Dissecting Treasury Market Resilience

Kristy A. E. Jansen Wenhao Li Lukas Schmid

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Abstract

How resilient is the U.S. Treasury market to foreign selling, inflation, and quantitative tightening? We answer this question by embedding an empirically estimated sector-level Treasury demand system in a forward-looking equilibrium model with risk-averse arbitrageurs who price expected future demand. Equal-sized foreign dollar retrenchments from different countries generate heterogeneous yield responses because countries differ in their maturity composition, yield elasticities, and macroeconomic sensitivity. Inflation affects long-term yields through opposing portfolio reallocations: falling foreign official demand amplifies the response, while the Fed's demand response offsets it. Retrenchment by foreign official holders therefore reduces Treasury yields' sensitivity to subsequent inflation shocks. At longer maturities, the yield impact of QT depends more on expected state-contingent Fed support than on the immediate reduction in the Fed's Treasury holdings. Treasury-market resilience therefore depends on who absorbs the shock, whether it persists, and how policy responds, not on the size of the shock alone.

Keywords: Treasury market resilience; inflation expectations; foreign demand; quantitative tightening; term premia; intermediation.

Jansen: USC Marshall School of Business, CEPR, and DNB, kjansen@marshall.usc.edu. Li: USC Marshall School of Business and NBER, liwenhao@marshall.usc.edu. Schmid: USC Marshall School of Business and CEPR, lukas@marshall.usc.edu. Views expressed are those of the authors and do not necessarily reflect official positions of DNB or the Eurosystem.

1. Introduction

The U.S. Treasury market is the world's deepest government bond market and underpins the dollar's role as a reserve currency. Yet the market has repeatedly come under stress as federal debt has risen: during the October 2014 flash rally, the September 2019 repo spike, the March 2020 dash for cash, and the dislocations around the 2023 regional bank failures. These episodes reveal a tension between Treasuries' status as the benchmark safe asset and the market's capacity to absorb shocks. Against this backdrop, we ask: how resilient is the U.S. Treasury market in the face of macroeconomic turmoil, such as price shocks in an increasingly inflationary environment? Can U.S. borrowing costs withstand contractions in foreign central banks' demand for Treasuries? Can the Federal Reserve reduce its balance sheet by implementing quantitative tightening (QT) in ways that contain pressure on Treasury yields? The answer likely differs across shocks. The challenge is to identify *which* shocks leave the market most fragile, *which* investors transmit or absorb them, and *which* policy interventions matter.

To answer these questions, we develop an equilibrium framework that allows us to quantify how Treasury yields respond to different shocks. We estimate demand curves from portfolio holdings for each major investor sector: banks, insurers and pension funds, money market funds (MMFs), mutual funds, exchange-traded funds (ETFs), Other U.S. investors, the Federal Reserve, and foreign official and private investors. Demand at each maturity responds to Treasury yields, bond characteristics, the relative supply of other safe assets measured through the agency-to-Treasury supply ratio, and macroeconomic conditions. Risk-averse arbitrageurs absorb the supply left by these sectors and clear the market. Within this framework, we measure resilience at a given maturity by the yield adjustment required to absorb a shock. Resilience is high when a small yield movement clears the market and low when a large movement is required. Current holdings measure how much Treasury risk an investor absorbs at prevailing yields and macroeconomic conditions. The yield elasticities and macroeconomic loadings measure whether that absorption expands or contracts as conditions change. Because yield elasticities and macroeconomic loadings differ across investors and maturities, resilience depends on which investors are exposed to a shock and where along the maturity spectrum it must be absorbed.

Our framework builds on Jansen, Li, and Schmid (2024) by combining a sector-level demand system estimated from portfolio holdings, following Koijen and Yogo (2019), with risk-averse arbitrageurs who form rational expectations about future demand and macroeconomic conditions, in the spirit of Vayanos and Vila (2021). This forward-looking structure makes shock persistence a critical determinant of price impact beyond its size. Arbitrageurs price the expected path of residual Treasury supply, so shocks with the same initial effect can move yields differently depending on how long they last. A temporary demand shock reverses quickly, whereas an inflation shock or permanent sector retrenchment changes expected demand persistently. A static implementation does not model persistence as a separate state and therefore assigns the same price impact to the same current imbalance. In our estimates, transitory latent-demand shocks account for a growing share of yield variation toward the long end, but their impact reverses quickly. At each maturity, current absorption is not a sufficient measure of Treasury market resilience: equilibrium yields also depend on how investor demand responds to market conditions and how long the resulting demand imbalance is expected to persist.

We apply the framework to three scenarios at the center of the current policy debate. Together they show how absorption differs across investors, changes with the macroeconomic environment, and depends on policy rules. In particular, we examine Treasury resilience around a retrenchment of foreign demand, examined country by country, in the wake of inflation shocks, and in the context of a contraction of the Federal Reserve's balance sheet associated with quantitative tightening (QT).

In the first scenario, we examine Treasury yield movements surrounding a country's permanent withdrawal fixed at \$10 billion. The 10-year responses range from -0.25 to 0.84 basis points across countries, even though the initial dollar contraction is the same. Current holdings alone do not rank the price impact of demand retrenchment. Canada and India hold similar amounts of Treasuries, yet the same withdrawal raises the 10-year yield by 0.67 basis points for Canada and only 0.27 basis points for India. Canadian demand responds more strongly as yields rise, so its withdrawal removes demand that would otherwise return as the market adjusts. Differences in yield sensitivity account for 68.8% of the cross-country dispersion in price impact. Countries also differ in how their Treasury demand responds to macroeconomic conditions. Canada's Treasury demand rises with U.S. debt/GDP, whereas China's falls, so losing Canadian demand becomes more costly when debt is high. The disruption caused by a country's retrenchment therefore depends on the demand it would have supplied as yields and macroeconomic conditions changed, not simply on the total size of the shock.

The broader point that dollar size alone does not determine yield impact also bears on a live policy question: how authorities finance foreign-exchange intervention affects U.S. government financing costs. Japan's Ministry of Finance reports about \$73.6 billion of yen support between late April and late May 2026 (Ministry of Finance, Japan 2026), and the U.S. Treasury has asked the Federal Reserve to enlarge its repo facility for foreign monetary authorities so that Japan could pledge Treasuries instead of selling them (CNBC 2026b,a). Using our model, we compare four routes, ordered by their effect on the 10-year yield: Fed repo financing, U.S. bill issuance, a temporary sale of Japan's U.S. Treasury holdings, and a permanent reduction in those holdings. Repo leaves the pledged securities off the market and has no direct yield effect. Bill issuance adds short-maturity supply and raises the 10-year yield by 0.49 basis points. A sale of Japan's

U.S. Treasury holdings delivers more dollar duration to the market than bill issuance and raises the 10-year yield by 2.62 basis points if expected to reverse, compared with 4.23 basis points if permanent.

In the second scenario, we use global supply-chain pressure to identify a cost-push supply shock and trace how it reaches Treasury yields through sectoral demand. The shock triggers opposing responses from foreign official investors and the Federal Reserve. As inflation rises, foreign official demand falls, adding 4.41 basis points to the 10-year yield response. The Fed's demand moves in the opposite direction and more than offsets this amplification. Together with the other macroeconomic and demand channels, these responses leave the aggregate 10-year yield increase at 4.24 basis points. Treasury market resilience to inflation therefore depends on the balance between foreign official selling and Federal Reserve absorption.

The inflation result reveals a second consequence of foreign retrenchment: a persistent withdrawal changes not only current yields but also how the market responds to later macro shocks. A \$100 billion contraction of foreign official or foreign private demand raises the 10-year yield by 4.72 and 4.29 basis points, respectively. Yet their effects on inflation exposure differ. Foreign official investors normally sell as inflation rises, whereas foreign private demand responds much less. Contracting foreign official demand therefore reduces the 10-year response to the same inflation shock by 0.236 basis points per \$100 billion withdrawn, compared with only 0.016 basis points after a foreign private contraction. Two withdrawals with similar effects on current yields can therefore leave the market with different exposure to subsequent shocks.

The third scenario distinguishes the Fed's current Treasury holdings from its expected response to future conditions around a contraction of its balance sheet. Passive runoff reduces current Treasury holdings but leaves the Fed's response to future conditions unchanged. Rule erosion weakens that response, including the Fed's tendency to buy more Treasuries as debt/GDP rises. We calibrate both policies to reduce Fed demand by \$10 billion at baseline yields and macroeconomic conditions. At 15 years, beyond the long-bucket clearing maturity, passive runoff raises the yield by 0.96 basis points, while rule erosion raises it by 1.55 basis points. In the model's Shapley decomposition, the Fed's response to rising debt accounts for 80% of the rule-erosion effect. Thus, the current reduction in Fed holdings alone does not pin down the effect on long-maturity yields. It also matters whether investors expect the Fed to purchase more Treasuries if debt/GDP rises going forward.

The three scenarios show that Treasury market resilience cannot be summarized by a shock's dollar size or its immediate yield effect. Equal-dollar foreign withdrawals can have different current price effects. Withdrawals with similar current price effects can leave different exposure to the next macro shock. Policies that reduce Fed holdings by the same amount can also imply different future purchases when debt rises. Because arbitrageurs price expected future demand, Treasury-market resilience depends on how demand responds and how long the response persists, not on the shock's size alone.

Related literature. We build on demand-based asset pricing. Koijen and Yogo (2019) establish the approach of estimating sectoral demand from holdings data. A growing body of work applies demand systems to fixed-income markets: Bretscher et al. (2025), Chaudhary, Fu, and Li (2025), Siani (2025), and Darmouni, Siani, and Xiao (2025) to corporate bonds; Koijen and Yogo (2026), Fang, Hardy, and Lewis (2025), and Jiang, Richmond, and Zhang (2024) to global sovereign debt and currencies; Koijen et al. (2021) and Jansen (2025) to euro-area government bonds; and Allen, Kastl, and Wittwer (2020), Doerr, Eren, and Malamud (2023), and Stein and Wallen (2025) to money-like and T-bill markets. Closest to our empirical setting, Eren, Schrimpf, and Xia (2026) and Chaudhary, Fu, and Zhou (2024) estimate demand systems for the U.S. Treasury market. Our starting point is Jansen, Li, and Schmid (2024), which develops the granular demand specification, market-clearing instrument, and equilibrium with risk-averse arbitrageurs used in this paper. We bring this framework to an updated panel covering roughly 80% of the market over 2011Q4–2024Q4. We also open up the role of macroeconomic shocks and distinguish permanent shifts in sectoral demand curves from transitory latent-demand shocks. Latent-demand shocks reverse within one period, macro shocks decay with the state, and demand-curve shifts are permanent. Arbitrageurs therefore price the same current imbalance differently depending on its persistence. This link between sectoral demand, shock persistence, and forward-looking pricing makes the framework suited to measuring resilience and evaluating policy counterfactuals. Every sector's demand curve also includes the relative supply of safe assets, connecting our sector-level approach to the aggregate evidence on Treasury demand, safe-asset supply, and near-money substitution (Krishnamurthy and Vissing-Jorgensen 2012; Nagel 2016; Cieslak, Li, and Pflueger 2024) and to work on the convenience and safe-asset properties of Treasuries (Jiang, Krishnamurthy, and Lustig 2021; Acharya and Laarits 2023). A related literature asks whether those properties are large enough to reconcile the market value of U.S. debt with the present value of fiscal surpluses (Jiang et al. 2024).

Our framework also relates to the preferred-habitat view of interest rates: Culbertson (1957), Modigliani and Sutch (1966), Guibaud, Nosbusch, and Vayanos (2013), Greenwood and Vayanos (2014), and Vayanos and Vila (2021). A recent strand brings this theory closer to the data: Droste, Gorodnichenko, and Ray (2024) and Kaminska and Zinna (2020) identify demand shocks from auctions and official holdings, Hanson, Malkhozov, and Venter (2024) and Khetan et al. (2023) quantify demand and supply in the swaps market, and Greenwood et al. (2023) and Gourinchas, Ray, and Vayanos (2025) connect habitat demand to exchange rates; Greenwood, Hanson, and Vayanos (2024) survey this literature. We add empirically estimated sector- and country-level demand curves to this structure and use it for the foreign, inflation, and balance-sheet exercises that the theory has treated abstractly.

Our inflation exercise connects two literatures. The first identifies supply-side sources of inflation and motivates the shock we study: Benigno et al. (2022) construct the supply-chain pressure index we use as an instrument, and di Giovanni et al. (2022), Comin, Johnson, and Jones (2023), and Liu and Nguyen (2023) quantify how much of the pandemic-era run-up such pressures explain, with estimates as large as half of the 2021–2022 increase. Bernanke and Blanchard (2025) weigh these supply shocks against labor-market tightness and find that the supply component dominates early in the episode. The second literature asks how inflation is priced in nominal Treasuries (Campbell, Sunderam, and Viceira 2017; Campbell, Pflueger, and Viceira 2020; Song 2017; Bekaert, Engstrom, and Ermolov 2021; Pflueger 2025; Cieslak and Pflueger 2023). These discussions are aggregate: a representative investor prices inflation risk, and the variation in that price is traced to macroeconomic regimes and the monetary policy rule. We add a component that this literature abstracts from: the composition of the investor base. Sectors differ in how their Treasury demand responds to inflation, so the same cost-push shock is priced differently depending on who absorbs it.

Because resilience is ultimately about the market's capacity to absorb stress, we also draw on the literature on Treasury market functioning and intermediary constraints (Duffie 2020; Duffie et al. 2023; Du, Hébert, and Li 2023; Barth and Kahn 2025) and on the broader intermediary asset-pricing tradition (He and Krishnamurthy 2013; Adrian, Etula, and Muir 2014; He, Kelly, and Manela 2017; Du, Tepper, and Verdelhan 2018; Haddad and Muir 2021; Siriwardane, Sunderam, and Wallen 2025). Our balance-sheet exercise speaks to the large literature on quantitative easing and tightening: Krishnamurthy and Vissing-Jorgensen (2011), D'Amico and King (2013), and Greenwood, Hanson, and Stein (2015) on supply and debt maturity, Haddad, Moreira, and Muir (2024) on the anticipation effect of asset-purchase rules, and Jiang and Sun (2024) and Selgrad (2023) on tightening and portfolio rebalancing.

Roadmap. Section 2 develops the framework, summarizes the demand system estimates, and distinguishes transitory latent-demand shocks from persistent macro shocks and permanent shifts in demand curves. Section 3 lays out the same-dollar foreign contraction experiment country by country and decomposes the cross-country yield dispersion into maturity composition, elasticity, and macro loadings. Section 4 identifies the cost-push inflation shock, contrasts foreign official amplification with the Fed's demand offset, and shows how persistent foreign retrenchment changes that transmission. Section 5 decomposes Federal Reserve balance-sheet policy into level and insurance channels and quantifies the cost asymmetry of QT designs. Section 6 concludes.

2. A Framework for Treasury Market Resilience

In this section, we develop the framework that we apply in the rest of the paper. We model the Treasury market as a system of estimated, sector-specific demand curves cleared by a competitive arbitrage sector, and we define resilience as the inverse of the yield response when a shock hits. The definition is general by design: a shock can move the macro state, shift a sector's demand parameters, or combine the two, so the foreign demand, inflation, and Fed balance-sheet exercises of Sections 3–5 are special cases of one broad setting rather than three separate exercises. Measuring resilience in this way requires knowing who holds Treasuries at each maturity and how elastically they do so, which is why the framework rests on granular, sector-level demand estimates rather than a representative investor.

2.1. Treasury Market Resilience: A Structural Framework

The Treasury market clears through the interaction of three types: heterogeneous *granular-demand investors*, each an institutional sector with its own estimated demand curve; the Federal Reserve, whose holdings we also represent by a demand curve but which we interpret as a policy rule; and a competitive arbitrage sector that absorbs the residual. We lay out these components in turn and then define resilience formally as a property of the resulting equilibrium.

The non-arbitrageur demand comes from the granular-demand investors together with the Fed; we index these sectors by $\iota \in \mathscr{I}$ and maturity buckets by $m \in \{\text{short, medium, long}\}$. Let y_t denote the vector of Treasury yields across buckets and let $\beta_t = (q_t^A, g_t, \pi_t, d_t)'$ collect four aggregate states that capture relative safe-asset supply, the business cycle, inflation, and the fiscal stance. The agency-to-Treasury supply ratio q_t^A is the beginning-of-quarter relative supply of the closest substitute safe asset; it is common across maturity buckets, avoiding a separate supply state for each. The GDP gap g_t measures the business cycle, over which risk appetite and the flight-to-safety demand for Treasuries vary. Core inflation π_t drives nominal yields and the monetary-policy reaction. Debt-to-GDP d_t captures the fiscal stance and the quantity of Treasury supply the market must absorb.

Granular demand. Sector ι's demand at bucket m is

$$Z_t^\iota(m) = \theta_0^\iota(m) + \alpha^\iota(m)' y_t + \theta^\iota(m)' \beta_t + u_t^\iota(m), \tag{1}$$

where $\theta_0^\iota(m)$ is the demand intercept, $\alpha^\iota(m)$ contains the own- and cross-maturity Treasury-yield loadings, $\theta^\iota(m)$ contains the macro loadings, and $u_t^\iota(m)$ is a latent demand shock. Appendix B.1

derives equation (1) from a local quadratic portfolio-choice problem.

The Federal Reserve. The Fed is one of the sectors $\iota \in \mathscr{I}$, and its holdings follow the same demand curve (1); only the interpretation differs. The Fed does not optimize a portfolio, so we read its demand curve as a policy rule mapping the macro state and yields into Treasury holdings, as in Jansen, Li, and Schmid (2024) and in the spirit of Vayanos and Vila (2021). Each parameter then carries a policy meaning. The intercept $\theta_0^{\text{Fed}}(m)$ is the additive, state-independent component of the rule: changing it translates Fed demand without changing how holdings respond to yields or macroeconomic conditions. The macro loading $\theta^{\text{Fed}}(m)$ is the rule's state contingency: a countercyclical balance sheet that expands when the macro state deteriorates absorbs duration risk in those states, while $\alpha^{\text{Fed}}(m)$ captures how strongly the Fed leans against yield movements. Because QE and QT are persistent rather than transitory, we represent them as shifts in these parameters rather than as latent shocks u_t^{Fed}. This underlies the balance-sheet exercise of Section 5, which separates an additive contraction through θ_0^{Fed} from an erosion of the state-contingent response carried by α^{Fed} and θ^{Fed}.

Aggregate states and monetary policy. The macro state follows a VAR(1),

$$\beta_{t+1} = \bar{\beta} + \Phi(\beta_t - \bar{\beta}) + \Sigma_\beta^{1/2}\varepsilon_{t+1}, \qquad \varepsilon_{t+1} \overset{\text{iid}}{\sim} N(0, I), \tag{2}$$

with steady state $\bar{\beta}$, persistence matrix Φ, and macro-innovation covariance Σ_β (distinct from the return covariance Σ below). The one-period rate r_t is set by a generalized Taylor rule that responds to the contemporaneous macro state and carries policy inertia,

$$r_{t+1} = \bar{r} + \phi_r'(\beta_{t+1} - \bar{\beta}) + \rho_r r_t + \sigma_r \varepsilon_{t+1}^r, \tag{3}$$

where ρ_r is the degree of inertia and the policy shock ε_{t+1}^r is independent of ε_{t+1}. The latent demand shocks u_t are i.i.d. with mean zero and independent of the macro and policy innovations, so arbitrageurs expect them to revert within one period. A latent demand shock therefore cannot represent a persistent change in a sector's behavior. We model such a change as a shift in the sector's demand parameters instead.

Risk-averse arbitrageurs. A risk-averse arbitrageur sector holds the residual between Treasury supply and the demand of all other sectors, forms rational expectations, and exhibits no non-pecuniary motive. A representative arbitrageur chooses Treasury positions $X_t(m)$ across maturities conditional on a predetermined background position $\tilde{X}_t$ in an outside fixed-income portfolio. We express rates in log-return units and use the first-order approximation $\exp(r_t) - 1 \approx r_t$ in the wealth and excess-return equations. Wealth evolves as

$$W_{t+1} = W_t(1+r_t) + \sum_m X_t(m)\big(R_{t+1}^{(m)} - r_t\big) + \tilde{X}_t\big(\tilde{R}_{t+1} - r_t\big), \tag{4}$$

where $R_{t+1}^{(m)}$ is the holding return on bucket m and r_t the one-period rate. The arbitrageur's outside asset position represents its broader fixed-income exposure. Its return loads on the same states,

$$\tilde{R}_{t+1} = \tilde{\phi}'\beta_t + \tilde{\phi}_r r_t + \tilde{\sigma}'\varepsilon_{t+1} + \tilde{\sigma}_r \varepsilon_{t+1}^r, \tag{5}$$

capturing that arbitrageurs' risk-bearing capacity in the Treasury market depends on their positions in other fixed-income markets, including interest-rate swaps (Du, Hébert, and Li 2023). Conditional on this background portfolio, the arbitrageur chooses Treasury positions to maximize expected next-period wealth net of a penalty for systematic risk,

$$\max_{\{X_t(m)\}_m} \; \mathbb{E}_t[W_{t+1}] - \frac{\gamma}{2}\mathbb{V}_t^{\text{sys}}(W_{t+1}), \tag{6}$$

where $\gamma > 0$ is risk aversion. The operator $\mathbb{V}_t^{\text{sys}}$ is the conditional variance generated by the macroeconomic and policy-rate innovations $(\varepsilon_{t+1}, \varepsilon_{t+1}^r)$; it excludes u_{t+1}. We assume that arbitrageurs receive no risk premium for exposure to one-period latent demand shocks. These shocks nevertheless affect prices, while their variance enters expected holding returns through the Jensen adjustment. The first-order conditions express expected excess returns as the product of bond risk exposures and time-varying prices of macro and interest rate risk; Appendix B derives them. Because arbitrageurs price expected excess returns rather than current yields, their position must be solved from equilibrium, not estimated from a reduced-form demand regression; their forward-looking pricing is also why the *persistence* of a disturbance, not just its size, is central to its yield impact.

Supply and market clearing. Treasury supply in bucket m responds to the macro state and the policy rate,

$$S_t(m) = \bar{S}(m) + \zeta(m)'\beta_t + \zeta_r(m)\, r_t, \tag{7}$$

which we estimate from issuance data. The loadings $\zeta(m)$ and $\zeta_r(m)$ capture how both total financing and the maturity composition of issuance respond to macro states and policy rates. Market clearing holds bucket by bucket, so that $\sum_{\iota \in \mathscr{I}} Z_t^{\iota}(m) + X_t(m) = S_t(m)$.

Affine equilibrium. We obtain equilibrium yields by combining investor demand, Treasury supply, and arbitrageurs' optimal positions with market clearing. The resulting zero coupon yield curve is affine, meaning linear up to a constant, in the macro state, the policy rate, and latent demand shocks:

$$\mathbf{y}_t = A\beta_t + A_r r_t + A_u u_t + C. \tag{8}$$

Here $\mathbf{y}_t$ contains yields at quarterly maturities from one quarter to 30 years, and u_t collects the latent demand shocks across sectors within the three maturity buckets. The matrices A, A_r, and A_u map these inputs into yields, while C is the constant component of the yield curve. Although we estimate demand and supply for only three maturity buckets, the equilibrium must track all 120 maturities. A bond with τ quarters remaining today has $\tau - 1$ quarters remaining next period, so its return over the next period depends on prices at both maturities. We therefore associate each bucket with a representative maturity and impose market clearing at that point on the curve. Appendix B derives the coefficient equations and describes the numerical solution.

Defining resilience. Equation (8) makes the yield at every maturity a function of two distinct objects: the *aggregate state* $x_t \equiv (\beta_t, r_t)$, which moves period to period, and the *structural parameters* $\Theta \equiv \{\theta_0^\iota, \alpha^\iota, \theta^\iota\}_{\iota \in \mathscr{I}}$ together with the supply, policy-rule, and arbitrageur parameters, which are fixed in estimation but can be changed in a counterfactual. The latent demand u_t is transitory. Because the resilience exercises concern persistent shifts in states or demand, we hold it at its mean and do not treat latent shocks as resilience scenarios. Write the equilibrium yield as $y_t(m) = \mathscr{Y}_m(x_t; \Theta)$, evaluated at $u_t = 0$.

A *scenario*, $\xi = (\Delta x, \Delta\Theta)$, changes the state, the parameters, or both. Resilience of maturity m to scenario ξ is the inverse of the yield response it induces,

$$\mathscr{R}_{m,t}(\xi) = \left| \mathscr{Y}_m(x_t + \Delta x;\ \Theta + \Delta\Theta) - \mathscr{Y}_m(x_t;\ \Theta) \right|^{-1}, \tag{9}$$

or, for a marginal scenario, the inverse directional derivative $\mathscr{R}_{m,t}(\xi) = \left|\partial_x \mathscr{Y}_m \Delta x + \partial_\Theta \mathscr{Y}_m \Delta\Theta\right|^{-1}$. High $\mathscr{R}$ means yields barely move; low $\mathscr{R}$ means the market clears only through a large yield adjustment. Both subscripts in $\mathscr{R}_{m,t}$ matter: the same scenario can move the short and long ends differently, because different sectors are marginal at each maturity, and the response is evaluated at the prevailing state x_t, so resilience varies with the macroeconomic state.

Each component of ξ carries a distinct economic meaning. The change Δx moves the aggregate state while holding the structural parameters fixed. In the inflation exercise, for example, Δx contains the joint movements in core inflation, the policy rate, the GDP gap, debt/GDP, and relative safe-asset supply produced by the identified cost-push shock. The change $\Delta\Theta$ instead alters the structural parameters: scaling a single sector's $(\theta_0^\iota, \alpha^\iota, \theta^\iota)$ in lockstep is a permanent contraction of that sector's demand curve, and shifting the policy-rule coefficients changes how the Fed responds to the macro state. A general ξ combines the two. Allowing a scenario to change the parameters as well as the state lets resilience capture permanent changes in who holds Treasuries and how policy is conducted, not only state shocks that leave that structure intact.

Current and state-contingent absorption. Equation (1) distinguishes absorption at the current state from how that absorption changes with market conditions. Investor ι's current absorption at maturity m is $Z_t^\iota(m)$ evaluated at baseline equilibrium yields and macroeconomic conditions, with latent demand at its mean. The yield loadings $\alpha^\iota(m)$ determine how that absorption changes as yields adjust across maturities, while the macro loadings $\theta^\iota(m)$ determine how it changes with the aggregate state. Together with Treasury supply, these responses determine the residual left to arbitrageurs. Because arbitrageurs price the expected path of the residual supply they must absorb, yields today depend on how long a macro shock or shift in demand is expected to last. Current absorption, state-contingent demand, and persistence therefore jointly determine resilience.

2.2. Demand Estimation

We estimate the demand system (1) sector by sector to characterize who holds Treasuries at each maturity and how holdings respond to Treasury yields and macro states. This subsection describes the holdings data and estimation, then highlights the features of the estimates that drive the resilience results and decomposes the sources of Treasury yield movements that motivate the paper's focus on persistent shocks.

We use the granular sector-level Treasury holdings dataset of Jansen, Li, and Schmid (2024), updated through 2024Q4 and covering 2011Q4–2024Q4 at quarterly frequency. Holdings are measured in market values across the major Treasury-holder groups and three maturity buckets ($\tau < 1Y$, $1Y \leq \tau < 5Y$, $\tau \geq 5Y$), with approximately 80% market coverage. Figure A1 shows the fraction and billions of U.S. Treasuries outstanding held by each investor type by maturity bucket.

We estimate demand curves for eight granular sectors: banks, insurers and pension funds, U.S. mutual funds, U.S. ETFs, MMFs, Other U.S. investors, foreign official investors, and foreign private investors. We estimate the Federal Reserve separately, interpreting its demand as a policy rule rather than market demand. Hedge funds and primary dealers are not modeled as demand sectors; together they form the arbitrageur sector that absorbs the market-clearing residual. The TIC SLT data also provide country-level foreign holdings (combining the official and private sector holdings), which we use only in Section 3 to disaggregate foreign investors' demand curves, not in estimating the model. Data sources and aggregation details are in Appendix A.

The macro state contains four aggregate variables. The agency-to-Treasury supply ratio, q_t^A, is beginning-of-quarter nonsecuritized agency debt divided by marketable coupon Treasury debt, so its loading is measured per percentage-point increase in relative agency supply. The GDP gap, g_t, is nominal GDP relative to nominal potential GDP, expressed in percentage points. Core inflation, π_t, is the year-over-year log change in core CPI measured at quarter-end. The debt ratio, d_t, is the outstanding amount of marketable Treasury securities relative to nominal potential GDP. These states capture variation in relative safe-asset supply, aggregate economic conditions, the inflation environment, and the total government debt burden. Their estimated loadings describe how sectoral Treasury holdings covary with these conditions at given yields and values of the other states. Alongside the aggregate states, each regression controls for coupon rates and bid–ask spreads. The seven sectors observed across all three maturity buckets also include maturity-bucket indicators; MMFs are observed only in the short-term bucket.

The agency/Treasury ratio and debt/GDP capture different supply margins. Debt/GDP measures Treasury supply relative to the economy, while the agency/Treasury ratio measures agency debt relative to Treasuries. Because the ratio's long-run decline mainly reflects growth in Treasury debt, we estimate its macro loading while holding debt/GDP fixed. The loading therefore reflects variation in relative agency supply beyond the change in Treasury debt.

We measure the ratio using values observed at the beginning of the quarter to limit simultaneity. The Federal Home Loan Bank (FHLB) system lends to member banks through advances and finances those loans by issuing agency debt. A bank can draw an advance and adjust its Treasury holdings within the same quarter. A ratio measured at quarter end could therefore reflect the same bank balance sheet decisions that determine Treasury demand. The beginning of quarter value is fixed before portfolios adjust. Appendix A shows that this timing removes the contemporaneous link to latent demand.

For each granular-demand sector, we estimate (1) using fixed-duration Treasury yields and an IV, instrumenting the endogenous Treasury yields with pseudo-yields constructed from a pseudo market-clearing condition as in Jansen, Li, and Schmid (2024) and Fang, Hardy, and Lewis (2025). The construction has three steps. We first regress Treasury demand for each granular demand investor and the Fed on bond characteristics and the aggregate states, excluding yields. We do the same for nominal supply in each maturity bucket. We then sum fitted demand across granular-demand investors and the Fed, impose market clearing on these fitted quantities, and invert the clearing condition to obtain the pseudo-yield $\check{y}_t(m)$ that equates implied demand to implied supply. Finally, $\check{y}_t(m)$ and the value-weighted pseudo-yield of the remaining buckets instrument the own- and cross-maturity Treasury yields. The seven regular private sectors share their yield loadings across maturity buckets. Because MMFs hold only bills, their equation contains the T-bill yield but no cross-maturity yield. The Fed is estimated in one stacked system: short and medium observations share yield loadings, while the long bucket has separate yield loadings.

The exclusion restriction requires the included bond characteristics and four aggregate state variables to be orthogonal to the contemporaneous sector-specific residual $u_t^l(m)$. The four state variables are aggregate quantities that are unlikely to respond within the quarter to an idiosyncratic shift in one sector's Treasury demand. An idiosyncratic shift in insurers' demand, for example, is unlikely to contemporaneously change the GDP gap, core inflation, or debt/GDP. As discussed above, the agency/Treasury ratio is measured from beginning-of-quarter amounts outstanding, so it is predetermined relative to the current-quarter holdings outcome. A current-quarter portfolio reallocation can change who holds these securities and their prices, but it cannot change quantities already set by Treasury and agency issuance and redemption decisions. The identifying assumption is therefore that, after conditioning on the other state variables and bond characteristics, they are unrelated to the current sector-specific residual. We additionally require the linear demand equation to capture demand well enough that the pseudo-yield's identifying power comes from the nonlinear market-clearing inversion. Under these conditions the pseudo-yield is orthogonal to $u_t^l(m)$. The Kleibergen–Paap statistic is 13.05 for each of the seven pooled three-bucket granular demand investor regressions. This exceeds our simulation-based size-controlled HAC threshold of 7.28 for the underlying two-endogenous-variable design, defined as the 90th percentile of the Kleibergen–Paap distribution at the 10% Nagar-bias boundary. For MMFs, the corresponding first-stage statistic is 1813.94. The Fed's stacked system has a joint Kleibergen–Paap statistic of 9.75 (Appendix Tables A2 and A7). Allowing all six sector yield loadings to vary freely across maturity buckets lowers the joint statistic to 3.89 and produces unstable medium- and long-bucket elasticities; we therefore retain the common-slope restriction. Full estimates are in Appendix C.

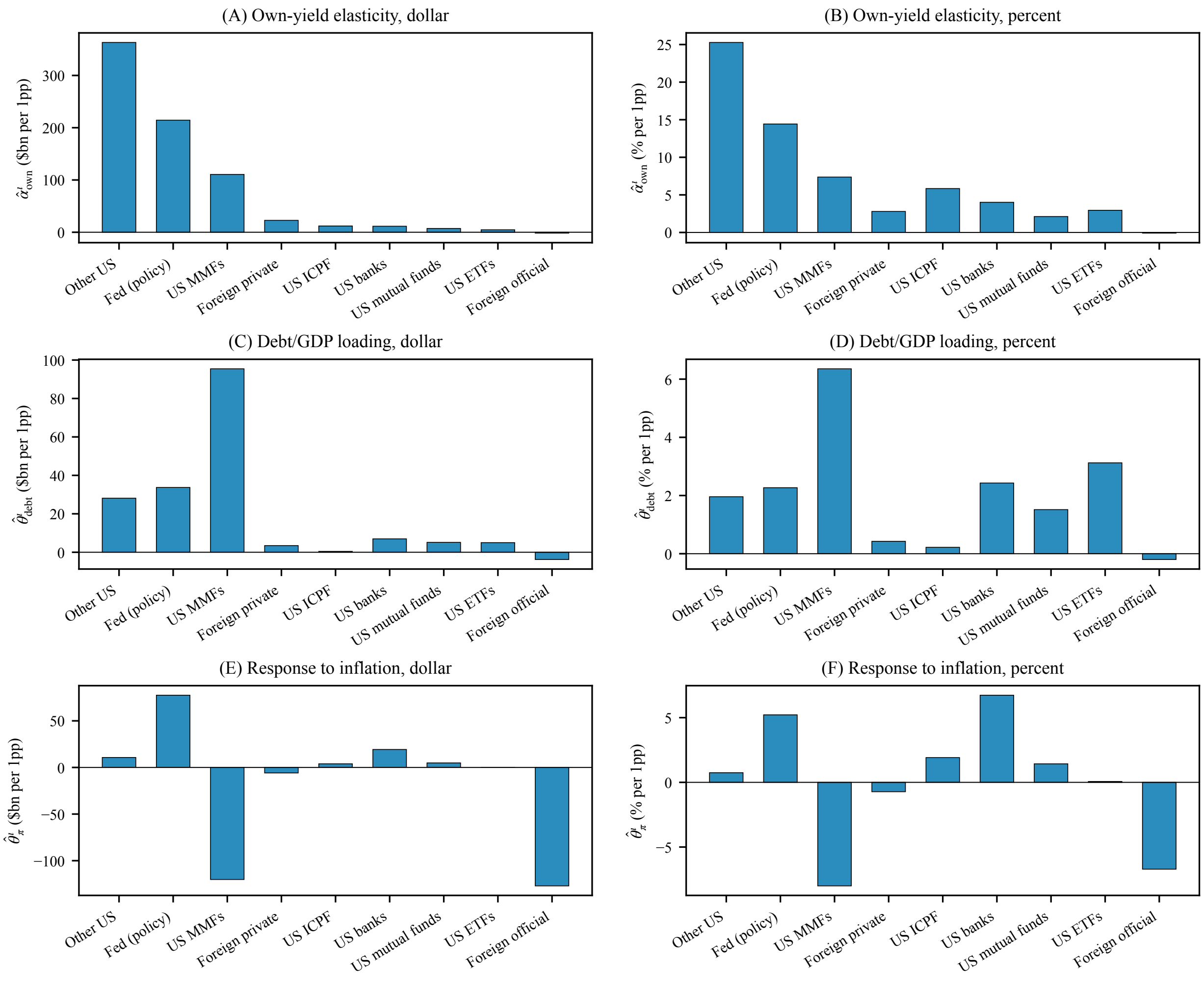
Figure 1 displays three features of the estimated sectoral demand curves: the own-yield elasticities and the macro loadings on debt/GDP and inflation. Each estimate is shown in dollars in left panels and as a percentage of the sector's average Treasury holdings in right panels. We pool the three maturity buckets for the granular sectors. For the Federal Reserve, we pool the short- and medium-bucket yield responses but estimate a separate long-bucket response and separate macro loadings by bucket; the figure reports the average across buckets.

The own-yield coefficients differ sharply across sectors. In dollar terms, Other U.S. investors have the largest positive point estimate, followed by the Federal Reserve's across-bucket average and MMFs. The inflation loadings show a different pattern. They are significantly negative for foreign official investors and MMFs and significantly positive for banks. The Federal Reserve's across-bucket average is positive. The contrast between foreign official investors and the Federal Reserve becomes central to the inflation counterfactuals in Sections 4.2 and 4.3, where their opposing responses shape the transmission of inflation shocks to yields.

The middle panels report the conditional change in sectoral holdings associated with a one-

Figure 1. **Demand Heterogeneity Across Sectors**

We report three estimated demand loadings per sector, in dollars ($bn per 1 percentage point, left column) and as a percent of the sector's average holdings (right column): the own-yield elasticity $\hat{\alpha}^{\iota}_{\text{own}}$ (Panels A and B), the debt/GDP loading $\hat{\theta}^{\iota}_{\text{debt}}$ (Panels C and D), and the core-inflation loading $\hat{\theta}^{\iota}_{\pi}$ (Panels E and F). Estimates pool the three maturity buckets (except for MMFs, which only operate in bucket 1) and the sectors are ordered by own-yield elasticity. The Fed's stacked specification pools short and medium yield loadings, permits separate long yield loadings, and is summarized by its across-bucket average. Sample: 2011Q4–2024Q4.



percentage-point increase in debt/GDP, holding yields and the other macro states fixed. The loadings are positive and significant for banks, ETFs, mutual funds, MMFs, Other U.S. investors, and the Federal Reserve. By contrast, the near-zero insurer and pension-fund loading is significantly below those for banks, ETFs, mutual funds, and Other U.S. investors (Appendix C.2). This pattern is consistent with pension and insurance liability-driven duration demand (Klingler and Sundaresan 2019; Khetan et al. 2023) that is not directly related to total debt/GDP.

The positive conditional debt/GDP loadings are consistent with several mechanisms, but the estimates do not distinguish among them. Treasuries, bank-created money, and shadow-bank money provide liquidity services and are imperfect substitutes (Krishnamurthy and Li 2023). More public safe-asset supply can therefore displace privately issued money-like claims and financial-sector lending (Greenwood, Hanson, and Stein 2015; Krishnamurthy and Vissing-Jorgensen 2015). Which sectors absorb additional Treasuries depends on their balance sheets. Treasuries qualify as level-1 liquid assets under U.S. liquidity regulation (Board of Governors of the Federal Reserve System 2026); stable funding supports banks' capacity to hold fixed-income assets (Hanson et al. 2015); and MMFs allocate between T-bills and repo (Doerr, Eren, and Malamud 2023). These mechanisms are most relevant for the positive bank and MMF loadings.

The Federal Reserve requires a different interpretation because its equation is a policy rule rather than a portfolio-demand equation. Its positive debt/GDP coefficients capture systematic accommodation of Treasury supply within the estimated rule. At 2024Q4 levels, a one-percentage-point increase in debt/GDP corresponds by construction to \$294.3 billion in additional Treasury supply. Summing the Federal Reserve's bucket loadings and dividing by this amount gives a fixed-yield absorption-equivalent share of 34%, the largest point estimate for an individual sector. Section 5 studies changes in the policy rule.

Neither foreign-sector loading is informative on its own: both t-statistics are below one in absolute value. Treasuries' safe-asset and liquidity services support foreign demand, while concerns about U.S. fiscal risk can work in the opposite direction (Jiang, Krishnamurthy, and Lustig 2021; Chari and Milesi-Ferretti 2026). Our estimates do not reveal a stable conditional response of either foreign sector to U.S. debt/GDP over the sample.

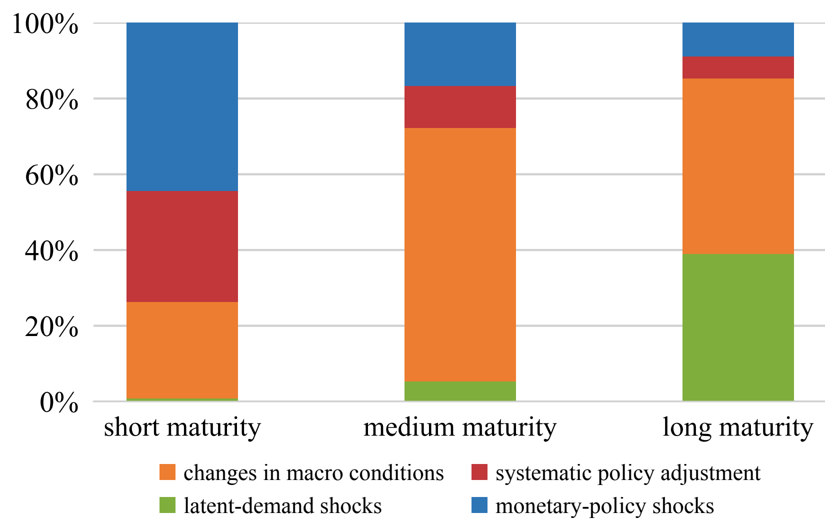
Appendix C.2 develops these mechanisms and reports the comparisons in full. Section 3 uses the corresponding country-level differences in macro loadings to explain why equal foreign withdrawals can have different effects on yields.

We next ask which forces account for quarterly Treasury yield movements. For each maturity bucket, aggregate latent demand is $u_t(m) = \sum_{\iota \in \mathscr{I}} u_t^{\iota}(m)$. We first decompose the R^2 from a regression of quarterly yield changes on changes in the four macro states, the policy rate, and aggregate latent demand. A predictor's Shapley value is its average incremental contribution to R^2 across all possible orderings of the predictors. This allocation accommodates correlated predictors and ensures that the contributions sum to the full-model R^2. We sum the four state contributions into macro conditions and then divide the policy-rate contribution between the systematic adjustment, $\hat{r}_t - r_{t-1}$, and the monetary-policy shock, $r_t - \hat{r}_t$.

The full model explains 0.92, 0.68, and 0.78 of quarterly yield changes in the short-, medium-, and long-maturity buckets, respectively. The sources of this explained variation shift sharply along the yield curve. Monetary-policy shocks are the largest component at the short end, whereas macro conditions dominate the medium and long buckets. Latent demand contributes little at short and medium maturities but becomes quantitatively important in the long bucket, where its contribution is second only to macro conditions.

Figure 2. **Shapley R^2 Decomposition of Quarterly Treasury Yield Changes**

For each maturity bucket, the first-stage Shapley decomposition allocates the full-model R^2 for quarterly yield changes across changes in the four macro states, the policy rate, and aggregate latent demand $\Delta u_t(m)$. Each Shapley value is the predictor's average incremental R^2 across all possible predictor orderings. We sum the four macro-state contributions and divide the policy-rate contribution between the systematic adjustment $\hat{r}_t - r_{t-1}$ and the monetary-policy shock $r_t - \hat{r}_t$. Each bar normalizes these contributions by the corresponding full-model R^2, which is 0.92, 0.68, and 0.78 for the short-, medium-, and long-maturity buckets. The underlying levels span 2011Q4–2024Q4; first differencing drops the initial observation.



Latent demand shocks and persistent shocks play complementary roles in the analysis. Because latent shocks are specific to the Treasury market and orthogonal to macro conditions and the policy rate, the associated yield movements and offsetting changes in arbitrageur positions identify arbitrageur risk aversion γ. The estimated γ governs the yield adjustment required for arbitrageurs to absorb Treasury risk. Both parts of the framework are therefore indispensable: demand estimation isolates an important source of yield variation, especially at the long end, and provides the variation that identifies arbitrageur risk-bearing capacity; the structural model then uses that capacity to quantify how persistent macro shocks and permanent shifts in sectoral demand affect Treasury yields.

2.3. Model Estimation

Evaluating the affine equilibrium (8) for the counterfactuals requires two objects beyond the demand system: the loadings (A, A_r) that map the macro state and the federal funds rate into yields, which reflect the prices of macro and interest-rate risk, and arbitrageur risk aversion γ. We estimate them in three steps. First, we jointly fit the systematic prices of risk and an unrestricted price intercept to Treasury prices. Second, we estimate γ from the joint price and quantity response to Treasury-specific latent demand. Finally, we reoptimize the systematic prices of risk, γ, and the constant outside-exposure terms while imposing the structural restriction on the price intercept. Appendix B derives the complete affine coefficient system and states the exact second-step objective.

The systematic comovement of yields with the macro state and the fed funds rate disciplines the prices of risk. Because arbitrageurs bear risk in other fixed-income markets such as interest-rate swaps and Treasury futures as well as in Treasuries, this comovement reflects a composite of their risk aversion and their outside-asset exposure. Macro–yield covariation therefore pins down (A, A_r) together with the outside-asset exposure, but cannot on its own separate γ from that exposure.

What separates γ is the yield variation that macro fundamentals and the policy rate leave unexplained, which is the residual traced to latent demand shocks. Such a shock is specific to the Treasury market: it moves the supply–demand imbalance arbitrageurs must absorb without disturbing the prices of risk, so the yield concession they require per dollar absorbed is governed by γ alone. That force shows up in the residual yield and in the offsetting adjustment of arbitrageur positions. Intuitively, the ratio of the two identifies γ: a more risk-averse arbitrageur needs a larger yield move to absorb the same quantity.

The final step estimates the two blocks jointly and ties down the reference-state yield level through the market-clearing restrictions rather than leaving it free. The resulting risk aversion is $\hat{\gamma} = 0.043$. Appendix B (Figures A2–A3) reports the model's fit to yields and to arbitrageur holdings.

2.4. Structural Shocks and Counterfactuals

The framework of Section 2.1 applies to any scenario, but the three counterfactuals in this paper share a common structure: each generates a persistent change in investor demand, so that arbitrageurs' forward-looking pricing, not just the contemporaneous market-clearing condition, governs the yield response. Section 2.2 showed that latent-demand shocks account for a rising share of yield changes with maturity but, because they are i.i.d., revert within a period; it is the persistent shocks that stress-test resilience. We first distinguish the two kinds of persistent disturbance the framework treats, and then describe the three counterfactual exercises that we focus on in this paper.

Macro shocks. A macro shock changes the aggregate state $x_t = (\beta_t, r_t)$. The macro variables in β_t evolve under the persistence matrix Φ of (2), while the policy rate r_t follows the generalized Taylor rule (3). Its persistence is therefore intermediate: neither transitory like the latent demand shock u_t, which reverts within a period, nor permanent like a structural demand curve shift. Because arbitrageurs price the expected future state, the equilibrium loadings A and A_r in (8) embed both macroeconomic dynamics and the monetary-policy rule. Persistence therefore affects the current yield response and how long it lasts, with the sign and magnitude determined jointly by investor demand responses and equilibrium price impact.

Structural demand curve shocks. A structural demand curve shock is a permanent shift in a sector's demand parameters: its intercept θ_0^ι, elasticity α^ι, and macro loading θ^ι. We model these as proportional scalings of the entire demand curve rather than translations of the intercept alone, since a country or sector reducing its presence in the market shrinks all of its responsiveness in lockstep. Because the shift is permanent, it changes the entire path of sectoral demand that arbitrageurs expect, not only the current period's clearing condition, and it permanently changes the market's exposure to subsequent shocks.

Demand-system frameworks such as Koijen and Yogo (2019) and Fang, Hardy, and Lewis (2025) estimate contemporaneous demand without modeling shock persistence as a separate state. Consequently, in a static implementation of those frameworks, the same current sectoral imbalance receives the same reduced-form price impact whether it is mean-reverting or permanent. This equivalence arises from the static implementation. In our model, forward-looking arbitrageurs distinguish between the shocks because they imply different future paths of demand.

We apply this distinction in three settings: foreign retrenchment changes an investor's demand curve, inflation changes the state at which every demand curve is evaluated, and QT changes either the level or the state contingency of the Fed's demand curve.

Foreign demand contractions (Section 3). We permanently scale down a country's fitted demand curve. The experiment matches the reduction in demand at baseline yields and macroeconomic conditions, while maturity composition, yield elasticities, and macro loadings vary across countries. It therefore holds the current contraction fixed while varying the state-contingent demand that is lost.

Inflation shocks (Section 4). The identified cost-push shock moves β_t and the policy rate jointly, tracing how each sector's demand curve responds to the same macroeconomic disturbance. Foreign official demand and Fed demand move in opposite directions. The retrenchment exercises then change the investor base present when the shock arrives, connecting the current withdrawal to the market's subsequent inflation exposure.

Federal Reserve balance-sheet policy (Section 5). We match the reduction in Fed demand at baseline yields and macroeconomic conditions under two policy counterfactuals. Passive runoff lowers θ_0^{Fed} while leaving the Fed's yield and macro-state responses unchanged. Rule erosion instead weakens the responses governed by α^{Fed} and θ^{Fed}. The comparison separates current Fed absorption from the demand investors expect as market conditions change.

3. Foreign Investor Demand Contractions

Foreign investors hold roughly one-third of U.S. Treasuries, but their shares of aggregate holdings do not measure their importance for market resilience. We instead ask how much the 10-year yield moves when each country permanently reduces its Treasury holdings by \$10 billion. This standardized shock puts every country on the same footing. Differences in yield impact then reflect three features of the country's demand curve: maturity composition, yield elasticity, and macro loadings.

3.1. Data: Country-Level Holdings

We estimate a demand curve for each country using quarterly holdings from the Treasury International Capital (TIC) SLT report. The balanced panel runs from 2011Q4 to 2024Q4 and contains 40 named countries plus an "Other" residual. TIC reports T-bills and long-term Treasuries ($\tau \geq 1$Y). Our model uses three buckets: $\tau < 1$Y, 1Y $\leq \tau < 5$Y, and $\tau \geq 5$Y. The short bucket uses each country's reported bill holdings, scaled to cover all sub-one-year maturities because TIC reports original-issue bills only (Appendix A). We divide each country's reported $\tau \geq 1$Y holdings between the medium and long buckets using aggregate TIC shares. This preserves the country-specific split between bills and longer-term Treasuries without imposing an unobserved country-specific split within the long bucket.

Belgium, Luxembourg, and the United Kingdom are major custodial centers, so their TIC totals may include Treasuries held for beneficial owners elsewhere (Tabova and Warnock 2021). To limit this custodial bias, we reduce the reported holdings of Belgium and Luxembourg by 50% and those of the United Kingdom by 20%.

3.2. Modeling Foreign Demand Contractions

For country i and maturity m, we estimate the demand curve

$$Z_{i,t}(m) = \theta_0^i(m) + \alpha^i(m)' y_t + \theta^i(m)' \beta_t + u_{i,t}(m). \tag{10}$$

The intercept $\theta_0^i(m)$ is the state-independent component of demand at each maturity. The coefficients $\alpha^i(m)$ measure the response to Treasury yields, and $\theta^i(m)$ contains the macro loadings. The residual $u_{i,t}(m)$ captures latent demand.

The same-dollar contraction experiment. We apply the standardized shock to the country's entire demand curve. A proportional contraction reduces its desired holdings and its responses to yields and macro conditions together:

$$Z'_{i,t}(m) = (1-\kappa^i)\left[\theta_0^i(m) + \alpha^i(m)' y_t + \theta^i(m)' \beta_t + u_{i,t}(m)\right], \tag{11}$$

for $m \in \{1,2,3\}$ (short, medium, and long). We choose κ^i so that the country sheds \$10 billion at the baseline equilibrium: $\kappa^i \bar{Z}^i = \$10\,\text{bn}$. Because the contraction is proportional within the country, the withdrawal follows its estimated allocation across the three maturity buckets.

Because every country sheds the same amount, the yield responses differ only through maturity composition, yield elasticity, and macro loadings. Maturity composition determines where the contraction falls across the curve. Yield elasticity determines how much demand returns as yields rise. Macro loadings determine how the lost demand would have moved with economic conditions.

3.3. Country Rankings: Holdings vs. Impact

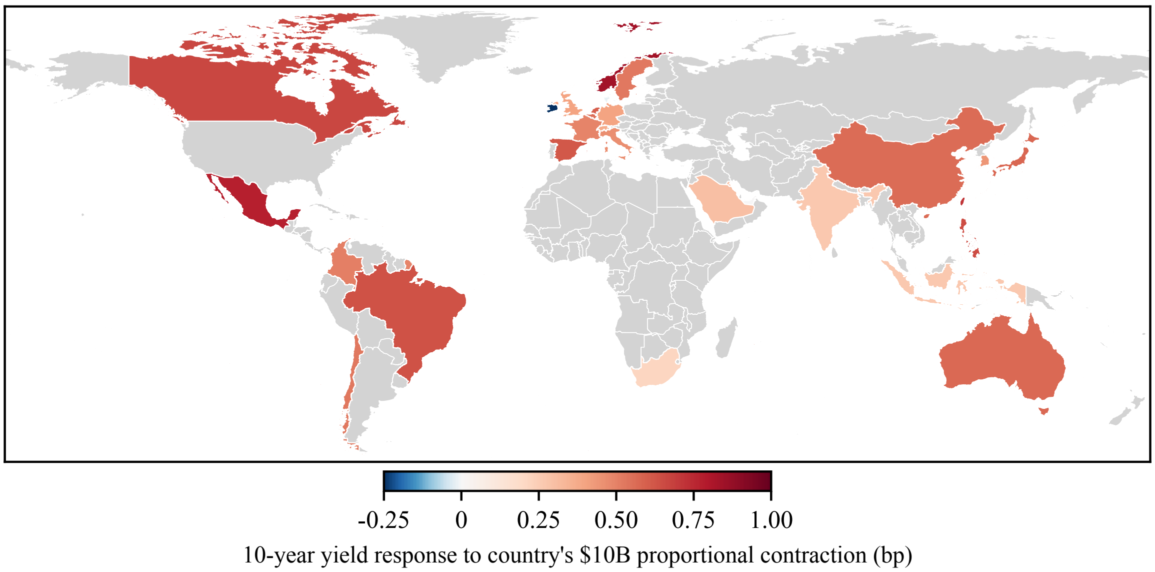
We estimate a demand curve for every country in the balanced panel, but the standardized experiment is only defined where a country holds at least \$10 billion. Since κ^i solves $\kappa^i \bar{Z}^i = \$10\,\text{bn}$, requiring $\kappa^i \leq 1$ is the same as requiring $\bar{Z}^i \geq \$10$ billion. We therefore analyze separately the 34 of 40 named countries that clear this bar. The cutoff is not a close call: the largest excluded country holds \$8 billion in steady state and the smallest included country \$19 billion, so no country sits near the threshold.[1]

Figures 3 and 4 summarize the country rankings. Figure 3 shows that the 10-year responses range from -0.25 basis points for Ireland to 0.84 basis points for Norway. Figure 4 compares these responses with holdings shares. Japan and China are the two largest holders, but the same

[1] Sorting on sample-average rather than model steady-state holdings selects the same 34 countries.

Figure 3. **World Map of Yield Impact from a $10 Billion Foreign Contraction**

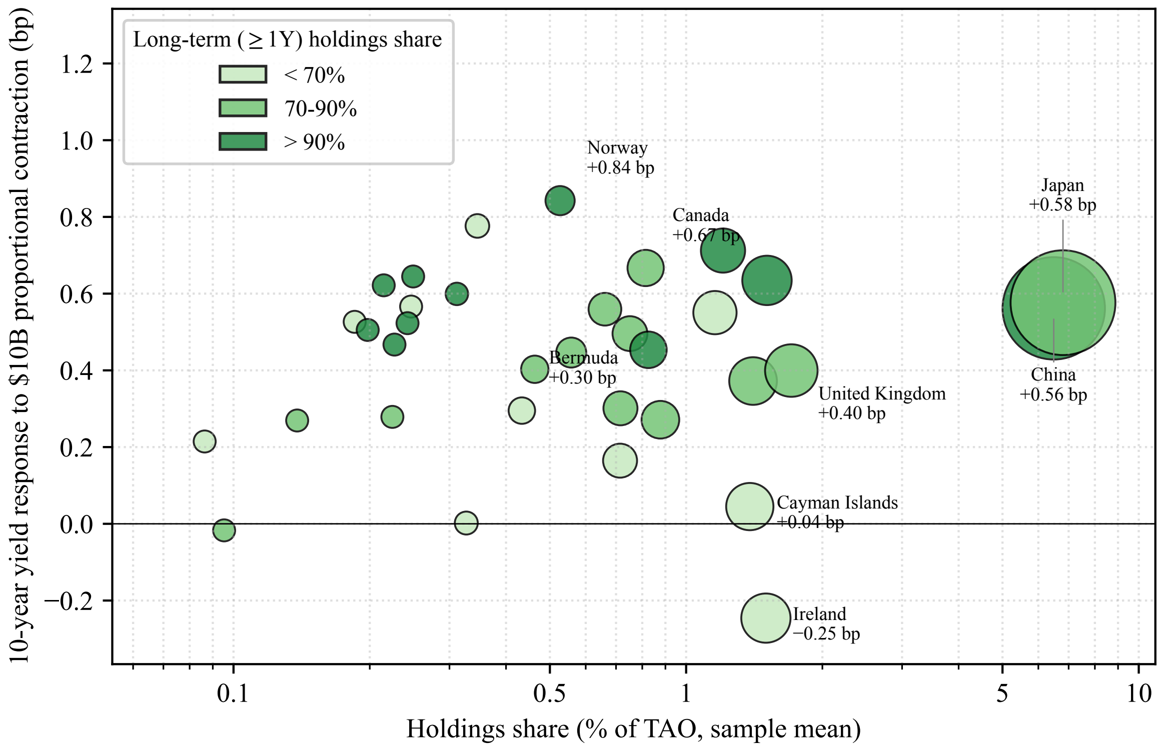
This figure maps the 10-year Treasury yield response to a permanent $10 billion contraction of each country's demand curve. Red indicates a yield increase, blue a decrease, and white zero. Light gray marks countries outside the balanced panel, together with the 6 panel countries holding less than $10 billion, for which the contraction is not defined.



$10 billion contraction raises the 10-year yield by only 0.58 and 0.56 basis points, respectively. Canada and India provide a sharper contrast among similarly sized holders: the same withdrawal raises the yield by 0.67 basis points for Canada and only 0.27 basis points for India. Holdings size is therefore a poor guide to price impact per dollar.

Figure 4. **Yield Impact versus Holdings Size Across Countries**

This figure plots each country's 10-year yield response to the \$10 billion contraction against its average Treasury holdings share. Bubble area is proportional to total holdings, and the horizontal axis is log-scaled. Color indicates the share held at $\tau \geq 1\text{Y}$, using cutoffs of 70% and 90%. The figure covers the 34 countries whose steady-state holdings support the \$10 billion contraction.



Differences in maturity composition help explain this divergence. Short-term Treasuries account for 8.7% of Japan's portfolio and 0.7% of China's, compared with 22.1% for the average foreign holder. A \$10 billion contraction therefore requires other investors to absorb 45 billion dollar-years of duration from Japan and 47.1 from China, against 39.7 for the average holder. Duration is only one of the three features, however, and Section 3.4 separates all three.

Same-dollar versus same-fraction. The \$10 billion experiment removes holdings size from the comparison. To put size back in, we also contract every country's demand curve by 10%. Japan then withdraws \$160.2 billion and raises the 10-year yield by 9.19 basis points. China withdraws \$153.6 billion and raises it by 8.55 basis points. These are the two largest effects. When the fraction rather than the dollar amount is fixed, holdings size again matters. Appendix Figure A5 reports the same 34 countries under this experiment.

3.4. Decomposing the Cross-Country Variation

The same-dollar experiment removes holdings size from the comparison, but countries still differ in maturity composition, yield elasticity, and macro loadings. We use a Shapley decomposition to measure how much each feature contributes to the difference between a country's yield impact and that of the average foreign holder.

To vary one feature without changing the others, we represent the demand removed in the experiment as a synthetic holder. Let $\omega^i(m)$ be the share of country i's withdrawal from maturity bucket m, with $\sum_m \omega^i(m) = 1$. We scale the country's yield and macro loadings by κ^i, so they describe the \$10 billion portion of its demand curve that is removed. For any maturity profile ω and loadings (α, θ), the synthetic holder's demand is

$$Z(m) = \omega(m) \cdot \$10\,\text{bn} + \alpha(m)'(y - \bar{y}) + \theta(m)'(\beta - \bar{\beta}), \tag{12}$$

where $\bar{y}$ and $\bar{\beta}$ are baseline yields and macroeconomic conditions. At the baseline, the two deviation terms are zero, so the synthetic holder holds $\omega(m) \cdot \$10\,\text{bn}$ in bucket m. Removing it therefore withdraws \$10 billion in the profile ω. Centering the two slope terms is important: changing α or θ leaves the size and maturity profile of the initial withdrawal unchanged.

Each feature then has a distinct role. The maturity profile ω determines where along the yield curve the withdrawal falls. The yield loadings α determine how much of the lost demand would have returned as yields rise. The macro loadings θ determine how that demand would have changed with economic conditions. Because arbitrageurs price the expected path of demand, changing θ can affect yields today even though the initial withdrawal is fixed. For each combination of the three features, we remove the corresponding synthetic holder and solve again for market clearing.

For each country, we begin with a synthetic holder whose three features equal their cross-country averages. Its removal raises the 10-year yield by $dy_{\text{avg}} = 0.43$ basis points. We then replace the average features with the country's own values. Using all three country values gives the yield impact of that country's standardized contraction, dy^i_{full}. The averages are computed after scaling every country to a \$10 billion withdrawal, so large holders do not dominate the benchmark.

Because the equilibrium is nonlinear, the contribution of one feature depends on which other features have already been replaced. We therefore use the Shapley value φ^i_c, which averages a feature's marginal contribution across all six possible orderings of the three features. This allocates the interactions among them and gives the exact identity

$$dy^i_{\text{full}} = dy_{\text{avg}} + \varphi^i_\alpha + \varphi^i_\theta + \varphi^i_\omega. \tag{13}$$

Equation (13) holds for every country with no residual. We compute the decomposition for all 34 countries in the standardized experiment. Appendix D.3 gives the formal construction.

Figure 5 shows that the three features often offset one another: their contributions have different signs for 26 of the 34 countries. Canada and India illustrate the dominant role of yield elasticity. Canada's elasticity contribution is positive, while India's is negative, and this difference more than accounts for the gap between their total impacts. Canadian demand responds more strongly as yields rise, so its withdrawal removes demand that would otherwise return as the market adjusts. Differences in maturity composition and macro loadings partly offset this gap. Appendix Table A6 reports the contributions for every country.

Table 1 summarizes these country-level contributions in two ways. The mean of $|\varphi_c^i|$ measures the typical size of a feature's contribution, regardless of its sign. The dispersion share measures how closely that contribution moves with the country's total deviation from the average and therefore how much the feature explains the country ranking. A feature can have a large mean absolute contribution but a small dispersion share if it moves yields by similar amounts across countries. Because equation (13) holds country by country, the dispersion shares sum to 100%. Appendix D.3 provides the formula and derivation.

Figure 5. **Attributing Each Country's Yield Impact to Its Demand Curve**

This figure decomposes each country's 10-year yield response to a permanent $10 billion contraction into contributions from yield elasticity, macro loadings, and maturity composition. The vertical line marks the impact of the average foreign holder, at 0.43 basis points. Positive contributions extend to the right of that benchmark and negative contributions to the left. The black dot equals the benchmark plus the three contributions and therefore marks the country's total yield impact. Countries are sorted by that impact. All entries are in basis points.

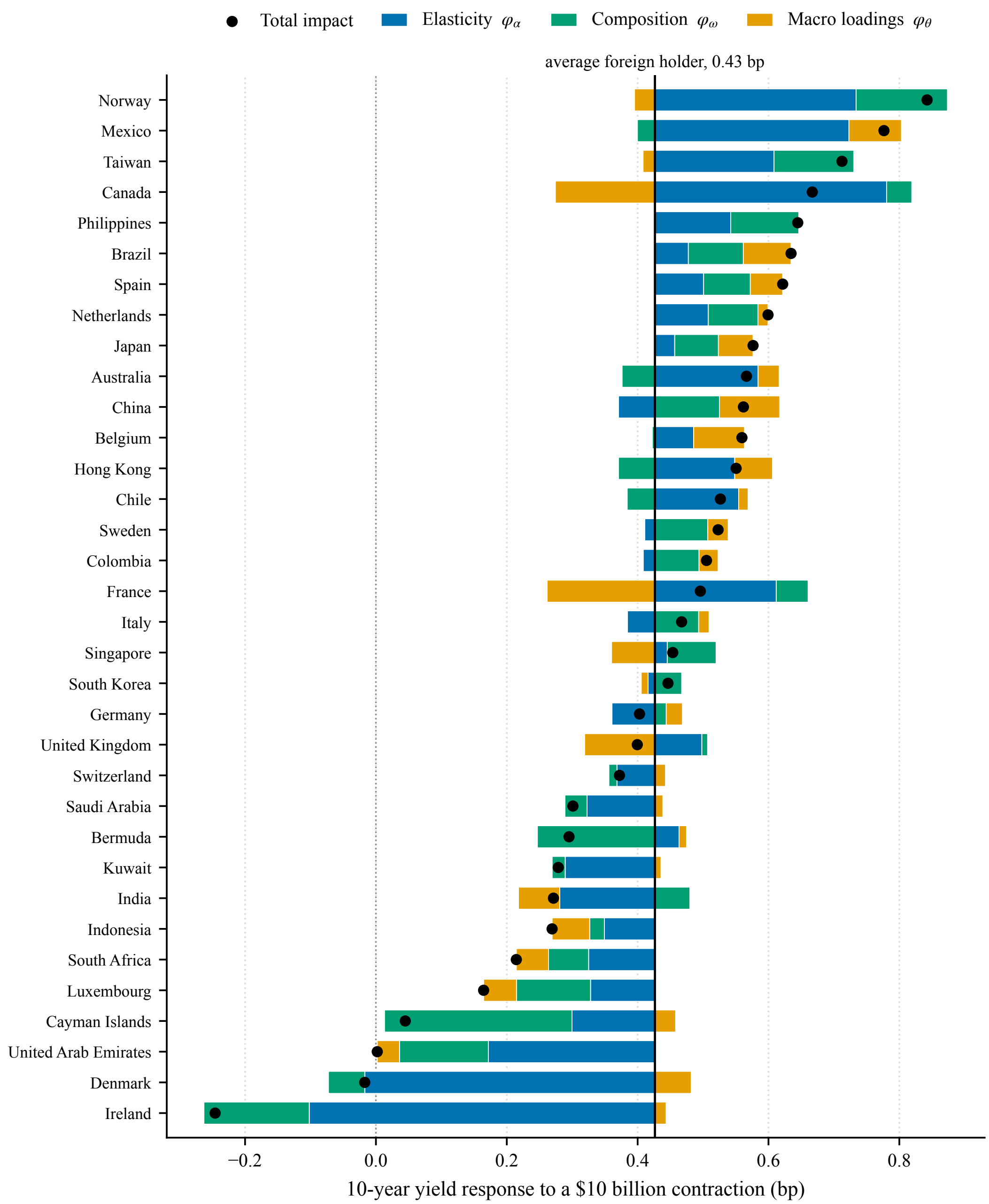


Table 1. **Which Feature of a Country's Demand Curve Drives Its Yield Impact?**

This table summarizes the country-level Shapley contributions in Figure 5. The first column reports the mean absolute contribution in basis points, the second reports its share of total mean absolute contributions, and the third reports its share of cross-country dispersion. Panel A compares yield elasticity, macro loadings, and maturity composition. Panel B decomposes the macro-loading contribution into the four aggregate states while holding each country's elasticity and composition fixed. Its dispersion shares therefore refer to dispersion within the macro component. Both share columns sum to 100% within each panel.

Feature	Mean $\lvert\varphi_c\rvert$ (bp)	Share of mean $\lvert\varphi_c\rvert$	Share of dispersion
Panel A. Features of the demand curve			
Yield elasticity (α^i)	0.134	52.5%	68.8%
Macro loadings (θ^i)	0.047	18.5%	2.2%
Composition (ST/LT mix, ω^i)	0.074	29.0%	29.0%
Panel B. Macro-loading component, by aggregate state			
Debt/GDP	0.034	29.6%	44.2%
Agency/Treasury supply	0.031	27.2%	2.5%
GDP gap	0.031	26.7%	30.5%
Core inflation	0.019	16.5%	22.8%

Panel A shows that yield elasticity is the dominant feature. It accounts for 52.5% of total mean absolute contributions and 68.8% of the cross-country dispersion in yield impact. Maturity composition is second, accounting for 29.0% and 29.0%, respectively. Macro loadings account for 18.5% of mean absolute contributions but only 2.2% of dispersion. They can therefore shift a country's yield impact without doing much to explain the country ranking.

The economic mechanism follows directly from the demand curves. When yields rise, an elastic investor would normally return and absorb part of the withdrawal. Losing that investor removes this stabilizing demand, which is why yield elasticity is the dominant source of cross-country differences. Maturity composition matters because a withdrawal concentrated at longer maturities transfers more duration to the rest of the market. Macro loadings matter because a permanent retrenchment also removes the demand a country would have supplied as economic conditions changed.

Panel B decomposes the macro contribution. Debt/GDP is the largest component by both average size and dispersion. The agency/Treasury supply ratio is similar in average size but explains only 2.5% of the macro component's dispersion. The GDP gap and core inflation contribute more to dispersion than their average sizes would suggest.

Canada and China illustrate why the sign of a macro loading matters. Canada's estimated Treasury demand rises with U.S. debt/GDP, whereas China's falls (Appendix Table A5). A permanent contraction removes these responses along with current demand. Higher debt therefore makes the loss of Canadian demand more costly but the loss of Chinese demand less costly. Because macro loadings explain only 2.2% of total cross-country dispersion, this distinction matters within the macro channel but does not drive the overall country ranking.

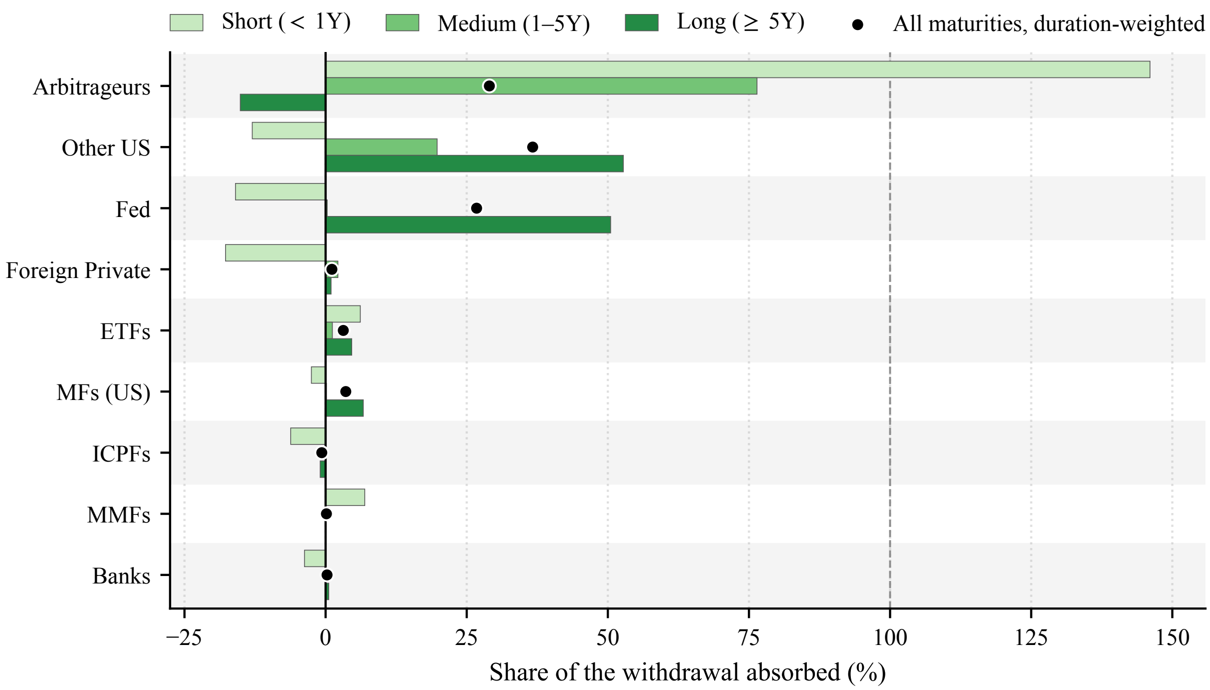
3.5. Who Absorbs the Lost Foreign Demand?

The country exercises measure the price impact of a contraction. To see who takes the other side, we return to the sector-level model. Figure 6 shows how the market reallocates Treasuries after a \$10 billion contraction of the aggregate foreign official demand curve, which withdraws 40 billion dollar-years of duration. In duration-weighted terms, Other U.S. investors absorb 14.68 billion dollar-years, arbitrageurs 11.61 billion dollar-years, and the Fed 10.71 billion dollar-years. Mutual funds and banks absorb smaller amounts, at 1.43 and 0.1 billion dollar-years.

The adjustment is not uniform across maturities. Arbitrageurs buy \$2.45 billion of short-term Treasuries and \$5.45 billion of medium-term Treasuries but sell \$0.3 billion at the long end. They absorb more than the whole of the short-bucket withdrawal while reducing their long-bucket holdings. Other U.S. investors and the Fed take the other side there, each absorbing about half of the long-bucket withdrawal. The key result is a broad reallocation accompanied by a maturity rotation: the market as a whole replaces the departing holder, but the sector that supplies the most dollars is not the sector that supplies the most duration. Appendix Table A9 reports the underlying changes in dollars.

Figure 6. **Sectoral Absorption of a Foreign Retrenchment**

This figure shows which sectors take the other side of a \$10 billion contraction of the aggregate foreign official demand curve. Each bar is the share of that maturity bucket's withdrawal absorbed by the sector, so 100% means the sector alone replaces the departing holder in that bucket and negative values mean the sector sells alongside it. The marker is the share of the total duration withdrawn, 40 billion dollar-years, that the sector absorbs; it is the convex combination of the sector's three bars weighted by each bucket's contribution to that duration, so it always lies within their span. The withdrawing sector is omitted because it is -100% in every bucket by construction. Appendix Table A9 reports the same quantities in billions of dollars.



3.6. Financing Japan's Yen Defense: Fed Repo, Bills, or Treasury Sales?

The same maturity and persistence differences matter for Japan's recent currency intervention. Currency intervention requires dollars. Japan's Ministry of Finance reports JPY 11.7349 trillion of intervention between April 28 and May 27, 2026, or about \$73.6 billion at contemporaneous exchange rates (Ministry of Finance, Japan 2026). The U.S. Treasury joined a second operation in August (CNBC 2026b). Treasury also asked the Federal Reserve to enlarge its repo facility for foreign monetary authorities. This would allow Japan to pledge Treasuries instead of selling them (CNBC 2026a).

Japan holds only 8.7% of its Treasury portfolio at the short end, compared with 22.1% for the average foreign holder. A Japanese Treasury sale therefore requires the market to absorb substantial duration. Table 2 compares four ways to raise \$73.6 billion. The routes differ in how much duration reaches the market and how long the withdrawal lasts. We use the disclosed intervention amount only as the scale of the experiment. The release reports the amount of intervention but not how it was financed; in particular, it does not say that Japan sold $73.6 billion of U.S. Treasuries.

Table 2. **Financing Japan's Yen Defense: The Treasury-Market Cost of Each Route**

This table compares four ways to finance $73.6 billion of yen support and reports their effects on the 10-year Treasury yield. S/M/L gives the allocation across maturity buckets. Duration weights those amounts by 0.5, 2.5, and 10.8 years. Bill issuance and the permanent contraction re-solve the equilibrium; the temporary sale uses the equilibrium impact matrix. Under a repo, no Treasuries reach the market, so the yield response is zero by construction. The Japanese Treasury sales are counterfactuals because the intervention release does not report how the operation was financed.

Financing route	**S/M/L (%)**	**Duration** ($bn-years)	**Δ10y** (bp)
Fed repo, pledged not sold	not traded	0.0	0.00†
U.S. bill issuance	100.0/0.0/0.0	36.8	+0.49
Japanese sale, temporary	8.7/65.0/26.3	330.9	+2.62
Japanese sale, permanent	8.7/65.0/26.3	330.9	+4.23

Bill issuance raises the 10-year yield by 0.49 basis points, compared with 4.23 basis points for a permanent Japanese sale. The bill route delivers 36.8 billion dollar-years of duration to the market. A sale that follows Japan's maturity composition delivers 330.9 billion dollar-years. The route that delivers less duration has the smaller yield effect.

Persistence creates a second difference. The temporary and permanent sales deliver the same duration to the market, but the temporary sale is expected to reverse. It raises the 10-year yield by 2.62 basis points, compared with 4.23 basis points for the permanent contraction.

Bill issuance still affects the 10-year yield because arbitrageurs transmit short-end supply across maturities. The zero under the repo route is a benchmark: the pledged Treasuries never reach the market, but the Fed creates reserves to fund the loan. Table 2 therefore ranks Treasury-market costs, not total costs.

The foreign exercises show how a departing investor's demand curve, maturity composition, and the persistence of the withdrawal determine current yield effects. Replacing the lost dollars restores market clearing today; it does not restore the departing investor's response to the next macro shock. Section 4.3 studies that exposure for an inflation shock.

4. Inflation and Macro Shocks

Section 3 studies permanent changes in the investor base. This section instead changes the macroeconomic state and traces the shock through the demand curves of the investors present when it arrives. Together, the two exercises show that resilience depends on both who holds Treasuries and how their demand changes with yields and macroeconomic conditions.

We identify a cost-push supply shock and follow its effect on Treasury yields. Foreign official demand falls as inflation rises and amplifies the increase in yields, while the Fed's demand moves in the opposite direction and more than offsets that pressure.

4.1. Identifying the Inflation Shock

An inflation shock does not move inflation alone. It also changes monetary policy, output, debt, and the relative supply of safe assets. We identify this joint movement with a multi-instrument proxy-SVAR (Mertens and Ravn 2013; Stock and Watson 2018). The quarterly system contains the federal funds rate, the GDP gap, core CPI inflation, debt/GDP, and the beginning-of-quarter agency/Treasury supply ratio. It is estimated over 1990Q1–2024Q4 ($T = 140$). We instrument the monetary policy shock with the quarterly change in the Wu and Xia (2016) shadow federal funds rate and the cost-push shock with the Federal Reserve Bank of New York's Global Supply Chain Pressure Index (GSCPI) (Benigno et al. 2022). The common identification window is 1998Q1–2024Q4 ($T_{id} = 108$).

The instruments provide adequate but not strong joint identification. The single-instrument statistics are 23.62 for the monetary instrument and 13.54 for the inflation instrument; the corresponding conditional statistics are 23.91 and 12.33. The heteroskedasticity-robust Kleibergen–Paap statistic is 13.17. The Stock and Yogo (2005) critical value of 7.03 applies to the homoskedastic Cragg–Donald statistic, which is 6.58 and falls below that threshold, but not directly to the robust Kleibergen–Paap statistic. The GSCPI remains useful because it measures supply-chain pressure before realized inflation and the resulting policy response. Appendix C.5 reports alternative instruments based on realized cost-push inflation and oil-supply shocks.

We feed the model the response to a one-standard-deviation cost-push shock, averaged over horizons $h = 0, \dots, 4$. This first-year average captures the delayed policy response while preserving the joint movements of all five variables. We convert the policy-rate response from annual percentage points to the model's quarterly rate. The other responses enter in the units shared by the proxy-SVAR and the structural model.

4.2. Foreign Official Amplification and the Fed Offset

Let $(\Delta\beta, \Delta r)$ denote the first-year average response, with the federal funds rate separated from the remaining macro state as in Section 2.1. The full equilibrium yield response at maturity τ is

$$\Delta y^{\text{full}}(\tau) = [A\Delta\beta + A_r\Delta r](\tau). \tag{14}$$

This is the total response after all demand curves, the policy rule, and arbitrageurs' expectations of future macroeconomic conditions are taken into account.

We next isolate the direct contributions of foreign official and Fed demand. Let $\Delta\pi$ be the inflation component of the identified shock. For $\iota \in \{\text{FO}, \text{Fed}\}$, the sector's direct demand response to inflation and its yield contribution are

$$\Delta Z^{D,\pi,\iota}(m) = \widehat{\theta}_\pi^\iota(m)\Delta\pi, \qquad \Delta y^{D,\pi,\iota}(\tau) = \left[A_u \Delta Z^{D,\pi,\iota}\right](\tau), \tag{15}$$

where $\widehat{\theta}_\pi^\iota$ is the sector's estimated inflation loading and A_u maps an additive demand change into yields. The latent demand shock u_t remains fixed at zero; $\Delta Z^{D,\pi,\iota}$ is the change in sectoral demand induced by inflation through the estimated macro loading. Each term uses only the sector's direct response to inflation; it excludes its responses to the agency/Treasury supply ratio, GDP gap, and debt/GDP. We collect the response to those variables, the policy rate, expectations, and all remaining demand in

$$\Delta y^R(\tau) = \Delta y^{\text{full}}(\tau) - \Delta y^{D,\pi,\text{FO}}(\tau) - \Delta y^{D,\pi,\text{Fed}}(\tau). \tag{16}$$

The three terms therefore sum exactly to the full response. The foreign official and Fed terms are attributions of their estimated inflation loadings, not counterfactuals that remove either sector from the market.

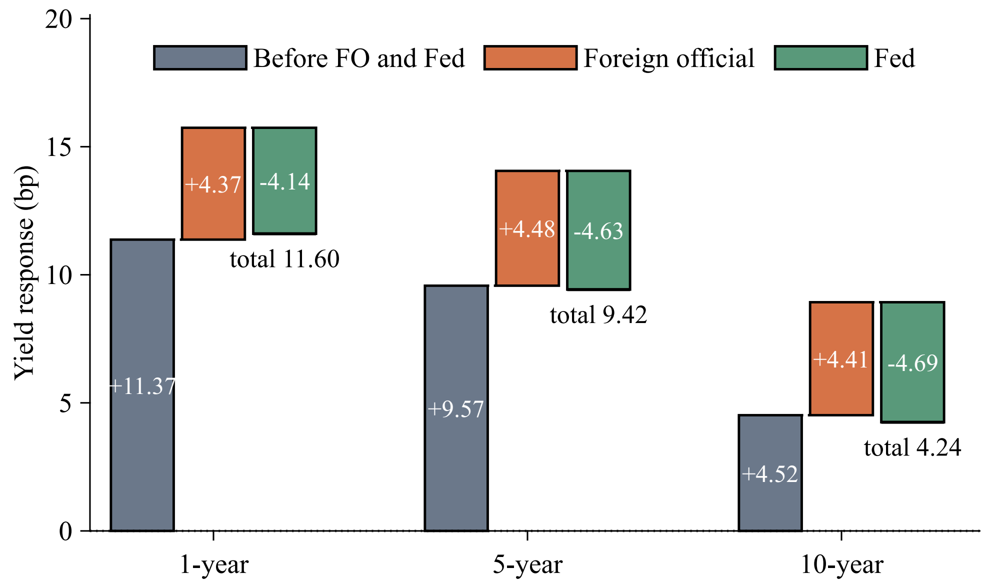
Figure 7 reports this decomposition. At 10 years, the response before the two highlighted demand contributions is 4.52 basis points. The decline in foreign official demand adds 4.41 basis points, raising the response to 8.93 basis points. The Fed then contributes -4.69 basis points, leaving the full response at 4.24 basis points. Foreign official demand therefore amplifies the inflation shock, while the Fed's demand response more than offsets that amplification.

4.3. Persistent Foreign Retrenchment Changes Inflation Exposure

A permanent foreign retrenchment changes both current yields and the market's response to later shocks. Per \$100 billion withdrawn, foreign official and foreign private contractions raise the

Figure 7. **Foreign Official Amplification and the Fed Offset**

This figure decomposes the yield response to a one-standard-deviation cost-push shock at the 1-, 5-, and 10-year maturities. The shock is identified with the GSCPI in the multi-instrument proxy-SVAR, and the joint macroeconomic response is averaged over horizons $h = 0$–4. The gray segment contains the response through the policy rule, expectations, other macroeconomic variables, and all remaining demand. The orange and green segments are the direct foreign official and Fed demand contributions defined in equation (15). The three segments sum to the full yield response. All labels and totals are in basis points.



current 10-year yield by 4.72 and 4.29 basis points, respectively. Their effects on the response to the same inflation shock are very different. The foreign official contraction reduces the 10-year response by 0.236 basis points per \$100 billion, compared with only 0.016 basis points after the foreign private contraction.

To construct the comparison, we contract 10% of either sector's demand curve, solve the new equilibrium, and then apply the same cost-push shock. The contractions withdraw \$560 billion of foreign official demand and \$240 billion of foreign private demand, so we report both effects per \$100 billion withdrawn. Let $\Delta y_\iota^\pi(\kappa)$ denote the yield response when fraction κ of sector ι's demand curve is removed. The change in inflation exposure is

$$\mathscr{E}_\iota^\pi(\kappa) = \Delta y_\iota^\pi(\kappa) - \Delta y_\iota^\pi(0). \tag{17}$$

Subtracting the baseline response removes the contraction's current yield effect and leaves the change in the response to the same inflation shock.

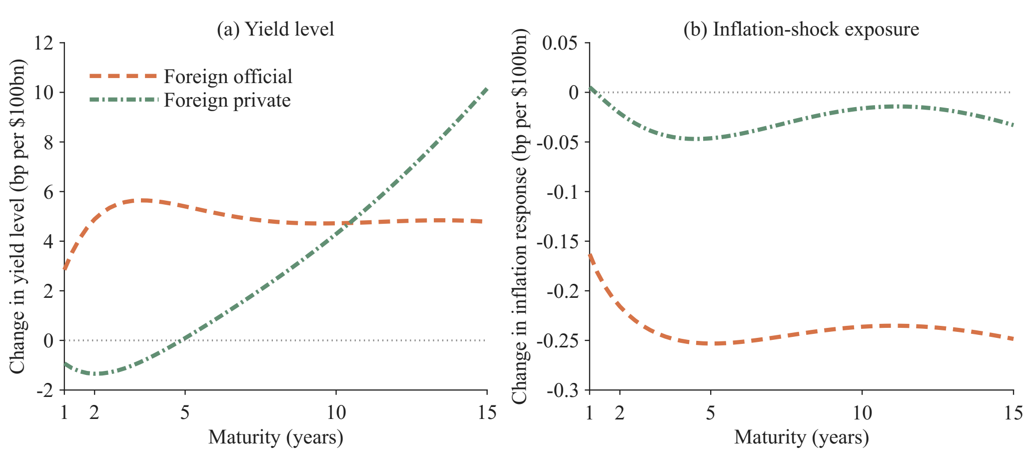
The official and private contractions have similar effects on the current 10-year yield. Their effects on inflation exposure differ. Removing foreign official demand lowers the 10-year response to the inflation shock by 0.236 basis points per $100 billion withdrawn, whereas removing foreign private demand lowers it by only 0.016 basis points. The signed official-minus-private difference is -0.22 basis points.

The mechanism is the distinction between current absorption and how demand changes with market conditions. Contracting only the foreign official intercept raises the 10-year yield by 24.84 basis points but leaves inflation exposure unchanged because the intercept does not respond to inflation. Contracting the yield elasticities changes exposure by -0.3 basis points, while contracting the macro loadings changes it by -1.03 basis points. Foreign official demand falls as inflation rises, so its presence amplifies the shock even though its baseline holdings lower yields. Retrenchment raises current yields but removes part of that amplification.

Figure 8 traces the response across maturities. The full 10% foreign official contraction lowers the 10-year inflation response from 4.24 to 2.92 basis points and the 15-year response to -0.26 basis points. The 15-year maturity lies beyond the longest bucket used to estimate demand, so the sign reversal at that maturity is an extrapolation of the affine yield curve. It does not mean that expected inflation no longer affects yields. Expected short rates alone contribute 5.3 basis points at 15 years. With less foreign official selling, the remaining portfolio demand, including the Fed's contribution, offsets most of that increase at the long end. The foreign private contraction leaves the response close to its baseline value.

Figure 8. **Inflation Exposure after Persistent Foreign Retrenchment**

This figure shows the yield response to the same one-standard-deviation cost-push shock under the baseline investor base, after a permanent 10% contraction of the foreign official demand curve, and after a permanent 10% contraction of the foreign private demand curve. The dotted line is the expectations-hypothesis response implied by the identified federal funds rate path and is unchanged across investor bases. Each counterfactual solves the forward-looking equilibrium again after the demand contraction.



At ten years, directly removing the estimated foreign official inflation response lowers the yield response by 0.44 basis points. Solving the equilibrium again lowers the response by another

0.88 basis points because retrenchment changes how the remaining investors adjust their holdings as yields respond to the same inflation shock. The exposure effect is therefore not simply 10% of the foreign official contribution in Figure 7.

Together, the current-yield and exposure exercises reveal two dimensions of investor demand. Current holdings and maturity composition determine where Treasury risk is absorbed today. Yield elasticities and macro loadings determine how that absorption changes with yields and macroeconomic conditions. Investors with similar current yield effects can therefore leave the market with different exposure to the next shock.

5. Federal Reserve Balance-Sheet Policy

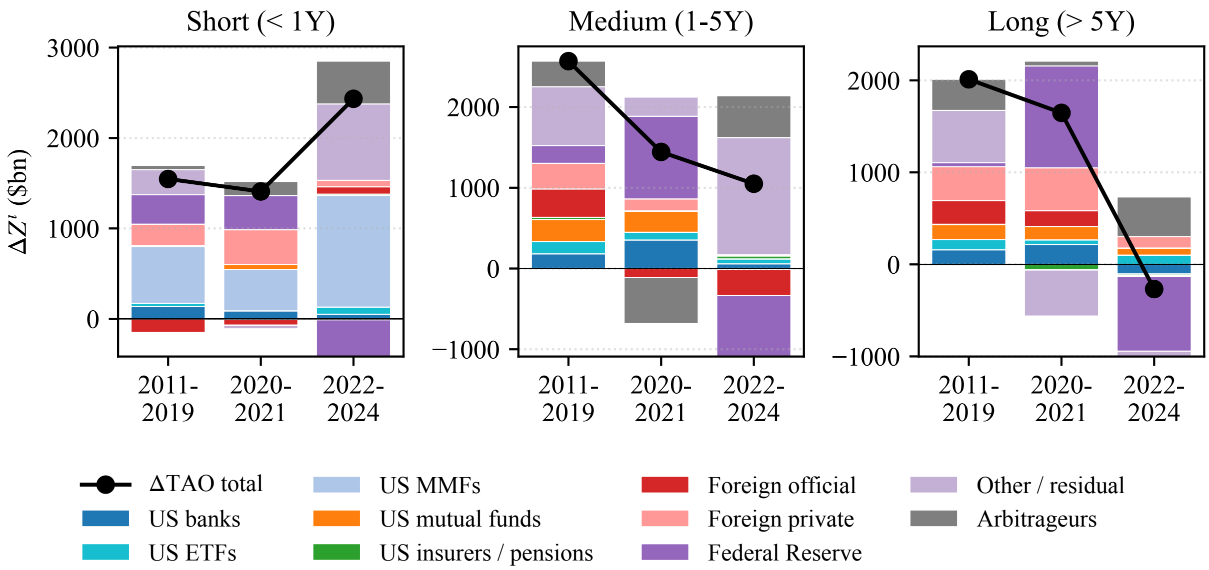
Sections 3 and 4 show that similar effects on current yields can mask different responses to future conditions. Federal Reserve balance-sheet policy provides a policy counterpart. We compare passive runoff and rule erosion after matching their reduction in Fed demand at baseline yields and macroeconomic conditions. Passive runoff leaves the Fed's response to future conditions unchanged, whereas rule erosion weakens that response.

5.1. Who Absorbed the Trend in Treasury Supply?

The difference between passive runoff and rule erosion cannot be seen in observed holdings alone. We first use the portfolio data to show which sectors took the other side of changes in Treasury supply and Fed holdings, and at which maturities. Marketable U.S. Treasury supply roughly tripled over the sample, but the sectors absorbing that expansion differed across maturities and over time. Figure 9 reports changes in holdings across three subperiods and three maturity buckets. The stacked bars show each sector's contribution, and the black markers show the total change in marketable Treasury supply.

Figure 9. **Sectoral Absorption of Treasury Supply by Maturity and Subperiod**

Each panel reports changes in Treasury holdings by sector for one maturity bucket and subperiod. The stacked bars sum to the aggregate change in Treasury supply, ΔTAO, shown by the black markers. Arbitrageurs combine primary dealers with domestic and foreign hedge funds.



The clearest shift is the Fed's move from a major buyer in 2020–2021 to a net seller in 2022–2024. The Fed reduced its holdings in all three maturity buckets, but different private sectors took the other side across the curve. Money market funds and Other U.S. investors absorbed most of the short-term expansion. Other U.S. investors and arbitrageurs absorbed medium-term issuance. At the long end, aggregate supply fell, while arbitrageurs absorbed much of the remaining adjustment associated with Fed runoff.

The figure describes current absorption by maturity. Aggregate purchases alone do not show where a sector accommodates Treasury supply: the same sector can buy at shorter maturities while selling at the long end. This matters for the counterfactuals because maturity composition determines where the remaining supply must be absorbed.

5.2. Decomposing the Two Channels

A decline in Fed holdings can carry two different messages. Under passive runoff, current Fed demand falls but the response of future purchases to yields and macroeconomic conditions is unchanged. Under rule erosion, that response also weakens. Actual market expectations may lie between these two cases. We compare them after calibrating each policy to reduce Fed demand by $10 billion at baseline yields and macroeconomic conditions.

The two policies affect different parts of the yield curve. At five years, passive runoff raises the yield by 0.49 basis points per \$10 billion, compared with 0.09 basis points under rule erosion. At fifteen years, the ordering reverses: runoff raises the yield by 0.96 basis points, while rule erosion raises it by 1.55 basis points, or 1.61 times as much. Rule erosion is therefore more concentrated at the long end. It slightly lowers the two-year yield by 0.1 basis points and steepens the curve from five to ten years by 0.6 basis points, compared with 0.19 basis points under runoff. The fifteen-year comparison uses the affine yield curve beyond the 10.8-year representative maturity at which the long bucket clears.

We implement passive runoff by lowering the Fed's intercept $\theta_0^{\text{Fed}}(m)$ and allocating the \$10 billion reduction across maturities in proportion to baseline Fed holdings. This changes current demand but leaves every yield elasticity and macro loading unchanged. We implement rule erosion by reducing the Fed's yield elasticities $\alpha^{\text{Fed}}(m)$ and macro loadings $\theta^{\text{Fed}}(m)$ by the same proportion, $\kappa^{\text{Rule}} \approx 0.1\%$, calibrated to the same baseline reduction.

A combined policy applies both changes and reduces baseline Fed demand by \$20 billion. The two effects are nearly additive at this scale: their interaction at fifteen years rounds to 0 basis points. The proportional reduction in the Fed's loadings is a policy experiment applied to the estimated demand curve, not a claim that policymakers can change each loading separately.

The difference between the policies is most important at long maturities. In the affine equilibrium (8), runoff changes the constant C but leaves the state and policy-rate loadings (A, A_r) unchanged. Rule erosion changes those loadings because it weakens the purchases investors expect when yields or macroeconomic conditions change. A long-term bond depends on a longer path of future Fed demand, so the loss of expected purchases in high-debt or stressed states matters more at the long end.

This mechanism is related to Haddad, Moreira, and Muir (2024), who show that an anticipated asset-purchase rule is valuable because investors expect purchases in adverse states. Our estimated Fed demand curve contains separate yield elasticities and macro loadings, allowing us to quantify the contribution of each expected Fed response to the equilibrium yield effect.

The Fed's response to debt/GDP is especially important. In the fixed-duration specification reported in Appendix Table A7, the long-bucket loading is \$56.17 billion per percentage point of debt/GDP, with a HAC standard error of \$7.43 billion ($p < 0.01$). Across the three maturity buckets, the Fed absorbs 34% of a marginal dollar of Treasury supply at unchanged yields, roughly one-third of the total absorbed by the estimated demand system.

The decomposition shows that this debt/GDP response drives most of the long-maturity rule effect. At fifteen years, the debt/GDP loading contributes 1.24 basis points, or 80% of the total 1.55-basis-point effect. The remaining yield elasticities and macro loadings contribute 0.31 basis points. At ten years, within the maturity range used for market clearing, debt/GDP accounts for 69% of the rule effect.

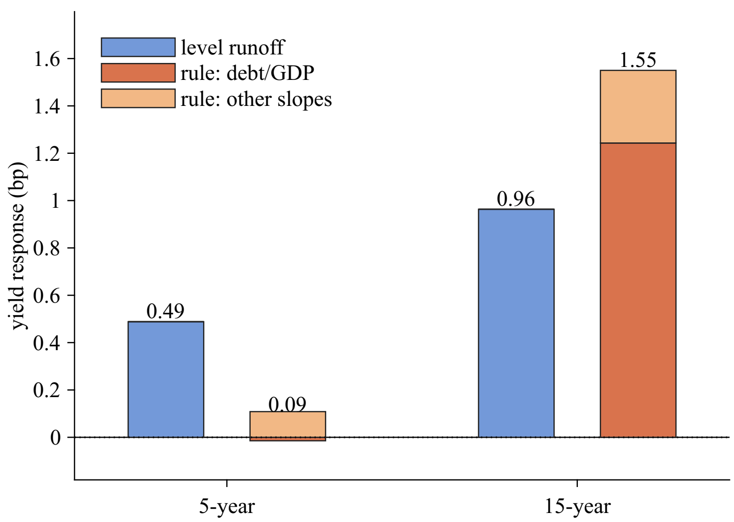
We obtain this attribution without changing the size of the policy experiment. At the same κ^{Rule}, we solve four cases: no reduction in the loadings, a reduction in debt/GDP alone, a reduction in all other loadings, and the full rule erosion. Let $v(S)$ be the fifteen-year yield response when the set of loading blocks S is reduced. The two-block Shapley contribution of debt/GDP is

$$\phi_D = \tfrac{1}{2}\{v(D) - v(\varnothing) + v(D,R) - v(R)\},$$

where R contains the yield elasticities and the remaining macro loadings. Debt/GDP contributes 1.24 basis points when changed first and 1.24 basis points when changed after the remaining loadings, so the ordering has little effect on the attribution. We do not match the sub-blocks separately in dollars because doing so would change the size of the policy experiment.

Figure 10. **Passive Runoff versus Rule Erosion at Five and Fifteen Years**

This figure compares two policies calibrated to reduce Fed demand by \$10 billion at baseline yields and macroeconomic conditions. Blue bars show passive runoff, implemented by lowering the Fed's intercept θ_0^{Fed}. Stacked bars show rule erosion, implemented by proportionally reducing the Fed's yield elasticities and macro loadings. The rule-erosion effect is divided into the contribution of the debt/GDP loading and the contribution of all remaining loadings using the two-block Shapley decomposition. The two components are evaluated at the same policy scale and sum to the total rule-erosion effect.



5.3. Who Absorbs QT?

Both QT policies are absorbed through a rotation across maturities rather than uniform buying by arbitrageurs. Table 3 shows that arbitrageurs buy Treasuries in aggregate under both policies, but buy in the short and medium buckets while selling at the long end. Section 3.5 finds the same type of rotation after a foreign official contraction. Who takes the other side therefore depends on the full demand system, not only on which sector withdraws.

Table 3. **Sectoral Portfolio Adjustment under Two QT Designs**

This table reports changes in sector holdings under two policies calibrated to reduce Fed demand by \$10 billion at baseline yields and macroeconomic conditions. Runoff lowers the Fed's intercept; rule erosion reduces its yield elasticities and macro loadings. The Fed row combines the direct contraction with the response to the resulting change in yields, while arbitrageurs hold the market-clearing residual. Positive entries denote purchases. All entries are in billions of dollars, and each maturity bucket sums to zero. Fed holdings can differ from the initial \$10 billion reduction after equilibrium yields adjust.

	Passive runoff (\$10 bn)			Rule erosion (\$10 bn)		
Sector	< 1y	1–5y	≥ 5y	< 1y	1–5y	≥ 5y
Banks	-0.1	0.0	0.1	0.0	-0.1	0.1
ETFs	0.1	0.1	0.1	0.1	0.1	0.0
ICPFs	-0.1	-0.1	0.0	-0.1	-0.1	0.1
MFs (US)	0.0	0.0	0.0	0.0	0.0	0.1
MMFs	0.1	0.0	0.0	0.0	0.0	0.0
Other US	-0.4	0.7	2.4	-0.5	-0.9	3.0
Foreign Official	-0.3	-0.3	-0.1	-0.2	-0.3	0.0
Foreign Private	-0.3	-0.2	0.0	-0.2	-0.3	0.2
Fed (direct + induced)	-1.6	-4.0	-1.7	-2.5	-0.8	-2.4
Arbitrageurs	2.7	3.8	-0.7	3.5	2.4	-1.2
Total	0.0	0.0	0.0	0.0	0.0	0.0

Other U.S. investors explain why arbitrageurs sell at the long end. They buy \$2.4 billion under runoff and \$3 billion under rule erosion, compared with equilibrium Fed reductions of \$1.7 billion and \$2.4 billion. After the smaller adjustments by other sectors, arbitrageurs sell \$0.7 billion under runoff and \$1.2 billion under rule erosion to clear the long bucket.

The arbitrageurs' long-bucket sale does not imply that long yields should fall. The table records who holds Treasuries after the current adjustment, while yields also reflect the expected path of Fed demand. Under rule erosion, investors no longer expect the same Fed purchases in high-debt or stressed states. Long yields can therefore rise even as arbitrageurs reduce their current long-bucket holdings.

The affine equilibrium makes this distinction explicit. At the 10.8-year clearing maturity, the 0.8-basis-point response to rule erosion consists of 0.87 basis points from the macro-state loadings, -0.04 basis points from the policy-rate loading, and -0.03 basis points from the constant. Almost all of the response comes through the loadings. Runoff instead leaves A and A_r unchanged because the intercept affects only the constant; it raises yields by increasing the amount arbitrageurs must absorb.

The two decompositions answer different questions. The Shapley decomposition identifies which parts of the Fed's demand curve drive the rule-erosion effect. The affine decomposition identifies whether the yield response comes through the state and policy-rate loadings or the constant. Both policies are calibrated to reduce Fed demand by the same amount at baseline yields and average macroeconomic conditions, but only rule erosion changes how Fed demand responds when those conditions change.

6. Conclusion

We develop a framework for measuring Treasury market resilience by the yield adjustment required to absorb changes in investor demand. The framework combines estimated sector and country demand curves with forward-looking, risk-averse arbitrageurs. Current holdings determine how much Treasury risk each investor absorbs at prevailing yields and macroeconomic conditions. Yield elasticities and macro loadings determine how that absorption changes with market conditions, while persistence determines how long arbitrageurs expect a demand change to last.

The foreign demand exercise shows why the size of an investor's holdings does not determine the effect of its withdrawal. Equal \$10 billion contractions produce different yield responses across countries because investors hold different maturity portfolios and have different yield elasticities and macro loadings. The largest foreign holder is therefore not necessarily the most disruptive to lose.

The inflation exercise shows how sector demand can amplify or offset the same macroeconomic shock. The identified cost-push shock raises the 10-year yield by 4.24 basis points. The decline in foreign official demand adds 4.41 basis points to this response, while the Fed contributes -4.69 basis points and more than offsets that amplification. Persistent retrenchment also changes the market's response to later shocks. A \$100 billion contraction in foreign official demand reduces the 10-year response to the same inflation shock by 0.236 basis points, compared with only 0.016 basis points after a foreign private contraction.

The quantitative tightening exercise separates current Fed holdings from the purchases investors expect under future conditions. Passive runoff and rule erosion both reduce Fed demand by \$10 billion at baseline yields and macroeconomic conditions, but their effects differ along the yield curve. Runoff raises the five- and fifteen-year yields by 0.49 and 0.96 basis points. Rule erosion raises them by 0.09 and 1.55 basis points, with the Fed's response to debt/GDP accounting for 80% of the fifteen-year effect.

The common result is that current holdings alone do not determine market resilience. Maturity composition determines where a demand change reaches the yield curve. Yield elasticities and macro loadings determine how much demand changes as yields and economic conditions adjust. Persistence determines how long the resulting imbalance is expected to last. Two investors that sell the same amount today can therefore have different effects on yields and leave the market with different exposure to the next shock.

These findings have direct policy implications. For financial stability, the composition of foreign investors across countries and maturities is more informative than their aggregate holdings alone. Foreign official retrenchment raises current yields because a large buyer leaves the market, but reduces inflation exposure because that investor would otherwise sell as inflation rises. For debt management, the cost of long-term issuance depends on both investor demand and arbitrageur capacity, so the maturity of issuance matters for market absorption. For monetary policy, the Fed affects long yields through both its current portfolio and the purchases investors expect when debt rises.

More broadly, combining estimated demand curves with forward-looking market clearing provides a way to measure both current absorption and how that absorption changes across states of the economy. The same approach can be used to study other episodes of Treasury market stress, other sovereign bond markets, and the interaction of fiscal and monetary policy along the yield curve.

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Internet Appendix of
“Dissecting Treasury Market Resilience”

Kristy A.E. Jansen   Wenhao Li   Lukas Schmid

A. Data Sources and Aggregation

This appendix describes the sources used to construct our granular U.S. Treasury holdings data and explains how we merge them. Section A.1 reports the data sources for U.S. Treasury holders, Section A.2 describes how we merge the holdings data, and Section A.3 provides the sources for the macro variables.

Table A1. **Data sources**

This table summarizes the investor-holdings data used in the paper.

Investor Type	**Data Source**	**Frequency**	**Period**	**Detail**
Banks	CALL Reports	Quarterly	1976Q1–2024Q4	Maturity bucket
Fed	Federal Reserve	Weekly	2003W1–2024W52	Security
Primary Dealers	Federal Reserve	Weekly	1998W5–2024W52	Maturity bucket
Hedge Funds	Form PF SEC	Quarterly	2011Q4–2024Q4	Aggregate
Insurers and Pension Funds	eMAXX	Quarterly	2010Q1–2024Q4	Security
U.S. Mutual Funds and ETFs	Morningstar	Quarterly	2002Q1–2024Q4	Security
Money Market Funds	Flow of Funds	Quarterly	1993Q1–2024Q4	Aggregate
Foreign Official and Private	Public TIC	Quarterly	2011Q4–2024Q4	T-bill/non T-bill

A.1. Treasury Holders

A. Banks: Call Reports

Banks are major investors in the U.S. Treasury market. We obtain banks’ holdings of U.S. Treasuries at the maturity-bucket level from Call Reports. Call Reports are regulatory filings required for all U.S. banks and include detailed information on a bank’s assets, liabilities, income, and expenses. The reports are filed quarterly and cover the period from the first quarter of 1976 through 2024Q4 in our sample. Banks report their aggregate U.S. Treasury holdings and their holdings in different maturity buckets of U.S. Treasuries and U.S. agency bonds combined. The maturity buckets are: $\tau < 3M$, $3M \leq \tau < 1Y$, $1Y \leq \tau < 3Y$, $3Y \leq \tau < 5Y$, $5Y \leq \tau < 15Y$, and $\tau \geq 15Y$. To obtain their allocation to U.S. Treasuries at different maturities, we assume that the fraction of Treasuries relative to agency bonds is fixed across maturities at a given point in time. Hence, at each point in time, we multiply the total maturity-bucket holdings by the fraction of Treasuries relative to the sum of Treasuries and agency bonds.

B. Fed: Federal Reserve

In the aftermath of the Great Financial Crisis, the Federal Reserve has become a major player in the U.S. Treasury market. The Federal Reserve System Open Market Account (SOMA) reports security holdings acquired through the Fed's open market operations. We obtain these data from the Federal Reserve Bank of New York's website.[1] The holdings are reported weekly at the security (CUSIP) level beginning in 2003.

C. Primary Dealers: Federal Reserve

To maintain transparency about U.S. and foreign primary dealers' trading activities, the Federal Reserve Bank of New York publishes their total weekly positions on its website.[2] Primary dealers have reported their holdings in conventional maturity buckets since early 1998. However, the specific maturity buckets reported change over time. The periods with the same reporting standards are January 1998 to June 2001, July 2001 to March 2013, April 2013 to December 2014, January 2015 to December 2021, and January 2022 onward. Generally, more recent data use finer maturity buckets. To maintain consistency over time, we treat July 2001 to March 2013 as the baseline and aggregate the maturity buckets of subsequent periods to match those of the baseline period. The final maturity buckets are T-bills, Treasuries with $1Y \leq \tau \leq 3Y$, $3Y < \tau \leq 6Y$, $6Y < \tau \leq 11Y$, and $\tau > 11Y$.

D. Hedge Funds: Form PF

We obtain aggregate U.S. and foreign hedge fund Treasury positions from Form PF that hedge funds file with the SEC.[3] As of 2011Q4, hedge funds must file Form PF if they are registered or are required to register with the SEC, manage private funds, and have at least $150 million in total assets. The Fed reports the totals separately for domestic and foreign hedge funds. We observe only aggregate Treasury positions, so we rely on the maturity distribution of primary dealers to infer maturity-bucket holdings. Specifically, we multiply primary dealers' maturity-bucket weights by the aggregate hedge fund Treasury positions at each point in time to obtain maturity-bucket-specific

[1] `https://www.newyorkfed.org/markets/soma-holdings`

[2] The data and the list of primary dealers that must report can be found here: `https://www.newyorkfed.org/markets/counterparties/primary-dealers-statistics`. Specifically, the Fed allows certain foreign-owned institutions to operate as primary dealers in the U.S. Treasury market if they meet specific criteria.

[3] We thank Moritz Lenel for directing us to this data source.

hedge fund holdings. Following Jansen, Li, and Schmid (2024), we treat hedge funds and primary dealers as arbitrageurs in the Treasury market.

E. Insurers and Pension Funds: eMAXX

eMAXX provides broad coverage of fixed-income holdings at the security (CUSIP) level (Becker and Ivashina 2015; Bretscher et al. 2025). We use its U.S. database for insurance companies and pension funds. Pension-fund coverage is more limited because reporting is voluntary, unlike the mandatory reporting by insurers. We consolidate repeated delivery vintages into one quarterly position, carry a definitive security-level snapshot forward for at most three quarters when no new report is available, and retain validated Treasury STRIPS. When eMAXX reports a co-managed fund both under individual managers and under an aggregate `CO-MANAGED` row, we retain the aggregate row to avoid double counting.

F. Mutual Funds and ETFs: Morningstar

We obtain security-level Treasury holdings of taxable U.S. mutual funds and taxable U.S. ETFs from Morningstar and keep the two investor types as separate sectors. We identify Treasuries by matching Morningstar CUSIPs to the CRSP Treasury database and convert Morningstar market values to billions of dollars. Reporting dates are uneven across funds. For each fund-quarter, we use the quarter-end portfolio when it is available and otherwise use that fund's latest reported portfolio within the quarter. The resulting quarterly series enter the estimation separately as U.S. mutual funds and U.S. ETFs.

G. Money Market Funds: FoFs

We obtain U.S. money market fund (MMF) Treasury holdings from the Financial Accounts of the United States (FoFs) from the Federal Reserve. Following Jansen, Li, and Schmid (2024), we assign MMF Treasury holdings to the shortest maturity bucket, since MMF Treasury holdings are almost entirely in T-bills or Treasuries with remaining maturity below one year.

H. Foreign Official and Private Investors: Public TIC

We obtain quarterly U.S. Treasury holdings by foreign investors from the Treasury International Capital Reporting System (TIC). Specifically, we use the public TIC Form SLT, which has been available since September 2011. TIC also provides a breakdown of total holdings into T-bills and non-T-bills. Beginning in December 2011, TIC distinguishes between foreign official and foreign private investors. To avoid double counting, we subtract the foreign hedge-fund holdings obtained through Form PF from the foreign-private TIC total. The Morningstar mutual-fund and ETF sectors contain taxable U.S. funds and therefore do not enter this adjustment.

A.2. Data Aggregation

For the data sources in Table A1 that are at the security level, we observe CUSIP identifiers, which we use to match the holdings data with the CRSP U.S. Treasury Database. The CRSP U.S. Treasury Database contains detailed bond-level information on U.S. Treasuries, including bond yields, prices, bond type, coupon rate, maturity date, issue date, and issuance size. We use the bond prices to convert nominal holdings to market values. For the sectors that report at a more aggregate level (banks, foreign investors, hedge funds, and primary dealers), we use their reported market-value holdings directly.

For investors that report at the CUSIP level, including insurers and pension funds, mutual funds, ETFs, and the Fed, it is straightforward to divide their holdings into the respective maturity buckets: $\tau < 1Y$, $1Y \leq \tau < 5Y$, and $\tau \geq 5Y$. For banks, we aggregate maturity buckets $\tau < 3M$ and $3M \leq \tau < 1Y$ to obtain the first bucket, $1Y \leq \tau < 3Y$ and $3Y \leq \tau < 5Y$ to obtain the second bucket, and $5Y \leq \tau < 15Y$ and $\tau \geq 15Y$ to obtain the third bucket. We follow a similar approach for primary dealers, assigning T-bills to bucket 1, $1Y \leq \tau \leq 3Y$ and $3Y < \tau \leq 6Y$ to bucket 2, and $6Y < \tau \leq 11Y$ and $\tau > 11Y$ to bucket 3. As motivated earlier, we assume that hedge funds have the same maturity-bucket distribution as primary dealers.

For foreign investors, we observe only the fraction held in T-bills rather than non-T-bills. To allocate foreign holdings across maturity buckets, we first multiply T-bill holdings by the inverse of the fraction of the CRSP universe's total amount outstanding in maturity bucket 1 that consists of T-bills at each point in time. On average, only 60% of the total amount outstanding in maturity bucket 1 consists of T-bills, while the remaining 40% consists of bonds and notes with less than one year to maturity. This adjustment more accurately reflects the remaining-maturity structure, but our estimates for foreign investors are similar when we assume that T-bills are the only securities held in bucket 1. We then subtract the additional fraction attributed to maturity bucket 1 from total non-T-bill holdings to compute holdings in the remaining maturity buckets. To determine the allocation between buckets 2 and 3, we choose the fraction such that the average durations of both the foreign official and foreign private investors' Treasury portfolios are consistent with Tabova and Warnock (2021) at each point in time. To assign the fractions, we take the bond durations of a 6-month, 3-year, and 15-year bond, respectively, as representative bonds for each maturity bucket. However, our main results do not depend on this choice. For instance, the results are qualitatively and quantitatively similar if we choose instead a 10-year or a 20-year bond for the third bucket.

To obtain the residual sector, we subtract the holdings of all investors from the total amount outstanding in each bucket. Because we observe the total foreign investor position, the residual sector consists only of U.S.-based investors, and we refer to it as "Other U.S. investors."

Finally, in our growing economic environment, portfolio holdings in dollar values will not be stationary. For stationarity, we scale all quantities in our regressions and in the model by the ratio of potential GDP (ticker `NGDPPOT` in FRED, which is nominal potential gross domestic product) at the end of our sample period to potential GDP in that quarter. For example, the ratio of potential GDP in 2024Q4 to that in 2011Q4 is 1.80. The dollar value of marketable Treasury supply in 2011Q4 is \$10.7 trillion, so its scaled value is about $10.7 \times 1.80 = 19.3$ trillion. We use nominal values so that the scaling adjusts for inflation as well as the growing scale of the economy. Nominal potential GDP, rather than nominal GDP, avoids cyclical fluctuations that would otherwise induce mechanical correlations through the scaling. The underlying assumption is that after this adjustment, quantities are stationary in the fundamental state variables. An alternative constant-growth scaling calibrated to the sample produces similar results.

A.3. Macro Data

We complement our dataset with four aggregate states that capture relative safe-asset supply, monetary and fiscal policy conditions, and aggregate economic activity.

First, we include the GDP gap and core inflation to capture aggregate economic conditions as well as the response of monetary policy to macroeconomic dynamics. Together, they reflect aggregate demand and supply fluctuations in the economy and drive monetary policy in the Taylor rule.

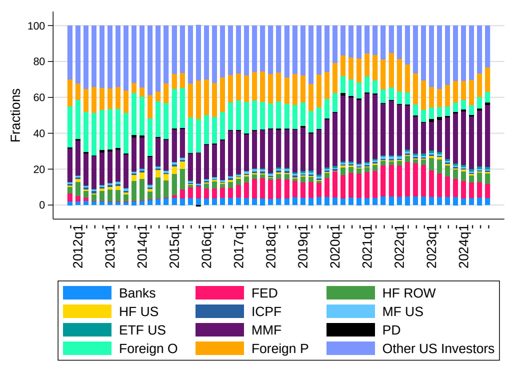
Second, we include the debt/GDP ratio to capture the overall supply and dynamics of government debt. As an indicator of the government's fiscal policy stance, the debt/GDP ratio is plausibly connected to the GDP gap and inflation.

Finally, we construct a relative safe-asset supply state from the Financial Accounts of the United States. Nonsecuritized agency debt equals GSE issues (`FL403161705.Q`) less securitized GSE issues (`FL403161795.Q`) plus federal budget-agency securities (`FL313161705.Q`). We divide this numerator by marketable Treasury securities excluding bills (`FL313161275.Q`) and multiply by 100. The value dated to quarter t uses the previous quarter end, so it is observed at the beginning of the holdings quarter. The agency/Treasury supply ratio is common across maturity buckets and enters the private-sector demand regressions, the Fed rule, Treasury supply, and the macro VAR.

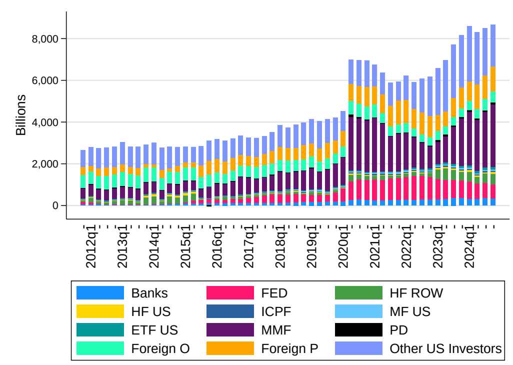
We record here the diagnostics behind the timing convention described in Section 2.2. Over 2011Q4–2024Q4 the ratio falls from 25.5 to 9.5 percentage points. Holding agency debt at its 2011Q4 level while letting the Treasury denominator evolve reproduces -15.77 of the -16.05

Figure A1. **Holdings of U.S. Treasuries by Maturity Bucket**

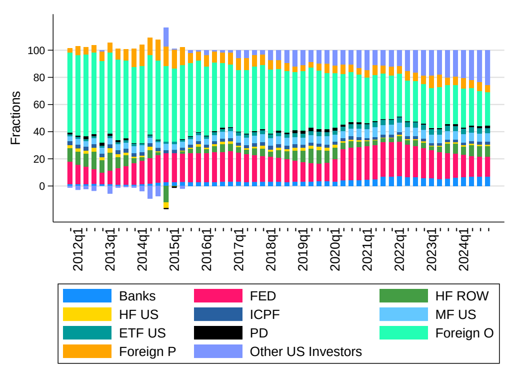
Left panels display the fraction of total U.S. Treasury outstanding (TAO) held by each investor type by maturity buckets. Right panels plot the corresponding market values (billions). Sectors are U.S. banks (Banks), Federal Reserve (FED), hedge funds outside the U.S. (HF ROW), U.S. hedge funds (HF US), U.S. insurance companies and pension funds (ICPF), U.S. mutual funds (MF US), U.S. exchange-traded funds (ETF US), U.S. money market funds (MMF), U.S. and foreign primary dealers (PD), foreign official (Foreign O), foreign private (Foreign P), and other U.S. investors (Other U.S. Investors). Other U.S. Investors is defined as the total U.S. Treasuries outstanding minus the holdings of all the other sectors. We report market values, and the quarterly sample period is 2011Q4–2024Q4.



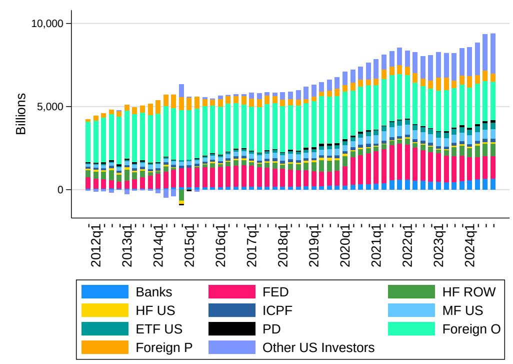
(a) $\tau < 1Y$: % Holdings as of TAO



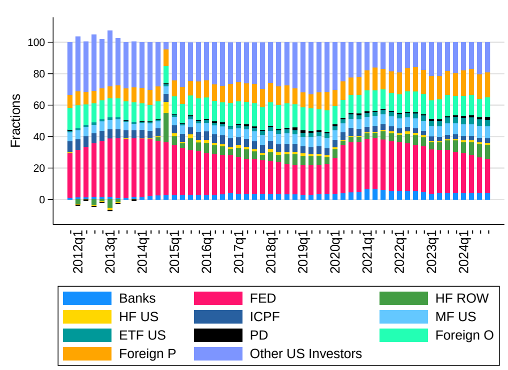
(b) $\tau < 1Y$: Total Holdings (billions)



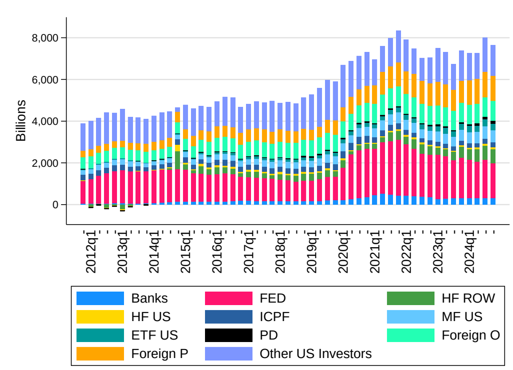
(c) $1 \leq \tau < 5Y$: % Holdings of TAO



(d) $1 \leq \tau < 5Y$: Total Holdings (billions)



(e) $\tau \geq 5Y$: % Holdings of TAO



(f) $\tau \geq 5Y$: Total Holdings (billions) percentage-point decline, so 98% of the movement is federal coupon issuance. Agency debt outstanding ends the sample \$61 billion below its starting value, the net of a \$384 billion decline in non-FHLB agency debt and a \$323 billion rise in Federal Home Loan Bank advances to member depositories. Quarterly changes are a different object: the change in agency debt outstanding regressed on the change in advances has a slope of 0.99 with $R^2 = 0.73$, and the two largest quarterly changes are +\$327 billion in 2023Q1 and +\$270 billion in 2020Q1.

Three facts support dating the state at the previous quarter end. First, the within-quarter change in the ratio, which is the component the convention discards, has a correlation of 0.29 with contemporaneous aggregate latent demand ($p = 0.04$), so a quarter-end-dated ratio would be contaminated. Second, that change is serially unforecastable, with a Ljung–Box statistic at four lags that does not reject white noise ($p = 0.41$) and a first-order autocorrelation of 0.16, so lagging the state removes the contaminated component rather than deferring it; consistently, aggregate latent demand does not forecast the following quarter's change in the ratio ($p = 0.23$), and the previous quarter's within-quarter change is uncorrelated with current latent demand for banks ($p = 0.87$) and in aggregate ($p = 0.76$). Third, re-estimating the demand system with a quarter-end ratio, holding the instruments at their production values, moves every sector's supply loading by less than one baseline standard error, with a median shift of 0.49 standard errors and a largest shift of 0.79, and raises the standard error in 8 of 8 sectors.

The variation that identifies the loading is therefore predetermined. After conditioning on the GDP gap, core inflation, and debt/GDP, 37% of the ratio's standard deviation survives, and that residual maps onto non-FHLB agency debt (partial $R^2 = 0.76$) and the Treasury coupon denominator (partial $R^2 = 0.43$) rather than onto the advance cycle (partial $R^2 = 0.35$, with the opposite sign). We report the loading as a conditioning state rather than as a causal agency-supply effect.

B. Model Derivations and Proofs

This appendix provides the model derivations and proofs supporting Section 2.1. We first micro-found the granular demand curve, then derive the affine equilibrium and the resilience objects.

B.1. Microfoundation of Granular Demand

We derive the yield-based sector demand in (1) from a mean-variance portfolio problem. The derivation gives an economic foundation for a linear demand schedule without assigning a causal interpretation to any individual state loading.

Let Z_t^ι collect sector ι's Treasury positions across the three maturity buckets. Sector ι also enters the period with a background position $\widetilde{Z}_t^\iota$ in an outside portfolio with return $\widetilde{R}_{t+1}^\iota$. We treat this background position as predetermined when the sector chooses its Treasury holdings. Given subjective conditional beliefs $(\mathbb{E}_t^\iota, \mathbb{V}_t^\iota)$, the sector solves

$$\begin{aligned} \max_{Z_t^\iota} \quad & \mathbb{E}_t^\iota[W_{t+1}^\iota] - \frac{\gamma^\iota}{2}\mathbb{V}_t^\iota(W_{t+1}^\iota) + V^\iota(Z_t^\iota), \\ W_{t+1}^\iota = {} & W_t^\iota(1+r_t) + Z_t^{\iota\prime}(R_{t+1} - r_t\mathbf{1}) + \widetilde{Z}_t^\iota(\widetilde{R}_{t+1}^\iota - r_t), \end{aligned} \tag{A1}$$

where R_{t+1} is the vector of Treasury holding returns and V^ι captures non-pecuniary motives such as liquidity, safety, regulation, or liability matching. We assume that its marginal value is locally affine,

$$\nabla V^\iota(Z_t^\iota) = \bar{V}_0^\iota - \bar{V}^\iota Z_t^\iota, \tag{A2}$$

where $\bar{V}^\iota$ is symmetric, and that subjective expected excess returns are locally linear in the aggregate states and Treasury yields:

$$\mathbb{E}_t^\iota[R_{t+1} - r_t\mathbf{1}] = \mu^\iota + \mathscr{B}_\beta^\iota \beta_t + \mathscr{B}_y^\iota y_t + \varepsilon_t^\iota. \tag{A3}$$

The direct yield dependence accommodates beliefs such as yield-curve extrapolation or reaching for yield. Let $\Sigma^\iota \equiv \mathrm{Var}_t^\iota(R_{t+1})$ denote the locally constant Treasury-return covariance matrix. We also approximate the risk exposure of the outside portfolio as

$$\mathrm{Cov}_t^\iota(R_{t+1}, \widetilde{R}_{t+1}^\iota)\widetilde{Z}_t^\iota = c_0^\iota + C^\iota \beta_t + \nu_t^\iota. \tag{A4}$$

Define $\xi_t^\iota \equiv \varepsilon_t^\iota - \gamma^\iota \nu_t^\iota$ and assume that ξ_t^ι is i.i.d., mean zero, and independent of the macroeconomic and monetary-policy innovations. Cross-sector correlation in ξ_t^ι is unrestricted.

The first-order condition for Treasury holdings is

$$\left(\gamma^\iota \Sigma^\iota + \bar{V}^\iota\right) Z_t^\iota = \mu^\iota + \bar{V}_0^\iota + \mathscr{B}_\beta^\iota \beta_t + \mathscr{B}_y^\iota y_t - \gamma^\iota(c_0^\iota + C^\iota \beta_t) + \xi_t^\iota. \tag{A5}$$

Assume that $K^\iota \equiv \gamma^\iota \Sigma^\iota + \bar{V}^\iota$ is positive definite, so the portfolio problem is strictly concave in Treasury holdings. Defining

$$\begin{aligned} \theta_0^\iota &\equiv (K^\iota)^{-1}\left(\mu^\iota + \bar{V}_0^\iota - \gamma^\iota c_0^\iota\right), & \alpha^\iota &\equiv (K^\iota)^{-1}\mathscr{B}_y^\iota, \\ \theta^\iota &\equiv (K^\iota)^{-1}\left(\mathscr{B}_\beta^\iota - \gamma^\iota C^\iota\right), & u_t^\iota &\equiv (K^\iota)^{-1}\xi_t^\iota, \end{aligned}$$

gives

$$Z_t^\iota = \theta_0^\iota + \alpha^\iota y_t + \theta^\iota \beta_t + u_t^\iota, \tag{A6}$$

which stacks equation (1) across maturities. The full matrix α^ι allows demand in each bucket to respond to yields at other maturities; these cross-maturity responses can arise from beliefs about returns, covariance across the term structure, and non-pecuniary portfolio curvature. The four columns of θ^ι correspond to the agency-to-Treasury supply ratio, the GDP gap, core inflation, and debt/GDP. The Fed follows the same reduced-form schedule, but we interpret its equation as a policy rule rather than as the solution to (A1).

B.2. Affine Equilibrium

Full maturity grid and bucket demand. The quantitative model is solved on quarterly zero-coupon maturities $\tau \in \{1,\ldots,N\}$, with $N = 120$. Let $\mathbf{y}_t \in \mathbb{R}^N$ and $p_t \in \mathbb{R}^N$ denote the full yield and log-price curves and let $\mathscr{D} \equiv \mathrm{diag}(1,\ldots,N)$. Then

$$p_t = -\mathscr{D}\mathbf{y}_t. \tag{A7}$$

The demand system is estimated at three representative bucket maturities $\mathscr{B} = \{b_1, b_2, b_3\}$. Let H be the $3 \times N$ matrix that selects these maturities and let $E = H'$. Thus the yield vector in (1) is $y_t = H\mathbf{y}_t = -H\mathscr{D}^{-1}p_t$. Summing demand across granular sectors and the Fed and embedding the three bucket quantities in the full maturity grid gives

$$Z_t = \theta_0^p - \alpha^p p_t - \theta^p \beta_t + u_t, \tag{A8}$$

where

$$\theta_0^p = E\sum_\iota \theta_0^\iota, \qquad \alpha^p = E\left(\sum_\iota \alpha^\iota\right)H\mathscr{D}^{-1}, \qquad \theta^p = -E\sum_\iota \theta^\iota, \qquad u_t = E\sum_\iota u_t^\iota.$$

Thus the embedded N-vector u_t has nonzero entries only at the three representative bucket maturities. Let $e_\tau \in \mathbb{R}^N$ denote the τth full-grid unit vector. Supply is embedded in the same way: $S_t = \bar{S} + \zeta\beta_t + \zeta_r r_t$, with nonzero entries only at $\mathscr{B}$. Market clearing determines arbitrageur holdings at every grid point,

$$X_t = S_t - Z_t. \tag{A9}$$

Prices, returns, and arbitrageur first-order conditions. Conjecture a full-curve affine price rule

$$p_t = A^p \beta_t + A_r^p r_t + A_u^p u_t + C^p. \tag{A10}$$

For $\tau \geq 2$, the one-quarter log holding return is

$$r_{t+1}^{(\tau)} = p_{t+1}(\tau - 1) - p_t(\tau), \tag{A11}$$

while $p_t(1) = -r_t$. We use the standard lognormal approximation for the conditional mean,

$$\mathbb{E}_t[R_{t+1}^{(\tau)}] \approx \mathbb{E}_t[r_{t+1}^{(\tau)}] + \frac{1}{2}\mathbb{V}_t\left(r_{t+1}^{(\tau)}\right). \tag{A12}$$

Write $A^p(\tau)$ for the column whose transpose is row τ of A^p and define $\widehat{A}^p(\tau) \equiv A^p(\tau) + \phi_r A_r^p(\tau)$. The arbitrageur chooses Treasury positions conditional on its predetermined background portfolio. Its exposure through that portfolio is parameterized as

$$\Sigma_\beta^{1/2}\widetilde{\sigma}\widetilde{X}_t = \Psi\beta_t + \Lambda r_t + \psi, \tag{A13}$$

$$\sigma_r\widetilde{\sigma}_r\widetilde{X}_t = \Psi_r\beta_t + \Lambda_r r_t + \psi_r. \tag{A14}$$

We maintain the quantitative model's restriction that the transitory innovations u_{t+1} do not carry a price of risk. They affect prices and the Jensen term in (A12), but not the two prices of systematic risk below. The Treasury first-order condition is therefore

$$\mu_t^{(\tau)} - r_t = \widehat{A}^p(\tau-1)'\lambda_{\beta,t} + A_r^p(\tau-1)\lambda_{r,t}, \tag{A15}$$

where $\mu_t^{(\tau)} \equiv \mathbb{E}_t[R_{t+1}^{(\tau)}]$ and

$$\lambda_{\beta,t} = \gamma\left(\sum_{j=2}^{N}\Sigma_\beta\widehat{A}^p(j-1)X_t(j) + \Psi\beta_t + \Lambda r_t + \psi\right), \tag{A16}$$

$$\lambda_{r,t} = \gamma\left(\sum_{j=2}^{N}\sigma_r^2 A_r^p(j-1)X_t(j) + \Psi_r\beta_t + \Lambda_r r_t + \psi_r\right). \tag{A17}$$

Coefficient system. Substituting (A10) into (A9), we write

$$X_t(\tau) = x_0(\tau) + x_\beta(\tau)'\beta_t + x_r(\tau)r_t + x_u(\tau)'u_t, \tag{A18}$$

where

$$
\begin{aligned}
x_0(\tau) &= \bar{S}(\tau) - \theta_0^p(\tau) + \alpha^p(\tau,:)C^p, \\
x_\beta(\tau)' &= \zeta(\tau)' + \theta^p(\tau)' + \alpha^p(\tau,:)A^p, \\
x_r(\tau) &= \zeta_r(\tau) + \alpha^p(\tau,:)A_r^p, \\
x_u(\tau)' &= \alpha^p(\tau,:)A_u^p - e_\tau'.
\end{aligned}
$$

Equations (A16)–(A17) are then affine. Define their coefficient blocks by

$$
\begin{aligned}
L_{\beta\beta} &= \gamma\left(\sum_{j=2}^N \Sigma_\beta \widehat{A}^p(j-1)x_\beta(j)' + \Psi\right), & L_{\beta r} &= \gamma\left(\sum_{j=2}^N \Sigma_\beta \widehat{A}^p(j-1)x_r(j) + \Lambda\right), \\
L_{\beta u} &= \gamma\sum_{j=2}^N \Sigma_\beta \widehat{A}^p(j-1)x_u(j)', & \ell_\beta &= \gamma\left(\sum_{j=2}^N \Sigma_\beta \widehat{A}^p(j-1)x_0(j) + \psi\right), \\
L_{r\beta} &= \gamma\left(\sum_{j=2}^N \sigma_r^2 A_r^p(j-1)x_\beta(j)' + \Psi_r\right), & L_{rr} &= \gamma\left(\sum_{j=2}^N \sigma_r^2 A_r^p(j-1)x_r(j) + \Lambda_r\right), \\
L_{ru} &= \gamma\sum_{j=2}^N \sigma_r^2 A_r^p(j-1)x_u(j)', & \ell_r &= \gamma\left(\sum_{j=2}^N \sigma_r^2 A_r^p(j-1)x_0(j) + \psi_r\right).
\end{aligned}
$$

Thus $\lambda_{\beta,t} = L_{\beta\beta}\beta_t + L_{\beta r}r_t + L_{\beta u}u_t + \ell_\beta$ and $\lambda_{r,t} = L_{r\beta}\beta_t + L_{rr}r_t + L_{ru}u_t + \ell_r$.

For $\tau \geq 2$, define the Jensen term

$$
J_\tau = \frac{1}{2}\widehat{A}^p(\tau-1)'\Sigma_\beta\widehat{A}^p(\tau-1) + \frac{1}{2}\left(A_r^p(\tau-1)\sigma_r\right)^2 + \frac{1}{2}A_u^p(\tau-1,:)\Sigma_u A_u^p(\tau-1,:)',
$$

where $\Sigma_u \equiv \mathbb{V}(u_t)$. Substituting the state dynamics and matching coefficients in (A15) gives

$$
\widehat{A}^p(\tau-1)'\Phi - A^p(\tau)' = \widehat{A}^p(\tau-1)'L_{\beta\beta} + A_r^p(\tau-1)L_{r\beta}, \tag{A19}
$$

$$
A_r^p(\tau-1)\rho_r - A_r^p(\tau) - 1 = \widehat{A}^p(\tau-1)'L_{\beta r} + A_r^p(\tau-1)L_{rr}, \tag{A20}
$$

$$
-A_u^p(\tau,:) = \widehat{A}^p(\tau-1)'L_{\beta u} + A_r^p(\tau-1)L_{ru}, \tag{A21}
$$

$$
\begin{aligned}
&A^p(\tau-1)'(I-\Phi)\bar{\beta} + A_r^p(\tau-1)(\bar{r} - \phi_r'\Phi\bar{\beta}) \\
&\quad + C^p(\tau-1) - C^p(\tau) + J_\tau
\end{aligned}
= \widehat{A}^p(\tau-1)'\ell_\beta + A_r^p(\tau-1)\ell_r. \tag{A22}
$$

The boundary conditions are $A^p(1) = 0$, $A_r^p(1) = -1$, $A_u^p(1,:) = 0$, and $C^p(1) = 0$.

Proposition 1 (Affine Equilibrium)**.** *Within the affine class (A10) and the lognormal approximation (A12), a price rule is an equilibrium if and only if its coefficients satisfy the boundary* *conditions and equations (A18)–(A22). The corresponding full yield curve is*

$$\mathbf{y}_t = -\mathscr{D}^{-1}(A^p\beta_t + A_r^p r_t + A_u^p u_t + C^p),$$

and selecting the rows in $\mathscr{B}$ gives the bucket yields used in (1). A solution is locally unique when the Jacobian of the complete coefficient system with respect to (A^p, A_r^p, A_u^p, C^p) is nonsingular. We do not impose conditions sufficient for global uniqueness; quantitatively, we select the solution on the branch connected to the estimated baseline.

The full-curve yield coefficients in (8) are therefore

$$(A, A_r, A_u, C) = -\mathscr{D}^{-1}(A^p, A_r^p, A_u^p, C^p). \tag{A23}$$

Proof. Equations (A11) and (A10), together with (2) and (3), give the four coefficient blocks on the left side of (A15). Market clearing gives (A18), which in turn gives the displayed coefficient blocks of $\lambda_{\beta,t}$ and $\lambda_{r,t}$. Equality for every (β_t, r_t, u_t) in the embedded support is therefore equivalent to (A19)–(A22), with the one-period bond imposing the boundary conditions. Because $\gamma > 0$ and the systematic return covariance matrix is positive semidefinite, the arbitrageur's objective is concave in Treasury positions conditional on the background portfolio; its first-order conditions are therefore sufficient. The yield statement follows from (A7), and local uniqueness follows from the implicit-function theorem applied to the complete coefficient system. □

B.3. Local Intercept Sensitivity and Scenario Resilience

For an additive intercept perturbation, the slope coefficients (A^p, A_r^p, A_u^p) remain fixed and only C^p changes. Define the roll-down difference matrix Δ_N by

$$e_1'\Delta_N = e_1', \qquad e_\tau'\Delta_N = e_{\tau-1}' - e_\tau', \quad \tau = 2, \ldots, N,$$

and define $Q \in \mathbb{R}^{N\times(K+1)}$ by $e_1'Q = 0$ and

$$e_\tau'Q = \begin{bmatrix} \widehat{A}^p(\tau-1)' & A_r^p(\tau-1) \end{bmatrix}, \quad \tau = 2, \ldots, N.$$

Finally, collect the systematic risk-exposure loadings in $G \in \mathbb{R}^{(K+1)\times N}$:

$$G = \begin{bmatrix} 0 & \Sigma_\beta \widehat{A}^p(1) & \cdots & \Sigma_\beta \widehat{A}^p(N-1) \\ 0 & \sigma_r^2 A_r^p(1) & \cdots & \sigma_r^2 A_r^p(N-1) \end{bmatrix}.$$

Differentiating the constant restrictions (A22) gives

$$(\Delta_N - \gamma QG\alpha^p)\, dC^p = -\gamma QG\, d\theta_0^p. \tag{A24}$$

Let $q_m \in \mathbb{R}^3$ denote the mth bucket unit vector. If $K_C \equiv \Delta_N - \gamma QG\alpha^p$ is nonsingular, a unit shift in sector ι's bucket-m intercept changes the bucket-m' yield by

$$\frac{\partial y_t(m')}{\partial \theta_0^\iota(m)} = e'_{b_{m'}} \mathscr{D}^{-1} K_C^{-1} \gamma QGE q_m. \tag{A25}$$

The inverse absolute value of (A25) is local resilience to a unit additive intercept shift. It is not the resilience measure for an arbitrary finite scenario. In particular, a proportional contraction of a sector's demand scales $(\theta_0^\iota, \alpha^\iota, \theta^\iota)$ jointly, changes the slope coefficient system, and must be re-solved. The paper's counterfactuals do exactly this and then compute resilience from the finite yield change in (9).

B.4. Rule Insurance and Its Debt-Supply Contribution

The rule-insurance experiment proportionally reduces the Fed's estimated yield elasticities and macro-state loadings, α^{Fed} and θ^{Fed}, while holding the demand intercept θ_0^{Fed} fixed. A common scale κ^{Rule} is chosen so that the full rule contraction reduces baseline-state Fed demand by \$10 billion. Because changes in α^{Fed} alter the equilibrium coefficient matrix and changes in θ^{Fed} alter its state loadings, each counterfactual rule implies a distinct equilibrium.

To attribute the full rule effect, partition the slopes into the debt/GDP block $D = \{\theta_D^{\text{Fed}}\}$ and the remainder $R = \{\alpha^{\text{Fed}}, \theta_{-D}^{\text{Fed}}\}$. Let $v(S)$ denote the counterfactual yield when the slopes in $S \subseteq \{D, R\}$ are reduced by the same κ^{Rule}. The two-block Shapley contributions are

$$\phi_D = \tfrac{1}{2}\big[v(D) - v(\varnothing) + v(D,R) - v(R)\big], \tag{A26}$$

$$\phi_R = \tfrac{1}{2}\big[v(R) - v(\varnothing) + v(D,R) - v(D)\big]. \tag{A27}$$

By construction, $\phi_D + \phi_R = v(D,R) - v(\varnothing)$ whenever all four equilibria exist on the branch connected to the baseline. The sub-blocks are not separately calibrated to \$10 billion: separate dollar matching would assign different policy scales to D and R and would no longer decompose the total experiment. In the current calibration all four equilibria solve to a residual RMS below 10^{-9}, so Section 5 reports both Shapley contributions and the total rule-insurance yield effect.

B.5. Estimation of the Risk-Aversion Parameter

This subsection records the estimation of γ outlined in Section 2.3. Given (A^p, A^p_r), equation (A21) is linear in A^p_u conditional on γ and has a unique solution whenever its coefficient matrix is nonsingular. We denote that solution by $A^p_u(\gamma)$. We do not require this mapping to be globally monotone; in fact, outside the economically relevant range it can change sign.

Let η_t be the observed log-price residual after removing $A^p\beta_t + A^p_r r_t + C^p$, and let X^{res}_t be observed arbitrageur holdings after removing the corresponding systematic holdings. For a bucket maturity b_m, the model-implied demand-shock component of arbitrageur holdings is

$$X^u_t(b_m;\gamma) = \left(\alpha^p(b_m,:)A^p_u(\gamma) - e'_{b_m}\right)u_t. \tag{A28}$$

The Step 2 estimator minimizes the normalized pricing and quantity errors

$$\widehat{\gamma}_2 = \arg\min_{\gamma\in\Gamma}\left\{\sum_{t,n\in\mathscr{F}}\left(\frac{\eta_t(n) - e'_n A^p_u(\gamma)u_t}{\bar{\eta}(n)}\right)^2 + \lambda_X\sum_{t,m}\left(\frac{X^u_t(b_m;\gamma) - X^{\mathrm{res}}_t(b_m)}{\bar{X}(m)}\right)^2\right\}, \tag{A29}$$

where $\mathscr{F}$ is the set of fitted maturities, $\bar{\eta}(n)$ and $\bar{X}(m)$ are mean absolute residuals, and the baseline specification sets $\lambda_X = 1$. We evaluate (A29) on a coarse grid over the admissible set Γ and refine around its lowest grid point, avoiding reliance on global convexity. The final step jointly reoptimizes γ, the systematic prices of risk, and the constant outside-exposure terms, with C^p solved from (A22) so that the reference-state price level satisfies the structural restrictions. The resulting estimate is $\hat{\gamma} = 0.043$.

B.6. Model Fit: Yields and Arbitrageur Holdings

We report the fit of the estimated model along the two dimensions targeted in Section 2.3. Figure A2 plots observed yields against model-implied yields with and without the latent demand component u_t at four maturities: the macro-and-policy block ($u_t = 0$) captures the level and trend, and adding u_t tightens the fit, most visibly at long maturities. Figure A3 compares model-implied arbitrageur holdings $X_t(m) = S_t(m) - \sum_\iota Z^\iota_t(m)$ with observed primary-dealer and hedge-fund positions across the three maturity buckets. Figure A4 plots the Step 2 objective and its price and quantity components over a range containing the Step 2 and final joint estimates.

Figure A2. **Model Fit: Treasury Yields**

This figure plots the model fit for Treasury yields. Each panel shows observed yields (black solid), model-implied yields without latent demand shocks ($u_t = 0$, blue dashed), and model-implied yields including u_t (red dash-dot), at the 3M, 1Y, 10Y, and 30Y maturities. Sample: 2011Q4–2024Q4.

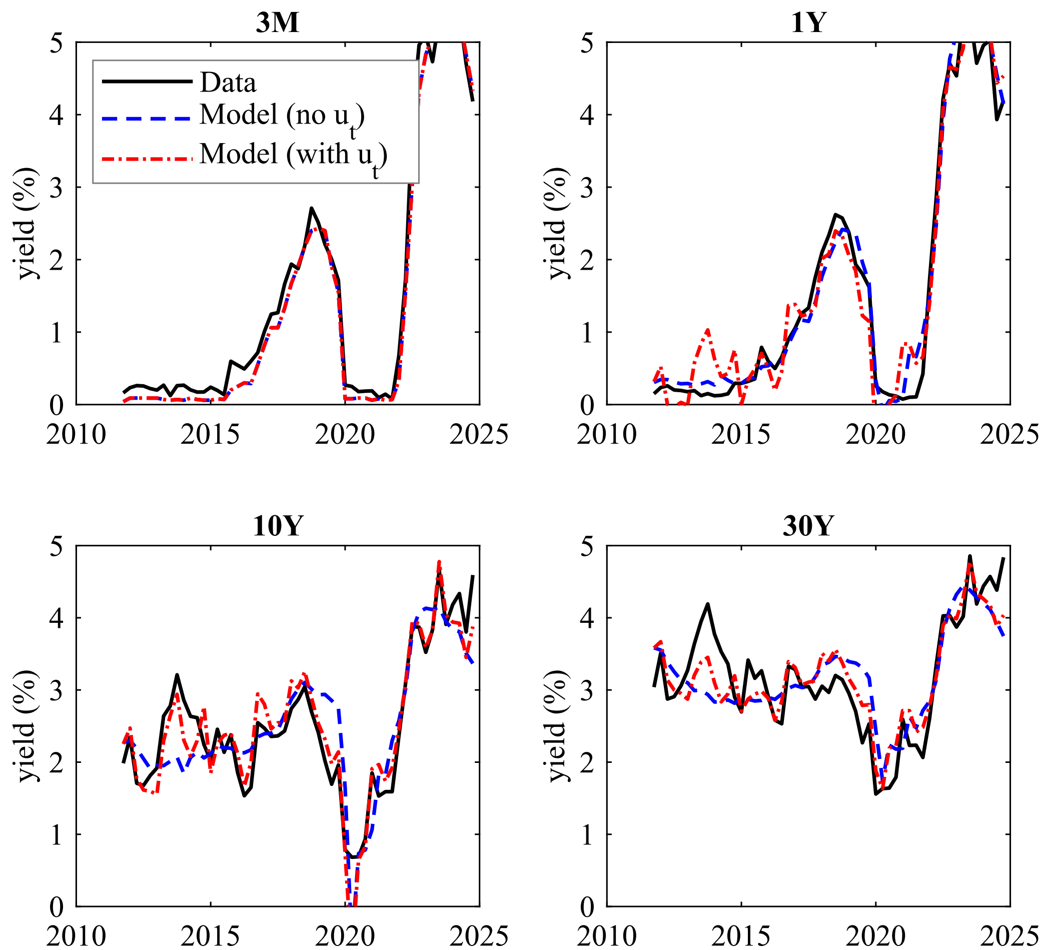


Figure A3. **Model Fit: Arbitrageur Holdings**

This figure compares model-implied arbitrageur holdings $X_t(m) = S_t(m) - \sum_\iota Z_t^\iota(m)$ (dashed) with observed positions aggregated from primary-dealer and hedge-fund data (solid), by maturity bucket. Sample: 2011Q4–2024Q4.

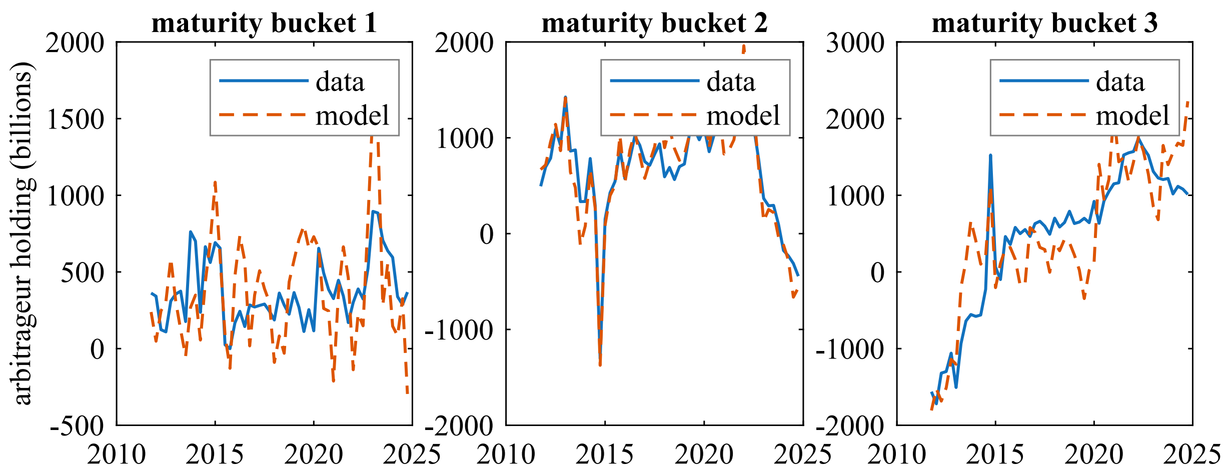
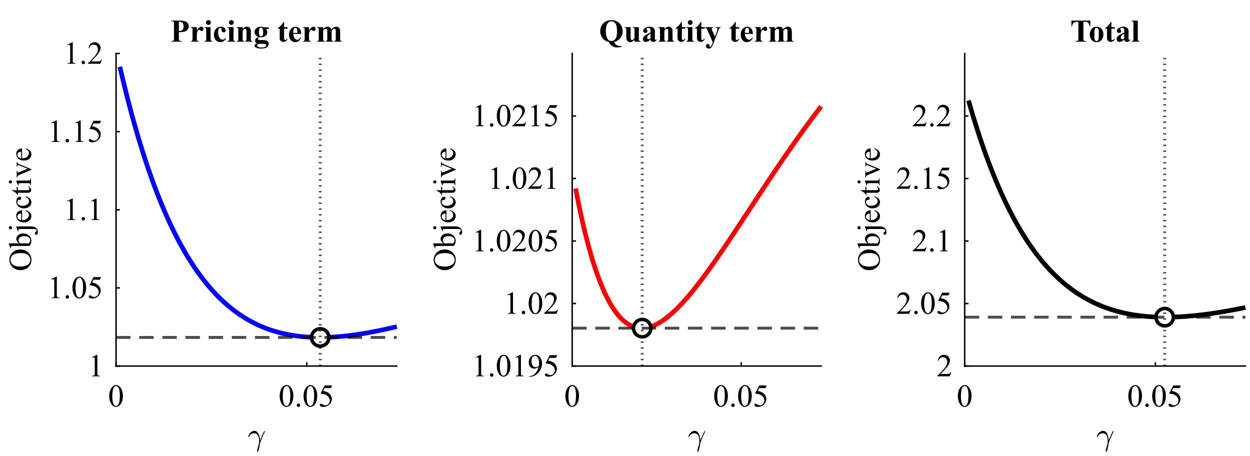


Figure A4. **Step-2 Objective Profile for γ**

This figure plots the Step 2 objective profile for arbitrageur risk aversion γ over a range containing both reported estimates. Left: pricing term $\mathscr{L}^{\text{price}}(\gamma)$; middle: quantity term $\mathscr{L}^{\text{qty}}(\gamma)$; right: total. The dotted line marks the Step 2 estimate $\hat{\gamma}_2$; the dashed line marks the final joint estimate $\hat{\gamma} = 0.043$.



C. Additional Empirical Results

This appendix reports additional empirical results supporting Section 2.

C.1. Full Demand Estimation Results

Table A2 reports the estimation used to construct the structural-model inputs: one IV regression per private sector with fixed-duration Treasury yields over the full 2011Q4–2024Q4 sample. The seven regular private sectors include own- and cross-yield elasticities. MMFs hold only bills, so their equation includes the T-bill yield but no cross-maturity yield and contributes 53 observations rather than 159. Every equation includes the beginning-of-quarter agency/Treasury supply ratio, the GDP gap, core inflation, debt/GDP, and bond controls. All coefficients consumed by the model come from this fit.

Table A2. **Sector-Level Demand Estimates Underlying the Structural Model**

This table reports the sector-level demand estimates underlying the structural-model inputs. Each column is one IV regression per sector using fixed-duration Treasury yields over 2011Q4–2024Q4. The seven regular private sectors include own and cross yields; the MMF equation includes only the T-bill own yield. The production state vector contains the beginning-of-quarter agency/Treasury supply ratio, GDP gap, core inflation, and debt/GDP. Coupon-rate and bid–ask-spread residuals also enter, and each three-bucket regression includes maturity-bucket fixed effects that are estimated but not reported (the single-bucket MMF equation has none). Each three-bucket sector has 159 observations; MMFs have 53. The supply-ratio loading is a conditional state coefficient, not a causal agency-supply estimate. Debt/GDP is carried in the estimation as a ratio while the other three states are already in percentage points, so its loading is divided by 100 for reporting and all four state loadings are per percentage point, as in Figure 1. The structural model consumes the unscaled coefficient. Appendix C.2 restates the loadings as shares of a marginal dollar of Treasury supply. HAC standard errors (Bartlett bandwidth 2.5, panel groups by maturity bucket) are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Banks	**ETF US**	**ICPF**	**MF US**	**MMF**	**Other U.S.**	**Foreign O**	**Foreign P**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$y_t(m)$	11.499	4.723	11.971	7.193	110.644***	363.161***	-1.678	22.769
	[18.681]	[12.828]	[10.895]	[20.748]	[34.240]	[125.965]	[89.476]	[60.455]
$y_t(-m)$	-14.488	18.998	-22.510**	-9.639		-116.068	-64.755	-62.180
	[21.130]	[13.029]	[11.277]	[23.426]		[161.279]	[116.881]	[68.453]
Coupon rate	0.348	-12.114	44.527**	-51.663	664.983**	374.404	-1012.404***	-210.490*
	[49.201]	[23.947]	[17.916]	[37.138]	[288.491]	[259.283]	[197.078]	[116.870]
Bid-ask spread	22.600*	14.962**	19.472**	10.942	-77.804	239.213**	-182.513***	-96.706**
	[12.073]	[7.514]	[7.814]	[13.722]	[64.324]	[103.515]	[69.795]	[49.293]
Agency/Treasury supply ratio	-10.241**	-0.159	2.859	1.788	31.872	40.570	60.732**	-26.544**
	[4.859]	[3.477]	[2.877]	[5.247]	[20.952]	[33.222]	[23.592]	[12.944]
Debt/GDP	6.959***	5.004***	0.450	5.143***	95.431***	28.123***	-3.773	3.466
	[1.613]	[0.961]	[0.905]	[1.463]	[7.739]	[10.336]	[8.296]	[4.831]
GDP gap	6.145	4.104	-3.466	13.542***	-11.844	-1.515	34.174	2.588
	[5.126]	[2.961]	[3.576]	[4.414]	[18.846]	[33.216]	[26.448]	[16.387]
Core inflation	19.298**	0.107	3.921	4.858	-120.187***	10.680	-127.047**	-5.906
	[9.412]	[5.426]	[4.036]	[8.109]	[37.985]	[53.212]	[50.565]	[29.554]
Observations	159	159	159	159	53	159	159	159
KP statistic (first stage)	13.047	13.047	13.047	13.047	1813.942	13.047	13.047	13.047

C.2. Interpreting the Debt/GDP Loadings

Section 2.2 reports that the debt/GDP loadings are positive and significant for most sectors and large in economic terms. That result raises two questions of unequal importance. The first is why the loadings are positive at all, since a portfolio problem alone does not deliver a larger desired position merely because more of an asset exists. The second is why they differ so much across sectors. This appendix takes them in that order, because the level is the more surprising of the two and because the cross-section is what disciplines any account of the level.

A. Units and the Marginal-Dollar Normalization

The estimation carries debt/GDP as a ratio, whereas the agency/Treasury supply ratio, the GDP gap, and core inflation are each multiplied by 100 when they are constructed. Over 2011Q4–2024Q4 the debt ratio has mean 0.778, standard deviation 0.093, and range 0.658 to 0.977, and both sides of every regression are scaled to 2024Q4 potential GDP as described in Appendix A. An unscaled coefficient is therefore in dollars per unit of debt/GDP, that is, per 100 percentage points, which makes it roughly one hundred times the other macro loadings for no economic reason. We divide it by 100 wherever it is reported, so that every state loading in the paper is per percentage point and Table A2 agrees with Figure 1. This is a reporting convention rather than a change to the estimation: the structural model consumes the unscaled coefficients, and rescaling an estimate together with its standard error leaves t-statistics and significance unchanged.

The supply equation (7) supplies a more interpretable scale. Its three bucket loadings on debt/GDP sum to $176.45 + 36.03 + 81.79 = 294.27$ billion dollars per percentage point, which is one percent of nominal potential GDP in 2024Q4 and is, by construction, what a one-percentage-point rise in the debt ratio adds to Treasury supply. Dividing a sector's loading by that sum therefore expresses it as the share of a marginal dollar of Treasury supply the sector absorbs at unchanged yields. Table A3 reports the normalization.

Two guards apply to the last row. First, the cross-sector total is not pinned to one and is not a validation check. Market clearing holds along the equilibrium path, not at unchanged yields, so no adding-up restriction applies to a column of partial derivatives taken at fixed yields. Nor does the naive reading of the total run in the model's direction: a sum above one says the granular sectors want more than the incremental supply at unchanged yields, which, read statically, would call for a yield decline, whereas the solved equilibrium has a positive yield loading on debt/GDP at every maturity. Reconciling the two requires the persistence of d_t under (2) and arbitrageurs' pricing of the expected supply path, which is a property of the solved model rather than an inference available from this table.

Second, the total is imprecise, with a standard error of roughly fifteen percentage points of potential GDP. That figure is itself computed treating the sector equations as independent, which the estimation does not impose, so it is a lower bound on the uncertainty as much as an estimate of it. We use the normalization to make individual loadings interpretable and draw no conclusion from their sum.

One bucket-level reading is worth recording. The MMF loading of 95.43 against a short-bucket supply loading of 176.45 implies that money funds absorb roughly 54% of marginal short-end Treasury supply at unchanged yields, consistent with the bill-market allocation mechanism described below.

Table A3. **Debt/GDP Loadings as Shares of a Marginal Supply Dollar**

This table restates the estimated debt/GDP loadings of Tables A2 and A7 as the share of a marginal dollar of Treasury supply each sector absorbs at unchanged yields. Loadings are reported per percentage point of debt/GDP. The normalizing constant is the sum of the three bucket loadings on debt/GDP in the estimated supply equation (7), which equals one percent of nominal potential GDP in 2024Q4, or $294.3 billion. Private-sector loadings are pooled across the three maturity buckets, so the sector total used in the share column is three times the reported coefficient; MMFs hold only bills and enter a single bucket. Federal Reserve loadings are bucket-specific and are reported separately. HAC standard errors are in the third column; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The cross-sector total is not restricted to one and is not a diagnostic; see the guards in the text.

	$\hat{\theta}_D^{\iota}$	HAC SE	Share of marginal supply dollar (%)
Panel A: Granular-demand sectors			
Money market funds (bills only)	95.43***	7.74	32.4
Other U.S. investors	28.12***	10.34	28.7
Banks	6.96***	1.61	7.1
U.S. mutual funds	5.14***	1.46	5.2
U.S. ETFs	5.00***	0.96	5.1
Foreign private	3.47	4.83	3.5
Insurers and pension funds	0.45	0.91	0.5
Foreign official	−3.77	8.30	−3.8
Panel B: Federal Reserve, by maturity bucket			
Short ($\tau < 1Y$)	28.94***	7.43	9.8
Medium ($1Y \leq \tau < 5Y$)	16.01**	6.24	5.4
Long ($\tau \geq 5Y$)	56.17***	7.42	19.1
Total			113.0

B. Economic Interpretation of the Positive Loadings

Three complementary mechanisms help interpret the positive debt/GDP loadings: substitution toward publicly supplied safe assets, sector-specific balance-sheet demand, and Federal Reserve accommodation. The estimated coefficient combines these forces, and their relevance differs across sectors.

Public safe-asset substitution. Treasuries provide safe and liquid claims directly, while banks and other intermediaries create private money-like claims backed by less liquid assets. Greater Treasury supply crowds out privately issued short-term claims and financial-sector lending in Greenwood, Hanson, and Stein (2015) and Krishnamurthy and Vissing-Jorgensen (2015). For our holdings equations, this provides a substitution mechanism: as the public supply of safe assets expands, investor portfolios shift toward Treasuries even if privately issued money-like liabilities do not expand.

Primary dealers and hedge funds form the arbitrageur sector that absorbs the market-clearing residual rather than an estimated demand sector (Barth and Kahn 2025). Their balance-sheet capacity therefore governs the yield adjustment required to intermediate the supply left by the granular sectors.

Arbitrageur risk-bearing capacity has not kept pace with supply: Treasuries outstanding per dollar of primary dealer assets grew by a factor of nearly four after 2007 (Duffie et al. 2023). In the model, arbitrageur risk aversion γ represents the resulting cost of absorbing the market-clearing residual. This constraint explains why greater sectoral absorption matters for equilibrium yields.

Sectoral balance sheets. The substitution mechanism operates differently across institutions. Banks, money funds, and asset managers have liabilities or benchmark-linked portfolios that generate demand for safe and liquid securities. The relevant mechanism is portfolio composition rather than the mechanical creation of deposits: over a full borrow-and-spend cycle the Treasury debits a buyer's deposit and then credits a recipient's, while the newly issued Treasury security remains in private portfolios.

For banks, liquidity regulation connects the liability and asset sides of the balance sheet: Treasury securities qualify as level-1 liquid assets under U.S. liquidity regulation (Board of Governors of the Federal Reserve System 2026). Hanson et al. (2015) show that stable funding supports banks' capacity to hold fixed-income assets. Together, these features give banks a natural role in absorbing additional Treasury supply.

For money funds, Doerr, Eren, and Malamud (2023) document strategic allocation between T-bills, private repo, and the Federal Reserve's overnight reverse repo facility, while Stein and Wallen (2025) study the intermediation of money-like assets. This allocation margin gives MMFs a direct channel for absorbing bill supply. Consistent with that mechanism, the MMF loading is the most precisely estimated in the table, at $t = 12.33$.

Three qualifications. First, the mechanism predicts a state-dependent bank loading, positive when deposits grow and negative when they shrink, whereas the specification estimates one constant loading; bank Treasury holdings fell over 2022–2024 while the market grew, so 6.96 averages across two regimes the mechanism says should differ in sign. Second, the asset-manager version of this channel works through supply-determined benchmark weights, which predicts index-driven ETF and mutual-fund demand concentrated at maturities of a year and above and near zero in bills; the pooled specification imposes a common loading across buckets and cannot test this.

Third, Other U.S. investors carry the second-largest loading and are a residual sector by construction, equal to total outstanding less all observed holders, so their loading is a composite of whatever the identified sectors do not absorb rather than an estimate for an identified group of investors.

Federal Reserve accommodation. The Federal Reserve's loadings are the largest single component of the aggregate, at 34% of a marginal supply dollar across the three buckets, and they are positive and significant in every bucket. The interpretation differs from the private sectors'. As Section 2.1 sets out, the Fed's equation is a policy rule rather than the solution to a portfolio problem, so its debt/GDP loading captures systematic accommodation of Treasury supply within the estimated rule. Haddad, Moreira, and Muir (2024) show that anticipated purchases under an asset-purchase rule can affect prices because purchases are expected in adverse states. The loading accounts for roughly a third of the system's estimated unchanged-yield absorption, and Section 5 asks the complementary counterfactual question of what happens when investors expect a weaker rule.

Foreign demand. Foreign official demand loads -3.77 on debt/GDP with a standard error of 8.3, and foreign private demand loads $+3.47$ with a standard error of 4.83. Neither is distinguishable from zero, and the 95% interval for foreign official demand runs from roughly -20 to $+12.5$. Treasuries' safe-asset and liquidity services support foreign demand (Jiang, Krishnamurthy, and Lustig 2021), but the composition of that demand moves with reserve management, exchange rates, Federal Reserve holdings, geopolitical fragmentation, and global risk conditions.

Chari and Milesi-Ferretti (2026) document that the decline in the foreign official Treasury share is associated with lower reserve accumulation, a higher Federal Reserve holdings share, dollar appreciation against other reserve currencies, and geopolitical fragmentation; they also find that foreign private holdings, unlike official holdings, rise in risk-off episodes. The near-zero debt/GDP loadings are consistent with foreign demand being organized around these portfolio forces rather than responding systematically to the scale of U.S. debt.

What the loadings measure. Regardless of which mechanism operates, the demand system conditions on quantities of safe assets as state variables, separately from their relative prices. Both sides of the substitution margin enter as states: the debt ratio measures Treasury supply, and the agency/Treasury supply ratio measures the supply of the closest privately produced substitute. A sector's response to relative safe-asset supply is therefore split between θ_D^ι and the loading on q_t^A, and neither is a response to a yield. The two states carry different parts of that margin. As Section 2.2 shows, the trend in q_t^A is its Treasury denominator, which d_t absorbs, so what identifies the q_t^A loading is the agency numerator. We report both as conditional state coefficients rather than as causal supply effects.

C. Cross-Sector Differences and the Common-Trend Alternative

The cross-sectional pattern reflects the difference between sectors with money-like liabilities or benchmark-linked assets under management and sectors with actuarial liabilities. Klingler and Sundaresan (2019) link pension funds' duration hedging to funding status, while Khetan et al. (2023) and Hanson, Malkhozov, and Venter (2024) document maturity-segmented pension and insurer demand in the swaps market. Because their duration demand is anchored by liabilities and funded status, insurers and pension funds have a weaker direct link to the scale of Treasury supply. Their loading, 0.45 with a standard error of 0.91, is close to zero and significantly below the loadings of the money-like sectors.

The individual t-statistic is not the evidence, since failing to reject zero is not the same as establishing it. The evidence is the contrast with the money-like sectors, which is significant in every pairwise comparison.

Table A4. **Debt/GDP Loadings: Money-Like Sectors versus Insurers and Pension Funds**

This table compares the estimated debt/GDP loadings of sectors with money-like liabilities or benchmark-linked assets under management with the loading of insurers and pension funds, whose liabilities are actuarial. Differences are computed from the pooled per-bucket coefficients reported in Table A2, in billions of dollars per percentage point of debt/GDP. Because each sector is estimated in a separate IV regression, the difference standard errors are computed under independence across sector equations. The estimation does not impose that restriction, and a system estimator allowing the sector-specific residuals $u_t^\iota(m)$ to covary would adjust these standard errors. Two-sided p-values.

Comparison	Difference	SE	t	p
Banks − insurers and pension funds	6.51	1.85	3.52	0.0004
U.S. ETFs − insurers and pension funds	4.55	1.32	3.45	0.0006
U.S. mutual funds − insurers and pension funds	4.69	1.72	2.73	0.0064
Other U.S. investors − insurers and pension funds	27.67	10.38	2.67	0.0077

This contrast is also the discipline for the level. The leading alternative reading of the positive loadings is that federal debt and private financial assets both trended upward over 2011–2024 and the regressions pick up the common trend. That reading predicts a positive loading for insurers and pension funds as well, since their assets grew over the sample and the period contains a large improvement in pension funded status. The prediction fails. We prefer this argument to a timing argument, that pensions were simply not much affected within the window, because a timing argument invites the question of why not and the funded-status improvement supplies an awkward answer.

The discipline is partial rather than complete. A direct test would condition each sector's demand on its own assets under management, or bank Treasury holdings on bank total assets, and ask whether the debt/GDP loading survives. We do not run that specification, so the evidence offered here is the cross-sector contrast rather than a within-sector control. Two further predictions of the expansion channel also remain untested in the reported specification: the bucket concentration of index-driven demand and the state dependence of the bank loading in deposit growth, both noted above.

C.3. Country-Level Foreign Demand Estimates

The country-level exercise disaggregates the foreign sector rather than re-estimating the main sector-level model. We estimate a Treasury demand curve for 40 named countries and an "Other" residual, using 53 quarters across three maturity buckets. Table A5 reports these estimates for the full panel, and the yield response to the \$10 billion contraction in Section 3 for the 34 countries that can shed that amount. The 6 countries holding less than \$10 billion are marked with a dagger and carry no reported response.

Table A5. The full panel of the same-dollar contraction experiment of Section 3: the 40 individually estimated foreign countries plus an 'Other' residual aggregate, showing holdings share of TAO (sample mean), aggregate steady-state holdings $\bar{Z}^i$ in \$bn, contraction fraction κ^i of the \$10 billion order in percent (calibrated on model-implied steady-state holdings, which differ modestly from the sample-mean $\bar{Z}^i$ shown), country-specific macro loadings on core inflation and debt/GDP from the per-country IV regression, each per percentage point, and equilibrium yield response in bp at the 2-, 5-, and 10-year maturities. The estimation sample is 2011Q4–2024Q4. The standardized order is feasible only where $\kappa^i \leq 1$, that is, where steady-state holdings are at least \$10 billion. For the 6 countries marked †, \$10 billion exceeds total holdings, so no yield response is reported and they are not analyzed separately in Section 3; their demand remains in the aggregate. Sorted by holdings share descending.

Country	Share (% TAO)	$\bar{Z}^i$ (\$bn)	κ^i (%)	$\hat{\theta}^i_\pi$ (per pp)	$\hat{\theta}^i_{\text{debt}}$ (per pp)	Δy_{2y} (bp)	Δy_{5y} (bp)	Δy_{10y} (bp)
Japan	6.80	1628	0.6	-27.2	+1.45	+0.45	+0.62	+0.58
China	6.49	1588	0.7	-44.1	-4.92	+0.78	+0.67	+0.56
United Kingdom	1.71	371	2.6	+6.0	+2.82	-0.73	-0.23	+0.40
Brazil	1.51	363	2.8	-11.3	-0.81	+0.66	+0.77	+0.63

(continued)

Country	Share (% TAO)	$\bar{Z}^i$ (\$bn)	κ^i (%)	$\hat{\theta}^i_\pi$ (per pp)	$\hat{\theta}^i_{\text{debt}}$ (per pp)	Δy_{2y} (bp)	Δy_{5y} (bp)	Δy_{10y} (bp)
Ireland	1.50	345	3.2	-19.2	-2.96	+0.08	-1.06	-0.25
Switzerland	1.41	327	3.1	-6.5	-0.07	+0.17	+0.12	+0.37
Cayman Islands	1.38	317	3.2	-4.7	-1.30	+0.16	-0.16	+0.04
Taiwan	1.21	283	3.5	-0.5	+1.68	+0.03	+0.64	+0.71
Hong Kong	1.16	271	3.7	-8.4	+0.13	+0.39	+0.69	+0.55
Other	0.93	204	5.0	+3.7	+2.53	-0.78	-0.01	+0.39
India	0.88	196	5.1	-5.7	+0.50	-0.43	-0.50	+0.27
Singapore	0.83	188	5.3	-3.1	+0.98	-0.36	-0.08	+0.45
Canada	0.81	175	5.2	+2.4	+2.22	-0.93	+0.16	+0.67
France	0.75	162	5.9	+3.3	+1.76	-1.00	-0.23	+0.50
Saudi Arabia	0.72	168	6.2	-8.1	-1.11	+0.31	+0.00	+0.30
Luxembourg	0.71	162	6.2	-1.9	+0.29	-0.33	-0.39	+0.16
Belgium	0.66	153	6.3	-2.8	+0.54	+0.30	+0.64	+0.56
Korea, South	0.56	128	7.9	-4.0	+0.00	+0.03	+0.12	+0.45
Norway	0.53	121	7.9	-1.0	+1.13	-0.15	+0.80	+0.84
Germany	0.46	109	9.4	-1.7	-0.22	+0.31	+0.22	+0.40
Bermuda	0.43	103	9.5	+1.2	+0.62	-0.01	+0.22	+0.30
Mexico	0.35	82	12.1	-2.9	+0.10	+0.56	+1.23	+0.78
United Arab Emirates	0.33	78	12.9	-3.2	-0.30	-0.02	-0.68	+0.00
Netherlands	0.31	71	14.1	-1.4	+0.18	+0.11	+0.48	+0.60
Philippines	0.25	58	17.3	-0.2	+0.29	+0.07	+0.56	+0.64
Australia	0.25	56	17.4	-0.3	+0.05	+0.24	+0.66	+0.57
Sweden	0.24	57	17.8	-1.7	-0.22	+0.44	+0.39	+0.52
Italy	0.23	53	19.1	-2.0	-0.04	+0.20	+0.20	+0.47
Kuwait	0.22	52	20.0	-1.2	-0.07	+0.09	-0.08	+0.28
Spain	0.21	49	19.3	-2.4	+0.05	+0.29	+0.55	+0.62
Colombia	0.20	47	21.0	-1.5	+0.07	+0.23	+0.30	+0.51
Chile	0.19	43	22.8	-0.3	+0.10	+0.20	+0.55	+0.53
Indonesia	0.14	34	29.1	-0.8	+0.19	-0.22	-0.29	+0.27
Denmark	0.10	23	43.5	-1.3	-0.07	+0.30	-0.64	-0.02
South Africa	0.09	20	52.6	-0.2	-0.04	-0.08	-0.24	+0.21
Finland†	0.04	9	121.2	-0.5	-0.12	—	—	—

(continued)

Country	Share (% TAO)	$\bar{Z}^i$ (\$bn)	κ^i (%)	$\hat{\theta}^i_\pi$ (per pp)	$\hat{\theta}^i_{\text{debt}}$ (per pp)	Δy_{2y} (bp)	Δy_{5y} (bp)	Δy_{10y} (bp)
New Zealand†	0.03	8	128.9	-0.5	+0.03	—	—	—
Guatemala†	0.03	7	129.7	+0.0	+0.13	—	—	—
Austria†	0.03	6	155.9	-0.3	-0.02	—	—	—
Trinidad and Tobago†	0.02	5	171.8	-0.1	+0.05	—	—	—
Venezuela†	0.01	2	452.1	+0.3	+0.06	—	—	—

Table A6 reports the per-country contributions behind Figure 5, for the same 34 countries.

Table A6. Per-country decomposition of the \$10 billion contraction in Section 3.4. Each row reports the contributions of price elasticity, macro loadings, and ST/LT composition to the country's 10-year yield impact, together with that impact. By equation (13) the three contributions plus the average holder's 0.43 basis points reproduce the total exactly. The countries whose fitted holdings fall below \$10 billion admit no proportional contraction at that size and are omitted. All entries in basis points, sorted by impact descending.

Country	φ_α	φ_θ	φ_ω	Δy_{10y}
Norway	+0.307	-0.031	+0.140	+0.84
Mexico	+0.297	+0.080	-0.027	+0.78
Taiwan	+0.182	-0.018	+0.122	+0.71
Canada	+0.354	-0.152	+0.039	+0.67
Philippines	+0.116	-0.002	+0.104	+0.64
Brazil	+0.051	+0.073	+0.084	+0.63
Spain	+0.074	+0.049	+0.071	+0.62
Netherlands	+0.082	+0.015	+0.076	+0.60
Japan	+0.030	+0.053	+0.067	+0.58
Australia	+0.158	+0.032	-0.050	+0.57
China	-0.056	+0.092	+0.099	+0.56
Belgium	+0.059	+0.078	-0.004	+0.56
Hong Kong	+0.122	+0.058	-0.056	+0.55
Chile	+0.128	+0.014	-0.042	+0.53
Sweden	-0.015	+0.031	+0.081	+0.52
Colombia	-0.018	+0.029	+0.067	+0.51

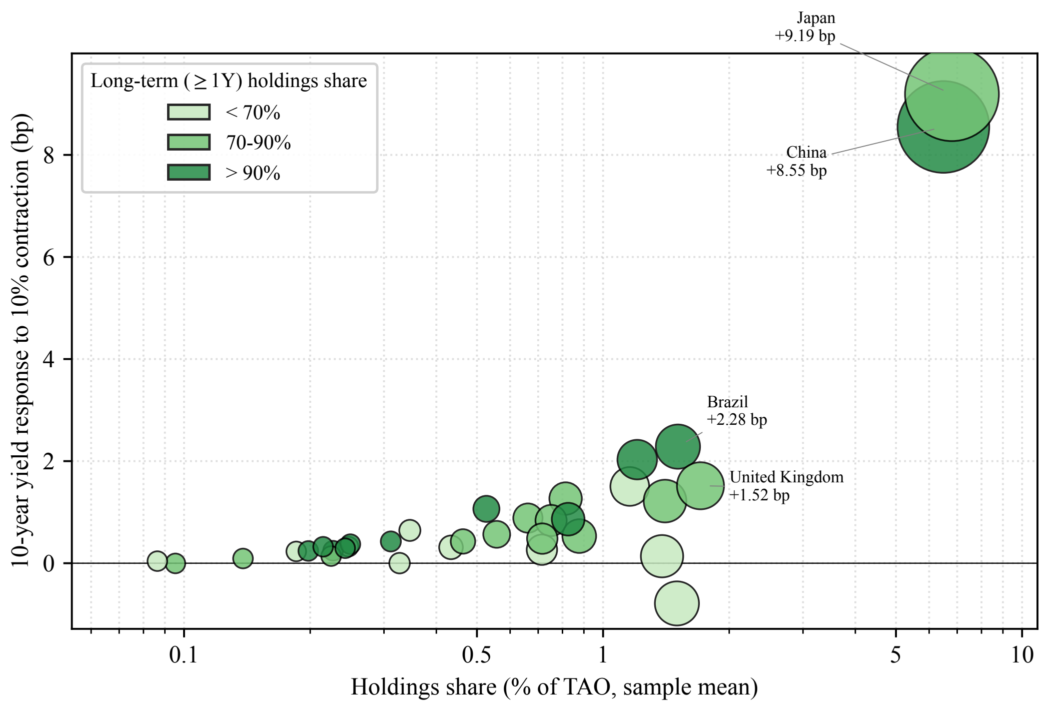
(continued)

Country	φ_α	φ_θ	φ_ω	Δy_{10y}
France	+0.185	-0.165	+0.049	+0.50
Italy	-0.042	+0.016	+0.067	+0.47
Singapore	+0.019	-0.066	+0.075	+0.45
South Korea	-0.011	-0.010	+0.041	+0.45
Germany	-0.066	+0.025	+0.017	+0.40
United Kingdom	+0.072	-0.107	+0.009	+0.40
Switzerland	-0.058	+0.016	-0.012	+0.37
Saudi Arabia	-0.104	+0.012	-0.034	+0.30
Bermuda	+0.037	+0.011	-0.180	+0.30
Kuwait	-0.137	+0.009	-0.020	+0.28
India	-0.145	-0.063	+0.053	+0.27
Indonesia	-0.077	-0.057	-0.022	+0.27
South Africa	-0.101	-0.049	-0.061	+0.21
Luxembourg	-0.098	-0.050	-0.113	+0.16
Cayman Islands	-0.127	+0.032	-0.287	+0.04
United Arab Emirates	-0.255	-0.034	-0.136	+0.00
Denmark	-0.443	+0.055	-0.055	-0.02
Ireland	-0.528	+0.017	-0.161	-0.25

Figure A5 plots the same-fraction experiment of Section 3.3 across the same 34 countries. It contracts each country's demand curve by 10% of its own holdings rather than by a fixed dollar amount. Because the dollar withdrawal scales with holdings, the largest countries produce the largest responses.

Figure A5. **Yield Impact of a 10% Holdings Contraction versus Holdings Size**

This figure plots each country's 10-year Treasury yield response to a permanent 10% contraction of its demand curve against its average Treasury holdings share. Bubble area is proportional to total holdings, and the horizontal axis is log-scaled. Color indicates the share held at $T \geq 1Y$, using cutoffs of 70% and 90%. Japan has the largest response at 9.19 basis points, followed by China at 8.55 basis points.



C.4. Fed Demand Estimates

Table A7 reports one stacked IV estimate of the Fed's demand curve using the same fixed-duration Treasury yields and the same four aggregate states as the private-sector regressions. The short and medium buckets share their own- and cross-yield loadings, while the long bucket has separate yield loadings because QE primarily targets longer maturities. Bond and macro coefficients remain bucket-specific. This common state specification allows the Fed and private demand curves to respond to the same state vector in equilibrium. Section 5 uses these coefficients for the level-runoff and rule-insurance counterfactuals.

Table A7. **Federal Reserve Demand Curve: Full IV Estimates**

This table reports one stacked IV estimate of the Fed's demand curve using fixed-duration Treasury yields. The short and medium buckets share the own-yield elasticity $\hat{\alpha}^{\text{Fed}}_{\text{own}}$ and cross-yield elasticity $\hat{\alpha}^{\text{Fed}}_{\text{other}}$; the long bucket has separate yield loadings. Loadings on bond controls, the beginning-of-quarter agency/Treasury supply ratio, debt/GDP, GDP gap, and core inflation are bucket-specific. As in Table A2, the debt/GDP loading is reported per percentage point; the model consumes the unscaled coefficient. These are the coefficients used by the structural model. Sample: 2011Q4–2024Q4. HAC standard errors (Bartlett bandwidth 2.5, panel groups by maturity bucket) are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	$\tau < 1Y$	$1Y \leq \tau < 5Y$	$\tau \geq 5Y$
	(1)	(2)	(3)
$y_t(m)$	37.895	37.895	567.362***
	[69.895]	[69.895]	[119.030]
$y_t(-m)$	-59.531	-59.531	-476.593***
	[128.399]	[128.399]	[65.387]
Coupon rate	-181.438	-1183.098***	-601.816
	[117.538]	[227.571]	[405.052]
Bid-ask spread	271.763***	-61.290	-146.358**
	[55.879]	[96.564]	[63.288]
Agency/Treasury supply ratio	-16.983	-40.496	93.528**
	[15.279]	[27.126]	[46.123]
Debt/GDP	28.943***	16.009**	56.168***
	[7.435]	[6.239]	[7.425]
GDP gap	-17.163	-7.183	-56.191**
	[12.144]	[15.866]	[25.631]
Core inflation	88.798***	-41.662	185.393***
	[28.991]	[49.094]	[37.135]
Observations	53	53	53
Joint pooled KP statistic		9.751	

The stacked system has a joint Kleibergen–Paap statistic of 9.75. Pooling the short and medium yield responses removes the separately estimated, nearly unidentified medium-bucket first stage while preserving a distinct long-maturity response. The estimate is sufficiently informative for the baseline Fed rule, though the joint statistic remains below conventional strong-instrument benchmarks and the counterfactual should therefore not be read as a precisely identified causal Fed reaction.

The 10-year yield lies inside the model's supported long-duration region and is the reference point for within-grid attribution. The QT exercise reports both 5- and 15-year yields to show how the level and rule channels differ across maturity along the same solved curve.

The agency/Treasury supply ratio enters the Fed equation exactly as it enters private demand, and the timing diagnostics in Appendix A apply here as well. Beginning-of-quarter timing makes the state predetermined relative to current-quarter Fed holdings. It remains an included conditioning state rather than an instrument or a causal Fed-response shock.

C.5. Robustness of the Macro Identification

Section 4.1 uses the Wu–Xia shadow-rate change as the monetary policy proxy and the FRBNY Global Supply Chain Pressure Index (Benigno et al. 2022) as the inflation proxy, with identification window $T_{id} = 108$. We report robustness along three dimensions: serial correlation in the VAR innovations, alternative inflation proxies, and alternative monetary proxies.

A. Serial Correlation in the VAR Innovations

The structural model imposes $\varepsilon_t = \beta_t - A\beta_{t-1}$ iid. A multivariate Ljung–Box test examines one implication of that assumption: absence of residual serial correlation. At lags 4 and 8, neither statistic rejects at conventional levels. This result does not establish independence or homoskedasticity. We therefore report both the heteroskedasticity-robust Kleibergen–Paap statistic and the homoskedastic Cragg–Donald statistic; only the latter can be compared directly with the Stock–Yogo critical value. The joint first stage is characterized as adequate rather than strong.

B. Alternative Inflation Proxies

For the primary GSCPI specification, the robust Kleibergen–Paap statistic is 13.17. The corresponding homoskedastic Cragg–Donald statistic is 6.58, below the Stock–Yogo 10% IV-size critical value of 7.03; that critical value does not apply directly to the robust Kleibergen–Paap statistic. We tested two alternative inflation proxies. Shapiro (2024)'s cost-push contribution to monthly PCE inflation has a marginal first-stage statistic of $\hat{F}^{\pi} = 11.04$ but a substantially weaker joint Kleibergen–Paap statistic of 5.20. Its loadings on the FFR residual (+0.079) and core CPI residual (+0.094) are comparable in magnitude, reflecting that cost-push PCE inflation moves contemporaneously with the Fed reaction function; the joint instrument matrix is correspondingly ill-conditioned. Baumeister and Hamilton (2019) structural oil supply shocks fail trivially because core CPI excludes energy components by construction ($\hat{F}^{\pi} < 0.1$). The GSCPI is preferred because it is measured upstream of the inflation outcome and the Fed reaction, captures the supply-chain disruption mechanism most directly responsible for the 2021–2022 inflation surge, and supplies the strongest joint first stage among the candidates. Even for the preferred proxy, we characterize joint identification as adequate rather than strong.

C. Alternative Monetary Proxies

Replacing the Wu–Xia shadow-rate change with the Bauer and Swanson (2023)-family Ch3m_Fed surprise yields a shorter identification window (2004Q3–2024Q3, $T_{id} = 81$). On this constrained window, the monetary first stage drops to $\hat{F}^r = 12.00$ (vs. 20.13 for Wu–Xia on the same window and 23.91 on the GSCPI specification's native window), and the structural-impact MAE rises to 30% (vs. 18% with Wu–Xia). The standardized sum $z_t^{r,\text{sum}} = z_t^{r,\text{WX}}/\sigma^{\text{WX}} + z_t^{r,\text{HF}}/\sigma^{\text{HF}}$ yields $\hat{F}^r = 26.89$ on the constrained sample, modestly improving on Wu–Xia alone but introducing an ad hoc equal-weighting choice. The principled multi-instrument alternative uses $z_t^{r,\text{WX}}$ and $z_t^{r,\text{HF}}$ as two separate columns and recovers the structural impact via the Stock and Watson (2018) over-identified rotation, but it is unstable in our sample because the leading-eigenvalue ordering of the structural rotation flips under bootstrap. Wu–Xia alone is the headline specification on empirical grounds (sharper identification, lower MAE) and economic grounds (continuous policy stance varies in every quarter, including the 2009–2015 ZLB period).

C.6. The Role of Bond–Stock Beta

Bond–stock comovement varies over time and may capture shifts between safe-haven and risk-taking regimes that also affect Treasury demand. We therefore ask whether the production estimates are robust to controlling directly for this comovement. For private sector ι, maturity bucket m, and quarter t, Panel A estimates

$$Z_t^{\iota}(m) = \theta_0^{\iota} + \alpha_{\text{own}}^{\iota} y_t(m) + \alpha_{\text{other}}^{\iota} y_t(-m) + \delta^{\iota\prime} B_t(m) + \lambda_m^{\iota} + \theta^{\iota\prime} X_t + u_t^{\iota}(m), \tag{A30}$$

where $B_t(m)$ contains the coupon-rate and bid–ask-spread residuals, λ_m^{ι} are maturity-bucket fixed effects, and X_t contains the agency/Treasury supply ratio, GDP gap, core inflation, and debt/GDP. The two Treasury yields are endogenous and are instrumented by the corresponding own- and other-maturity pseudo-yields. For MMFs, which hold only bills, the equation contains only the T-bill own yield and its pseudo-yield instrument. Panel B adds the 120-trading-day rolling beta of daily seven-year zero-coupon Treasury returns with respect to daily stock returns. The observations, instruments, and all other regressors are identical across panels.

Table A8. **Demand-System Robustness to Bond–Stock Beta**

This table compares the production private-sector IV demand specification (Panel A) with an otherwise identical specification that adds bond–stock beta (Panel B). Columns cover all eight private sectors. The seven three-bucket sectors have 159 observations; MMFs have 53 and include only the T-bill own yield. Both panels use the same observations, fixed-duration Treasury yields, four aggregate states, bond controls, and pseudo-yield instruments. As in Table A2, the debt/GDP loading is reported per percentage point. The minimum Kleibergen–Paap statistic changes from 13.047 to 12.919. The reported R^2 is calculated from structural residuals at the 2SLS estimates. HAC standard errors are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Coefficient	Banks	ETF U.S.	ICPF	MF U.S.	MMF	Other U.S.	Foreign O	Foreign P
Panel A: Common relative-supply specification								
Own yield	11.499	4.723	11.971	7.193	110.644***	363.161***	-1.678	22.769
	[18.681]	[12.828]	[10.895]	[20.748]	[34.240]	[125.965]	[89.476]	[60.455]
Other yield	-14.488	18.998	-22.510**	-9.639		-116.068	-64.755	-62.180
	[21.130]	[13.029]	[11.277]	[23.426]		[161.279]	[116.881]	[68.453]
Agency/Treasury supply ratio	-10.241**	-0.159	2.859	1.788	31.872	40.570	60.732**	-26.544**
	[4.859]	[3.477]	[2.877]	[5.247]	[20.952]	[33.222]	[23.592]	[12.944]
GDP gap	6.145	4.104	-3.466	13.542***	-11.844	-1.515	34.174	2.588
	[5.126]	[2.961]	[3.576]	[4.414]	[18.846]	[33.216]	[26.448]	[16.387]
Core inflation	19.298**	0.107	3.921	4.858	-120.187***	10.680	-127.047**	-5.906
	[9.412]	[5.426]	[4.036]	[8.109]	[37.985]	[53.212]	[50.565]	[29.554]
Debt/GDP	6.959***	5.004***	0.450	5.143***	95.431***	28.123***	-3.773	3.466
	[1.613]	[0.961]	[0.905]	[1.463]	[7.739]	[10.336]	[8.296]	[4.831]
R^2	0.85	0.93	0.95	0.95	0.94	0.70	0.96	0.42
KP statistic	13.047	13.047	13.047	13.047	1813.942	13.047	13.047	13.047
Panel B: Adding bond–stock beta								
Own yield	11.590	5.500	12.227	7.586	79.806**	370.285***	-1.787	22.796
	[18.791]	[13.067]	[10.774]	[20.766]	[32.958]	[126.528]	[88.482]	[60.915]
Other yield	-14.289	20.695	-21.951*	-8.780		-100.492	-64.993	-62.122
	[20.756]	[13.215]	[11.497]	[23.717]		[163.935]	[120.167]	[67.549]
Agency/Treasury supply ratio	-10.210**	0.110	2.948	1.924	29.767*	43.035	60.694**	-26.535**
	[4.761]	[3.512]	[2.877]	[5.246]	[17.931]	[32.854]	[23.882]	[12.887]
GDP gap	6.117	3.860	-3.546	13.418***	-8.959	-3.750	34.208	2.580
	[5.127]	[2.873]	[3.598]	[4.419]	[17.066]	[33.158]	[26.282]	[16.157]
Core inflation	19.323**	0.319	3.991	4.966	-123.969***	12.624	-127.077**	-5.898
	[9.459]	[5.490]	[4.035]	[8.167]	[39.485]	[53.562]	[50.805]	[29.671]
Debt/GDP	6.998***	5.335***	0.559	5.311***	89.774***	31.161***	-3.819	3.477
	[1.589]	[1.001]	[0.973]	[1.471]	[6.826]	[10.434]	[9.047]	[5.076]
Bond–stock beta	-5.194	-44.448	-14.642	-22.495	1003.780***	-407.835	6.228	-1.523
	[77.658]	[40.064]	[35.491]	[60.562]	[266.354]	[499.255]	[406.187]	[231.531]
R^2	0.85	0.93	0.95	0.95	0.95	0.70	0.96	0.42
KP statistic	12.919	12.919	12.919	12.919	1509.452	12.919	12.919	12.919
Observations	159	159	159	159	53	159	159	159

Bond–stock beta is insignificant at the 5% level for all seven three-bucket private sectors, whose yield estimates remain stable. It is positive and significant for MMFs; adding it reduces the MMF own-yield coefficient from 110.64 to 79.81, but the coefficient remains positive and significant and the robust first-stage statistic remains above 1,500. We treat beta as a robustness control rather than an additional equilibrium state and retain the common four-state specification as the model input.

C.7. Subsample Limitation

We also attempted to re-estimate the complete structural model over pre-COVID and post-ZLB subsamples using the common relative-supply state. These estimates do not provide valid structural robustness checks. The pre-COVID private-demand first stage collapses to a Kleibergen–Paap statistic of 0.044. The post-ZLB statistic is 8.21, but its second-stage equilibrium search, like the pre-COVID search, produces numerically singular systems rather than a stable solution on the baseline-connected branch. We therefore do not report subsample counterfactuals. This failure is a limitation of the current sample rather than evidence of structural stability.

D. Additional Quantitative Results

This appendix reports additional quantitative results that supplement the three counterfactual sections.

D.1. Term Structure of Market Elasticity

Market elasticity is the inverse of yield impact per dollar. At maturity m, it is $|\partial y(m)/\partial \theta_0(m)|^{-1}$. Its term structure is the central methodological finding of Jansen, Li, and Schmid (2024). Their Figure 1 documents that market elasticity declines sharply with maturity in the estimated demand system: the short bucket can absorb several dollars of net supply per basis point of yield, while the long bucket absorbs only a fraction. The downward slope is what makes long-maturity holders disproportionately important for term-premium dynamics. This paper takes the term structure as given and applies it to the three counterfactual exercises; we reference Jansen, Li, and Schmid (2024) for the derivation and estimation.

D.2. Additional Foreign Demand Results

Full country-level impact table. Table A5 reports each country's estimated demand characteristics (holdings share, $\bar{Z}^i$, κ^i, $\hat{\theta}^i_\pi$, $\hat{\theta}^i_{\text{debt}}$) and the equilibrium yield response at the 2-, 5-, and 10-year maturities. It covers all 40 named countries plus the "Other" residual aggregate. The 6 countries with steady-state holdings below \$10 billion are marked with a dagger: the standardized contraction exceeds everything they hold, so no yield response is reported and they are not analyzed separately in Section 3.

Channel decomposition. The decomposition of each country's yield impact into the three components of its demand curve (price elasticity α^i, macro loadings θ^i, and ST/LT composition) is reported in Section 3, Figure 5 and Table 1. The composition share reported there is limited by the data: TIC SLT publishes only two maturity groupings per country (T-bills and a long-term total), and the within-LT split is held at the aggregate share, so cross-country variation in composition reduces to the ST/LT ratio.

Largest-holder diagnostic. Both individual \$10 billion counterfactuals solve directly for China and Japan. They raise the ten-year yield by 0.56 and 0.58 basis points, respectively. When imposed simultaneously, the two contractions raise the ten-year yield by 1.47 basis points, compared with 1.14 basis points from summing the separate experiments. The resulting 0.33-basis-point interaction shows that the equilibrium effects are not additive.

D.3. The Synthetic-Holder Construction and the Exactness of the Decomposition

This subsection states the construction behind Figure 5 and Table 1 and shows why both aggregations in that table are exact rather than approximate.

The synthetic holder. Let $N = \{\omega, \alpha, \theta\}$ index the three features of a country's demand curve. Each country's coefficient matrix is first scaled by its own κ^i, so that every row group describes a \$10 billion withdrawal rather than a portfolio of the country's size, and the cross-country average is taken over these scaled matrices. For a coalition $S \subseteq N$, let $b(S)$ be the demand block that uses country i's scaled values for the features in S and the average values for those in $N \setminus S$, as defined in equation (12). Because the slope terms are centered at the baseline, every $b(S)$ sheds exactly \$10 billion in exactly the profile the coalition specifies.

The characteristic function. Write Θ for the baseline aggregate demand parameters and $y_{10}(\cdot)$ for the equilibrium ten-year yield obtained by solving (8). Define

$$v(S) \;=\; 100\left[y_{10}\big(\Theta - b(S)\big) - y_{10}(\Theta)\right], \tag{A31}$$

the ten-year yield change in basis points when the synthetic holder is removed from the market and the equilibrium is re-solved. The subtraction in (A31) is the additive aggregation of Section 2.1: the block's intercept, its yield elasticities, and its macro loadings leave the corresponding aggregate objects together. By construction $v(\emptyset) = dy_{\text{avg}}$, the average foreign holder, and $v(N) = dy^i_{\text{full}}$, the country itself.

Exactness. The Shapley value of feature c is its marginal contribution averaged over all orderings of N,

$$\varphi_c \;=\; \sum_{S \subseteq N \setminus \{c\}} \frac{|S|!\,\big(|N|-|S|-1\big)!}{|N|!}\left[v(S \cup \{c\}) - v(S)\right], \tag{A32}$$

which for three features requires the eight equilibrium solves indexed by S. The efficiency property of the Shapley value (Shapley 1953) states that the values exhaust the grand coalition,

$$\sum_{c \in N} \varphi_c \;=\; v(N) - v(\emptyset),$$

which is equation (13). Efficiency holds for any characteristic function, and that generality is what this exercise needs: v is the solution to a fixed point, so the yield impact is not additive in the three features, exactly as the largest-holder diagnostic above shows it is not additive across countries. A decomposition that varies one feature at a time therefore leaves an interaction term unallocated, whereas (A32) distributes it across the features. The solver checks the identity for every country and stops if it fails by more than 10^{-8} basis points.

Dispersion shares. Efficiency also makes the second aggregation in Table 1 exact. Writing $D^i = dy^i_{\text{full}} - dy_{\text{avg}}$, efficiency gives $D^i = \sum_c \varphi^i_c$, so by bilinearity of the covariance,

$$\text{Var}(D) \;=\; \text{Cov}\Big(\textstyle\sum_c \varphi_c,\, D\Big) \;=\; \textstyle\sum_c \text{Cov}(\varphi_c, D),$$

so the shares $\text{Cov}(\varphi_c, D)/\text{Var}(D)$ sum to one across the three features. The first aggregation, the cross-country mean of $|\varphi_c|$, does not rely on efficiency. The two measure different things, which is why the table reports both.

Panel B. Panel B applies the same construction one level down. The four aggregate-state loadings are the players, while ω^i and α^i stay at the country's own values throughout, so the identity becomes $\sum_k \varphi_k^i = dy^i_{\text{full}} - dy^i_{\theta=\text{avg}}$, where the second term is the impact of a synthetic holder carrying the country's own composition and elasticity but the average macro loadings.

D.4. Sectoral Absorption in Dollars

Figure 6 reports sectoral absorption of a foreign retrenchment as a share of the withdrawal, which puts the duration aggregate on the same axis as the maturity buckets and keeps the smaller sectors legible. This subsection reports the same exercise in billions of dollars, for readers who want the underlying amounts. Each maturity bucket sums to zero because Treasury supply is fixed. This zero-sum restriction is a market-clearing guard imposed by the figure rather than an object it displays.

Table A9. **Sectoral Absorption of a Foreign Retrenchment**

This table reports changes in sector holdings after a $10 billion contraction of the aggregate foreign official demand curve. The first three columns report billions of dollars by maturity bucket. The last column weights these changes by bucket duration. Each column sums to zero by market clearing. Figure 6 plots the same quantities as shares of the withdrawal.

Sector	< 1y	1–5y	≥ 5y	Duration-weighted
	Change in Treasury holdings ($bn)			($bn-years)
Banks	-0.06	+0.01	+0.01	+0.10
ETFs	+0.10	+0.09	+0.09	+1.25
ICPFs	-0.10	-0.01	-0.02	-0.27
MFs (US)	-0.04	+0.01	+0.13	+1.43
MMFs	+0.12	+0.00	+0.00	+0.06
Other US	-0.22	+1.41	+1.05	+14.68
Foreign Official	-1.68	-7.13	-1.99	-40.02
Foreign Private	-0.30	+0.16	+0.02	+0.45
Fed	-0.27	+0.02	+1.00	+10.71
Arbitrageurs	+2.45	+5.45	-0.30	+11.61
Net ($bn)	0.00	0.00	0.00	0.00