Special delivery

How delivery options can substantially distort rich/cheap metrics for US Treasury futures

- With year-end weighing heavy on funding markets, front-end Treasury futures are trading quite rich to their CTD bonds, but the story looks a bit more complicated out the curve…
- In particular, rich/cheap metrics for UXY and WN, and to a lesser extent TY, FV and US, are all substantially influenced by the value of strategic delivery options
- Delivery optionality—in today's yield curve environment, most notably the wildcard option—can comprise the majority of the net basis in these contracts and has an outsized influence on implied repo rates, particularly as the roll period (just prior to the delivery month) approaches
- These effects cause futures contracts to appear optically cheap relative to their true dislocation from cash bonds
- In this note we discuss recent trends in US Treasury futures delivery options and their influence on both the CTD net basis (BNoC) and implied vs CTD repo rates
- We also highlight option-adjusted net basis and implied repo rates, which can be used to more cleanly assess where futures are trading relative to cash

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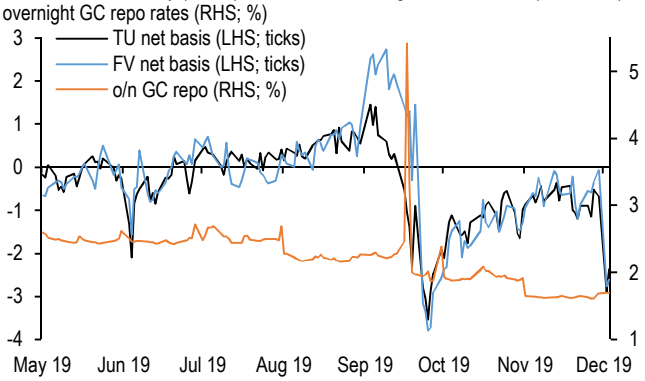
As funding markets and various front-end plumbing issues come into focus, so too has cash/futures RV and the hunt for opportunities in the bond basis. Since the September episode in overnight repo, the CTD basis net of carry (BNoC) across contracts fell sharply, as futures strongly outperformed their cash counterparts (**Exhibit 1**). While this led to a negative net basis in the front end (e.g. TU and FV contracts), things were not so simple further out the complex. The WN contract in particular has failed to see a meaningfully negative net basis, and UXY also looks quite positive at the moment for both the March and soon-to-expire December futures (**Exhibit 2**). Likewise, when comparing these contracts' implied repo rates to term repo on their CTD bonds (another popular rich/cheap metric) these contracts have appeared optically quite "cheap" relative to cash. What gives?

Exhibit 1: Following the September shakeup in repo markets, the CTD basis dropped sharply, and turned negative for front-end futures contracts, recovering only partially since

CTD basis net of carry (BNoC) for TU and FV rolling front* contracts (LHS; ticks) vs overnight GC repo rates (RHS; %)

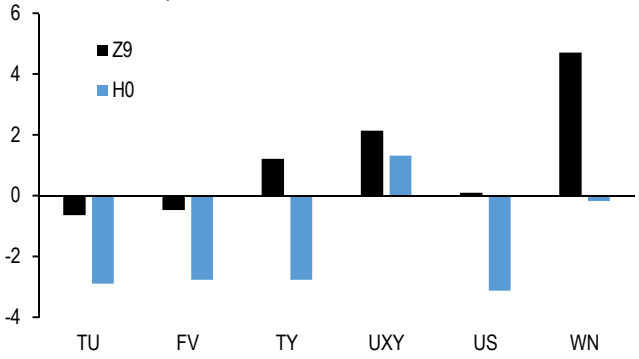


* Front contract is the next contract to expire, except in delivery months, where we roll to the following contract (e.g. in December 2019, this would be TUH0)

Source: J.P. Morgan, Reuters

Exhibit 2: But further out the curve looks can be deceiving, as the net basis has appeared optically positive, and at times quite *high*

CTD basis net of carry for the December and March futures contracts; ticks



Note: Current as of 12/3/19

Source: J.P. Morgan, Reuters

For most of the post-crisis era, **measures like the BNoC and/or comparing the implied repo rate** to the CTD bond's term repo rate to delivery provided relatively clean rich/cheap metrics for the cash/futures basis. But **as meaningful option value has crept back into the contracts these RV metrics have become somewhat polluted and require adjustment to reflect divergence from fair value.** This happened first—and still most prominently—with the newer "ultra" contracts (WN and UXY), but has meaningfully affected every contract beyond TU in recent years. In this note we briefly enumerate the most important delivery options and how they impact the contracts. We then highlight "option-adjusted" rich/cheap metrics that can be used to asses true dislocations in the cash/futures basis.

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Optionality is back across the complex, mostly in the form of the 'wildcard'

The cash/futures CTD basis (i.e. the *gross* basis) is driven first and foremost by carry. Someone short the futures contract intending to make delivery (or trade the basis) typically needs to source the cheapest-to-deliver (CTD) bond, and hold it until they can make delivery. In the meantime, the short earns carry, which causes the future to typically trade at a discount relative to the CTD's clean price. Thus to judge how rich/cheap a contract is relative to the CTD, investors will typically reference the basis net of carry (or *net* basis, aka BNoC). But this too is not a clean rich/cheap metric due to option value—someone short the future gets to decide which eligible bonds get delivered, and when in the contract's delivery month to make delivery. These choices deliver the short meaningful option value that can persistently widen the net basis, i.e. they cause futures to trade cheap to cash, even adjusted for carry. **Thus a true rich/cheap metric is the option-adjusted net basis, or OA BNoC**.

Pre-crisis, when yields were closer to the 6% level from which CTD conversion factors are derived, the **switch option was the most important of these delivery options.** As yields moved around, the cheapest-to-deliver bond would shift, preferentially to shorter duration bonds in a rally and higher duration bonds in a selloff. This reduced the future's convexity relative to a cash bond of the same duration, and caused the future to trade at a structural discount. While the CTD bond still switches on occasion in multiple contracts, the switch is essentially valueless. Yields today are much lower than the 6% reference rate, which causes the shortest duration bonds in the eligible delivery basket to always become CTD. When a switch does occur, it typically causes a shift into a bond with a nearly identical duration, and thus the option fails to meaningfully change the contract's convexity profile.

Immediately **post-crisis**, meaningful optionality was more or less gone from U.S. Treasury futures. But as long-end yields moved ever-lower, a couple of important changes occurred. **First**, CTD conversion factors got smaller. And **second,** carry to delivery likewise diminished as the curve flattened meaningfully. Both of these factors conspired to make the **wildcard option** quite valuable, first in the ultra-contracts, and then more recently across the curve. The wildcard option arises from a quirk of the futures exchange: the invoice price a short would earn from making delivery each day is frozen after pit-close in Chicago, at 3pm Eastern time. But the underlying CTD bond continues to trade after this time, remaining quite liquid until at least 5pm Eastern time, and notice of intent to deliver need not be made until 8pm Eastern. If a substantial rally occurs post-3pm, assuming the short holds a duration-hedged amount of the cash bond against the future contracts, they will notice a tidy intraday P/L on the bond leg that has not occurred on the futures invoice price. If the short does nothing, this profit will be erased the next morning when the future begins to trade again. But if the short makes delivery into the contract, one can realize a small profit. The profit does not occur on the entirety of the bond notional, since the short needs to make delivery, after all, at the invoice price. But the duration-hedged notional is typically larger than the required delivery amount **when conversion factors are low**, and this "tail" of excess bond notional can be sold away at the current prevailing bond price.

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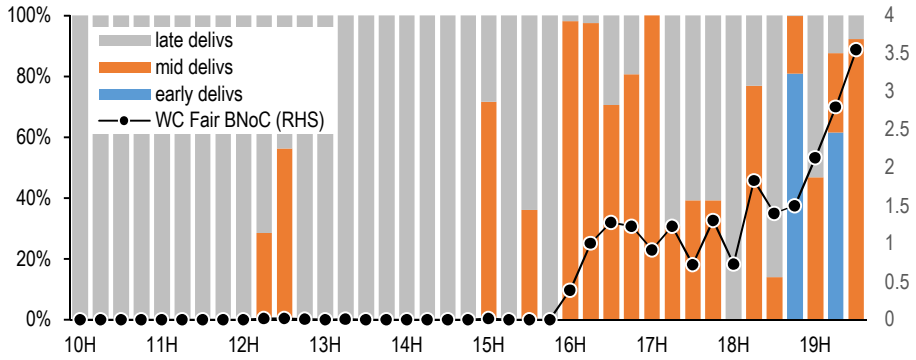
What makes this an option-like payoff is no equivalent loss need be suffered if the market sells off—while the bond's mark-to-market would indeed be negative, the short need only wait for the next morning, when the future begins to trade again, for this loss to be erased. This optionality is what leads to the future trading at a discount. Complicating matters is the opportunity cost of exercising the wildcard. Making delivery early in the month will cause the short to forgo any carry on the underlying CTD that they would have earned in the subsequent few days. For this reason, the wildcard is more likely to be exercised later in the delivery month. A final consideration is the opportunity cost of exercising the wildcard today versus waiting for an *even larger* post-close rally (plus an extra day's carry) tomorrow. For a detailed framework for pricing this option, see *Good things come to those who wait*, M. Salem et al., 5/18/18.

Exhibit 3: Mid-month deliveries into the WN contract have become the rule, not the exception, as the WN wildcard option has risen in value

Percentage of deliveries in the WN contract broken out into early/mid/late* in the month (LHS; %) versus wildcard fair value BNoC* (RHS; ticks)



* **Early** deliveries are those occurring within three business days of the first delivery date, **late** deliveries are those occurring within three business days of last delivery, and **middle** deliveries occur on any other day of the contract month

† Wildcard fair value BNoC is the solved for by finding the net basis that precisely cancels the option's value, assuming 1bp/2hr post-close volatility in yields and 2bp/2hr on FOMC days. For details see *Good things come to those who wait*, M. Salem et al., 5/18/18. Valuations shown as of the last day before the delivery month.

Source: J.P. Morgan, Reuters, CME

The wildcard is hardly a theoretical construct designed to annoy CTD basis traders. **Since 2016**, when we estimate this option gained meaningful value (e.g. a few ticks), **the WN contract has seen a majority of deliveries occurring mid-month** (**Exhibit 3**, e.g. not within a few business days of either first or last delivery date). While WN is consistently the worst-offender owing to a very low conversion factor (0.6141 for the WNH0 contract), **other contracts have gained substantial option value** as carry to delivery (and thus the opportunity cost of exercising the wildcard) has fallen across the curve (**Exhibit 4**). To be sure, the wildcard is not the only factor that can drive mid-month deliveries. With carry hovering near-zero, and CTD switches occurring in contracts between bonds of disparate coupons, carry has sometimes dipped negative mid-month, likewise incentivizing early delivery. This has likely occurred in TU in recent quarters.

Why should wildcard optionality be enforced? After all, the vast majority of open interest in Treasury futures promptly rolls from front to back contracts a few days ahead of the delivery window, leaving a small quantity of users genuinely interested in taking or making delivery of the underlying bonds. The key user base here are levered funds, which make up roughly half of open interest in futures throughout the year (typically facing the asset manager community which of late has been mostly

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net long the complex). Should the wildcard be grossly mispriced, a substantial fraction of levered funds, who generally can take delivery if need be, could remain in the contract to realize the differential, in expectation. That said, **the wildcard *has* been mispriced in the past, even in the WN contract.** And we've noted in many past futures rollover outlooks that this mispricing tended to fade during the roll period, when the open interest fell to just the community of investors actively policing delivery dynamics. **This dynamic went a good part of the way towards explaining a very consistent bearish cyclical in the WN calendar roll**—a cyclical that has subsided as the WN wildcard has become more fairly priced well ahead of the calendar roll (e.g., see Exhibit 7 below). While recent dynamics are more efficient in that contract, opportunities tend to exist elsewhere in the complex, particularly since conversion factors, carry, late-day volatility and the prevalence of event risk late in the delivery period all serve to push the wildcard's fair value up and down by a substantial amount each quarter.

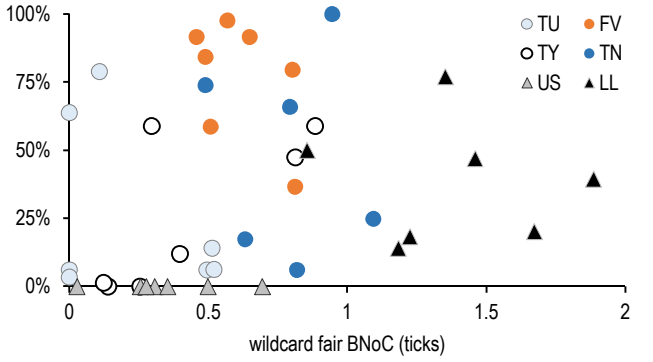
How much is this worth for the rich/cheap metrics?

We estimate the wildcard option of late has been worth roughly three ticks to the net basis in WN and roughly 0.5-1.5 ticks elsewhere, most often in TN but sometimes in FV and TY as well. A very small amount of optionality has also appeared in US as of the last roll. In elevated vol environments, the option can easily increase in value by an additional 50-100%, and FOMC meetings timed towards the end of the delivery month can likewise boost its value substantially.

While a few ticks sounds like chump change, this must be placed in the context of the net basis, which is almost always just a few ticks in value. Beyond this, we note just how large open interest is in the deep and liquid Treasury futures market—WN alone commands roughly $40mn/tick in P/L across all current open interest. **And as of mid-November, wildcard optionality could explain a majority of the variation in net basis from FV to WN (Exhibit 5).**

Exhibit 4: And likewise, mid-month deliveries have picked up across contracts in recent quarters, complicating how to properly compute both implied and CTD term repo

Percentage of deliveries occurring mid-month* versus wildcard far value BNoC†; %



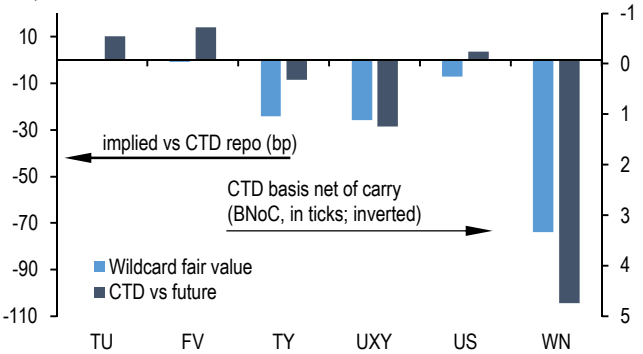
* Mid-month deliveries defined as those occurring more than three business days after the start of the month and more than three business days prior to the last delivery date

† Wildcard fair value BNoC assessed as in Exhibit 3. Valuations shown as of the last day before the delivery month.

Source: J.P. Morgan, CME

Exhibit 5: Across contracts, the wildcard often dominates the divergence of the CTD basis from "fair value", whether you measure this via implied repo or the CTD net basis (BNoC)

Z9 CTD/futures basis rich/cheap metrics vs wildcard option fair value* measured two ways: via implied repo vs CTD repo (LHS; bp) and via the net basis (RHS; ticks) as of mid-November



* Wildcard option valued as in Exhibit 3. To convert the WC fair value BNoC to an implied repo differential, see the formula in the appendix to this note.

Source: J.P. Morgan, Reuters, CME

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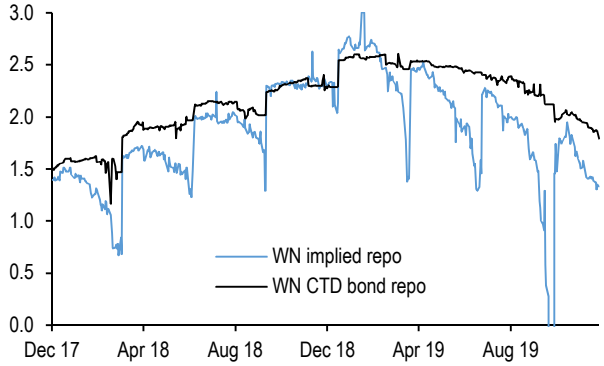
Another rich/cheap metric popular for assessing futures vs. cash is the implied repo rate, and here the wildcard option can really wreak havoc. Implied repo measures the annualized percentage return a trader would earn selling the futures contract, immediately sourcing the underlying cash bonds, and holding them to *optimal* delivery. If optionality is of no consequence, the implied repo rate should converge to the term repo rate on offer for the underlying CTD bond. A higher implied repo implies futures are rich relative to cash, and a lower implied repo means they are cheap. On a given day, under given delivery assumptions, **the divergence of implied and CTD repo maps one-to-one to the BNoC: a non-zero repo differential is caused by a non-zero BNoC**, meaning these two rich/cheap metrics are logically equivalent (see the Appendix to this note for details).

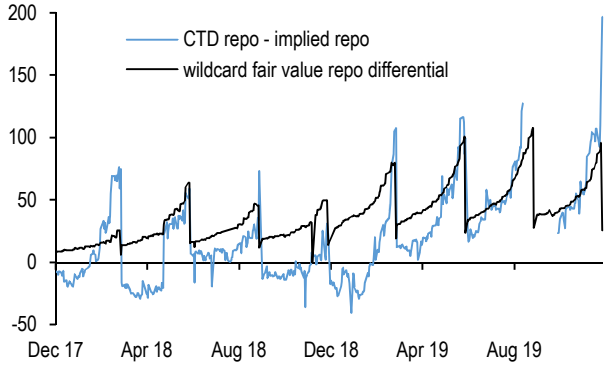
That said, the implied/term repo differential is far less well behaved than the BNoC, particularly in the presence of optionality. To see this, consider the recent behavior of the WN contract. WN's implied repo has plunged as the delivery month approaches each quarter (**Exhibit 6**) opening up a 50-100bp gap between this rate and the CTD term repo to delivery—all this from just a few ticks of option value! This happens due to the rate being annualized: as the number of days to last delivery shrinks, a constant BNoC drives a larger and larger wedge between the term and implied repo rates. Thus the effect is merely optical. In fact, our wildcard fair value model can do a pretty good job modeling this quarterly cyclical (**Exhibit 7**), the cyclical itself having converged to such fair value models more faithfully in recent rolls, as the wildcard has become more efficiently priced.

Exhibit 6: The ultra-bond future's implied repo level has shown a strong, cyclical divergence from repo on the underlying CTD bond…
WN CTD bond repo to optimal delivery vs WN implied repo; %



Note: WN contract is the "front" contract (next to be delivered) except in delivery months, where it is the following quarter's contract (e.g. in December 2019, it's the WNH0 contract)
Source: J.P. Morgan, Reuters

Exhibit 7: …a divergence well explained in recent quarters by the value of the wildcard option
WN CTD repo less implied repo vs wildcard fair value repo differential*; bp



Note: We eliminate 9/15/19-10/15/19, i.e. the September repo event, for clarity
* Wildcard fair value solved for by finding the net basis that precisely cancels the option's value, assuming 1bp/2hr post-close volatility in yields and 2bp/2hr on FOMC days. We then convert this to an implied repo differential using the formula presented in the appendix to this note.
Source: J.P. Morgan, Reuters

While WN is again the biggest culprit, optionality has likewise distorted implied/term repo differentials across the complex, **by roughly 10-30bp in the TYZ9, UXYZ9 and USZ9 contracts as of mid-November** (again Exhibit 5). This is less evidence of how valuable the wildcard is and more evidence of how poorly behaved implied repo is as a rich/cheap metric as the roll (and delivery) period approaches. Furthermore, in the presence of delivery dynamics (not only the wildcard option, but also the role of negative carry, discussed below), implied repo becomes a cumbersome metric to deal with, since the precise number of days until optimal delivery is unknown—as Exhibits 3, 4 and later 8 attest to, *last* delivery is often a poor assumption. And as the days-to-likely-delivery shifts around, the increasingly small denominator of the implied repo formula makes this metric very poorly behaved, particularly into the roll and delivery periods.

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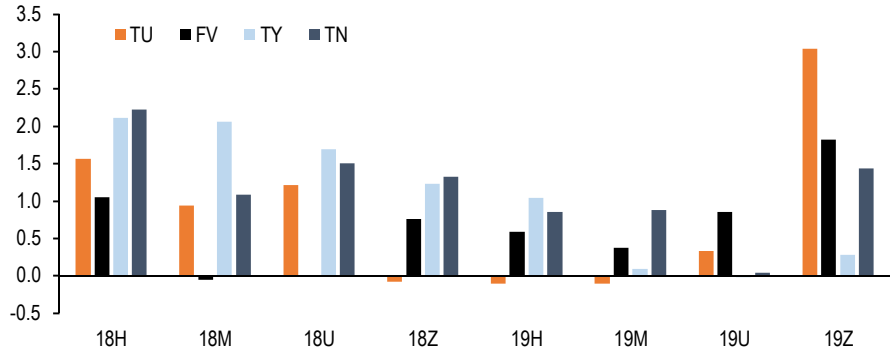
Just like option-adjusted net basis (OA BNoC) is a useful, clean rich/cheap metric for futures, we can likewise introduce an **option-adjusted implied repo rate**, by adding the option value back into the implied repo to properly compare to the CTD bond rate. The formula for this is presented in the appendix to this note, and while it's a cute result to keep in mind, we nonetheless view OA BNoC as a far better-behaved metric for the reasons enumerated above. That said, OA implied repo can be a useful metric where option value is moderate and optimal delivery is more or less well understood.

Exhibit 8: Low-to-negative carry has arisen recently across much of the U.S. Treasury futures complex, driving early delivery in TU and enriching the wildcard option everywhere else
Percentage of deliveries in the WN contract broken out into early/mid/late* in the month; %



Source: J.P. Morgan

Negative carry alone need not meaningfully impact futures fair value, but *does* affect implied repo

With a flatter yield curve, negative carry has become an important feature in TU, and occasionally FV and TY futures contracts (**Exhibit 8**). **To avoid bleeding carry, a rational investor short the futures contract would opt to make delivery as soon as possible in the delivery month.** In TU this behavior arrives like clockwork whenever talk of rate cuts moves to the forefront (**Exhibit 9**). For the most recent Z9 roll, negative carry was not a front-and-center concern, but the story may be a bit different in H0.

For modestly negative carry on contracts with low conversion factors (e.g. FV, TN and to some extent TY), wildcard optionality can again muddy the waters. Rather than incentivizing early delivery, the wildcard can now compel the short to *wait beyond* first delivery in hopes of a large post-close rally (see *Good things come to those who wait* for details).

Under any of these scenarios, both implied repo and the net basis must be computed assuming first or mid-month delivery, rather than last delivery. In periods where quarter and year-end repo market stress are anticipated (e.g. right now!) this can meaningful change *both* the implied and CTD term repo rates. This was briefly a concern in TYZ9, but falling finance rates allayed the risk of early delivery therein. Heading into March, with quarter-ends still proving somewhat challenging for repo markets, similar concerns can arise should early delivery become a concern.

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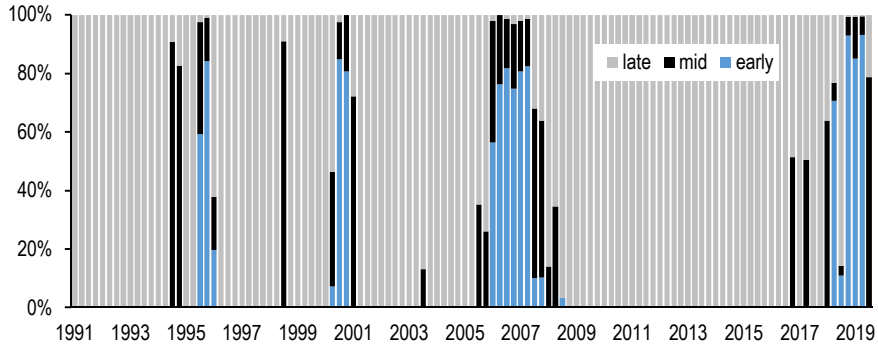
Exhibit 9: For the 2-year contract, negative carry compels early delivery whenever the front-end of the curve inverts, a situation quite prevalent over the past two years

Percentage of deliveries in the TU contract broken out into early/mid/late* in the month (LHS; %)



* **Early** deliveries are those occurring within three business days of the first delivery date, **late** deliveries are those occurring within three business days of last delivery, and **middle** deliveries occur on any other day of the contract month

Source: J.P. Morgan, CME

Appendix: The link between BNoC and implied repo, and an option-adjusted implied repo rate

We define some basic futures metrics here to aid in the discussion above. We also show the link between a divergence in implied and CTD repo rates and a non-zero CTD net basis. Finally, we introduce an "option-adjusted" implied repo rate which corrects for any contract option value to provide a cleaner comparison with cash bonds.

To start, the CTD basis or "**gross basis**" is defined as the CTD bond's clean price, **P**, less the future price, **F**, multiplied by the CTD's conversion factor, **C**.

$$gross\ basis = P - F \cdot C$$

This can be broken down into two components, carry to delivery, and the basis net of carry, or **BNoC**.

$$gross\ basis = carry\ to\ deliv + BNoC$$

Implied repo is defined as the percentage return a short would make sourcing the CTD bonds and delivering them into the futures contract.

$$implied\ repo\ rate = \frac{invoice\ price - purchase\ price}{purchase\ price} \times \frac{360}{n_{days}}$$

Where the invoice price is the profit made by the *short* upon delivery (Futures price times conversion factor) and both these prices are dirty prices—the invoice price includes accrued interest on the bond as of delivery, and the purchase price as of trade settlement.

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We can understand the link between implied/term repo rates and the BNoC with a bit of algebra. Starting with implied repo, and making use of the definitions above:

$$\begin{aligned} \textit{implied repo rate} &= \frac{\textit{invoice price} - \textit{purchase price}}{\textit{purchase price}} \times \frac{360}{n_{days}} \\ &= \frac{F \cdot C + I_{deliv} - (P + I_{trade})}{P + I_{trade}} \times \frac{360}{n_{days}} \\ &= \frac{-(P - F \cdot C) + (I_{deliv} - I_{trade})}{P + I_{trade}} \times \frac{360}{n_{days}} \\ &= \frac{-(\textit{CTD basis}) + (\textit{carry to deliv} + \textit{CTD repo})}{P + I_{trade}} \times \frac{360}{n_{days}} \\ &= \frac{-\textit{BNoC} + \textit{CTD repo}}{P + I_{trade}} \times \frac{360}{n_{days}} \\ &= \textit{CTD repo rate} - \frac{\textit{BNoC}}{\textit{CTD dirty price}} \times \frac{360}{n_{days}} \end{aligned}$$

Where **I**(deliv) and **I(**trade) are accrued interest on the bond as of delivery and trade settlement dates, and thus the different between the two is carry + CTD repo. **N**days here is calendar days between settlement and delivery. From this final formula, it's evident that **the implied and CTD repo rates differ by precisely the net basis**, but this relationship is muddied by the bond dirty price and, more importantly, the number of days to delivery. For instance, as you go from the start of November (60 days to delivery) to the end (30 days to delivery), the role of the BNoC doubles, driving an increasingly larger wedge between the two repo rates.

Finally, we can introduce an option-adjusted implied repo, making use of the above algebra. To do this we break the BNoC into two components, the option value, and the option-adjusted BNoC (OA BNoC):

$$\begin{aligned} \textit{implied repo rate} &= \textit{CTD repo rate} - \frac{\textit{BNoC}}{\textit{CTD dirty price}} \times \frac{360}{n_{days}} \\ &= \textit{CTD repo rate} - \frac{\textit{option value}}{\textit{CTD dirty price}} \times \frac{360}{n_{days}} - \frac{\textit{OA BNoC}}{\textit{CTD dirty price}} \times \frac{360}{n_{days}} \end{aligned}$$

And rearranging:

$$\boxed{\textit{OA implied repo rate} = \textit{implied repo rate} + \frac{\textit{option value}}{\textit{CTD dirty price}} \times \frac{360}{n_{days}}}$$

The final term in this formula (option value / dirty price * 360/N) is what's plotted in Exhibit 7, and compares nicely to the implied vs term repo rates. Any divergence between the OA implied repo rate and the CTD bond's term repo can thus be interpreted as a pure divergence from "fair value" (though of course this is not guaranteed to correct over your trade horizon). Or, as a simple formula:

$$\textit{OA implied repo rate} \stackrel{?}{=} \textit{CTD repo rate}$$

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