Intermediary Balance Sheets and the Treasury Yield Curve

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**Treasury “Inconvenience”?**

**Pre-GFC:**
- Treasury bonds were convenient (low yield relative to swap rates)
  - i.e. positive swap spreads (swap rate - Treasury yield)
- Covered interest parity (CIP) violations were roughly zero

**Post-GFC:**
- Treasury bonds are inconvenient (negative swap spreads)
- CIP violations are non-zero

Du et al 2018, Jermann 2020: CIP/swap spread reflect limits to arbitrage

This paper: unified framework to explain yields, positions, CIP, and swap rates
- Sign of position, swap spreads coincide (“regimes”)
- Regime determines effects of QE/QT and other policies
Known: (i) swap spread pos. to neg. and (ii) CIP zero to neg.
New Facts: (i) dealer net position neg. to pos. and (ii) CIP/swap spread correlation

Note: net position is not “inventory”
Interpretation: swap spread/CIP are arbitrages that use balance sheet

Interpretation of position vs. spread: dealers care about swap-hedged Treasury returns
What We Do: Part 1

- Model dealers’ demand for Treasury bonds
  - Accounting for funding spreads, balance sheet costs, interest rate risks

- By constructing long and short arbitrage bounds for Treasury yields
  - Novel approach: no-arbitrage-style reasoning that accommodates balance sheet costs
  - Affine term structure model.

- Show that actual yields switched bounds as dealer net positions changed
  - close to short bound when dealers were short (pre-GFC)
  - close to long bound when dealers were long (post-GFC)
  - i.e. prices and quantities move together across regimes

- Part 2: interact dealers as arbitrageurs with return-seeking clients
Broader Agenda: Asset Pricing with Arbitrage

- Du, Hébert, Huber (2022): Is the risk that arbitrage spreads get bigger priced?
  - Yes; it is a substantial component of dealers’ SDFs

- Hébert (2022): What can we learn about the optimality of policy from the signs of arbitrage spreads?
  - A lot: we can infer what kinds of externalities would justify current policy
Related Literature

- Jermann 2020: calibration in which dealer constraints explain negative swap spreads
  - We measure quantities, quantify constraints with CIP, explain quantity-slope correlation

- He, Nagel, and Song 2021: shares focus on dealer constraints and swap spreads.
  - They compare GFC vs. COVID crisis events; explanation: sign of customer shocks
  - We compare pre- and pre-GFC periods; explanation: regimes, no change in shocks

- Our view: Treasurys are convenient to clients but inconvenient to intermediaries.
  - Treasury convenience: Longstaff 2004, Krishnamurthy and Vissing-Jorgensen 2012, Greenwood, Hanson, and Stein 2015, etc.

- The market equilibrium model in Hanson, Malkhozov, and Venter 2022 is similar in spirit to ours but focuses on the swap market. Complementary approach.

- Arbitrage view of dealers unlike return-seeking commercial banks (Haddad and Sraer 2020).
Three zero-cost, \( n \)-period, balance-sheet-using arbitrages

1. Long Treasury vs. swap:
   - buy \( n \)-period Treasury, yield \( y_{n,t} \), financed at \( r_t^{long} \), pay swap fixed rate \( r_{n,t} \), receive swap floating rate \( r_t \)

2. Short Treasury vs. swap:
   - short-sell \( n \)-period Treasury, yield \( y_{n,t} \), borrow bond against cash collateral, receive \( r_t^{short} \) on cash, receive swap fixed rate \( r_{n,t} \), pay swap floating rate \( r_t \)

3. \( n \)-period CIP trade:
   - borrow dollars at \( r_t \), convert to euros, lend euros, use currency forward to convert back to dollars, “synthetic” dollar rate \( r_t^{syn} \geq r_t \)
   - use swaps to lock in \( r_t^{syn} - r_{t+j} \) for \( n \) periods (details unimportant)
Balance-Sheet Neutral Treasury Trading Strategies

(A) Long Treasury

- Treasury Bonds $y_{n,t}$
- Financing $r_t^{long}$
- Dollar Lending in FX Swap $r_t^{syn}$
- Unsecured Funding $r_t$

(B) Short Treasury

- Treasury Bonds Borrowed $y_{n,t}$
- Interest rate on cash $r_t^{short}$
- Dollar Lending in FX Swap $r_t^{syn}$
- Unsecured Funding $r_t$

- Unsecured Funding $r_t$
A Simple Model of Dealers and Arbitrage

- Consider a dealer that chooses between trading a single $n$-period zero-coupon Treasury bond, v.s. CIP arbitrage.

- $Q$ reflects dealer’s SDF for zero-cost, zero-balance-sheet trades (i.e. derivatives).
  - exists assuming no arbitrage within derivatives
  - no direct implications for bond prices (non-zero cost, non-zero balance sheet)

- Define the expected next-period bond price as
  \[ p_Q \equiv \exp(-(n-1)y_Q) \equiv E^Q[\exp(-(n-1)y_{n-1,1})] \]

  - swap rates are hiding in $p_Q$ via $Q$
Dealer’s Problem

\[
\max_{q^{bond}, q^{syn}} \left( e^{r^{syn}} - e^{r} \right) \cdot q^{syn}
\]

synthetic lending spread (CIP violation)

\[
+ \left( \frac{p_Q}{e^{-ny}} - e^{r^{long}} \right) \cdot \max\{q^{bond}, 0\}
\]
sell after one period

\[
+ \left( e^{r^{short}} - \frac{p_Q}{e^{-ny}} \right) \cdot \max\{-q^{bond}, 0\}
\]
earn return on cash collateral

subject to balance sheet constraint:

\[
|q^{bond}| + q^{syn} \leq \bar{q}
\]

● Assume dealers do CIP arbitrage \(q^{syn} > 0\).
The Short Regime

- Short regime (the optimal $q^{bond} < 0$): dealer FOC implies

$$e^{-ny} = \frac{p_Q}{e^{r_{short}} - (e^{r_{syn}} - e^r)}$$

- Denote the short-regime yield as $y^s$. Consider a special case of one-period bond ($p_Q = 1$). The log-linearized version is

$$r - y^s \approx r^{syn} - r + (r - r^{short})$$

- swap spread  
- balance sheet cost  
- security borrowing cost
The Long Regime

- Long regime (the optimal $q^{bond} > 0$): dealer FOC implies

$$e^{-ny} = \frac{p_Q}{e^{r_{long}} - e^r + e^{r_{syn}}}$$

- Denote the long-regime yield as $y^l$. Consider a special case of one-period bond ($p_Q = 1$). The log-linearized version is

$$r - y^l \approx - (r_{syn} - r) + (r - r^{long})$$

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No Arbitrage Pricing with Balance Sheet Costs

● Generalize previous logic to multi-period setting
  ▶ and multiple bond maturities, without assuming fixed balance sheet size

● Premise: a dealer SDF prices all zero-cost, zero-balance sheet trading strategies

● Construct near-arbitrage bounds:
  ▶ If yield sufficiently high: buy bond, finance with borrowing, hedge with swap; offset balance sheet with less CIP trade
  ▶ Wait until yield reverts or maturity approaches, then unwind
  ▶ Not exact arbitrage because of residual basis risk, e.g., swap floating rate vs. financing rate
  ▶ This defines the “net long yield,” “net short yield” constructed in similar fashion
Multi-Period Net Long and Net Short Curve

- All yields are now in annualized units, each period is one month
- Swap rates still hiding in $Q$
- Arbitrage bound: Dealers must be willing to long if $y_{n,t} \geq y_{n,t}^l$, defined recursively by
  \[ e^{-\frac{n}{12}y_{n,t}^l} = \frac{E_t^Q[e^{-\frac{n-1}{12}y_{n-1,t+1}}]}{e^{\frac{1}{12}r_t^long} - e^{\frac{1}{12}r_t} + e^{\frac{1}{12}r_t^{syn}}} \]
- Arbitrage bound: Dealers must be willing to short if $y_{n,t} \leq y_{n,t}^s$, defined recursively by
  \[ e^{-\frac{n}{12}y_{n,t}^s} = \frac{E_t^Q[e^{-\frac{n-1}{12}y_{n-1,t+1}}]}{e^{\frac{1}{12}r_t^{short}} + e^{\frac{1}{12}r_t} - e^{\frac{1}{12}r_t^{syn}}} \]
The Term Structure Model

- Fit term structure model to OIS, CIP curves
- Use standard affine TS approach as in Joslin, Singleton, and Zhu (2011)
- Then construct net long and net short curves
- Key point: TS model for interpolation, Jensen’s inequality, etc... Balance sheet costs + funding spreads are key inputs, determined by data
Estimating Buy and Sell Curves

- Affine term-structure model (based on Duffie (1996), Joslin, Singleton, and Zhu (2011)):

\[ z_{t+1} = k_0^P + K_{1,t} \cdot z_t + (\sum_z)^{1/2} c_{z,t+1}, c_{z,t+1} \sim N(0, I_N), \]

\[ m_{t+1} = - (\delta_0 + \delta_1 \cdot z_t) - \frac{1}{2} \lambda T \cdot z_t + \lambda_T e_{z,t+1}, \lambda_t = (\sum z^{-1})(\lambda_0 + \Lambda_1 z_t) \]

- Augment with “macro” factors \( x_t = (x_{1,t}, x_{2,t}, y_{6,t}^{\text{bill}}) \)

\[ x_{1,t} = \ln((1 - h)(e^{1/12} r_{t}^{\text{long}} - e^{1/12} r_t) + e^{1/12} r_t^{\text{syn}}), \text{ (for buy curve)} \]

\[ x_{2,t} = \ln(e^{1/12} r_t^{\text{short}} - (e^{1/12} r_t^{\text{syn}} - e^{1/12} r_t)), \text{ (for sell curve)} \]

- Assume \( y_{6,t} = y_{6,t}^{b} = y_{6,t}^{s} = y_{6,t}^{\text{bill}} \) (unwind when bond is equivalent to 6-mo bill)

- affects short-maturity bonds, not so much for long maturities

- long: tri-party repo financing short: security lending rates

- Fit the OIS curves and the basis curves.
OIS Curve Fit

6-month maturity

1-year maturity

3-year maturity

5-year maturity

10-year maturity

20-year maturity
Cross-Currency Basis Fit
The Net Long and Net Short Curves

6-month maturity
6-year maturity
3-year maturity
5-year maturity
10-year maturity
20-year maturity
The Net Long and Net Short Curves (difference w.r.t. OIS)
Treasury Yields Relative to Long/Short Curves and Dealer Positions

2-year maturity

5-year maturity

10-year maturity

20-year maturity
Takeaways

- Pre-GFC, yields were near net short curve (“short regime”)
  - net long vs. net-short gap small due to small balance sheet costs
  - swap spreads positive due to sec. lending vs OIS spreads

- Post-GFC, treasury yields are near net long curve (“long regime”)
  - net long vs. net-short gap large due to large balance sheet costs
  - swap spreads negative due to balance sheet costs + switch from sec. lending to tri-party repo rates

- Validates arbitrage-centric view of dealer net positions

- Next questions:
  - What caused the pre- to post-GFC changes? (speculative)
  - What are the policy implications of being in the long vs. short regime?
What We Do: Part 2

- Interact dealers with clients seeking returns
  - Key: dealers care about swap-hedged returns, clients about unhedged returns
  - Two-period, two-market model (treasury bonds and synthetic dollars)
  - Swaps and money markets exogenous
  - Comparative-statics depend on regime
  - +Tsy supply can generate regime switch

Policy implications:
- Curve flattening and quantitative tightening will constrain dealer balance sheets
- Leading to higher treasury yields, CIP basis
- Regulatory (SLR) exemptions and swap lines can help
New Fact iii: Dealers Buy High and Sell Low

- Net position decreases in term spread (proxy term premium), contra Jermann 2020
- Interpretation: dealers don’t care about unhedged Treasury returns, clients do
An Equilibrium Model

- **Agents:**
  - intermediary: dealers and levered clients (consolidated, see appendix),
  - real-money Treasury investors (e.g., pension funds)
  - FX-hedge foreign Treasury investors (e.g., foreign life insurance companies)
  - other agents demanding synthetic dollars

- **Exogenous:** swaps, money markets (incl. t-bills), security lending, expected future bond prices ($y_P$, $y_Q$)

- **Endogenous:** current $n$-period treasury bond yield ($y$), synthetic dollar lending rates ($r^{syn}$)
  - Idea: model single period of a more dynamic model
  - single bond maturity: simplification to avoid thinking about substitutability

- **Note:** $y$, $y^{bill}$, and $y_Q$ are not linked by usual arb. formula
  - the SDF associated with $Q$ does not price bonds
Intermediaries solve static problem described earlier, with constraint

$$|q^{bond}| + q^{syn} \leq \bar{q}$$

Real-money investors (e.g., pension funds and mutual funds) demand

$$D_{U}^{bond} = D_{U}(ny - (n - 1)y_P - y^{bill})$$

Exp. Dollar Return vs Bill

FX-hedged foreign investors (e.g., foreign life insurance companies) demand

$$D_{H}^{bond} = D_{H}(ny - (n - 1)y_P - r^{syn})$$

Exp. Dollar Hedged Excess Return

Key point: clients care about unhedged Treasury returns, not swap-hedged returns
Market Clearing

- Bond supply: $S^{bond}$ (in notional, i.e., number of bonds)

- Treasury market:

$$\exp(-ny)S^{bond} = q^{bond} + D^{bond}_U + D^{bond}_H$$

Treasury bond supply in dollars

- Synthetic lending market:

$$q^{syn} = D^{bond}_H + D^{syn}(r^{syn} - r)$$

intermediary supply of syn lending

residual demand

- Each unit of FX-hedged bond requires synthetic financing
The equilibrium is unique

Equilibria can be classified as long/intermediate/short based on $q^{bond}$

Comparative statics differ across equilibria. For example:
- long regime: larger bond supply $S^{bond}$ increases $y$ and $r^{syn}$.
- short regime: larger bond supply $S^{bond}$ increases $y$ but decreases $r^{syn}$.

Key regime determinant: bond supply and OIS term premium.
- Bond supply high (low): long (short) regime
- swap term premium high (low): short (long) regime
The Long Regime

Long Regime (High, Higher, Highest Supply)

- Market Clearing + Balance Sheet (high supply)
- Market Clearing + Balance Sheet (higher supply)
- Market Clearing + Balance Sheet (highest supply)
- Dealer Net Long Curve (10bps OIS term prem.)
- Dealer Net Long Curve (20bps OIS term prem.)
The Short Regime

- **Treasury Term Spread**
- **CIP Violation**
- **Short Regime** (Low, Lower, Lowest Supply)
- **Market Clearing + Balance Sheet**
  - (lowest supply)
  - (lower supply)
  - (low supply)
- **Dealer Net Short Curve**
  - (10bps OIS term prem.)
  - (20bps OIS term prem.)
Explaining the Data

- Pre-GFC: Short regime, ample balance sheet capacity
  - almost no CIP violations, swap rates + Treasury yields move in parallel
  - Treasury curve flatter than swap curve (positive spreads)

- Post-GFC: Long regime, scarce balance sheets capacity
  - Treasury curve steeper than swap curve (negative swap spreads)
  - Large CIP violations, CIP + swap spreads correlated
  - Dealers positions correlated with yield curve slope
Key Changes Pre/Post GFC

- Supply of treasurys has expanded, dealer balance sheets have contracted
Regimes and Treasury Market Fragility

- Crises reduce dealer capacity $\bar{q}$.

- In the short regime (pre-2009) a bad shock to intermediary balance sheet decreases the Treasury yield relative to swaps.

- In the long regime (post-2009) a bad shock to intermediary balance sheet increases the Treasury yield relative to swaps.
  - An explanation of the Treasury market turmoil in March 2020 (Duffie (2020)).
  - Our explanation does not rely on “selling pressure” in the Treasury market (He, Nagel, and Song (2022)). Quantifying both forces is an interesting future direction.
Policy Implications

- **Caveat:** partial equilibrium holds fixed swap and money market rates
  - prices changes here will dampen other price and quantity responses
  - interpret Tsy yield and lending rate as *relative spreads to swaps*.

- **Synthetic lending rate** $r^{syn}$ is the rate on all non-repo-financed, balance-sheet-using assets.

<table>
<thead>
<tr>
<th>Policy Type</th>
<th>Long Regime</th>
<th>Short Regime</th>
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<tbody>
<tr>
<td></td>
<td>Tsy Yield</td>
<td>Lending Rate</td>
</tr>
<tr>
<td>QT (purchasing bills, selling bonds)</td>
<td>$\uparrow$</td>
<td>$\uparrow$</td>
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<tr>
<td>$\downarrow$ Term premium</td>
<td>$\uparrow$</td>
<td>$\uparrow$</td>
</tr>
<tr>
<td>SLR Exemptions</td>
<td>$\downarrow$</td>
<td>$\downarrow$</td>
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<tr>
<td>Swap line (Fed synthetic $ lending)</td>
<td>$\downarrow$</td>
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Looking Ahead: Monetary Policy Tightening Cycles

- Current yield curve (right figure)
  - Fed has begun hiking and QT, RRP active

- Model predicts:
  - large dealer net long position
  - widening basis
  - more negative swap spreads
  - higher bond yields

- Significant market stress
  - SLR exemptions or swap lines can help
Appendix
Hedge Funds and Primary Dealers

- PD Net Coupon Tsy Holding (Bln)
- Short position in Tsy futures of levered funds (bln)
Dealer Net Treasury Positions are not Inventory

- Easy to short Treasurys, hard to short other bonds