Granular Treasury Demand with Arbitrageurs

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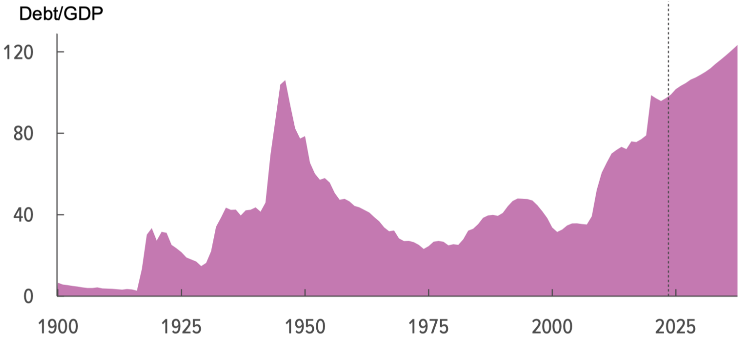
The Rise of the U.S. Debt Burden



- Since the rise in debt levels, the U.S. Treasury market experienced several high-stake disruptions (e.g., Taper tantrum, March 2020, tariff turmoil).
  - Raises concerns about investors' capacity to absorb U.S. debt.

This Paper

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- We quantify an equilibrium model of the Treasury market with a novel granular dataset.
- A methodological advance to combine insights of two influential literatures:
  - Demand-based asset pricing (Koijen and Yogo 2019):
    Contribution: Allowing for no-arbitrage conditions.
  - Preferred habitat view (Vayanos and Vila 2021):
    Contribution: Introducing cross elasticities and quantification with granular data.

Step #1: Estimate empirically tractable demand curves

- Collect a novel dataset on most U.S. Treasury holdings at the maturity level:
  1. Granular-demand investors (e.g., insurance companies, MMFs, banks)
  2. The Federal Reserve

- Use the following ingredients to estimate demand curves:
  1. Own and cross price elasticity (using an IV methodology)
  2. Bond characteristics (e.g., coupon rate, maturity)
  3. Macroeconomic variables (e.g., inflation, GDP gap, credit spread)

- Why demand estimation? To capture rich heterogeneity of institutional features.
  1. Banks: liquidity regulation, capital regulation, etc.
  2. Insurance companies: long-duration liabilities and capital regulation.
  3. Fed: policy goals.

Step #2: Embed estimates in Treasury equilibrium model

- A quantitative equilibrium model extending Vayanos and Vila (2021) with cross-maturity substitution, monetary policy rule, and arbitrageurs' outside assets.

- Model entirely estimated using data, including arbitrageurs' Treasury holdings.
  - Who are arbitrageurs? – Primary dealers and hedge funds (Hanson and Stein 2015; Du, Hebert, Li 2023).

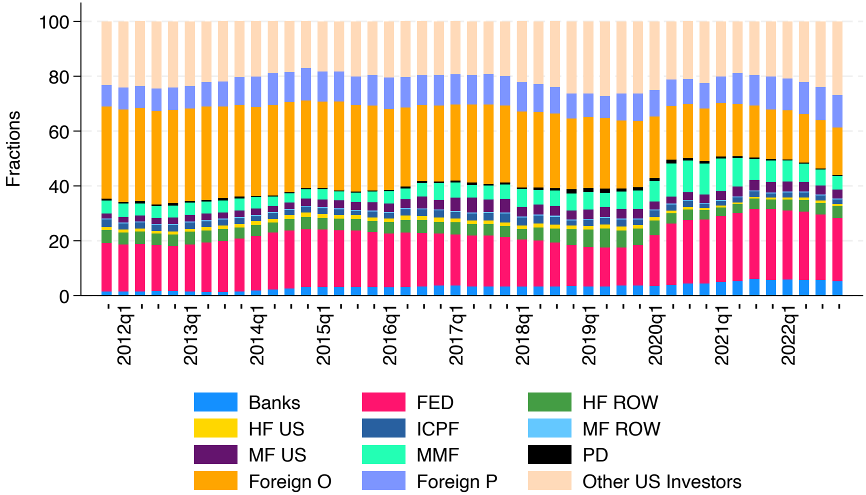
- Model estimation reveals:
  1. A downward-sloping term structure of Treasury market elasticity.
  2. Positive term premium response to monetary policy tightening, explaining the puzzle of excess long-term rate sensitivity.
  3. Power of QE policy hinges on perceived persistence of Fed purchases.

Data Sources

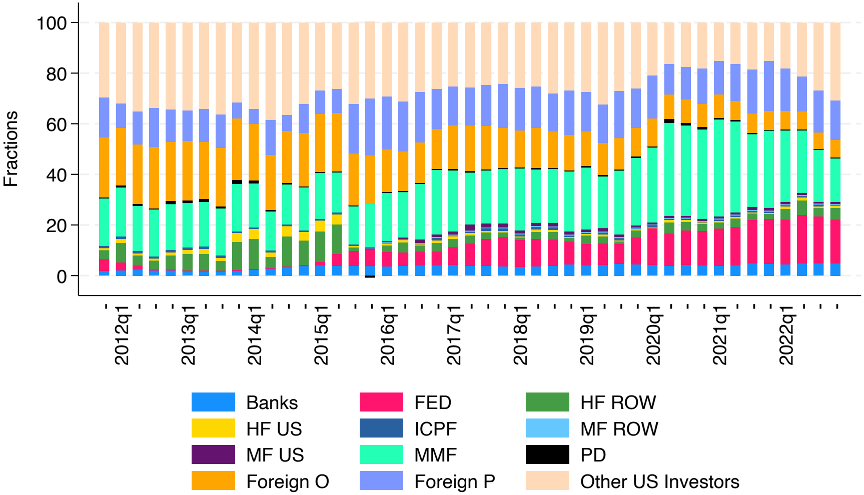
Investor Type	**Data Source**	**Frequency**	**Period**	**Detail**
Banks	CALL Reports	Quarterly	1976Q1-2022Q4	Maturity bucket
Fed	Federal Reserve	Weekly	2003W1-2022W52	Security
Primary Dealers	Federal Reserve	Weekly	1998W5-2022W52	Maturity bucket
Hedge Funds	Form PF SEC	Quarterly	2011Q4-2022Q4	Aggregate
Insurers and Pension Funds	eMAXX	Quarterly	2010Q1-2022Q4	Security
Money Market Funds	IMoneyNet	Monthly	2011M8-2022M12	Security
Mutual Funds	Morningstar	Monthly/Quarterly	2000M1-2022M12	Security
ETFs	ETF Global	Daily/Monthly	2012M1-2022M12	Security
Foreign Official and Private	Public TIC	Quarterly	2011Q4-2022Q4	T-bill/non T-bill

- We group data into three maturity buckets: $T \leq 1Y$, $1Y < T \leq 5Y$, and $T > 5Y$.
- Sample period: 2011Q4-2022Q4.

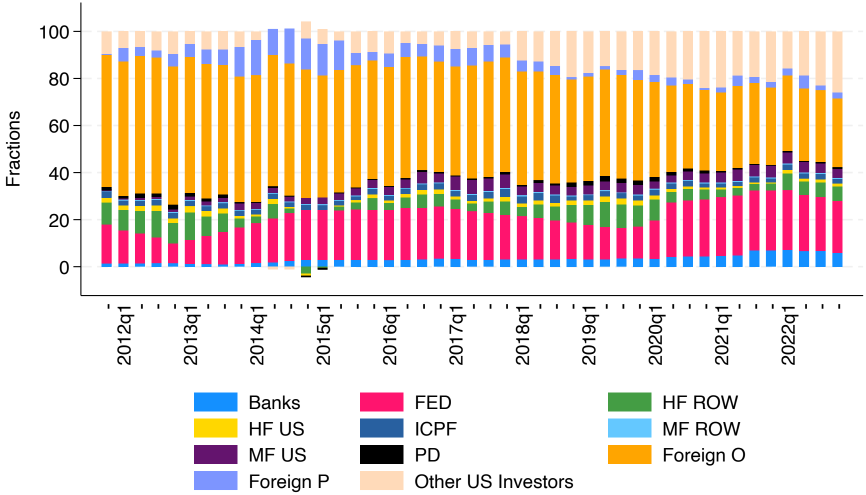
Who Holds What (% of total debt) - Aggregate



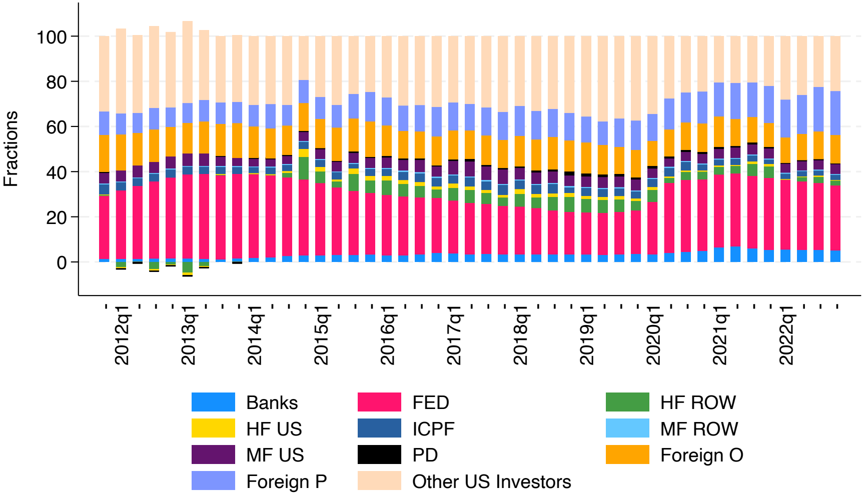
Who Holds What (% of total debt): maturity $\leq$ 1Y



Who Holds What (% of total debt): 1Y $<$ maturity $\leq$ 5Y



Who Holds What (% of total debt): maturity > 5Y



Demand System

- We estimate demand curves for each sector ι:

$$Z_t^\iota(m) = \theta_0^\iota + b_1^\iota y_t(m) + b_2^\iota y_t(-m) + (b_3^\iota)'\mathbf{x}_t(m) + (b_4^\iota)'\mathbf{Macro}_t + u_t^\iota(m)$$

  - Three maturity buckets: $T \leq 1Y$, $1Y < T \leq 5Y$, and $T > 5Y$.
  - $Z_t^\iota(m)$: dollar value of holdings in maturity bucket m for sector ι, standardized by potential GDP.
  - $y_t(m)$: bond yield.
  - $y_t(-m)$: value-weighted bond yield other maturities.
  - $\mathbf{x}_t(m)$: coupon, maturity, and bid-ask spread.
  - $\mathbf{Macro}_t$: GDP gap, inflation, credit spread, and debt/GDP.

- Challenge: latent demand directly affects yields. Need an instrument for yields.
  - Use extracted pseudo yields (Koijen and Yogo, 2020; Fang, Hardy, and Lewis, 2022)

Instruments for Yields

Following Koijen and Yogo (2020) and Fang, Hardy, and Lewis (2022), we construct "pseudo yields" $\tilde{y}_t(m)$ as instruments:

1. Extract predictable component of demand, $\hat{Z}_t^\iota(m)$, excluding yields:

$$Z_t^\iota(m) = \underbrace{\hat{\theta}_0^\iota + (\hat{b}_3^\iota)'\mathbf{x}_t(m) + (\hat{b}_4^\iota)'\mathbf{Macro}_t}_{\equiv \hat{Z}_t^\iota(m)} + \epsilon_t^\iota(m)$$

2. Extract predicted component of supply, $\hat{S}_t(m)$, by regressing on macro variables.

3. Pseudo yields from equating predictable demand with supply:

$$\sum_\iota \hat{Z}_t^\iota(m) = \frac{\hat{S}_t(m)}{(1+\tilde{y}_t(m))^{\tau(m)}}$$

Demand System Results - Granular-Demand Investors

	Banks	ICPF	MF ROW	MF US	MMF	Other US Investors	Foreign O	Foreign P
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$y_t(m)$	63.850**	3.833	6.934*	137.258***	436.596*	172.272	-33.849	32.697
	[26.277]	[11.461]	[3.716]	[47.699]	[236.128]	[199.313]	[115.257]	[94.669]
$y_t(-m)$	-72.167**	-1.247	-3.663	-152.400***	-611.375*	-17.813	-94.278	-42.745
	[28.676]	[13.518]	[4.025]	[53.939]	[367.663]	[257.566]	[154.463]	[125.330]
Coupon Rate	-148.638***	3.053	-4.817	-137.838**	55.752	182.530	-480.953**	-315.103*
	[35.111]	[18.189]	[4.853]	[61.177]	[545.299]	[319.718]	[191.041]	[180.040]
Bid-Ask Spread	7.730	18.664***	3.059**	12.692	136.693	109.723	-102.377**	-65.497
	[7.921]	[4.472]	[1.206]	[16.243]	[140.086]	[76.916]	[46.128]	[56.216]
$\mathbb{1}\{1Y \leq \tau < 5\}$	56.159***	148.746***	12.952***	189.591***		-427.082***	2923.108***	-346.709***
	[15.057]	[4.427]	[2.132]	[26.569]		[122.524]	[91.434]	[83.651]
$\mathbb{1}\{\tau \geq 5\}$	-68.055	182.999***	9.623	36.298		451.302	148.771	44.390
	[47.867]	[20.885]	[7.022]	[91.367]		[413.365]	[226.244]	[186.195]
Credit Spread	15.144	-12.095	0.784	-37.701	-512.281**	286.080	95.977	-30.513
	[20.288]	[13.631]	[2.489]	[40.149]	[202.541]	[185.470]	[90.280]	[130.369]
Debt/GDP	648.082***	-7.771	41.743***	-18.509	5592.173***	2142.833**	-1806.284***	651.782
	[79.844]	[48.167]	[10.595]	[135.214]	[1277.801]	[919.753]	[572.490]	[536.095]
GDP Gap	11.000***	-4.501**	1.424***	12.121**	-75.617***	-9.814	-10.512	8.537
	[3.708]	[1.885]	[0.460]	[5.146]	[21.914]	[29.890]	[17.207]	[17.759]
Core Inflation	16.814**	-0.440	-2.254***	-3.223	59.070	-13.744	-74.315*	3.339
	[6.870]	[3.300]	[0.854]	[11.134]	[95.780]	[49.601]	[40.866]	[33.921]
Observations	135	135	135	135	45	135	135	135
Kleibergen-Paap Statistic (*first stage*)	11.13	11.13	11.13	11.13	4.27	11.13	11.13	11.13

Demand System Results - Fed

	$\mathbb{1}\{\tau < 1Y\}$	$\mathbb{1}\{1Y \leq \tau < 5Y\}$	$\mathbb{1}\{\tau \geq 5Y\}$
	(1)	(2)	(3)
$y_t(m)$	-14.733	-49.318	**385.678****
	[100.514]	[208.133]	[157.594]
$y_t(-m)$	120.213	112.178	**-478.703*****
	[146.510]	[254.479]	[79.222]
Coupon Rate	-35.947	-2557.515***	246.631
	[186.162]	[256.424]	[248.683]
Bid-Ask Spread	203.700***	102.781	-177.449***
	[59.059]	[75.504]	[65.788]
Credit Spread	24.368	206.475	-231.120*
	[82.169]	[138.053]	[137.150]
Debt/GDP	3643.632***	429.732	4649.721***
	[398.422]	[564.090]	[1020.458]
GDP Gap	-6.980	-16.387	-49.862**
	[7.078]	[14.768]	[22.644]
Core Inflation	46.812	-61.166	155.350***
	[40.232]	[40.724]	[29.301]
Observations	45	45	45
Kleibergen-Paap Statistic (*first stage*)	4.27	9.58	14.67

- Positive elasticity
  - QE affects term premium (Bernanke 2013, Fed speech).
  - Financial conditions targeting (Caballero, Caravello, and Simsek (2024))
  - Policy rule on yields (Haddad, Moreira, and Muir (2024)).
- Negative cross elasticity
  - "Reducing the size of the balance sheet reinforces the shift toward a less accommodative monetary policy stance" — FOMC Minutes, March 2022.

Model Setup

- Three types of agents: granular-demand investors, the Fed, and arbitrageurs.
- State of the economy: macro factor β_t and monetary policy rate r_t.
- Macroeconomic dynamics: $\beta_{t+1} = \bar{\beta} + \Phi(\beta_t - \bar{\beta}) + \Sigma^{1/2}\epsilon_{t+1}$.
- Monetary policy rule: $r_{t+1} = \bar{r} + \phi_r'(\beta_{t+1} - \bar{\beta}) + \rho_r r_t + \sigma_r \epsilon_{t+1}^r$.
  - Inertial Taylor rule (Stein and Sunderam (2018); Campbell et al. (2020))
- Treasury supply: $S_t^{(\tau)} = \bar{S}^{(\tau)} + \zeta(\tau)'\beta_t + \zeta_r(\tau) r_t$.

Model Setup

- Non-arbitrageur demand (including the Fed and granular-demand investors)

$$Z_t(\tau) = \theta_0(\tau) - \alpha(\tau)' \underbrace{p_t}_{\text{log(price)}} - \theta(\tau)' \underbrace{\beta_t}_{\text{macro}} + \underbrace{u_t(\tau)}_{\text{latent demand}}$$

- Arbitrageur:

$$\max_{\{X_t(\tau)\},\tilde{X}_t} E_t[W_{t+1}] - \frac{\gamma}{2} Var_t(W_{t+1})$$

$$s.t. \quad W_{t+1} = W_t(1 + r_t) \quad + \underbrace{\sum_{\tau=2}^{N} X_t(\tau)(R_{t+1}^{(\tau)} - r_t)}_{\text{Treasury excess return}} \quad + \underbrace{\tilde{X}_t(\tilde{R}_{t+1} - r_t).}_{\text{Outside asset excess return}}$$

- Treasury market clearing: $Z_t(\tau) + X_t(\tau) = S_t(\tau)$.

A Simplified Model for Intuition

- We assume $N = 2$: two maturities that represent "short" and "long".
- Non-arbitrageur demand response to yields:

$$\begin{pmatrix} a & -b \\ -b & a \end{pmatrix},$$

so Treasury demand increases in its own yield, but decreases in the other-maturity yield.

- Set $K = 1$ so β_t is a one-dimensional "supply" factor.
- $\phi_r = 0$, $\bar{r} = 0$, $\zeta_r = 0$...

Model Intuition: Decomposition of Treasury Pricing

$$p_t^{(1)} = -r_t$$

$$p_t^{(2)} = -\frac{1+\rho_r+\gamma\sigma_r^2 b}{1+\frac{a}{2}\gamma\sigma_r^2} r_t - \frac{\gamma\sigma_r^2(\zeta(2)+\theta(2))}{1+\frac{a}{2}\gamma\sigma_r^2}\beta_t + \frac{\gamma\sigma_r^2}{1+\frac{a}{2}\gamma\sigma_r^2}u_t(2) + \frac{\frac{1}{2}-\gamma\bar{S}^{(2)}+\gamma\theta_0(2)}{\frac{1}{\sigma_r^2}+\frac{a}{2}\gamma}.$$

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Proposition: *Monetary policy rate r_t plays a dominant role for short-maturity Treasuries, while macro shocks and latent demand shocks become more important for long-maturity Treasuries.*

Model Intuition: Arbitrageur Risk Aversion

Proposition: *Arbitrageur risk aversion γ increases the price impact of demand shocks.*

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- $\gamma \to 0$: arbitrageurs are risk neutral and arbitrage to the full extent

$$p_t^{(2)} = -(1+\rho_r)r_t + \frac{1}{2}\sigma_r^2.$$

- $\gamma \to \infty$: so arbitrageurs "drop out" of the market

$$p_t^{(2)} = -\frac{2b}{a}r_t - \frac{2}{a}(\zeta(2)+\theta(2))\beta_t + \frac{2}{a}u_t(2) + \frac{2}{a}(\theta_0(2) - \bar{S}^{(2)}).$$

Model Intuition: Monetary Policy and the Yield Curve

Proposition: *If $2b/a > 1 + \rho_r$ (strong cross elasticity), a positive monetary policy shock increases the term premium. If $2b/a < 1 + \rho_r$ (weak cross elasticity), the opposite is true.*

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- Under strong cross elasticity, when short rate increases,
  - Non-arbitrageurs: Cross substitution $\rightarrow \downarrow$ long-term Treasury holdings.
  - Arbitrageurs: $\uparrow$ long-term Treasury holdings $\rightarrow \uparrow$ risk premium.

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- Under strong cross elasticity, when short rate increases,
  - Non-arbitrageurs: Cross substitution $\rightarrow \downarrow$ long-term Treasury holdings.
  - Arbitrageurs: $\uparrow$ long-term Treasury holdings $\rightarrow \uparrow$ risk premium.

- Consistent with positive risk premium response to monetary policy tightening (Bekaert, Hoerova, and Duca (2013); Hanson and Stein (2015); Gertler and Karadi (2015); Drechsler, Savov, and Schnabl (2018); Kekre, Lenel, and Mainardi (2024)).

- Opposite to baseline results in Vayanos and Vila (2021).

Model Estimation

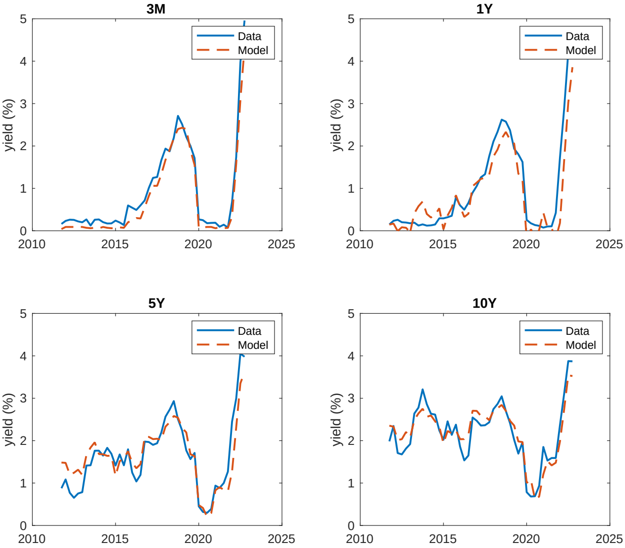
- Step 1: We estimate VAR dynamics for macroeconomic variables, monetary policy rule, and Treasury supply from the data 2011–2022. We explicitly obtain demand functions: $Z_t = \theta_0 - \alpha p_t - \theta \beta_t + u_t$.

- Step 2: We estimate remaining parameters to minimize

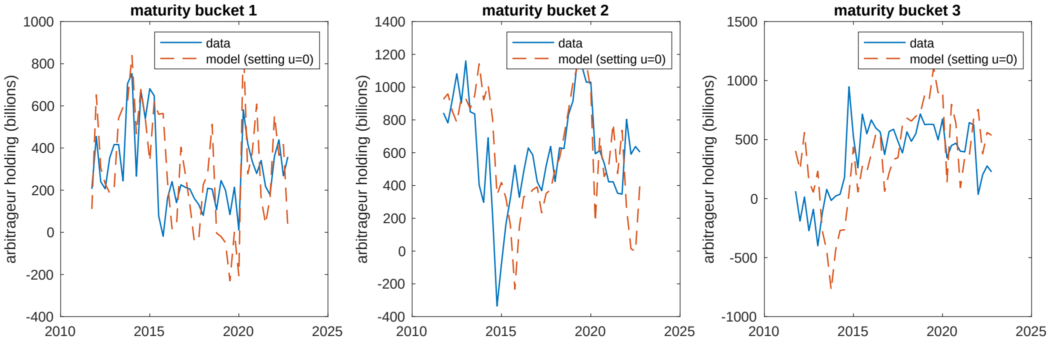
$$\min_{\{\gamma,\text{ par for outside asset}\}} \mathbb{E}\left[M \cdot (h - h^o)^2 + \sum_t \sum_\tau (y_t(\tau) - y_t^o(\tau))^2\right],$$

where $y_t^o(\tau)$ is observed yield and h^o is average arbitrageurs' long-term Treasury holding in the data. Set M large to guarantee $h \to h^o$.

Model Fit on Treasury Yield Dynamics

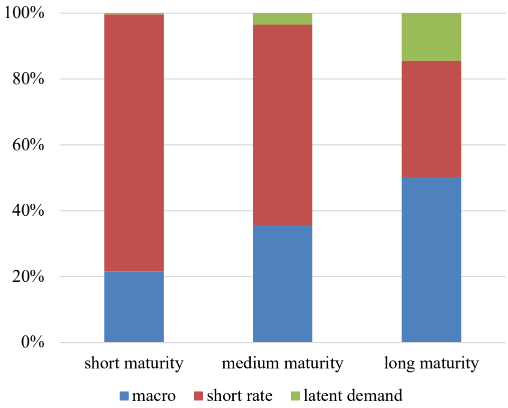


Model Fit on Arbitrageur Holdings

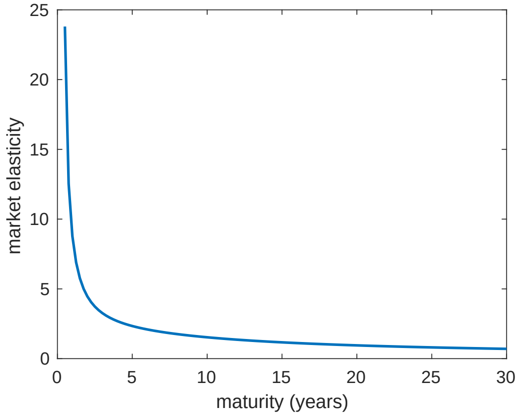


Decomposition of Treasury Pricing: Short rate, Macro, and Latent demand

- Relative contribution of different driving factors, using Shapley R^2 values.

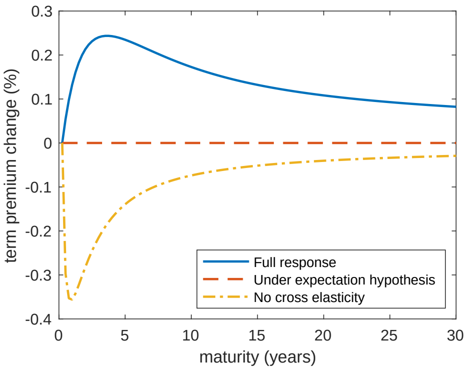


The Term Structure of Treasury Market Elasticity



- Downward-sloping term structure of market elasticity.
- Aggregate elasticity about 5 (or a multiplier of 0.2).

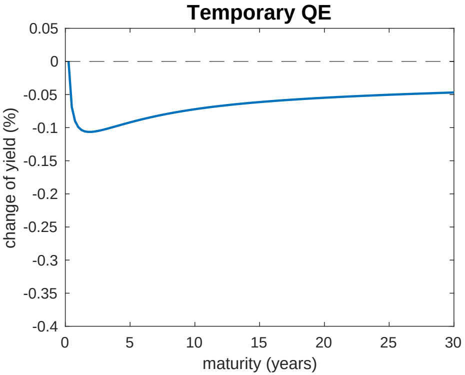
Term Premium Response to Monetary Policy: The Role of Cross Elasticity

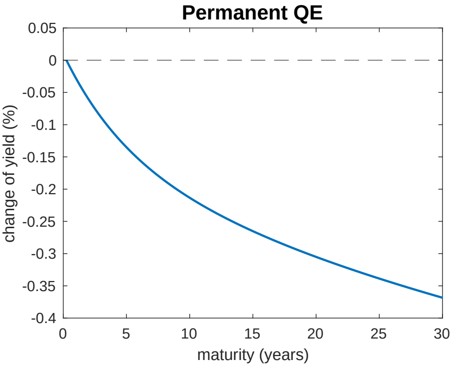


- Higher short-term rate → granular-demand investors reduce long-term holdings (due to cross substitution) → arbitrageurs increase holdings and term premium rises.
- Shutting off cross elasticity, term premium response flips sign.

Quantitative Easing

- We represent QE as shocks to the Fed demand for long-term (>5Y) Treasuries.
    - $100 billion "QE" shock (extra demand).





Conclusion

- Using a novel dataset of U.S. Treasury holdings, we uncover:
  1. Significant cross-elasticity for most investors.
  2. Fed's long-term Treasury holdings significantly react to Treasury yields.
- We connect granular demand estimation with arbitrage in an equilibrium model.
- Model estimation reveals:
  1. A downward-sloping term structure of Treasury market elasticity.
  2. Positive term premium response to monetary policy hike, due to cross elasticity.
  3. Power of QE policy hinges on perceived persistence of Fed purchases.

Appendix

Investor Demand According to Portfolio Optimization

- Mean-variance optimization with non-pecuniary benefits V^ι from Treasury holdings.
- Expectation $\mathbb{E}^\iota[R^{(\tau)}_{t+1} - r_t] = \mu^\iota_\tau \cdot \beta_t + \phi^\iota_\tau y_t$. Yield dependence (reaching for yield, heuristic expectation, etc.)
- Optimal portfolio holding:

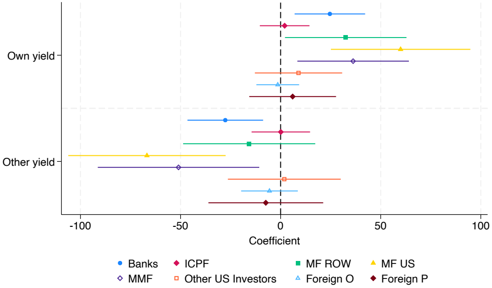
$$Z^\iota_t = \left(\mathbb{V}^\iota(R_{t+1}, R_{t+1}) + \frac{1}{\gamma^\iota}\bar{V}^\iota\right)^{-1}\left(\frac{1}{\gamma^\iota}\left(\mu^\iota\beta_t + \phi^\iota y_t + \bar{V}^\iota_0\right) - \mathbb{V}^\iota(R_{t+1}, \tilde{R}^\iota_{t+1})\tilde{Z}^\iota_t\right).$$

- Expanding the "outside portfolio" term as affine in β_t plus a noise term, we get

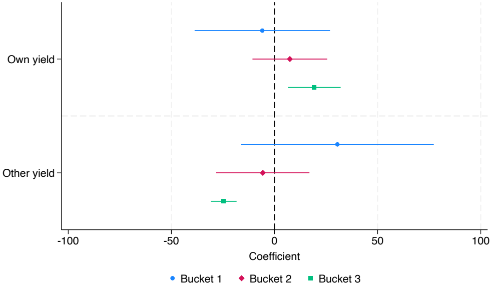
$$Z^\iota_t = \theta^\iota_0 + B^\iota y_t - \theta^\iota\beta_t + u^\iota_t$$

- Note: pure arbitrageurs ($V^\iota = 0$, $\mathbb{E}$ rational) demand **does not directly depend on** y_t.

Demand Elasticities by Investor Type



(a) Granular-demand investors



(b) Fed

Decomposition of Treasury Pricing: Supply and Demand Shocks

- Relative contribution of sectoral demand and supply shocks (short-rate shock excluded)