally, note that such a course of action would have attenuated the effects of the short squeeze episode that hit the T-Bond futures market in 2014 as a result of the unexpected fall in interest rates that forced short traders to unwind their futures positions at higher prices (see Eisen 2014).

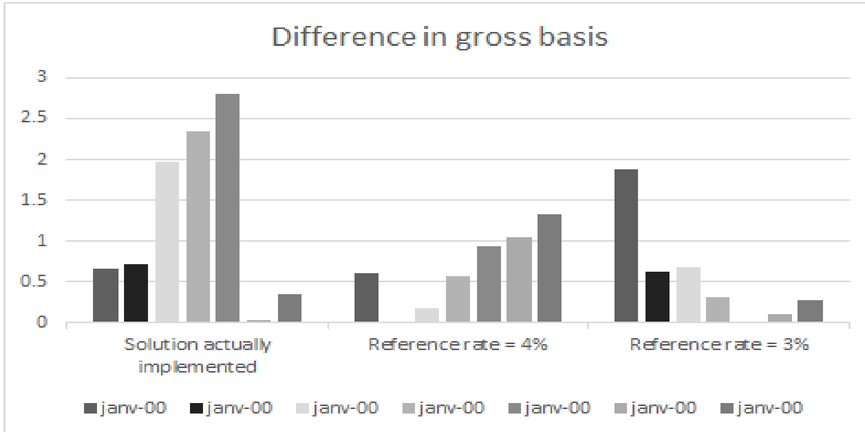

Figure 10: Comparison of the gross basis differences according to three possible scenarios.

This figure illustrates the evolution of the gross basis difference between the second and the first CTDs, under three scenarios: The first scenario is the solution actually implemented by the CME Group (exclusion of the T-Bond 5-3/8% of February 2031 from the deliverable basket from June 2015 onwards). The second scenario is the reduction of the reference coupon rate to 4%, without excluding any bond from the deliverable basket. The third scenario is the reduction of the reference coupon rate to 3%, without excluding any bond from the deliverable basket.

4.4 Impact on futures prices and calendar spreads

In Figure 11, we present the evolution of the quoted prices of T-Bond futures over the period spanning March 1985 to September 2015, along with the futures prices that would theoretically have been observed, starting from March 2014, if the reference coupon rate had then been lowered to 4% and 3%, respectively (theoretical futures prices are reported in Table 9). Figure 11 shows that futures prices are currently trading at their highest historical levels with respect to par. This is due to the high discrepancy between the yield of the notional bond (a 6% bond with 20 years to maturity) and that of currently available securities. This premium has been exacerbated by the exclusion of the bond 5-3/8% of 15 February 2031 from the June 2015 contract, which provoked a substantial upward jump in the futures price ($9 with respect to the price of the preceding contract on the first day of the delivery month). On the other hand, lowering the reference coupon rate to values that better reflect the actual level of the yield curve (see, e.g., the recent 30-year yields in Table 3) would have significantly lowered futures prices and brought them closer to parity.

Table 9: Prices of U.S. T-Bond futures under three different scenarios.

Futures Contract	Mar-14	Jun-14	Sep-14	Dec-14	Mar-15	Jun-15	Sep-15
Observed Futures Price	135.1875	137.1875	140.125	143.53125	145.813	154.97	156.13
Theoretical Futures Price (4%)	106.9738	111.8298	113.7351	116.4619	118.0970	116.4796	117.6987
Theoretical Futures Price (3%)	90.6476	94.9970	98.1267	102.0724	105.5373	101.1116	102.3263

This table reports the observed prices of U.S. T-bond futures as well as their theoretical prices, under two different assumptions about the level of the reference coupon rate, namely, 4% and 3%, over the period spanning March 2014 to September 2015. Observed quoted prices are obtained from Bloomberg. Theoretical futures prices are computed using the pricing model proposed in Ben-Abdallah et al. (2012).

As can be seen in Figure 11, substantial drops in T-Bond futures prices did occur in the past. More specifically, recall that, as of March 2000, the response of the CBOT to a long period of high futures prices due to long-term yields far below the reference coupon level (8% at that time) was to reduce it to 6%. Futures prices dropped $17 from one contract to the next, and this resulted in an exceptional calendar spread of around $20 in December 1999.

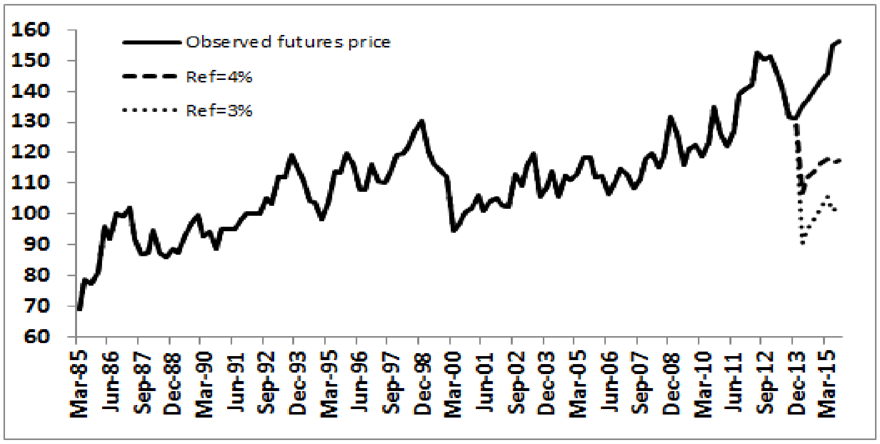

Figure 11: Prices of U.S. T-bond futures.

This figure plots the quoted prices of U.S. T-Bond futures over the period spanning March 1985 to September 2015 (123 contracts), obtained from Bloomberg. Theoretical prices of T-Bond futures from March 2014 to September 2015 are also represented under two alternative scenarios: where the reference coupon rate is lowered to 4% and 3%, respectively.

Applying a reduction in the reference coupon rate necessarily entails a significant downward jump in futures prices (in the scenarios examined in Table 9, futures prices drop $24 and $40, respectively) and a corresponding substantial calendar spread.

Notice that the solution implemented by the CME Group, which consisted of excluding one bond from the set of deliverable bonds, resulted in a jump in the futures price and in a calendar spread of $(-13.875) for a nominal $100 contract on the first day of the delivery month between the successive March 2015 and June 2015 contracts. It is worthwhile mentioning that, under a perfect conversion system, all bonds would be equal for delivery, and the exclusion of one deliverable issue would not affect the futures price at all. However, because the conversion system is not perfect,[4] futures prices and calendar spread jumps are expected to occur whenever a CTD grade leaves the deliverable basket. Accordingly, all the options proposed by the CME Group in addressing the five-year-gap-issue involve a substantially high jump in the calendar spread, albeit at different points in time, that would need to be managed.

If the reference coupon were lowered to 4%, in addition to the calendar spread jump occurring at the time the rate is changed, a second jump would be recorded between the December 2015 and March 2016 futures, due to the fact that the 4% rate is not sufficiently low to prevent the isolated T-Bond 5-3/8% of February 2031 from being the CTD for December 2015. Nevertheless, this second jump would be expected to be relatively smaller than the one experienced in March 2015, due to the smaller bias in the conversion factors computed under the 4% yield curve assumption.

However, if the reference coupon rate were lowered to 3% instead, there would be no second jump in the calendar spread between December 2015 and March 2016, thanks to the significant shift in the bonds contending for CTDs under this scenario.

We conclude that lowering the reference coupon rate to 3% would have been a viable solution, lowering the futures prices to more reasonable levels, albeit requiring special measures similar to those that were introduced by the CME Group to help traders manage the March-June 2015 roll.

4.5 A longer-term perspective

On September 17, 2015, after a long cycle of rate cuts following the last financial crisis, the U.S. Federal Reserve had its most closely watched monetary policy meeting and decided to put off its first interest-rate

[4] The CBOT conversion factor system makes all bonds equal for delivery only when the term structure of interest rates is flat at the notional coupon rate level.

hike since June 2006, thus keeping it unchanged at its current historic low level close to zero (see FOMC 2015). Moreover, market specialists consider that this most anticipated interest-rate move will not be taking place soon and that the market still has long to wait before policy makers' concerns about the lack of inflation, the global economy and market volatility abate (Belvedere, 2015). Note that even after the FED gradually starts increasing its key short-term interest rate, it is expected that hikes will be modest and their pace will be slow, so that rates will remain low, far from their pre-crisis levels, for a long time.

Therefore, long-maturity T-Bonds will continue to be auctioned at low yields in the future, as has been the case since the last financial crisis (e.g., at 2.875% for the August 2015 auction). As a result, the deliverable baskets into the T-Bond futures contracts are expected to be composed of grades bearing low coupon rates (far from 6%) for a long time to come. Under such a low-interest-rate environment, the conversion factor system will continue to perform poorly by favoring the delivery of the highly predictable lowest-duration issues. Moreover, since they are directly related to the difference between the long-term yield and the reference coupon rate, the cost of delivering bonds other than the CTD and the risk of market manipulation will remain significant.

In line with the current situation, it is interesting to observe the evolution of futures prices between 1998 and 2005 in Figure 9 and to recall what occurred during this period. In 1998–1999, long-term bond yields were far below the notional coupon level of 8% (reaching as low as 5% in December 1998), favoring delivery of the lowest-duration bond, while the second CTD was significantly more expensive. Futures prices were very high, reaching $130.1875 in December 1998. In order to address these issues, the CBOT decided to reduce the reference coupon rate, starting with the March 2000 futures contract. At that time, the yield curve was nearly flat at the level of 6%, and the reference coupon rate was reduced from 8% to 6%. Thanks to this correction, the conversion factor system worked well between 2000 and 2005, during which time all eligible bonds were approximately equal for delivery.

Given the anticipation that interest rates will remain low in the foreseeable future, the alternative solution, consisting of lowering the notional coupon to 3%, would seem to be an advantageous course of action. It would reduce futures prices, basis volatility, basket heterogeneity and short-squeeze risk, and has already proven to be effective in a similar situation.

5 Concluding remarks

We find that the CME Group's solution was satisfactory for addressing the five-year-gap issue, and made it possible to avoid a situation where the incentives for market manipulation and the possibility of a short squeeze would have been at their highest in the history of the U.S. T-Bond futures in 2015. This solution, however, concerned only three contracts. We show that an alternative solution, such as lowering the reference coupon rate to 3%, would have produced better outcomes in the short run. Given that it is expected that interest rates will remain very low in the near future, this alternative solution would also be more efficient in the long run.

We conclude that the real issue is not a five-year gap in maturities in the set of deliverable bonds, but rather the current conversion factor system's imperfections, which were compounded by the large gap between long-term T-Bond yields and the reference coupon rate, accentuating the heterogeneity between the plausible contenders for CTD status. Lowering the reference coupon rate, as was done in March 2000, would still be a sustainable solution, as the number of bonds in the deliverable basket is presently relatively low.

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