An Overlooked Coupon Effect in Treasury Futures Contracts

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There is an overlooked coupon effect that impacts the cheapest to deliver note or bond for the Chicago Board of Trade's U.S. Treasury note and bond futures contracts. The coupon effect results from calculating conversion factors for shorter terms to maturity than are actually the case on the first delivery date.

The CBOT rounds maturities down to the nearest quarter. Such a calculation induces a bias toward the lowest-coupon deliverables, at least when yields are in the neighborhood of 6%. This coupon effect influences both the cheapest to deliver instrument and the futures price.

This article concerns how coupon differences and pull to par determine the cheapest to deliver (CTD) note or bond for the Chicago Board of Trade's U.S. Treasury note and bond futures. This coupon effect has not been recognized heretofore. It affects both the choice of CTD and the futures price.

Treasury note and bond futures contracts, which are traded on the Chicago Board of Trade (CBOT), are two of the oldest financial futures contracts. Early financial futures were modeled after agricultural contracts, which require physical delivery of the goods, if they are not offset. Consequently, the seller (the short) of a Treasury note or bond futures contract who chooses to make delivery rather than liquidate the position by offset must deliver some Treasury note or bond. Many financial futures that were developed later have cash settlement.

To avoid squeezes, the CBOT allows the seller to deliver one of several (or many) Treasury issues. Multiple deliverables also allow for varying schedules of new issues. The set of all issues that meet the delivery requirements for a particular contract is called the *deliverable basket*. The CBOT rules determining which Treasury issues are acceptable for delivery into the bond contract specify those that have at least 15 years to maturity from the first day of the delivery month. The deliverable basket for Treasury note contracts includes Treasury notes with 6½ through 10 years to maturity.

On the delivery date, the seller of the futures contract (the short) is required to deliver to the buyer (the long) \$100,000 par value of one of the deliverables. The seller chooses which issue. At first blush, the choice of deliverable seems obvious. The lowest-coupon bond will have the lowest dollar price, and it should be cheapest to deliver. To make the basket more nearly equally cheap to deliver, the CBOT adjusts the invoice for each Treasury issue that can be delivered to satisfy the Treasury bond futures contract by a conversion factor, designed to make each deliverable bond, regardless of coupon rate, approximately equally cheap to deliver if the yield curve is flat at 6%.

When it selects the issue to be delivered, the short will pick the issue from the deliverable basket that will produce the highest return on a cash-and-carry trade. In a cash-and-carry trade, a cash bond is purchased with borrowed funds (e.g., via a repurchase agreement) while simultaneously shorting the Treasury bond futures contract. The bond purchased will be delivered to satisfy the short futures position.

The rate of return for this trade is referred to as the *implied repo rate*. Once the implied repo rate is calculated for each bond in the deliverable basket, the issue selected will be the one that has the highest implied repo rate. This bond is CTD. *The highest implied repo rate can be negative.*

Implied repo calculations, which use today's futures price to determine the final invoice, implicitly assume that futures prices do not change from the initial settlement date to the ultimate delivery date. Of course, the actual futures price at delivery is unknowable, and it is very likely to be different from today's futures price. If the hedger has the right combination of futures and cash bonds, interim price movements will not matter (much) to the final holding-period returns. Having to trade in even numbers of contracts and including interest earned or paid on marked-to-market cash flows can make the holding-period returns different from the implied repo.

Benninga and Wiener [1999, p. 39] note that "an extensive literature dealing with the CTD when the term structure is flat has somehow become mired in the misconception that the CTD is characterizable in terms of the duration." In a footnote, they continue that Jones [1985] seems to have been the first to have stated that duration is the determining factor in choosing the CTD, and that similar statements are found in textbooks (e.g., Edwards and Ma [1992]).

The explanation of why duration should determine CTD proceeds as follows. As interest rates rise, all deliverables' prices fall, and the longest-duration bonds/notes fall fastest, making them CTD. Conversely, prices rise as interest rates decline, with the shortest-duration notes and bonds rising least, making them CTD. Curve-steepening or flattening can enhance or diminish the duration effect but as yields get farther away from the notional coupon, the duration effect dominates.

For several years prior to March 2000, interest rates were far enough below the notional coupon (then 8%) that there was no mystery about which issue would be CTD into each bond contract. It would certainly be the shortest-duration instrument—US 11.25% 2/15/2015. This issue was and will almost certainly continue to be the all-time champion CTD in terms of longevity. This phenomenon reinforced the mistaken belief that movements in CTD are purely a matter of duration.

As of March 2000, the notional coupons of the hypothetical underlying issues for U.S. Treasury note and bond contracts were changed from 8% to 6%. This seemingly small change has had a profound impact on which instruments are CTD. Much less well known, and less well understood than the duration effect, is the fact that there is also a wholly separate *coupon effect* that influences which note or bond in the deliverable basket is CTD.

The coupon effect results from calculating conversion factors for shorter terms to maturity than the bonds actually have on the first delivery date. In calculating conversion factors, the CBOT rounds the maturities *down* to the nearest quarter. These calculations induce a bias toward the lowest-coupon deliverables, at least when yields are in the neighborhood of 6%. While many researchers include a footnote or a text passage that the CBOT rounds down to the next quarter to calculate conversion factors, nearly none voices any concern over the possible impact of that choice. Our research is devoted to examining this overlooked coupon effect.[1]

Our results suggest that for yields in the neighborhood of the 6% notional coupon rate (where markets spent considerable time in 1995–2001), the lowest-coupon Treasury in the deliverable basket will be CTD. This result holds for yields both above and below 6%. Moreover, this issue remains CTD for a notable range of yields. A 40 basis point range appears to be appropriate.

I. CONVERSION FACTOR DEFINITION AND PULL TO PAR

The coupon effect determining CTD that we describe comes from the confluence of pull to par and the CBOT's definition of conversion factor. We first consider the pieces separately.

The first half of the coupon effect in Treasury futures contracts is attributable to pull to par. Treasury bonds mature at par. Prior to maturity, the price can be quite far from par. For example, on February 6, 2004, US 11.25 2/15/2015 traded at about 162% of par. In early 2015, that bond will trade very close to par, irrespective of market yields, and it will mature at par. The predictable price change as premium prices decline and discount prices increase over time at constant yields is called *pull to par*.

To be sure, it is possible for the US 11.25 2/15/2015 to increase in price over the next few months if market yields drop. Similarly, discount bonds can decline farther in price if yields increase. Still, because all Treasuries mature at par, those movements become dampened as maturities (and durations) shorten. Then, the expected price movement to par resumes.

EXHIBIT 1

Pull to Par—Time Path of Premium, Par, and Discount 10-Year Notes

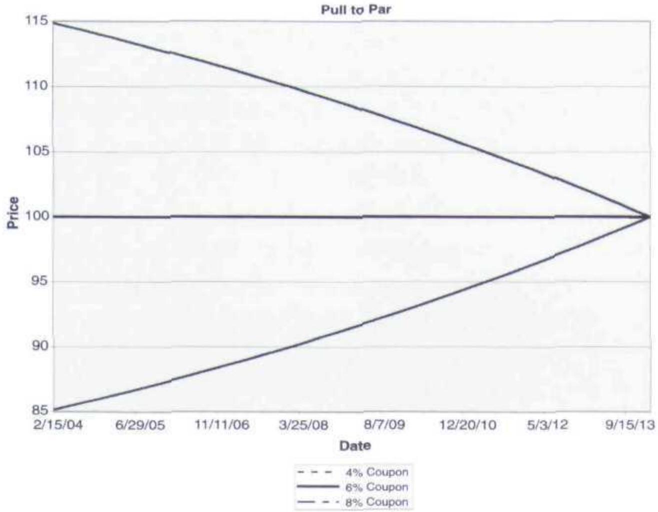

Exhibit 1 plots the time path of three ten-year note prices at a constant 6% yield. Their coupons are 8%, 6%, and 4%. The 8% coupon begins with about a 15 point premium, and the 4% begins with about a 15 point discount. The 6% coupon bond trades nearly identically to 100 for the entire time.

The reason pull to par matters in futures contracts is that conversion factors are set as of a specific date; they are not variable depending on the delivery date. For a 6% coupon bond or note with a conversion factor at or near one, the effect is irrelevant. The more the coupon deviates from the 6% yield used to compute conversion factors, the more important the precise choice of maturity for computing conversion factors becomes.

The second half of the coupon effect on CTD is the CBOT's definition of conversion factor. The latest rules for bonds read, in part:

> 1836.01 Standards—The contract grade for delivery on futures contracts made under these regulations shall be long term U.S. Treasury bonds which if callable are not callable for at least 15 years or if not callable have a maturity of at least 15 years. All bonds delivered against a contract must be of the same issue. For settlement, the time to maturity (time to call if callable) of a given issue is calculated in complete three month increments (i.e. 15 years and 5 months = 15 years and 1 quarter) from the first day of the delivery month. The price at which a bond with this time to maturity (time to call if callable) and with the same coupon rate as this issue will yield 6% according to bond tables prepared by the Financial Publishing Co. of Boston, Mass., is multiplied times the settlement price to arrive at the amount which the short invoices the long.

Similarly, for the ten-year U.S. Treasury note futures contract:

> 2436.01 Standards—The contract grade for delivery on futures contracts made under these regulations shall be U.S. Treasury Notes which have an actual maturity of not less than six and one-half years and not more than ten years. All notes delivered against a contract must be of the same issue. For settlement, the time to maturity of a given issue is calculated in complete quarter year increments (i.e. 8 years, 10 months, 17 days is taken to be 8 years, 9 months) from the first day of the delivery month. The price at which a note with this time to maturity and with the same coupon rate as this issue will yield 6%, according to bond tables prepared by the Financial Publishing Co. of Boston, Mass., is multiplied by the settlement price to arrive at the amount at which the short invoices the long.

The important point in these passages is that the rules round the term to maturity *down* to the next quarter-year for all issues in the deliverable basket.

All Treasury bonds other than TIPS mature on February 15, May 15, August 15, or November 15. All deliverable ten-year notes mature on the same dates.

Treasury futures contracts trade with March, June, September, and December expiration dates. Conversion factors are computed as of the first day of the delivery month. For example, on June 1, 2004, a deliverable note that will mature on August 15, 2012, with an actual maturity of 8 years and 2½ months would be rounded down to 8 years maturity, for the conversion factor calculation. The deliverable will be priced on June 1, 2004, as if it matured on June 1, 2012. There are 2½ months of pull to par built into the conversion factors if shorts deliver on the first of the delivery month and 1½ months of pull to par if they deliver on the last delivery day.

If the deliverable basket's coupons are clustered close to one another, especially if they are clustered close to 6% (i.e., the notional coupon), then it appears that the conversion factor definition, and how it handles the pull to par, makes essentially no difference to which bonds or

EXHIBIT 2

Implied Repo and CTD for Hypothetical 10-Year Futures Contracts

Panel A *First-of-Month Delivery*

Coupon Rate (%)	Maturity Date	Market Price	Yield	Modified Duration	Conversion Factor	Implied Repo (%)
	1	2	3	4	5	6
6.625	5/15/2007	103.6177	6.00%	5.53	1.0351	5.892%
6.125	8/15/2007	100.7461	6.00%	5.67	1.0071	5.902%
5.5	2/15/2008	96.8597	6.00%	6.07	0.9694	5.902%
5.625	5/15/2008	97.5779	6.00%	6.29	0.9765	5.892%
4.75	11/15/2008	91.5795	6.00%	6.77	0.9180	5.892%
5.5	5/15/2009	96.4804	6.00%	6.93	0.9657	5.892%
6	8/15/2009	100.0000	6.00%	6.88	0.9999	5.902%
6.5	2/15/2010	103.7194	6.00%	7.05	1.0363	5.902%
5.75	8/15/2010	98.0731	6.00%	7.48	0.9810	5.902%

Note: Contract date = 6/1/2000.
Cash settlement = 2/15/2000 and Futures Delivery = 6/1/2000.
Contract Price = 100.

Panel B *Month-End Delivery*

Coupon Rate (%)	Maturity Date	Market Price	Yield	Modified Duration	Conversion Factor	Implied Repo (%)
	1	2	3	4	5	6
6.625	5/15/2007	103.6177	6.00%	5.45	1.0351	5.902%
6.5	2/15/2010	103.7194	6.00%	6.98	1.0363	5.878%
6.125	8/15/2007	100.7461	6.00%	5.59	1.0071	5.838%
6	8/15/2009	100.0000	6.00%	6.80	0.9999	5.821%
5.75	8/15/2010	98.0731	6.00%	7.40	0.9810	5.792%
5.625	5/15/2008	97.5779	6.00%	6.22	0.9765	5.770%
5.5	5/15/2009	96.4804	6.00%	6.85	0.9657	5.757%
5.5	2/15/2008	96.8597	6.00%	6.00	0.9694	5.753%
4.75	11/15/2008	91.5795	6.00%	6.69	0.9180	5.649%

Note: Contract date = 6/1/2000.
Cash settlement = 2/15/2000 and Futures Delivery = 6/30/2000.
Contract Price = 99.968175.

notes will be CTD. In reality, this is not the case. For example, for the June 2000 ten-year note contract, the coupons in the deliverable basket ranged from $4^3/_4$% to $6^5/_8$%. Issues with coupons below 6% receive some windfall gains because they get $2^1/_2$ months of appreciation when priced at 6% yield on the first delivery date with maturity rounded down. Issues with coupons above 6% have premature price depreciation.

II. ILLUSTRATION

A simple example of a ten-year note contract will illustrate this clearly. We use the June 2000 note contract.[2] In the examples below, we look at implied repo rates as a proxy for holding-period returns for trades entered on February 15.

Exhibit 2 demonstrates futures deliverables when conversion factors are calculated as of the first delivery date—June 1—but maturities are not rounded down. In Panel A, column 1 shows the maturity date of each of the Treasuries in the deliverable basket. Column 2 shows the current market price of each note, assuming a cash settlement date of February 15, 2000. Column 3 confirms that each issue was priced to yield 6%. Column 4 gives each note's modified duration, and column 5 presents the conversion factors calculated using the price of the deliverable note on the first delivery day of the contract month. Note that this differs from actual futures contracts in that maturities are not rounded down to the nearest quarter. Finally, the last column is the implied repo rate.

The implied repo rate is the rate of return from this trade: Buy a Treasury from the deliverable basket, short Treasury futures contracts, and deliver the selected Treasury issue on the futures delivery date.[3]

Recall that the trade that leads to this implied repo is building synthetic cash, and the money market equivalent of a 6% bond yield is 5.902%. The reason there are small differences in return for some issues is that Treasury notes and bonds accrue their coupons on an actual/ actual day-count basis. For the span we are considering here, notes on the February/August payment cycle have 182 days in the denominator. Notes on the May/November cycle have 182 days in the denominator until the May 15 coupon payment and 184 days in the denominator from May 15 to futures delivery, either June 1 or June 30. The upshot is that the issues on the May/November payment cycle earn a slightly lower implied repo than issues on the February/August cycle because of a slightly slower rate of coupon accrual at the end of the holding period.

The results in Panel A of Exhibit 2 display no pull to par, and all the deliverables are nearly equally cheap to deliver. The conversion factors do the job that conversion factors are supposed to do; they handicap the deliverables to make them substitutes for one another.

Panel B of Exhibit 2 presents the deliverables for month-end settlement, but with conversion factors still calculated as of the first of the month. The cash note settlement date is February 15, and futures delivery is June 30.

The reason we compare end-of-month settlement is to demonstrate that there is a coupon effect unless one uses a different conversion factor for each possible delivery date. This effect cannot be repaired by redefining the conversion factor as of the last day of the month. That would simply move the effect from the last delivery day to the first. Here, the initial futures price must be different from 100 to make the implied repo rate on the CTD equal 5.902%.

EXHIBIT 3

Implied Repo and CTD for Actual 10-Year Futures Contracts

Panel A *First-of-Month Delivery*

Coupon Rate (%)	Maturity Date 1	Market Price 2	Yield 3	Modified Duration 4	Conversion Factor 5	Implied Repo (%) 6
4.75	11/15/2008	91.5795	6.00%	6.77	0.9195	6.422%
5.5	2/15/2008	96.8597	6.00%	6.07	0.9702	6.173%
5.5	5/15/2009	96.4804	6.00%	6.93	0.9662	6.054%
5.75	8/15/2010	98.0731	6.00%	7.48	0.9814	6.028%
5.625	5/15/2008	97.5779	6.00%	6.29	0.9769	6.017%
6	8/15/2009	100.0000	6.00%	6.88	1.0000	5.934%
6.125	8/15/2007	100.7461	6.00%	5.67	1.0071	5.892%
6.5	2/15/2010	103.7194	6.00%	7.05	1.0358	5.746%
6.625	5/15/2007	103.6177	6.00%	5.53	1.0342	5.610%

Note: Contract date = 6/1/2000.
Cash settlement = 2/15/2000 and Futures Delivery = 6/1/2000.
Contract price = 100.

Panel B *Month-End Delivery*

Coupon Rate (%)	Maturity Date 1	Market Price 2	Yield 3	Modified Duration 4	Conversion Factor 5	Implied Repo (%) 6
4.75	11/15/2008	91.5795	6.00%	6.77	0.9195	6.153%
5.5	2/15/2008	96.8597	6.00%	6.07	0.9702	6.054%
5.5	5/15/2009	96.4804	6.00%	6.93	0.9662	5.971%
5.75	8/15/2010	98.0731	6.00%	7.48	0.9814	5.979%
5.625	5/15/2008	97.5779	6.00%	6.29	0.9769	5.955%
6	8/15/2009	100.0000	6.00%	6.88	1.0000	5.934%
6.125	8/15/2007	100.7461	6.00%	5.67	1.0071	5.918%
6.5	2/15/2010	103.7194	6.00%	7.05	1.0358	5.842%
6.625	5/15/2007	103.6177	6.00%	5.53	1.0342	5.766%

Note: Contract date = 6/1/2000.
Cash settlement = 2/15/2000 and Futures Delivery = 6/30/2000.
Contract price = 100.

Panel C *First-of-Month Delivery Priced for Coupon Effect*

Coupon Rate (%)	Maturity Date 1	Market Price 2	Yield 3	Modified Duration 4	Conversion Factor 5	Implied Repo (%) 6
4.75	11/15/2008	91.5795	6.00%	6.77	0.9195	5.902%
5.5	2/15/2008	96.8597	6.00%	6.07	0.9702	5.647%
5.5	5/15/2009	96.4804	6.00%	6.93	0.9662	5.536%
5.75	8/15/2010	98.0731	6.00%	7.48	0.9814	5.503%
5.625	5/15/2008	97.5779	6.00%	6.29	0.9769	5.499%
6	8/15/2009	100.0000	6.00%	6.88	1.0000	5.409%
6.125	8/15/2007	100.7461	6.00%	5.67	1.0071	5.367%
6.5	2/15/2010	103.7194	6.00%	7.05	1.0358	5.222%
6.625	5/15/2007	103.6177	6.00%	5.53	1.0342	5.094%

Note: Contract date = 6/1/2000.
Cash settlement = 2/15/2000 and Futures Delivery = 6/1/2000.
Contract Price = 99.8440.

Because month-end delivery makes the February 15 futures price lower, that is the price that would prevail in the market. The higher price associated with June 1 delivery would allow returns higher than 5.902% for participants who postpone delivery until the last day.

Now, consider futures contracts as they are actually structured on the CBOT. The results are presented in Exhibit 3. The conversion factors in all panels are calculated according to the CBOT rules, which round down to the nearest quarter and are rounded to four decimal places. The 4.75% coupon note is CTD, and, more important, it has the lowest coupon. In fact, the deliverable basket sorts nearly monotonically by coupon for this collection of deliverables. The one exception is for two coupons that are extremely close, but on different halves of the February/August versus May/ November payment cycle.

Notice as well that the maturity dates and modified durations are a jumble. With the bonds priced at 6%, there should not yet be a duration effect in determining CTD, and there is not. Only a coupon effect shows up at this point.

These conversion factors, the ones in actual use, do a significantly worse job of handicapping the deliverable basket. So, unless the CBOT changes to different conversion factors for each delivery date, there will be a coupon effect in determining CTD. The effect is greater when yields have been away from 6% (the notional coupon) by a significant amount (causing Treasuries to be issued with significantly higher or lower coupons than 6%), and then return to the neighborhood of 6%.

Panel B of Exhibit 3 presents the CTD sorting and implied repo for delivery on the last day of the delivery month. Because the pull to par effect is reduced from 2½ months to 1½ months, there is less of an implied repo difference between CTD and richest to deliver, but the amount is still economically significant.

As an aside, the short side of a Treasury futures contract has the option to choose which note or bond to deliver and when. Traditionally, this option is divided into four components: 1) quality option, 2) timing option, 3) end-of-month option, and 4) wild card option. We address the *quality option*, the short's choice of deliverable bond, the CTD. Embedded in our analysis is an interaction between the quality option and the timing option. Because the CTD depends on premature pull to par, the delivery date influences how much extra pull to par occurs. If delivery is delayed until the end of the month, the extra pull to par is lower than for deliveries on the first of the month.

The delivery date depends on the CTD's current yield compared with short-term funding costs. Typically, the U.S. yield curve slopes upward and gives shorts an incentive to deliver on the last day of the month instead of the first. This inclination is reinforced by keeping the other aspects of the delivery option alive as long as possible. With our flat yield curve, first of the month delivery is optimal.

Recall in Panel A of Exhibit 2 that the implied repo is nearly the same for the entire basket at 5.902%. Where must the contract be priced with actual conversion factors on the deliverables to make the implied repo of the CTD 5.902%? The result is in Panel C of Exhibit 3. The price of the contract must be lowered from 100 to 99.8440 to have the implied repo on the CTD be 5.902%, if delivery takes place on the first delivery day. The delivery option begins in the money significantly, approximately 5/32nds of a point of price, even before taking into account possible yield changes.

III. CONCLUSION

The results of this study demonstrate that the cheapest to deliver on a Treasury futures contract depends on coupon differences as well as duration differences. This phenomenon occurs when the yields of the securities in the deliverable basket are close to the notional coupon. The coupon effect comes from the pull to par as a result of the Chicago Board of Trade's conversion factor formula. Further, the coupon effect reduces the price of futures contracts because the delivery options are in the money from the outset.

ENDNOTES

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[1]Two other coupon effects pertain in Treasury futures contracts. The second coupon effect can be seen by differentiating the CTD relationship at expiration (bond price divided by conversion factor) with respect to coupon and maturity, and solving for the optimum (see Kilcollin [1982], Kane and Marcus [1984, 1986], Livingston [1984, 1987], Jones [1985], Arak, Goodman, and Ross [1986], Hegde [1987], and Benninga and Wiener [1999]). For the most part, this effect fits under the rubric of delivering the highest-duration notes and bonds when yields are above the discount rate used in calculating conversion factors, now 6% and formerly 8%, and delivering the lowest-duration notes and bonds when yields are below the discount rate used in calculating the conversion factors. Livingston [1984] and Benninga and Wiener [1999] show that the duration rule breaks down when the deliverable basket is deeply discounted—e.g., prices in the 50s and 60s.

The third coupon effect in Treasury futures contracts comes from the early empirical observation that bond yields increase with bond coupon (see Kilcollin [1982], Livingston [1984, 1987], Meisner and Labuszewski [1984], Arak, Goodman, and Ross [1986], and Kane and Marcus [1986]). If higher-coupon bonds have higher yields, then there should be a tendency for the highest-coupon bonds to be CTD. This effect was attributable to different treatments of coupon income and capital gains for bonds. Multiple changes in the tax laws appear to have eliminated this effect.

[2]The June 2004 contract has deliverables whose coupons range from $3^5/8$% to 5%. Because no 6% and above coupons are included, the earlier contract provides a better illustration.

[3]If the contract were priced precisely at par, the implied repo rate would not equal 5.902%, as it must to avoid arbitrage. The market price of the contract on February 15 that makes the implied repo 5.902% is 100.0012. It differs from 100 because bonds priced with yields equal to their coupon rate trade at a slight (or small) discount to par other than on coupon dates. The 100.0012 price would never be observed because the minimum tick size in ten-year note futures is 1/2 of a 32nd, or 0.015625. But, to make the numbers agree, we use the calculated price.

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