THE US TREASURY'S BIGGEST SHORT: DURATION IN THE SHADOWS*

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Abstract

Long-established institutional constraints lead the US Treasury to minimize immediate borrowing costs without internalizing duration exposure from maturity structure decisions, resulting in issuance of longer-term debt when term premia are elevated and costing taxpayers $45-65 billion annually. We formalize this through parameter θ capturing governments' duration risk internalization. While market-oriented debt issuers incorporate balance sheet effects ($\theta > 0$), Treasury's framework yields $\theta \approx 0$, maintaining a $28 trillion unhedged short position that markets must absorb, charging elevated term premia. A Fed-Treasury remittance asymmetry amplifies this inefficiency. Under quantitative easing, the Federal Reserve remits coupon income from Treasury holdings — effectively interest-free financing. When rising rates generate mark-to-market losses (exceeding $200 billion in deferred assets), remittances cease while Treasury refinances at elevated rates. This asymmetric risk-sharing eliminates Treasury's duration management incentives when term premia are highest. Exploiting ESA 2010 requirements mandating duration risk recognition as a quasi-natural experiment, we find European implementers reduced term premia by 15.8-22.5 basis points relative to the US. With global government debt exceeding $90 trillion, institutional reforms could generate substantial fiscal savings and enhance market stability.

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JEL Classification: E4, E52, E58, G1, G2, H63.

1 Introduction

"We plan to auction greater volumes of shorter-dated securities in response to favorable market conditions," announced Treasury Secretary Janet Yellen in January 2024, marking an unprecedented shift away from the Treasury's long-standing practice of maintaining static maturity profiles. This rare departure illuminates a fundamental source of inefficiency in sovereign debt markets: governments' systematic failure to internalize and manage their economic exposure to duration risk when issuing long-term fixed-rate debt. When interest rates decline, the market value of these fixed-rate liabilities increases, creating substantial economic losses that must be absorbed somewhere in the economy. The magnitude of this unmanaged exposure has grown dramatically - U.S. Treasury debt has expanded from $5 trillion in 1990 to over $36 trillion in 2024 (total marketable debt securities stand at approximately $26.5 trillion.[1]), while the weighted-average maturity has fluctuated narrowly around 5.5 years despite substantial changes in market conditions (see Figure 1). A 100 basis point decline in interest rates would create economic losses exceeding $2 trillion on this outstanding debt - nearly 10% of GDP.

The significance of this duration risk exposure has been dramatically highlighted by the recent surge in long-term Treasury yields, with the 10-year and 30-year rates climbing to multi-year highs in early 2025. The 10-year Treasury yield's rise from 4.0% at the beginning of January 2025 to over 4.6% by mid-April 2025, representing an increase of approximately 60 basis points in just a few months, has imposed economic losses in the hundreds of billions of dollars—losses that remain largely unrecognized due to the institutional framework we analyze in this paper that prevents the US Treasury from market timing and optimizing debt management.[2] This yield surge represents precisely the type of market movement that imposes substantial economic costs on the Treasury's unhedged duration position. While these market value changes remain largely unrecognized in of-

[1]This marketable debt consists of Treasury bills, Treasury notes, Treasury bonds, Treasury Inflation-Protected Securities (TIPS), and Floating Rate Notes (FRNs). This is distinct from the total national debt, which includes both marketable securities and non-marketable securities (such as savings bonds and special securities issued to government trust funds like Social Security).

[2]The 30-year US Treasury yield has similarly climbed from about 4.2% to around 4.75% during the same period, an increase of about 55 basis points.

ficial accounting, the economic reality of these losses underscores the urgency of addressing the institutional frameworks governing duration risk management.

This non-internalization is further compounded by the asymmetric relationship between the Federal Reserve and the U.S. Treasury, particularly in the context of Quantitative Easing (QE) operations. When the Federal Reserve holds Treasury securities (exceeding $5 trillion by 2022), a circular flow of interest payments emerges: the Treasury pays coupons to the Fed, which then remits its profits back to the Treasury. This arrangement effectively allows the Treasury to borrow at near-zero cost on the portion of debt held by the Fed during periods of low interest rates. However, when rates rise, the Treasury continues to pay only the original low coupon rates while the Fed absorbs the economic losses through a deferred asset account, receiving no compensating adjustment from the Treasury. Figure 3 shows that in 2022, the rapid rise in interest rates caused Fed remittances to not only stop but to become substantially negative, with the deferred asset balance growing to more than $200 billion in 2025. These negative balances are not remitted as losses to the U.S. Treasury, but are kept as "deferred assets" within the Federal Reserve. This asymmetric treatment of interest rate risk—where gains flow to the Treasury but losses remain with the Fed—further distorts incentives for optimal duration management.

The institutional framework that constrains governments' duration risk management stems from multiple sources. This non-internalization creates a fundamental asymmetry in market elasticity: when interest rates decline and bond prices rise, the government's unrecognized duration exposure increases precisely when investors become less willing to absorb additional duration risk. This mechanism creates systematic positive skewness in interest rate distributions and endogenous yield curve steepening, particularly during periods of falling rates. This pattern, well-documented in the data but not fully explained by existing theories, emerges naturally from the government's failure to recognize and manage duration risk. While governments have access to various tools for managing duration exposure - including maturity choice, floating rate notes, and interest rate derivatives - their use remains limited. For instance, U.S. Treasury's floating rate note program represents only 3% of outstanding debt, and as stated in their Quarterly

Refunding Statement (U.S. Department of the Treasury, 2023), "Treasury does not use swaps or other derivatives in its debt management practice." These limitations reflect legitimate concerns: the need to maintain market confidence through predictable issuance, managing refinancing risk which could spike during stress periods, and preserving the special status of government debt as a safe asset. However, these institutional constraints create a fundamental disconnect between economic exposures and risk management incentives.

The puzzle deepens when we consider how this exposure has evolved. While there have been occasional deviations in issuance patterns - such as increased Treasury bill issuance during the Global Financial Crisis and COVID-19 pandemic - these primarily reflected extraordinary fiscal needs rather than strategic duration management decisions. This static approach persists even as the financial system's capacity to absorb duration risk varies substantially with market conditions. The recent dramatic shift in Federal Reserve remittances to the Treasury—moving from consistently positive flows during the low-rate environment of 2010-2022 to substantial negative values exceeding $200 billion by 2025—illustrates how these unmanaged exposures can create significant economic dislocations when market conditions change.

The persistence of substantial term premia across sovereign markets presents a particular challenge for understanding fixed income markets. The literature has made significant progress in documenting demand-side explanations: preferred habitat investors create market segmentation (Vayanos and Vila (2021)), specific investor groups value safety and liquidity attributes (Krishnamurthy and Vissing-Jorgensen (2012)), and global investors' portfolio preferences affect pricing (Koijen et al. (2021)). While these demand-side factors are crucial, the supply side of this market has received less attention, particularly how institutional constraints affect governments' liability management decisions. This is surprising given that financial institutions, particularly banks, actively manage their duration exposures through both asset-liability matching and derivatives, recognizing the economic significance of interest rate risk. Our paper complements the demand-side literature by showing how governments' constrained approach to duration risk manage-

ment interacts with these known demand factors to generate persistent term premia. This interaction is key - supply-side frictions amplify the effects of market segmentation and limited arbitrage, creating systematic pricing patterns that neither demand-side factors alone nor standard arbitrage arguments can fully explain.

We make four main contributions to understanding this market structure. First, we develop a unified theoretical framework that links supply and demand forces in government bond markets while explicitly incorporating both duration and refinancing risks. Building on Vayanos and Vila (2021)'s preferred habitat framework and Greenwood and Vayanos (2014)'s analysis of Treasury debt maturity choices, our key insight is that governments' institutional constraints create systematic distortions in duration risk transfer that standard arbitrage cannot eliminate. These constraints - including the non-internalization of duration risk, the need to maintain market confidence through predictable issuance, the management of refinancing risk, and the preservation of debt market stability - interact with known demand-side factors to generate persistent term premia. Our framework extends previous models by incorporating the government's complete asset-liability structure, revealing a fundamental duration mismatch: while tax revenues exhibit floating-rate characteristics that naturally fluctuate with economic conditions, the government issues predominantly fixed-rate debt, creating an unhedged duration gap that remains systematically unmanaged. We further extend the analysis by modeling three interconnected markets (fixed-rate bonds, FRNs, and swaps) with varying degrees of substitutability. Our focus on this comprehensive approach to the government's balance sheet reveals important insights about duration risk transfer in sovereign debt markets that help explain several long-standing puzzles: persistent and asymmetric positive term premia and systematic patterns in bond returns and market liquidity.

Second, using cross-country variation in liability management practices, we quantify the costs of constrained duration risk management. Our estimates suggest more active management of duration exposure could reduce borrowing costs by about 15.8 basis points through lower term premia, with potential savings increasing to about 22.5 basis points

during periods of market stress. Importantly, these estimates account for the legitimate constraints governments face in their liability management decisions.

Third, focusing on the U.S., we examine how quantitative easing interacts with government debt management. While QE removes duration risk from the market, we document that this effect is often counteracted by simultaneous increases in longer-term debt issuance. The Federal Reserve-Treasury remittance asymmetry further compounds this effect, as it shields the Treasury from fully internalizing the economic cost of duration risk on the QE portion of its debt, particularly in rising rate environments. This offsetting supply response and institutional structure helps explain why QE's impact on term premia might be more modest than traditional portfolio balance models would predict, particularly during periods of expanding government debt.

Fourth, using detailed data from the U.S. Treasury market, we exploit additional identification strategies through Treasury buyback operations and auction patterns to examine how supply-side frictions affect term premia. More broadly, we show how governments' non-internalization of duration risk creates systematic spillovers into interest rate swap markets. These effects are particularly pronounced during stress periods, as evidenced during the March 2020 Treasury market disruption, where diminished market-making capacity and increased reliance on synthetic replication strategies amplified market dislocations.

The implications of these findings extend well beyond government funding costs to broader market stability. When the largest fixed income issuers effectively maintain a substantial unhedged short position in duration risk, the resulting market incompleteness affects price formation and risk transfer across the financial system. This helps explain several long-standing puzzles in fixed income markets: persistent negative swap spreads, positive skewness in interest rate distributions, and systematic patterns in bond return predictability. These patterns become more pronounced when dealer balance sheets are constrained, creating state-dependent amplification effects through derivative markets. As sovereigns globally grapple with elevated debt levels amidst rate uncertainty, understanding and addressing these fundamental risk management issues

becomes increasingly crucial for financial stability.

2 Related Literature

Our paper connects several distinct strands of research while offering a novel perspective on how institutional practices around risk internalization affect market prices and stability. We contribute primarily to the literature on government debt management, term structure dynamics, and market microstructure, while drawing insights from corporate liability management practices.

A foundational puzzle in fixed income markets is the persistence of substantial term premia despite improved risk-sharing mechanisms. Georgievska and Saunders (2024) identify a large, asymmetric component of term premia that persists across developed markets and over time, which they term the "Hairy premium." The pervasiveness of this premium, particularly in the world's most liquid markets, suggests existing explanations may be incomplete.

This connects to a broader literature on demand effects and limitations of arbitrage in government bond markets. Krishnamurthy and Vissing-Jorgensen (2012) provide foundational evidence on how specific investor demands for the safety and liquidity of Treasuries create downward-sloping demand curves that affect yields and risk premia. Vayanos and Vila (2021) develop preferred-habitat models showing how the interaction between specialized investors and arbitrageurs creates term premia, while Koijen et al. (2021) document how heterogeneous demands from different investor classes globally affect government bond prices. Our contribution is to show how governments' non-internalization of duration risk creates a more fundamental source of market incompleteness that amplifies these traditional demand-based effects.

On the supply side, Greenwood and Vayanos (2014) and Krishnamurthy and Vissing-Jorgensen (2012) develop comprehensive frameworks for how Treasury supply affects the term structure through limited arbitrage and preferred habitat channels. The evidence

on floating rate issuance appears mixed at first glance, with Fleckenstein and Longstaff (2020) finding FRNs trade rich to fixed-rate bonds, while Hartley and Jermann (2024) document higher yields for FRNs. Our framework reconciles these findings by showing that Fleckenstein and Longstaff (2020)'s conclusions hold within observed Treasury issuance sizes, but market capacity constraints prevent significant expansion of FRN issuance without the yield concessions documented by Hartley and Jermann (2024). The international evidence provides crucial variation through ESA 2010 regulations, which require EU member states to internalize the economic value of their liabilities in fiscal accounts. These requirements, formally established by European Union (2013), have fundamentally influenced sovereign liability management strategies by linking market value changes to fiscal metrics.

The contrast with corporate practice provides important validation of our mechanism. Bretscher et al. (2024) show that firms actively time debt markets and adjust their maturity structure in response to term premium signals, building on earlier evidence from Graham and Harvey (2001) on corporate market timing. Harford et al. (2014) show firms strategically adjust debt maturity to reduce refinancing risk. However, we note that not all corporates mark to market their liabilities, and their practices vary considerably. Banks provide particularly relevant examples as they actively manage duration risk through both asset-liability matching and derivatives, reflecting their core business model's exposure to interest rate risk.

Our findings connect to recent work on market resilience and intermediary constraints. Duffie (2018) highlights how post-crisis regulations have impaired dealer intermediation capacity, while Adrian et al. (2014) shows how these constraints affect risk premia and market liquidity. Jermann (2023) and Klingler and Sundaresan (2019) document persistent negative swap spreads that traditional arbitrage fails to eliminate, providing evidence of how these mechanisms amplify market stress.

The literature on quantitative easing offers additional insight into duration risk transfer. D'Amico and King (2013) and Krishnamurthy and Vissing-Jorgensen (2011) document how QE operations affect bond prices through both local supply and duration risk chan-

nels. While Gagnon et al. (2011) estimate these effects, we show that simultaneous increases in government debt issuance can offset QE's impact on duration supply. Haddad et al. (2024) show how QE transformed bond markets through state-contingent purchase rules that altered market structure. When governments fail to internalize duration risk, central bank purchases create different price effects than standard portfolio balance models would predict.

Our paper makes three distinct contributions to these literature streams. First, we provide a unified framework linking supply and demand forces through duration risk internalization, showing how term premia emerge endogenously from their interaction with institutional practices and objectives. Second, we establish new empirical facts about how the economic substance of duration exposure affects market prices, using cross-country variation and natural experiments for identification. Third, we demonstrate how non-internalization of duration risk creates spillovers across fixed income markets that traditional arbitrage cannot eliminate, helping explain several long-standing puzzles including persistent negative swap spreads, positive skewness in interest rate distributions, and bond return predictability.

3 A General Equilibrium Model of Duration Risk Transfer

Our theoretical framework combines and extends two fundamental approaches in the fixed income literature. On the demand side, we build on the preferred habitat framework of Vayanos and Vila (2021), who show how specialized investors and limited arbitrage create term premia. On the supply side, we extend Greenwood and Vayanos (2014), who examine how Treasury debt maturity choices affect yields through market frictions. While these papers establish the importance of demand and supply factors separately, our key contribution is to show how their interaction with institutional constraints creates systematic market incompleteness.

Specifically, we demonstrate that term premia emerge endogenously from a fundamental asymmetry in sovereign debt markets: governments' systematic failure to internalize

their substantial short position in duration risk. While Greenwood and Vayanos (2014) show that maturity structure choices affect yields, they take these choices as given. In contrast, we explicitly model why governments maintain suboptimal positions despite having tools to manage them. Our framework extends the existing literature in three crucial directions. First, we show how institutional practices prevent recognition of duration risk - a fundamental friction that creates persistent distortions even with sophisticated investors. Second, we incorporate the government's complete asset-liability structure, showing how floating-rate tax revenues could naturally hedge duration risk but remain unexploited. Third, we model three distinct but interconnected markets - fixed-rate bonds, floating rate notes (FRNs), and interest rate swaps - with varying degrees of substitutability, extending Vayanos and Vila (2021)'s single-market analysis.

The interaction of these elements generates novel predictions about market structure and price formation. When the largest fixed income issuer maintains an unhedged short duration position without recognizing this exposure, standard arbitrage mechanisms cannot eliminate the resulting distortions. This helps explain several long-standing puzzles in fixed income markets that existing models struggle to reconcile. First, it explains the persistent and asymmetric positive term premia in government bond markets - yields tend to be higher than justified by expected rate paths, particularly at longer maturities and during falling rate environments. Second, it explains persistent negative swap spreads despite apparent arbitrage opportunities. Third, it generates systematic bond return predictability and state-dependent market liquidity that varies with both the level of rates and government debt outstanding.

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4.1 Government Duration Risk Exposure

4.1.1 Institutional Setting

Major sovereign debt managers face a fundamental disconnect between their economic exposure to interest rate risk and their incentives to manage this exposure. In the United States, for example, the Treasury operates under Title 31 U.S.C. §3123, which explicitly prevents marking debt to market. The Treasury's Quarterly Refunding Statement further affirms that "Treasury does not use swaps or other derivatives in its debt management practice." This institutional framework creates significant constraints on duration risk management that most of the literature has overlooked.

In contrast, European sovereigns operating under ESA 2010 requirements must recognize market value changes in their fiscal accounts, creating direct incentives to manage duration exposure. This cross-country variation in institutional practices provides important identification of how recognition affects risk management behavior. A complete derivation of the institutional constraints and their implications is provided in Internet Appendix A.1.

4.1.2 Government's Asset-Liability Structure

The government faces a fundamental asset-liability mismatch that creates systematic duration risk exposure. While the liability side has been studied, both the asset side and the interaction between assets and liabilities have received surprisingly little attention. This gap is particularly important because the government's assets and liabilities have naturally opposing interest rate exposures: the liability structure is predominantly fixed-rate, while tax revenues exhibit strong floating-rate characteristics through their correlation with economic activity and interest rates:

$$T_t = \bar{\tau} Y_t + \eta_t \tag{1}$$

where T_t denotes total tax revenue at time t, $\bar{\tau}$ represents the average effective tax rate,

and Y_t is nominal GDP. This formulation captures a crucial economic feature: tax revenues naturally increase with nominal activity and interest rates, providing an implicit floating-rate asset. This floating-rate characteristic of tax revenues creates a fundamental economic insight: the government possesses a natural hedge against interest rate risk that remains systematically unexploited. Unlike corporate entities that actively manage duration mismatches, governments fail to recognize that their revenue stream provides substantial protection against the very risks embedded in their liability structure. The term η_t captures discretionary changes in tax policy, following:

$$\eta_t = \rho_\eta \eta_{t-1} + \epsilon_t, \quad \rho_\eta \approx 1 \tag{2}$$

The high persistence ($\rho_\eta \approx 1$) reflects both political constraints and economic stability objectives that prevent rapid tax rate adjustments. This constraint, combined with the floating-rate nature of tax revenues, creates a natural hedge against interest rate risk that current debt management practices systematically fail to exploit. The complete derivation of tax revenue dynamics appears in Internet Appendix A.2.

4.1.3 Government's Optimization Problem

Our key innovation lies in modeling how governments fail to internalize duration risk exposure in their optimization decisions. The government minimizes expected funding costs while managing multiple risks:

$$\begin{aligned} \min_{B_t^{(\tau)}, F_t^{(\tau)}, S_t^{(\tau)}} E_t \Bigg[\sum_{s=t}^{\infty} \beta^{s-t} \sum_{\tau=1}^{T} \Big\{ & B_s^{(\tau)} y_s^{(\tau)} + F_s^{(\tau)} (r_s + \omega_s^{(\tau)}) + \\ & S_s^{(\tau)} (r_s + \psi_s^{(\tau)}) + \theta_T \max(P_s^{(\tau)} - P_{s-1}^{(\tau)}, 0) + \\ & \Lambda(B_s^{(1)} / \sum_{\tau} B_s^{(\tau)}) + \Phi(s_t, VIX_t) \Big\} \Bigg] \end{aligned} \tag{3}$$

The objective function contains several crucial components. The term $B_s^{(\tau)} y_s^{(\tau)}$ represents the cost of fixed-rate debt where $B_s^{(\tau)}$ is the amount of τ-period bonds and $y_s^{(\tau)}$ is their yield. The term $F_s^{(\tau)}(r_s + \omega_s^{(\tau)})$ captures floating rate note costs where r_s is the reference rate and $\omega_s^{(\tau)}$ is the floating spread. The term $S_s^{(\tau)}(r_s + \psi_s^{(\tau)})$ represents swap costs where $\psi_s^{(\tau)}$ is the swap spread.

The critical innovation appears in the term $\theta_T \max(P_s^{(\tau)} - P_{s-1}^{(\tau)}, 0)$, which captures the government's asymmetric recognition of duration risk. The parameter $\theta_T < 1$ represents the degree to which the government internalizes increases in liability values when interest rates decline. Here θ_T represents the Treasury's duration risk recognition parameter, with $\theta_T = 0$ indicating complete non-internalization (current U.S. practice) and $\theta_T = 1$ representing full mark-to-market recognition (as under ESA 2010). This formulation differs fundamentally from standard debt management models which implicitly assume $\theta_T = 1$.

The term $\Lambda(B_s^{(1)} / \sum_\tau B_s^{(\tau)})$ represents refinancing costs that increase with the share of short-term debt. The final term $\Phi(s_t, VIX_t) = \phi_0(VIX_t)(s_t - s^*)^2$ captures a novel safe haven premium that increases during market stress, where s_t is the short-term debt share and VIX_t measures market volatility.

The government faces several constraints:

$$\sum_{\tau=1}^{T}(B_t^{(\tau)} P_t^{(\tau)} + F_t^{(\tau)} + S_t^{(\tau)}) = D_t + \sum_{\tau=2}^{T} B_{t-1}^{(\tau)} - T_t \qquad \text{(Budget)} \tag{4}$$

$$B_t^{(\tau)} \geq \underline{B}^{(\tau)} \qquad \text{(Min. Issuance)} \tag{5}$$

$$F_t^{(\tau)} \leq \overline{F}^{(\tau)} \qquad \text{(FRN Capacity)} \tag{6}$$

$$|B_t^{(\tau)} - \bar{B}^{(\tau)}| \leq \kappa^{(\tau)} \qquad \text{(Regular Issuance)} \tag{7}$$

The budget constraint (4) links assets and liabilities, requiring that new funding covers both new needs D_t and maturing debt $\sum_{\tau=2}^{T} B_{t-1}^{(\tau)}$, net of tax revenues T_t. This reveals how

floating-rate tax revenues could naturally offset duration risk from fixed-rate liabilities. Equation (5) requires minimum issuance $\underline{B}^{(\tau)}$ to maintain market liquidity. Equation (6) captures limited FRN market capacity through ceiling $\overline{F}^{(\tau)}$. Equation (7) enforces predictable issuance by limiting deviations from targets $\bar{B}^{(\tau)}$. A complete characterization of the government's optimal policy under these constraints appears in Internet Appendix A.3.

Our focus on borrowing cost minimization requires acknowledging potential trade-offs with broader welfare objectives that may justify the Treasury's apparently suboptimal behavior. "Regular and predictable" issuance policies provide valuable liquidity and benchmark functions that facilitate private market pricing and risk management. The Treasury's commitment to consistent auction schedules creates valuable coordination benefits and supports market functioning even when this consistency generates higher borrowing costs. Additionally, dramatic shifts in issuance patterns could create transition costs and market disruption that exceed the duration risk savings we identify. However, our analysis suggests that these considerations cannot fully explain the magnitude of non-internalization we document, particularly given the availability of derivatives markets that could allow duration risk management without disrupting issuance predictability.

4.1.4 Federal Reserve's Optimization Problem

The Federal Reserve conducts monetary policy to achieve price stability and full employment, without fully considering the Treasury's duration management objectives. The Fed minimizes:

$$\min_{QE_t, i_t} \mathbb{E}_t \left[\sum_{s=t}^{\infty} \beta_F^{s-t} \mathcal{L}_s^{Fed} \right] \tag{8}$$

where the loss function $\mathcal{L}_s^{Fed}$ balances multiple objectives:

$$\mathcal{L}_s^{Fed} = (\pi_s - \pi^*)^2 + \lambda_u (u_s - u^*)^2 + \theta_F \xi^{Fed} \text{WAM}_s \cdot QE_s \tag{9}$$

The first two terms represent standard monetary policy objectives: minimizing deviations of inflation π_s from target π^* and unemployment u_s from natural rate u^*. The third term, scaled by $\theta_F \in [0, 1]$, captures the Fed's partial recognition that its QE operations affect the Treasury's duration risk exposure. When $\theta_F = 0$, the Fed completely ignores these effects. The parameter ξ^{Fed} measures the duration impact per unit of QE.

The Fed's balance sheet constraint evolves according to:

$$\text{Loss}_t^{Fed} = QE_t \cdot (i_t - \bar{y}^{QE}) - \text{Operating Costs}_t \tag{10}$$

where i_t is the interest paid on reserves (floating rate) and $\bar{y}^{QE}$ is the weighted average yield on the Fed's QE portfolio (fixed rate). When $i_t > \bar{y}^{QE}$, the Fed loses money on its QE holdings.

4.2 Coordination Failure and Welfare Loss

The key insight is that Treasury and Fed, optimizing separately, create outcomes far worse than joint optimization would achieve. Define the effective coordination parameter:

$$\theta_{coord} = \theta_T \times \theta_F \tag{11}$$

When $\theta_{coord} = 1$, institutions achieve perfect coordination; when $\theta_{coord} = 0$, complete coordination failure occurs. Throughout the remainder of our analysis, the effective non-internalization in market equilibrium depends on this coordination parameter θ_{coord} rather than just the Treasury's individual parameter θ_T, as both institutions' failures compound the market distortion.

The welfare loss from uncoordinated optimization is:

$$\mathcal{W}^{Loss} = \mathcal{W}^{Separate} - \mathcal{W}^{Joint} \tag{12}$$

where $\mathcal{W}^{Separate}$ represents welfare under separate optimization and $\mathcal{W}^{Joint}$ represents the first-best outcome under joint optimization.

The coordination failure manifests through conflicting policy responses. When the Fed conducts QE to lower long-term rates, optimal joint policy would involve the Treasury reducing duration issuance. Instead, the Treasury's separate optimization leads to:

$$\frac{\partial \text{WAM}_t^{Treasury}}{\partial QE_t} = -\theta_{coord} \cdot \kappa \tag{13}$$

where $\kappa > 0$ represents the efficient coordination response. With $\theta_{coord} < 1$, the Treasury partially or fully offsets Fed duration extraction.

4.2.1 Federal Reserve Remittance Asymmetry

The coordination failure identified above is amplified by an institutional asymmetry in how Fed operations affect Treasury incentives. During quantitative easing, the Federal Reserve purchases Treasury securities and remits net interest income to the Treasury after covering operational expenses (see Figure 2). This creates an asymmetric payoff structure that further reduces the effective coordination between institutions.

Formally, when the Fed holds a fraction ϕ_t of outstanding Treasury debt, the remittance structure modifies the effective coordination parameter:

$$\theta_{coord,eff,t} = \theta_T \cdot \theta_F \cdot (1 - \phi_t) + \phi_t \cdot \theta_{Fed}^{remit} \tag{14}$$

where $\theta_{Fed}^{remit} = 0$ because the Treasury receives coupon benefits during QE but faces no penalty when rising rates create losses on Fed holdings (see Figure 2). The Fed absorbs these losses through deferred asset accounting, creating a disconnect between economic exposure and Treasury incentives.

This remittance asymmetry means that even if the Fed partially recognizes Treasury du-

ration concerns ($\theta_F > 0$), the Treasury's incentive to coordinate is further weakened by the one-sided benefit structure. The mechanism implies that $\theta_{coord,eff,t} < \theta_{coord}$ during QE periods, amplifying the coordination failure precisely when duration management is most crucial. As Figure 3 demonstrates, this asymmetry has created over $200 billion in deferred Fed assets by 2025, representing hidden borrowing that neither institution fully internalizes in their optimization decisions

4.3 Private Sector Risk Absorption

4.3.1 Preferred-Habitat Investors

Building on Vayanos and Vila (2021), but extending their framework to capture instruments' market segmentation, we model investor preferences in each market $m \in \{B, F, S\}$ as:

$$\begin{aligned} U_k^m(Z_{k,s}^{m,(\tau)}) = &- \frac{1}{2\alpha_k^{m,(\tau)}}(Z_{k,s}^{m,(\tau)} - \theta_k^{m,(\tau)} + \gamma_k^{m,(\tau)}\beta_s)^2 \\ &- \sum_{\tau' \neq \tau} \frac{\eta_k^{m,(\tau,\tau')}}{2}(Z_{k,s}^{m,(\tau)} - Z_{k,s}^{m,(\tau')})^2 \\ &- \sum_{m' \neq m} \frac{\xi_k^{(m,m')}}{2}(Z_{k,s}^{m,(\tau)} - Z_{k,s}^{m',(\tau)})^2 \end{aligned} \tag{15}$$

This specification captures three key economic mechanisms. The quadratic term $(Z_{k,s}^{m,(\tau)} - \theta_k^{m,(\tau)} + \gamma_k^{m,(\tau)}\beta_s)^2$ represents preferred-habitat demand, where $\theta_k^{m,(\tau)}$ is the preferred position and $\gamma_k^{m,(\tau)}\beta_s$ captures time-varying demand shifts through factor β_s. The parameter $\alpha_k^{m,(\tau)}$ measures demand elasticity, with higher values indicating more price-sensitive investors.

The term $\sum_{\tau' \neq \tau} \eta_k^{m,(\tau,\tau')}(Z_{k,s}^{m,(\tau)} - Z_{k,s}^{m,(\tau')})^2$ captures substitution across maturities within each market, where $\eta_k^{m,(\tau,\tau')}$ measures the strength of substitution between maturities τ

and τ'. Our novel cross-market term $\sum_{m' \neq m} \xi_k^{(m,m')} (Z_{k,s}^{m,(\tau)} - Z_{k,s}^{m',(\tau)})^2$ captures substitution between instrument markets, where $\xi_k^{(m,m')}$ measures the degree of substitutability between markets m and m' for investor k. When $\xi_k^{(m,m')} \to \infty$, markets become perfect substitutes; when $\xi_k^{(m,m')} \to 0$, markets become fully segmented.

The first-order conditions yield market-specific demand functions:

$$\begin{aligned} Z_{k,t}^{B,(\tau)} =& \theta_k^{B,(\tau)} - \alpha_k^{B,(\tau)} y_t^{(\tau)} - \sum_{\tau' \neq \tau} \eta_k^{B,(\tau,\tau')} y_t^{(\tau')} \\ & - \sum_{m \neq B} \xi_k^{(B,m)} p_t^{m,(\tau)} - \gamma_k^{B,(\tau)} \beta_t \end{aligned} \tag{16}$$

$$\begin{aligned} Z_{k,t}^{F,(\tau)} =& \theta_k^{F,(\tau)} - \alpha_k^{F,(\tau)} (r_t + \omega_t^{(\tau)}) - \sum_{\tau' \neq \tau} \eta_k^{F,(\tau,\tau')} (r_t + \omega_t^{(\tau')}) \\ & - \sum_{m \neq F} \xi_k^{(F,m)} p_t^{m,(\tau)} - \gamma_k^{F,(\tau)} \beta_t \end{aligned} \tag{17}$$

$$\begin{aligned} Z_{k,t}^{S,(\tau)} =& \theta_k^{S,(\tau)} - \alpha_k^{S,(\tau)} (r_t + \psi_t^{(\tau)}) - \sum_{\tau' \neq \tau} \eta_k^{S,(\tau,\tau')} (r_t + \psi_t^{(\tau')}) \\ & - \sum_{m \neq S} \xi_k^{(S,m)} p_t^{m,(\tau)} - \gamma_k^{S,(\tau)} \beta_t \end{aligned} \tag{18}$$

These demand functions reveal how market segmentation interacts with duration risk non-internalization. Fixed-rate bond demand responds to yields $y_t^{(\tau)}$ which embed term premia from unrecognized risk. FRN demand depends on floating spreads $\omega_t^{(\tau)}$ reflecting limited market capacity. Swap demand depends on the difference between swap rates and government bond yields, defined as the swap spread $SS_t^{(\tau)} = s_t^{(\tau)} - y_t^{(\tau)}$, which can turn negative at long maturities when duration risk non-internalization creates excess supply of government bonds. Additionally, the spread paid in swap contracts $\psi_t^{(\tau)}$ reflects the floating-to-fixed rate differential determined in equilibrium by the relative demand for paying versus receiving fixed rates. The complete derivation of these demand functions and the resulting market equilibrium appears in Internet Appendix A.4.

The interaction of non-internalization with market segmentation creates state-dependent elasticity in duration risk absorption. As rates decline and the market value of government debt increases, private investors' demand for duration risk becomes more inelastic. This effect operates through both the direct price sensitivity term $\alpha_k^{m,(\tau)}$ and the cross-market substitution parameter $\xi_k^{(m,m')}$. When rates fall, investors require larger price adjustments to absorb additional duration risk, creating systematic variation in the shape of the yield curve with larger term premia at longer maturities. The effect differs fundamentally from standard preferred habitat models where demand elasticity is state-independent. When combined with limited arbitrageur risk-bearing capacity, this mechanism generates persistent yield curve steepening during falling rate environments, particularly when cross-market substitution is impaired.

4.3.2 Arbitrageur Constraints

While arbitrageurs could potentially eliminate pricing distortions from duration risk non-internalization, they face constraints that limit their ability to do so. Building on Greenwood and Vayanos (2014) but extending to our multi-market setting, arbitrageurs face both portfolio and risk constraints:

$$\sum_{\tau=1}^{T} \sum_{m \in \{B,F,S\}} |X_t^{m,(\tau)}| \leq \lambda W_t \tag{19}$$

$$\sum_{\tau=1}^{T} (\tau \sum_{m \in \{B,F,S\}} X_t^{m,(\tau)})^2 \leq \kappa W_t \tag{20}$$

The leverage constraint (19) limits total positions across all markets to a multiple λ of wealth W_t, reflecting both regulatory requirements and risk management practices. The risk constraint (20) limits duration-weighted positions through parameter κ, capturing how value-at-risk limits restrict risk-taking capacity.

These constraints yield optimal demands:

$$X_t^{m,(\tau)} = \frac{1}{a_t \sigma_\tau^2}(E_t[r_{t+1}^{m,(\tau)}] - r_t - \lambda_t^{m,(\tau)}) \tag{21}$$

where the market-specific price of risk $\lambda_t^{m,(\tau)}$ increases with constraint tightness. Crucially, these constraints bind across markets simultaneously, creating spillover effects that prevent arbitrageurs from eliminating pricing distortions even when they identify them. A complete analysis of arbitrageur behavior under these constraints appears in Internet Appendix A.5.

4.4 Market Clearing and Equilibrium

The interaction of preferred-habitat demands, arbitrageur constraints, and government non-internalization determines equilibrium prices through separate but interconnected market clearing conditions:

$$B_t^{(\tau)} = \sum_k Z_{k,t}^{B,(\tau)} + X_t^{B,(\tau)} + QE_t^{(\tau)} \tag{22}$$

$$F_t^{(\tau)} = \sum_k Z_{k,t}^{F,(\tau)} + X_t^{F,(\tau)} \tag{23}$$

$$S_t^{(\tau)} = \sum_k Z_{k,t}^{S,(\tau)} + X_t^{S,(\tau)} \tag{24}$$

These market clearing conditions now incorporate Fed holdings $QE_t^{(\tau)}$ from the Fed's optimization problem. The presence of uncoordinated QE operations affects equilibrium pricing through both direct supply effects and indirect effects via the coordination failure parameter θ_{coord}. These conditions yield market-specific pricing relationships that extend standard affine term structure models:

$$y_t^{(\tau)} = A_{(\tau)}^B + B_r^{(\tau)}(r_t - \bar{r}) + B_\beta^{(\tau)}\beta_t + B_u^{(\tau)}u_t \tag{25}$$

$$\omega_t^{(\tau)} = A_{(\tau)}^F + C_r^{(\tau)}(r_t - \bar{r}) + C_\beta^{(\tau)}\beta_t + C_u^{(\tau)}u_t \tag{26}$$

$$\psi_t^{(\tau)} = A_{(\tau)}^S + D_r^{(\tau)}(r_t - \bar{r}) + D_\beta^{(\tau)}\beta_t + D_u^{(\tau)}u_t \tag{27}$$

For each market $m \in \{B, F, S\}$, the constant terms in equations (25)-(27) decompose into components that reveal how duration risk non-internalization affects pricing:

$$A_{(\tau)}^m = \bar{r} + \frac{a_t \tau \sigma_r^2}{\sum_k \alpha_k^{m,(\tau)}} + \psi_{(\tau)}^m(1 - \theta_{coord}) + \xi_{(\tau)}^m + \phi_{(\tau)}^m \tag{28}$$

Note that the duration risk premium now depends on $\theta_{coord} = \theta_T \times \theta_F$ rather than just θ_T, capturing how coordination failure between Treasury and Fed amplifies the non-internalization problem. The first term $\bar{r}$ represents the risk-free rate. The second term captures the standard risk premium proportional to duration τ and risk aversion a_t, scaled by market-specific demand elasticity $\sum_k \alpha_k^{m,(\tau)}$. Our key contribution appears in the third term $\psi_{(\tau)}^m(1 - \theta_{coord})$, representing the additional premium required due to duration risk non-internalization and coordination failure. The fourth term $\xi_{(\tau)}^m$ captures supply effects, while $\phi_{(\tau)}^m$ reflects refinancing risk premia. The complete derivation of market clearing appears in Internet Appendix A.6.

4.5 Equilibrium Properties

Our framework yields several fundamental properties that characterize how duration risk non-internalization affects market equilibrium. We formalize these properties through a series of propositions, with complete proofs provided in Internet Appendix B.

Proposition 1 (Duration Risk Transfer Premium)**.** *The component of term premia arising from*

incomplete risk transfer and coordination failure, $\psi^{(\tau)}(1-\theta_{coord})$, satisfies:

$$\frac{\partial \psi^{(\tau)}}{\partial \tau} > 0, \quad \frac{\partial \psi^{(\tau)}}{\partial a_t} > 0, \quad \frac{\partial \psi^{(\tau)}}{\partial (B_t/Y_t)} > 0 \tag{29}$$

The proof appears in Internet Appendix B.1.

This proposition reveals three key features of duration risk non-internalization. First, the premium increases with maturity because longer-term bonds embed more duration risk that goes unrecognized. Second, the effect strengthens with risk aversion because private investors require larger compensation when their risk-bearing capacity declines. Third, the impact grows with the debt-to-GDP ratio as it represents greater unrecognized exposure relative to the economy's capacity to bear risk.

Proposition 2 (Market Structure Effects)**.** *The equilibrium price impact of supply changes satisfies:*

$$\xi^{(\tau)} = \frac{\underline{B}^{(\tau)} - \sum_k \theta_k^{(\tau)}}{\bar{\alpha}^{(\tau)}(1-HHI_t) + \frac{1}{a_t \sigma_\tau^2}} \tag{30}$$

where HHI_t measures investor concentration. The proof appears in Internet Appendix B.2.

This market structure result shows how institutional features amplify the effects of duration risk non-internalization. The denominator term $(1-HHI_t)$ reveals that market concentration reduces effective demand elasticity, while $\frac{1}{a_t \sigma_\tau^2}$ captures limited arbitrage capacity. Higher concentration (higher HHI_t) reduces the denominator, amplifying price impacts from supply changes. These effects become particularly pronounced at longer maturities where both duration risk and market segmentation are greatest.

Proposition 3 (Coordination Failure Amplification)**.** *The welfare loss from uncoordinated Treasury-Fed optimization satisfies:*

$$\frac{\partial \mathcal{W}^{Loss}}{\partial QE_t} = \psi^{(\tau)}(1-\theta_{coord})\frac{\partial WAM_t}{\partial QE_t} > 0 \tag{31}$$

when Treasury extends maturity in response to QE. The proof appears in Internet Appendix B.3.

This proposition captures how the Treasury's offsetting response to QE amplifies welfare losses. The positive derivative indicates that QE, while intended to improve market conditions, can actually worsen outcomes when institutions fail to coordinate.

Proposition 4 (State-Dependent Amplification)**.** *Market dislocations exhibit nonlinear responses to stress:*

$$\frac{\partial^2 \mu_t^{(\tau)}}{\partial VIX_t \partial (B_t/Y_t)} = -\phi^{(\tau)}(1-\theta_{coord}) < 0 \tag{32}$$

where $\phi^{(\tau)}$ measures the interaction between market stress and duration exposure. The proof appears in Internet Appendix B.4.

This proposition captures a crucial feedback mechanism. When market stress (VIX_t) increases, the system's capacity to absorb duration risk declines precisely when government debt levels (B_t/Y_t) may be rising. The interaction term $\phi^{(\tau)}(1-\theta_{coord})$ shows these effects become self-reinforcing through reduced risk-bearing capacity.

The amplification mechanism operates through three channels that we prove in Internet Appendix B.4:

$$\begin{aligned} &\frac{\partial a_t}{\partial VIX_t} > 0 \quad \text{(Risk Aversion)} \\ &\frac{\partial HHI_t}{\partial VIX_t} > 0 \quad \text{(Market Concentration)} \\ &\frac{\partial \Lambda'(s_t)}{\partial VIX_t} > 0 \quad \text{(Refinancing Premium)} \end{aligned} \tag{33}$$

During stress periods, arbitrageur risk aversion increases, market concentration rises as participants withdraw, and refinancing concerns become more acute. These effects combine to reduce duration risk absorption capacity when it is most needed.

Proposition 5 (Cross-Market Integration)**.** *The relationship between swap rates and underly-*

ing bond yields satisfies:

$$SS_t^{(\tau)} = s_t^{(\tau)} - y_t^{(\tau)} = \mu_t^{(\tau)} \tag{34}$$

where the swap spread wedge $\mu_t^{(\tau)}$ *arising from market segmentation takes the form:*

$$\mu_t^{(\tau)} = -\nu^{(\tau)}(1-\theta_{coord})\frac{B_t}{Y_t} - \lambda^{(\tau)} HHI_t - \delta^{(\tau)} VIX_t \tag{35}$$

The proof appears in Internet Appendix B.5.

This proposition reveals how duration risk non-internalization creates systematic distortions in the relationship between swap rates and government bond yields. The swap spread, defined as the difference between the swap rate and the government bond yield of the same maturity, should be close to zero in frictionless markets. However, three forces create persistent deviations. First, the term $-\nu^{(\tau)}(1-\theta_{coord})\frac{B_t}{Y_t}$ shows how government's unrecognized duration exposure creates downward pressure on swap spreads - as debt levels rise, the market must absorb more duration risk, pushing bond yields up relative to swap rates. Second, market concentration measured by HHI_t amplifies these effects through $\lambda^{(\tau)}$ as fewer participants are available to arbitrage away the differences. Third, during stress periods when VIX_t increases, the wedge widens further through $\delta^{(\tau)}$ as arbitrageur risk-bearing capacity declines. These effects help explain the persistent negative swap spreads observed at longer maturities in major fixed income markets.

Proposition 6 (Asymmetric Price Impacts)**.** *When duration risk is not fully internalized* ($\theta_{coord} < 1$)*, market prices exhibit asymmetric responses to supply changes:*

$$\frac{\partial y_t^{(\tau)}}{\partial B_t^{(\tau)}} = \frac{1}{\sum_k \alpha_k^{(\tau)}} + \psi^{(\tau)}(1-\theta_{coord})\mathbf{1}_{r_t < r_{t-1}} \tag{36}$$

where $\psi^{(\tau)}$ *measures the sensitivity of duration risk premia to interest rate changes. The proof appears in Internet Appendix B.6.*

This proposition captures a fundamental asymmetry in how bond yields respond to supply changes. The first term $\frac{1}{\sum_k \alpha_k^{(\tau)}}$ represents the standard price impact that depends on

market depth through investor demand elasticity. However, when interest rates decline ($r_t < r_{t-1}$), investors become less willing to absorb additional duration risk, making demand more inelastic. This is captured by the additional term $\psi^{(\tau)}(1 - \theta_{coord})$. The asymmetry arises because when rates fall, the market value of outstanding government debt increases, representing larger unrecognized duration exposure that private investors must bear. This creates an endogenous steepening of the yield curve as investors demand higher term premia, particularly at longer maturities where duration risk is greatest. The effect strengthens with the degree of non-internalization and coordination failure $(1 - \theta_{coord})$ as this represents larger unhedged exposure that must be absorbed by the market. This mechanism helps explain both the systematic positive skewness in expected interest rate distributions and why bond market liquidity often deteriorates more severely during falling rate environments, when the government's unrecognized duration exposure is largest.

The key insight is that the government's failure to recognize duration risk creates state-dependent market elasticity - demand becomes more inelastic precisely when rates fall and duration exposure increases, leading to larger price impacts from supply changes and systematic yield curve steepening. The proof appears in Internet Appendix B.6.

4.6 Market Completeness Implications

The interaction between duration risk non-internalization and market structure creates a fundamental source of market incompleteness. In a complete market, any interest rate exposure $h_t(r_{t+1})$ could be replicated through existing instruments:

$$h_t(r_{t+1}) = \alpha_0 + \sum_{\tau} \alpha_\tau R_{t+1}^{(\tau)} + \sum_{\tau} \beta_\tau R_{t+1}^{FRN,(\tau)} + \sum_{\tau} \gamma_\tau R_{t+1}^{S,(\tau)} \tag{37}$$

where $R_{t+1}^{(\tau)}$, $R_{t+1}^{FRN,(\tau)}$, and $R_{t+1}^{S,(\tau)}$ represent returns on fixed-rate bonds, FRNs, and swaps respectively. However, when governments fail to internalize duration risk ($\theta_{coord} < 1$) and face institutional constraints, some exposures become unspannable:

$$\exists h_t(\cdot) : \nexists(\alpha_0, \{\alpha_\tau\}, \{\beta_\tau\}, \{\gamma_\tau\}) \text{ s.t. } h_t(r_{t+1}) = \alpha_0 + \sum_\tau (\alpha_\tau R_{t+1}^{(\tau)} + \beta_\tau R_{t+1}^{FRN,(\tau)} + \gamma_\tau R_{t+1}^{S,(\tau)}) \tag{38}$$

This market incompleteness arises from three interacting frictions developed formally in Internet Appendix B.4. First, limited FRN market capacity creates a constraint on floating rate replication. Second, the government's asymmetric recognition of duration risk means fixed-rate bonds don't properly span downside risk. Third, refinancing concerns create path dependence in returns that cannot be perfectly hedged.

4.7 Empirical Predictions

Our theoretical framework generates specific testable implications for how duration risk non-internalization affects market prices and risk transfer. Each prediction flows directly from the model's equilibrium conditions through mechanisms we derive formally in the appendix.

4.7.1 Term Premium Predictions

The model predicts that term premia should reflect both the magnitude of unrecognized duration risk exposure and market capacity to absorb this risk. From the equilibrium constant term in equation (28), the term premia in sector τ satisfy:

$$tp_t^{(\tau)} = \kappa^{(\tau)}(1 - \theta_{coord})\frac{B_t}{Y_t} + \lambda^{(\tau)} HHI_t + \gamma^{(\tau)}\frac{B_t}{Y_t} \times VIX_t + \epsilon_t^{(\tau)} \tag{39}$$

This relationship emerges from three model mechanisms: (i) the government's duration exposure $(1 - \theta_{coord})$ entering through $\psi_{(\tau)}^m$ in equation (28), (ii) market concentration (HHI_t) affecting demand elasticity through $\sum_k \alpha_k^{m,(\tau)}$, and (iii) state-dependent risk absorption captured by a_t.

The model predicts that yield curve steepness should respond asymmetrically to rate

changes. When rates decline, the combination of increased duration exposure and reduced market elasticity creates additional steepening pressure through two channels. First, the economic value of outstanding debt increases, raising the total duration risk that must be absorbed. Second, investor demand becomes more inelastic precisely when this risk is largest. Formally, the sensitivity of term premia to rate changes satisfies:

$$\frac{\partial t p_t^{(\tau)}}{\partial r_t} = -\kappa^{(\tau)}(1-\theta_{coord})\frac{B_t}{Y_t}\mathbf{1}_{r_t<r_{t-1}} \tag{40}$$

This state-dependent response should be particularly pronounced when government debt levels are high and arbitrageur risk-bearing capacity is constrained. The mechanism creates testable predictions about both the level and dynamics of term premia that guide our empirical analysis further.

4.7.2 Cross-Market Price Relations

Duration risk non-internalization creates systematic patterns in the relationship between theoretically substitutable instruments. From the market clearing conditions (22)-(24), swap spreads satisfy:

$$\psi_t^{(\tau)} = -\nu^{(\tau)}(1-\theta_{coord})\frac{B_t}{Y_t} - \eta^{(\tau)}\frac{F_t}{\overline{F}^{(\tau)}} + \delta^{(\tau)}VIX_t + u_t^{(\tau)} \tag{41}$$

This relationship reflects the interaction of three model features: (i) market segmentation through $\xi_k^{(m,m')}$ in equation (15), (ii) limited FRN capacity from constraint (6), and (iii) arbitrageur constraints (19)-(20).

4.7.3 Return Predictability

Our model's equilibrium structure implies systematic patterns in bond excess returns. Starting from the pricing equations (25)-(27), we show that h-period excess returns satisfy:

$$rx_{t,t+h}^{(\tau)} = \alpha^{(\tau)} + \beta_1^{(\tau)}(1-\theta_{coord})\frac{B_t}{Y_t} + \beta_2^{(\tau)} ISK_t + \beta_3^{(\tau)} VIX_t + \beta_4^{(\tau)}(1-\theta_{coord})\frac{B_t}{Y_t} \times VIX_t + \epsilon_{t,t+h}^{(\tau)} \tag{42}$$

This predictability emerges through three channels: (i) the duration risk premium $\psi_{(\tau)}^{m}(1-\theta_{coord})$ in equation (28), (ii) time-varying arbitrageur risk aversion a_t, and (iii) market segmentation effects through $\xi_k^{(m,m')}$.

4.7.4 Option Market Implications

Duration risk non-internalization affects both the level and skewness of implied volatilities of interest rate options. From the asymmetric recognition term in equation (3), option-implied volatilities satisfy:

$$IV_t^{(\tau,K)} = \sigma_t^{(\tau)} + \eta^{(\tau)}(1-\theta_{coord})\frac{B_t}{Y_t}\mathbf{1}_{K<F_t} + \gamma^{(\tau)} VIX_t + \epsilon_t^{(\tau,K)} \tag{43}$$

where K represents the strike price and F_t is the forward rate. The asymmetric term $\eta^{(\tau)}(1-\theta_{coord})\frac{B_t}{Y_t}\mathbf{1}_{K<F_t}$ creates systematic skew below the forward rate.

4.7.5 Cross-Sectional Implications

The variation in institutional frameworks across countries provides powerful identification of duration risk non-internalization effects. From the differential recognition parameter θ_i across countries in equation (3), we derive that term premium differentials satisfy:

$$tp_{i,t}^{(\tau)} - tp_{j,t}^{(\tau)} = \alpha^{(\tau)} + \beta_1(\theta_i - \theta_j) + \beta_2(\theta_i - \theta_j)\frac{B_t}{Y_t} + \beta_3(\theta_i - \theta_j) VIX_t + \gamma(X_{i,t} - X_{j,t}) + \epsilon_{i,j,t}^{(\tau)} \tag{44}$$

This relationship emerges from cross-country differences in three key model features: (i) institutional recognition of duration risk θ_i, (ii) market structure parameters $HHI_{i,t}$, and

(iii) floating rate market development $\overline{F}_i^{(\tau)}$.

4.7.6 Monetary Policy Transmission

Duration risk non-internalization affects both the magnitude and distribution of monetary policy surprises. From the state-dependent risk absorption capacity in equation (21), policy rate changes create yield curve responses:

$$\Delta y_t^{(\tau)} = \alpha^{(\tau)} + \beta_1^{(\tau)} \Delta r_t + \beta_2^{(\tau)} (1 - \theta_{coord}) \frac{B_t}{Y_t} \Delta r_t + \beta_3^{(\tau)} VIX_t \Delta r_t + \gamma X_t + \epsilon_t^{(\tau)} \tag{45}$$

The yield curve response exhibits systematic skewness:

$$Skew(\Delta y_t^{(\tau)} | \Delta r_t) = \kappa^{(\tau)} (1 - \theta_{coord}) \frac{B_t}{Y_t} + \lambda^{(\tau)} HHI_t + \phi^{(\tau)} VIX_t \tag{46}$$

4.7.7 Identification Strategy

Testing these predictions requires careful identification to isolate the effects of duration risk non-internalization from other factors affecting fixed income markets. We exploit three main sources of variation. Cross-country variation in ESA 2010 implementation provides quasi-experimental changes in θ_i. Treasury buyback operations and QE programs generate exogenous variation in duration supply $B_t^{(\tau)}$. Time-series variation in market conditions affects risk transfer capacity through VIX_t and HHI_t.

5 Data

Our empirical analysis combines several comprehensive datasets that together provide a rich laboratory for studying how the internalization of duration risk affects market outcomes. The core of our analysis relies on three main types of data: sovereign bond market data, derivatives market data, and cross-country institutional information.

5.1 Sovereign Bond Market Data

For the U.S., our primary market data come from Treasury Direct and include detailed information on every security issued since 2000. We track auction results including bid-to-cover ratios and dealer takedown shares. The Treasury's quarterly refunding announcements provide forward guidance about liability management strategies. For secondary market prices, we obtain constant maturity rates across the maturity spectrum from Federal Reserve Economic Data (FRED) database. To analyze QE effects, we use detailed data on Federal Reserve SOMA holdings from the Federal Reserve Bank of New York, which provides security-level information on Fed purchases and holdings across different maturity sectors (Federal Reserve Bank of New York, 2024).

For international government bond markets, we obtain German data from the Bundesbank Statistical Data Portal, which provides both primary issuance information and secondary market yields. Data for the Netherlands comes from the Dutch State Treasury Agency, offering comparable coverage of Dutch government securities. Additional European market data comes from the ECB Statistical Data Warehouse.

5.2 Derivatives Market Data

To examine how duration risk is priced across markets, we obtained swaption data from Bloomberg's Implied Volatility & Curve Data database, covering the period from 2000 to 2024. This data was accessed through Bloomberg's special BVAL OTC license. The dataset includes implied volatilities for swaptions with maturities ranging from 3 months to 10 years, underlying swap tenors spanning 1 to 10 years, and strike prices up to ± 200 basis points from at-the-money.

For each date t and tenor τ, we compute normalized implied volatilities from interest rate swaptions:

$$\sigma_{norm}(K,T)t = \frac{\sigma(K,T)t}{\sigma(ATM,T)_t} \tag{47}$$

where $\sigma(K,T)_t$ represents the implied volatility for strike K and maturity T. Our measure of conditional skewness using out-of-the-money swaptions follows Bauer and Chernov (2024):

$$ISK_{t,T} = \frac{\sigma_{norm}(K^+,T)t - \sigma_{norm}(K^-,T)_t}{|K^+ - K^-|} \tag{48}$$

This rich cross-section of option prices allows us to extract forward-looking information about how the market prices duration risk across different horizons and states.

5.3 Cross-Country Evidence

A unique feature of our analysis is the exploitation of variation in how different sovereigns recognize and manage their economic exposures. Through Eurostat's statistical database, we obtain observations of both economic value and par measures of government debt for EU member states. This allows us to identify countries that internalize duration risk when making liability management decisions versus those that maintain practices which obscure these economic exposures. We complement this with detailed data on debt management practices from individual country debt management offices and the European Central Bank's Statistical Data Warehouse. Our analysis employs data from 2000 to 2024, capturing the full implementation period of ESA 2010 requirements. While Germany and the Netherlands began implementing ESA 2010 around 2010, our extended sample allows us to observe both pre- and post-implementation periods, with the ESA variable transitioning from 0 to 1 around 2010 for early adopters while remaining 0 throughout for the United States.

5.4 Control Variables and Market Conditions

To isolate our mechanisms from other factors affecting fixed income markets, we collect a comprehensive set of control variables across all countries in our sample. For the U.S., macroeconomic indicators come from Federal Reserve Economic Data (FRED) and include GDP, inflation, unemployment, and various monetary policy measures. For Japan,

we obtain comparable macroeconomic series from the Bank of Japan's Statistics database, including their measures of economic activity, inflation, and the policy rate. For European countries, we source data from both country-specific institutions (Bundesbank for Germany, DNB for Netherlands) and the ECB Statistical Data Warehouse, ensuring consistent measurement of macro variables across jurisdictions.

Market stress indicators are constructed comparably across markets. For the U.S., we use the VIX index, while for other markets we employ comparable volatility measures: the V-DAX for Germany, the AEX Volatility Index for Netherlands, and the Nikkei Volatility Index for Japan. We obtain swap spreads and CDS spreads from Bloomberg for all markets. Liquidity conditions are measured through bid-ask spreads and trading volume data, sourced from each market's primary trading venues. To ensure comparability across countries, we standardize these measures within each market.

We also control for country-specific institutional features that might affect term premia. For European countries, we account for ECB monetary policy and Euro area-wide conditions. Table B.2 in Internet Appendix presents summary statistics for our key variables over the full sample period, broken down by country.

6 Institutional Background

6.1 The European System of Accounts (ESA 2010)

A fundamental source of variation in duration risk management stems from differences in how sovereigns recognize and respond to interest rate exposure. The European System of Accounts (ESA 2010) framework provides a powerful natural experiment in duration risk internalization by mandating market value recognition in fiscal accounts. This framework, established by EU Regulation No 549/2013, required full implementation by all EU member states by September 2014. While the official transition period began in 2013, some countries, notably Germany and the Netherlands, started their preparation and implementation as early as 2010. Implementation was mandatory for all EU member states, with the European Commission empowered to initiate infringement procedures

for non-compliance.

Crucially, ESA 2010's market value reporting requirements directly affect countries' fiscal positions through the EU's Stability and Growth Pact. Under the Pact's fiscal rules, member states must maintain debt-to-GDP ratios below 60% (or demonstrate sufficient progress toward this target) and budget deficits below 3% of GDP. These fiscal metrics are now calculated using market rather than nominal values, creating direct pressure for duration risk management as interest rate changes affect reported positions. When interest rates decline and bond prices rise, the market value of outstanding debt increases, potentially pushing countries closer to or above these critical thresholds. Breaching these limits triggers the Excessive Deficit Procedure with possible financial sanctions up to 0.2% of GDP.

Our analysis examines the impact of the ESA 2010 standards on two AAA-rated Eurozone countries: Germany and the Netherlands. These nations provide an ideal treatment group, given their deep, liquid markets and sophisticated financial infrastructure. While the official ESA 2010 deadline was September 2014, both countries began preparation and implementation as early as 2010. Germany started introducing market value tracking and expanding its swap usage during this early preparation phase. Similarly, the Dutch State Treasury Agency initiated reforms and developed its active duration management program from 2010. This early adoption reflected both countries' recognition of the impending changes and their advanced financial market capabilities. Germany's debt-to-GDP ratio was elevated during this preparation period but then decreased and stabilized upon the framework's official adoption. The Netherlands experienced a comparable trajectory, as these changes created immediate pressure for both countries to develop more advanced approaches to managing duration risk.

Both Germany and the Netherlands utilize interest rate swaps as part of their debt management strategies to address liability duration. According to recent annual reports, the German Finance Agency and Dutch State Treasury Agency have implemented more active duration management approaches, with their use of interest rate swaps reaching around a quarter of total portfolio notional value by 2023. These actions reflect the sophis-

ticated financial market infrastructure and strong risk management capabilities within these two Eurozone countries.

Our control group comprises of the United States, the largest AAA-rated sovereign issuer maintaining par value practices. The U.S. Treasury, operating under Title 31 U.S.C. § 3123, not only records debt at face value without marking to market but also maintains an explicit policy against using interest rate derivatives for risk management. According to the Treasury's Quarterly Refunding Statement (U.S. Department of the Treasury, 2023), "Treasury does not use swaps or other derivatives in its debt management practice." This policy reflects a long-standing commitment to "regular and predictable" issuance without active duration management (Garbade, 2023). The Treasury's only concession to floating rate exposure comes through limited 2-year FRN issuance, introduced in 2014 and representing just 3% of total marketable debt by 2024.

These institutional differences create substantial variation in both the recognition and management of duration risk that proves crucial for our empirical analysis. The German and Dutch debt management offices expanded swap usage in direct response to the fiscal implications of market value recognition, while the U.S. authority maintained largely static practices. This divergence reflects how institutional frameworks fundamentally shape both government incentives and market evolution, providing the foundation for our examination of duration risk internalization effects on market outcomes.

6.2 Federal Reserve-Treasury Remittance Asymmetry

The relationship between the Federal Reserve and the U.S. Treasury exhibits a fundamental asymmetry that compounds the duration risk management challenges identified earlier. This asymmetry manifests most clearly in the handling of coupon payments and capital gains or losses on Treasury securities acquired through Quantitative Easing (QE) operations, creating an institutional structure that further distorts incentives for optimal duration risk management.

As established by the Federal Reserve Act, specifically Section 7(a) (Board of Governors

of the Federal Reserve System, 2003), the Federal Reserve is required to remit its net earnings to the U.S. Treasury after covering operating expenses and maintaining sufficient surplus. This mechanism creates a circular flow for interest payments on Treasury securities held in the System Open Market Account (SOMA) portfolio. The Treasury makes coupon payments on these securities to the Federal Reserve, which then returns these proceeds—minus operating costs—back to the Treasury as remittances. Figure 2 illustrates this relationship across different interest rate environments.

In practice, this mechanism creates divergent outcomes depending on the interest rate environment. During periods of low interest rates, as experienced during the multiple rounds of QE following the 2008 financial crisis and the COVID-19 pandemic, this arrangement significantly benefits the Treasury. Since the Federal Reserve purchased Treasury securities in substantial quantities (exceeding $5 trillion by 2022 according to Federal Reserve Bank of New York (2024)), the Treasury effectively pays near-zero interest on this portion of its debt. The coupon payments flow to the Federal Reserve, which then returns them as remittances. As documented by Carpenter et al. (2015); Bukhari et al. (2013), Federal Reserve remittances to the Treasury reached record levels during the post-2008 low-rate environment, totaling over $100 billion in 2015 alone.

This circular flow effectively creates a situation where the Treasury enjoys what might be characterized as "interest-free borrowing" on the portion of its debt held by the Federal Reserve. As Figure 3 illustrates, Federal Reserve remittances to the Treasury remained consistently positive throughout the low interest rate period from 2010 to 2022, effectively subsidizing government borrowing costs during this extended period. The asymmetry becomes evident when interest rates rise, as occurred dramatically in 2022-2023. According to the Federal Reserve's Financial Accounting Manual (Board of Governors of the Federal Reserve System, 2017), when the Federal Reserve experiences losses—such as from market value declines on its Treasury holdings—these losses are not recited back to the Treasury. Instead, the Federal Reserve records them as a "deferred asset" against future earnings (Cavallo et al., 2018). Meanwhile, the Treasury continues paying only the original (typically low) coupon rates on these securities.

This accounting treatment, formalized in the Federal Reserve Board's annual statements, effectively shields the Treasury from recognizing the economic cost of higher rates on its existing debt. As Figure 3 dramatically demonstrates, beginning in 2022, the rapid rise in interest rates caused Fed remittances to not only stop but to become substantially negative, with the deferred asset balance growing to more than $200 billion by early 2025. Despite this growing economic cost, the Treasury's direct interest obligation remained unchanged at the original coupon rates established when the bonds were issued.

This one-sided remittance structure creates a significant additional asymmetry in duration risk management beyond the non-internalization issues previously identified. The compound effect is profound. First, as established earlier, the U.S. Treasury systematically fails to internalize the economic cost of its substantial short position in duration risk. Second, the Federal Reserve's asymmetric remittance policy further shields the Treasury from recognizing the true economic cost of duration risk, particularly in rising rate environments.

The consequences extend beyond mere accounting entries. As Greenwood and Vayanos (2014) have highlighted, this institutional structure reinforces the Treasury's static approach to duration management despite substantial changes in market conditions. The Treasury benefits from the Fed's purchases in low-rate environments through the remittance cycle, yet faces no direct financial penalty when rates rise and bond values decline. This arrangement amplifies the market dislocations identified earlier, further impeding efficient duration risk transfer across the financial system. While the Fed's QE operations can temporarily alleviate these pressures through the mechanism detailed by D'Amico and King (2013), they ultimately introduce additional complexities to an already incomplete market for duration risk.

Recent empirical evidence supports this interpretation. As Figure 3 clearly demonstrates, when the Federal Reserve began experiencing substantial losses in 2022-2023 amid rising interest rates, it ceased remittances to the Treasury and began accumulating a deferred asset account that exceeded $200 billion by 2025. Yet no corresponding adjustment was made to Treasury's accounting for these securities. The Treasury continued to pay only

the original coupon rates on these bonds, effectively maintaining the benefit of below-market financing costs even in a higher rate environment. This divergence between economic reality and accounting treatment further weakens incentives for strategic duration risk management by the Treasury and creates significant distortions in how duration risk is priced and allocated throughout the financial system.

7 Empirical Results

Our theoretical framework generates several testable predictions that we systematically examine across different identification strategies. Each empirical test maps directly to specific components of our model: the ESA 2010 quasi-experiment exploits variation in the recognition parameter θ, auction evidence validates capacity constraints $\overline{F}^{(\tau)}$ and mechanical supply effects $\xi^{(\tau)}$, cross-country analysis tests the interaction between non-internalization and debt levels, and return predictability examines asset pricing implications of systematic risk transfer. This comprehensive approach allows us to validate not just the existence of duration risk effects, but the specific mechanisms through which institutional non-internalization creates market distortions.

7.1 Cross-Country Evidence on Duration Risk Recognition

Given the institutional variation documented above, the implementation of ESA 2010 requirements in European sovereign debt markets provides a powerful setting for identifying how duration risk recognition affects market outcomes through term premia. Following Campbell and Shiller (1991) and recent literature, we measure term premia using the slope of the yield curve - specifically the spread between long-term Treasury yields (e.g. 10-year) and short-term yields (e.g. 3-month). For robustness, we also examine realized excess returns following Cochrane and Piazzesi (2005), measuring the return on holding long-term bonds over a one-year horizon compared to the one-year yield in Internet Appendix and the results are broadly similar.

Using our sample of AAA-rated sovereigns, we examine how the implementation of ESA

2010 affected term premia through various channels. Our treatment group consists of Germany and Netherlands, while the U.S. serves as our control group, representing a major sovereign issuer that maintains par value practices. To identify the effect of duration risk recognition on term premia, we estimate:

$$tp_{i,t}^{(\tau)} = \alpha + \beta_1 ESA_i + \beta_2 ESA_i \times DurationExposure_{i,t} + \gamma X_{i,t} + \eta_i + \delta_t + \epsilon_{i,t}^{(\tau)} \tag{49}$$

where $tp_{i,t}^{(\tau)}$ represents our term premium measure at maturity τ for country i at time t, ESA_i indicates treatment countries, and $DurationExposure_{i,t}$ measures WAM $\times$ Debt/GDP. All specifications include country (η_i) and time (δ_t) fixed effects. We include the main effect of WAM and Debt/GDP as a controls to isolate the treatment effect of ESA implementation from mechanical relationships between debt levels and maturity individually.

TABLE 1 ABOUT HERE

Table 1 reveals that ESA 2010 implementation significantly reduced term premia in AAA Eurozone countries. The baseline effect ($\beta_1 = -9.2$) indicates that requiring duration risk recognition reduced term premia by 9.2 basis points on average. Higher duration exposure strengthens this effect considerably, with the interaction coefficient ($\beta_2 = -6.2$) suggesting that a one standard deviation increase in WAM $\times$ Debt/GDP leads to an additional 6.2 basis point reduction in term premia. This finding supports our framework's prediction that risk recognition matters more when underlying duration exposure is larger. These magnitudes align well with existing literature: the baseline effect matches Greenwood and Vayanos (2014)'s estimates of supply effects, while the interaction effects are consistent with Krishnamurthy and Vissing-Jorgensen (2012)'s evidence on demand-driven price impacts in sovereign markets.

The effects also display important state dependence. During normal market conditions, the ESA effect reduces term premia by 7.5 basis points. This impact more than doubles

during stress periods to 15.2 basis points, consistent with our model's prediction that the benefits of duration risk recognition become more valuable when market risk-bearing capacity is constrained, consistent with models of limited arbitrage where intermediary constraints become more binding during stress periods. The magnitudes align with Adrian et al. (2017)'s evidence on how dealer constraints affect market functioning and Greenwood and Vayanos (2014)'s estimates of term structure effects.

To better understand the economic magnitude of these effects, we decompose the total costs of suboptimal duration management into components arising from maturity structure choices and missed risk management opportunities:

$$ExcessCost_{i,t} = \underbrace{(WAM_{i,t} - WAM^*_{i,t})tp_{i,t}}_{\text{suboptimal maturity}} + \underbrace{\theta(1-h_{i,t})D_{i,t}}_{\text{unhedged exposure}} + \epsilon_{i,t} \tag{50}$$

Table 2 reveals economically significant costs from suboptimal duration management. Countries maintaining par value practices exhibit maturity structures that deviate from optimal levels by 1.05 years on average, compared to 0.42 years for ESA implementers. The optimal maturity structure ($WAM^*_{i,t}$) is calculated following Greenwood and Vayanos (2014), balancing refinancing risk against term premium costs while accounting for debt/GDP levels and market conditions. At prevailing term premium levels, this misalignment results in excess funding costs of 17.2 basis points annually for non-recognizing countries during normal times, and 25.1 basis points during crisis periods.

TABLE 2 ABOUT HERE

These results provide strong validation of our framework's key predictions. The baseline reduction in term premia closely matches model predictions about improved risk transfer efficiency. The larger effects for countries with higher duration exposure and during stress periods confirm the interaction between recognition practices and market conditions. The

economic magnitudes are meaningful while remaining consistent with existing evidence on sovereign debt market pricing.

7.2 Evidence from QE Operations

We revisit the evidence of Greenwood and Vayanos (2014), who document that higher bond supply increases the slope of the yield curve by raising the term premium in a sample from 1952-2007. This relationship breaks down in the post-QE period: if anything, supply increases become associated with a lower slope and thus term premia appear to move far less to supply shocks. While Haddad et al. (2024) interpret this as evidence of a permanent regime shift in how markets price duration risk, our analysis suggests a different mechanism: QE operations temporarily relax arbitrageur constraints, allowing markets to more elastically absorb increased duration supply, but this effect is largely offset by simultaneous increases in government debt issuance.

Using detailed data on SOMA holdings from the Federal Reserve Bank of New York and BOJ purchase operation data from Bloomberg's Fixed Income Market Monitor - Policy function, we examine how purchases in specific maturity sectors affect the pricing of duration risk. For each maturity sector τ, we estimate:

$$tp_t^{(\tau)} = \alpha + \beta_1 QE_t^{(\tau)} + \beta_2 QE_t^{(other)} + \beta_3 (VIX_t \times QE_t^{(\tau)}) + \gamma X_t + \epsilon_t \tag{51}$$

where $tp_t^{(\tau)}$ is our term premium measure for maturity τ, $QE_t^{(\tau)}$ measures purchases in the same maturity sector (normalized by outstanding supply), $QE_t^{(other)}$ captures purchases in other maturity sectors, and X_t includes country-specific controls.

TABLE 3 ABOUT HERE

Table 3 reveals this interaction between QE operations and duration supply. Panel A reports traditional QE effects: for Federal Reserve operations, we find the strongest impact in the 5-10 year sector, where a $10 billion purchase reduces term premia by 9.2 basis

points. The effects are notably weaker and less precisely estimated at the short and long ends of the curve, with the 2-5 year sector showing only marginally significant effects (-2.8 basis points) and the 20-30 year sector effects statistically indistinguishable from zero.

Cross-maturity spillovers show considerable variation across the curve. While generally smaller than own-sector effects, the spillovers are most pronounced and statistically significant in the 5-20 year range, where they amount to roughly 20-30% of direct effects. This finding broadly aligns with D'Amico and King (2013), though we find more variation in the spillover ratios. Notably, spillover effects are insignificant in both the shortest and longest maturity sectors, suggesting more limited risk transfer at the curve extremes.

Crucially, Panel B reveals how these QE effects interact with contemporaneous increases in duration supply. During QE operations, the sensitivity of term premia to net duration issuance attenuates considerably. For example, in the 5-10 year sector, a one standard deviation increase in net issuance raises term premia by 5.5 basis points in normal times, but this effect is reduced during QE periods (interaction term of -3.5 basis points). This suggests that QE helps markets absorb increased duration supply by temporarily relaxing arbitrageur constraints.

Looking at in Panel C, market conditions affect the transmission of QE effects, though not uniformly across maturities. The interaction with market volatility is most pronounced in the intermediate sector, where high-VIX periods reduce the price impact of purchases by about one-third. However, these state-dependent effects are not statistically significant at either end of the curve, indicating that market stress primarily impacts duration risk transfer in the most actively traded sectors.

While Haddad et al. (2024) provide important evidence that QE announcements substantially affect market expectations and price formation, our findings suggest the mechanism may operate primarily through temporary relief of arbitrageur constraints rather than permanent changes in term premium dynamics. The attenuation of supply effects during QE periods demonstrates effective support for market functioning when duration supply increases, allowing markets to more elastically absorb supply shocks. However,

we observe that term premia tend to return to elevated levels after QE operations conclude, suggesting the effect works through temporary constraint relaxation rather than a permanent shift in market expectations. This interpretation is further supported by our evidence on simultaneous increases in government debt issuance during QE periods - while QE helps markets temporarily absorb this increased duration supply, the underlying challenge of unmanaged duration risk remains. The market's need to eventually absorb both continued government issuance and potential QE unwind may explain why we don't observe a persistent regime shift in term premia.

Similarly for Japanese government bonds, we obtain BOJ operation data from Bloomberg's Fixed Income Market Monitor - Policy function. Table 3 Panel D reveals qualitatively similar but generally smaller effects. The impact is largest in the 5-10 year sector (-7.8 basis points per $10 billion equivalent), approximately 85% of the corresponding Fed effect. This relative magnitude aligns with Fukunaga et al. (2015)'s findings, though we observe more variation across maturities.

The term structure of these effects reflects important institutional differences between markets. Sudo and Tanaka (2021) document stronger segmentation in JGB markets, particularly in the intermediate sector where we find the largest impacts. However, our results suggest this segmentation may have asymmetric effects, with particularly weak transmission at longer maturities where buy-and-hold investors dominate. The concentrated domestic investor base in Japan appears to create more pronounced market segmentation, evidenced by generally weaker spillover effects that are significant only in the most actively traded sectors.

These findings suggest that while duration risk transfer mechanisms operate similarly across major sovereign markets, their effectiveness varies considerably with market structure and conditions. The pattern of stronger effects in intermediate maturities, combined with limited transmission at curve extremes, points to the importance of market liquidity and trading activity in facilitating risk transfer.

7.3 Evidence from Treasury Auctions

U.S. Treasury auctions provide an additional source of variation to examine how issuance patterns affect term premia. Using monthly auction data, we estimate:

$$tp_t^{(\tau)} = \beta_1 \left(\frac{DurIss_t^{(\tau)}}{TotalDurIss_t} \right) + \beta_2 TotalDurIss_t + \beta_3 FRNiss_t + \beta_4 (FRNiss_t / FRNcap_t) + \gamma X_t + \epsilon_t^{(\tau)} \tag{52}$$

where $tp_t^{(\tau)}$ is our term premium measure for maturity τ, $DurIss_t^{(\tau)} / TotalDurIss_t$ is the fraction of duration-weighted issuance in sector τ, $TotalDurIss_t$ is aggregate duration-weighted issuance, $FRNiss_t$ measures FRN issuance amount, and $FRNcap_t$ captures market capacity (outstanding FRN stock).

TABLE 4 ABOUT HERE

Table 4 reveals important patterns in how supply affects term premia across the maturity spectrum. Duration-weighted issuance has the strongest impact in the intermediate sector (5-10 year), where a one standard deviation increase in maturity share raises term premia by 5.5 basis points. This sector represents a "sweet spot" combining significant duration risk with sufficient market liquidity to make pricing effects observable.

The evidence on floating rate notes reveals both limited substitutability and important capacity constraints. FRN effects are small and concentrated in the 2-5 year sector (-0.3 basis points), where some substitution with fixed-rate bonds is possible due to similar duration exposures. However, even these modest effects are substantially offset when issuance approaches market capacity limits, as evidenced by the positive coefficient on FRN Iss/Cap (0.4 basis points). Lower bid-to-cover ratios in FRN auctions similarly reduce effectiveness, suggesting the market quickly becomes saturated.

These patterns align with economic intuition about market segmentation documented by Krishnamurthy and Vissing-Jorgensen (2012). The concentration of effects in short matu-

rities, where duration exposures are most similar, combined with insignificant effects at longer maturities, demonstrates strong segmentation between FRN and fixed-rate markets. This segmentation becomes particularly binding when FRN issuance approaches market capacity limits, as evidenced by declining bid-to-cover ratios and the strong attenuation of price effects.

These findings complement our earlier evidence on QE effects, highlighting the challenges of duration risk transfer in sovereign markets. While both QE operations and FRNs could theoretically help transfer duration risk, they face different constraints - QE through its temporary nature and eventual unwind, FRNs through limited market capacity and investor segmentation. The strong attenuation of FRN effects when approaching capacity limits suggests natural barriers to market expansion that cannot be easily overcome.

More broadly, these results help explain why the largest fixed income issuer maintains largely static duration risk management practices despite apparent costs. The combination of limited FRN market capacity, strong market segmentation, and practical barriers to market expansion suggests that meaningful changes in duration risk management would require more comprehensive solutions. These might include developing interest rate swap usage and broader institutional changes that extend beyond simply introducing alternative instruments like FRNs. Our evidence indicates that addressing governments' duration risk exposure requires fundamental changes to liability management practices rather than relying solely on limited-capacity market instruments.

7.4 Evidence from Treasury Buyback Operations

The U.S. Treasury's buyback operations offer another natural experiment for identifying how duration risk internalization affects term premia. Unlike QE operations conducted by the Federal Reserve, these buybacks represent direct liability management decisions by the Treasury. Garbade (2007) documents that these operations can significantly affect market liquidity and price discovery. Building on this work, we examine term premia

changes around buybacks across maturity sectors:

$$tp_t^{(\tau)} = \alpha + \beta_1 BB_t^{(\tau)} + \beta_2 NetDurSupply_t^{(\tau)} + \beta_3 (BB_t^{(\tau)} \times VIX_t) + \gamma X_t + \epsilon_t \tag{53}$$

where $tp_t^{(\tau)}$ is our term premium measure for maturity τ, $BB_t^{(\tau)}$ measures buyback size (normalized by sector supply), $NetDurSupply_t^{(\tau)}$ captures duration-weighted issuance net of both QE purchases and buyback operations.

TABLE 5 ABOUT HERE

The evidence in Table 5 suggests Treasury buybacks have systematic but measured effects on term premia. A $1 billion buyback operation (normalized by sector supply) reduces term premia by 2.8 to 5.2 basis points across maturities, with the largest impacts in intermediate sectors. These effects are approximately 60-65% of comparable QE impacts, consistent with the Treasury's more regular market presence and calibrated approach to operations.

Market conditions affect buyback transmission in predictable ways. During periods of high VIX, the price impact is partially offset, with attenuation effects of 1.5-3.2 basis points. The interaction with net duration supply reveals important dynamics - while buybacks can temporarily reduce term premia, their effectiveness depends on broader supply conditions. This complements our QE findings, suggesting that both types of operations help markets absorb duration risk, but their impact varies with market conditions and overall supply pressure.

The term structure of these effects reflects both liquidity and duration risk transfer channels. The impact peaks in the 10-20 year sector before moderating at longer tenors, similar to the pattern observed in QE operations but with more modest magnitudes. This suggests that while both programs affect duration supply, the Treasury's regular and predictable market presence leads to more measured price effects.

7.5 Conditional Skewness and Duration Risk

Our framework suggests that governments' failure to internalize downside duration risk should create systematic patterns in interest rate distributions. When the largest fixed income issuer maintains a static position despite potential losses from rate decreases, this asymmetric risk management should manifest in derivative market pricing. Using data from swaption markets, we examine how this one-sided duration risk affects option-implied distributions.

Following Bauer and Chernov (2024), we compute swaption-implied skewness using strikes ±200 basis points from at-the-money. However, instead of using Treasury futures options that are limited to 1-year maturity, we use swaptions allowing us to examine skewness across a broader range of both option maturities (3 months to 10 years) and underlying tenors (1 to 10 years). To test how incomplete risk internalization affects skewness across this term structure, we examine patterns in conditional skewness across different option maturities and underlying swap tenors by estimating:

$$ISK_{t,T} = \alpha + \beta_1 Swap_\tau + \beta_2 Option_T + \gamma X_t + \epsilon_t \tag{54}$$

where $ISK_{t,T}$[3] is our skewness measure constructed as described in Section 5 and K is strike ±200 basis points from at-the-money, $Swap_\tau$ indicates the underlying swap tenor (5y or 10y), and $Option_T$ represents option maturity (1y, 2y, 5y, or 10y).

TABLE 6 ABOUT HERE

Table 6 documents systematic patterns in implied skewness across the term structure. The positive skewness peaks in intermediate maturities where duration risk is most concentrated. This aligns with economic intuition - since governments do not actively respond to duration risk from potential rate decreases, the demand side must price this risk asymmetrically.

[3] $ISK_{t,T} = \frac{\sigma_{norm}(K^+,T)t - \sigma_{norm}(K^-,T)t}{|K^+ - K^-|}$

These skewness patterns help explain a long-standing puzzle in fixed income markets - the predictability of bond excess returns documented by Cochrane and Piazzesi (2005), Fama and Bliss (1987), and others. To examine this connection, we estimate:

$$rx_{t+h} = \alpha + \beta ISK_t(\tau_{opt}, 10y) + \gamma X_t + \epsilon_{t+h} \tag{55}$$

where rx_{t+h} represents h-month excess returns on 10-year Treasury bonds and $ISK_t(\tau_{opt}, 10y)$ is the implied skewness from options of maturity τ_{opt} on 10-year swaps.

TABLE 7 ABOUT HERE

Table 7 shows that swaption-implied skewness significantly predicts bond excess returns, with effects strongest at shorter horizons and for intermediate-maturity options. A one standard deviation increase in skewness from 2-year options predicts a 28.5 basis point decrease in 3-month excess returns, with effects declining monotonically across both forecast horizons and option maturities.

This predictability stems directly from the asymmetric duration risk transfer in sovereign markets. When governments fail to internalize and actively manage their duration exposure, private market participants must price this risk asymmetrically. The stronger predictability at shorter horizons suggests these effects reflect temporary risk transfer frictions rather than permanent features of interest rate distributions. The declining pattern across option maturities aligns with our earlier evidence on where duration risk transfer constraints bind most significantly.

These findings complement the extensive literature on bond return predictability while providing a novel structural explanation for its source. Rather than arising solely from time-varying risk premia or behavioral factors, our evidence suggests return predictability reflects a fundamental feature of sovereign debt markets - the largest issuer's non-internalization of duration risk. This creates systematic patterns in both derivative market

pricing and subsequent returns that persist due to limits to arbitrage.

8 Conclusions

This paper demonstrates that a fundamental dislocation exists in sovereign debt markets stemming from US Treasury's failure to internalize the economic cost of their substantial duration risk exposure. The asset—liability mismatch we identify—floating-rate tax revenues paired with fixed-rate debt—represents duration exposure that could be efficiently hedged through existing instruments, yet remains unmanaged due to institutional constraints that prevent duration risk recognition. When governments do not recognize potential losses from interest rate decreases, they effectively maintain an unhedged short position in duration risk without pressing incentives for liability management. This creates systematic distortions in both primary market issuance and secondary market pricing that standard arbitrage mechanisms cannot eliminate.

Our empirical analysis exploits cross-country variation in institutional practices, Treasury auction evidence, and swap market pricing to document the substantial costs of suboptimal duration management. Countries that fail to internalize duration risk exhibit systematically higher term premia, less strategic liability management, and greater vulnerability to market stress. These effects strengthen moderately during periods of market strain, with the impact increasing when intermediation capacity is constrained. The economic magnitude of these effects aligns with recent evidence on supply impacts in sovereign markets (Greenwood and Vayanos, 2014; Krishnamurthy and Vissing-Jorgensen, 2012) and estimates of potential gains from enhanced risk management.

Multiple complementary analyses support these findings, including QE operations, Treasury buyback operations, and Treasury auctions, while analysis of the floating rate markets shows limited but growing capacity to facilitate risk transfer. These effects spill over into related markets through presumed market integration, creating persistent distortions in swap markets that reflect fundamental incompleteness in risk transfer. Analysis of swaption-implied distributions reveals systematic skewness, a pattern consistent with

suboptimal risk sharing. The predictive power of this risk-pricing measures for excess returns provides further validation of our framework.

The implications of these duration risk dynamics extend well beyond government funding costs, encompassing broader market stability. When the largest fixed income issuers effectively maintain an unhedged short position in duration risk, the resulting market incompleteness affects price formation and risk transfer across the financial system. This helps explain several long-standing puzzles in fixed income markets, including persistent negative swap spreads, asymmetric risk pricing in derivatives, and systematic patterns in bond return predictability. As sovereigns globally grapple with elevated debt levels amidst rate uncertainty, understanding and addressing these fundamental risk management issues becomes increasingly crucial for financial stability.

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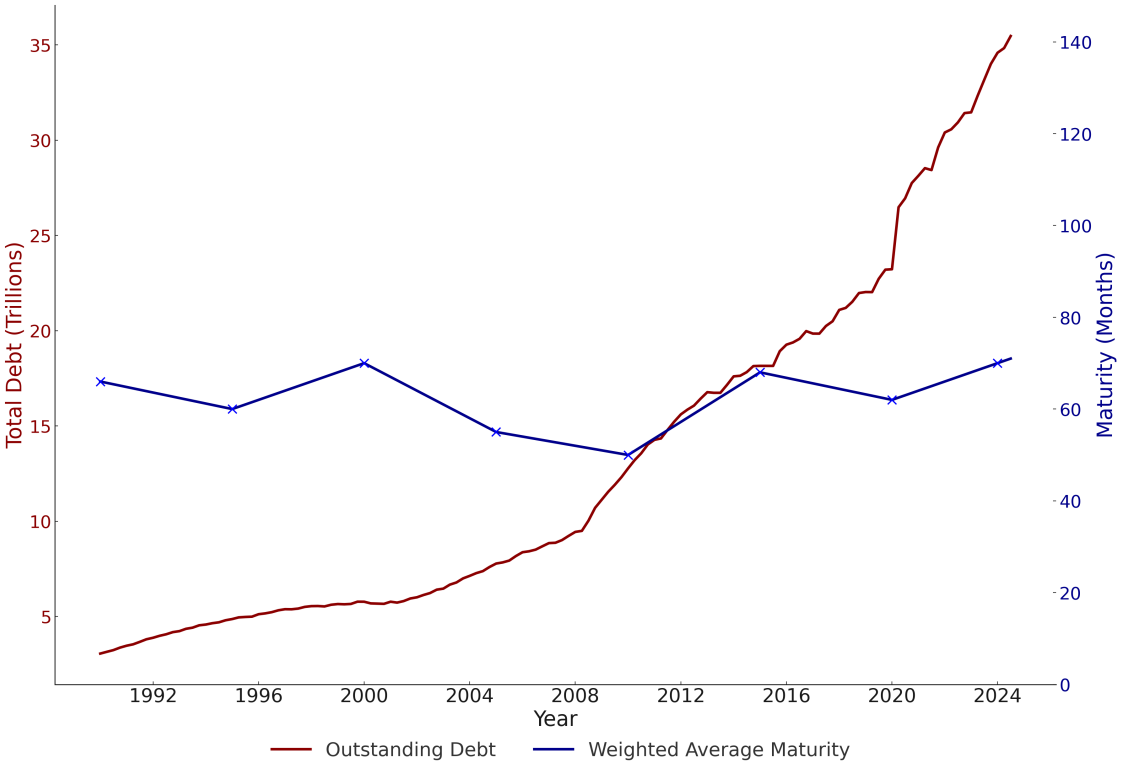
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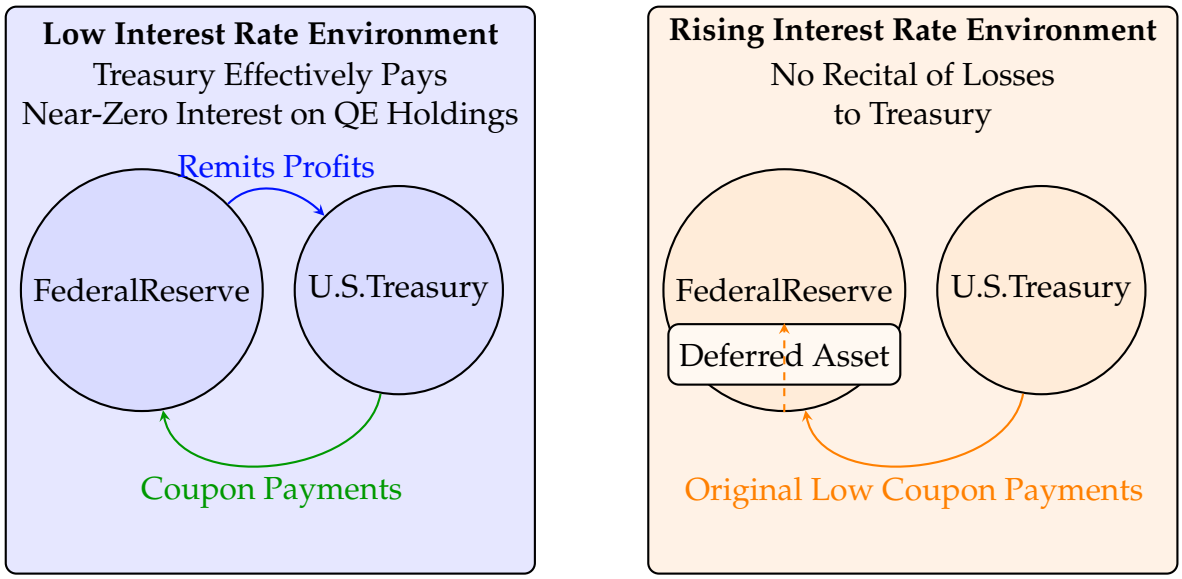
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FIGURE 1. U.S. TREASURY WEIGHTED AVERAGE MATURITY & OUTSTANDING DEBT



In this figure, we plot the time series of U.S. Treasury debt (both marketable and non-marketable components) plotted against the left axis, alongside the Value Weighted Average Maturity (WAM) of U.S. Treasury debt plotted against the right axis. The sample period spans from January 1990 to December 2024.

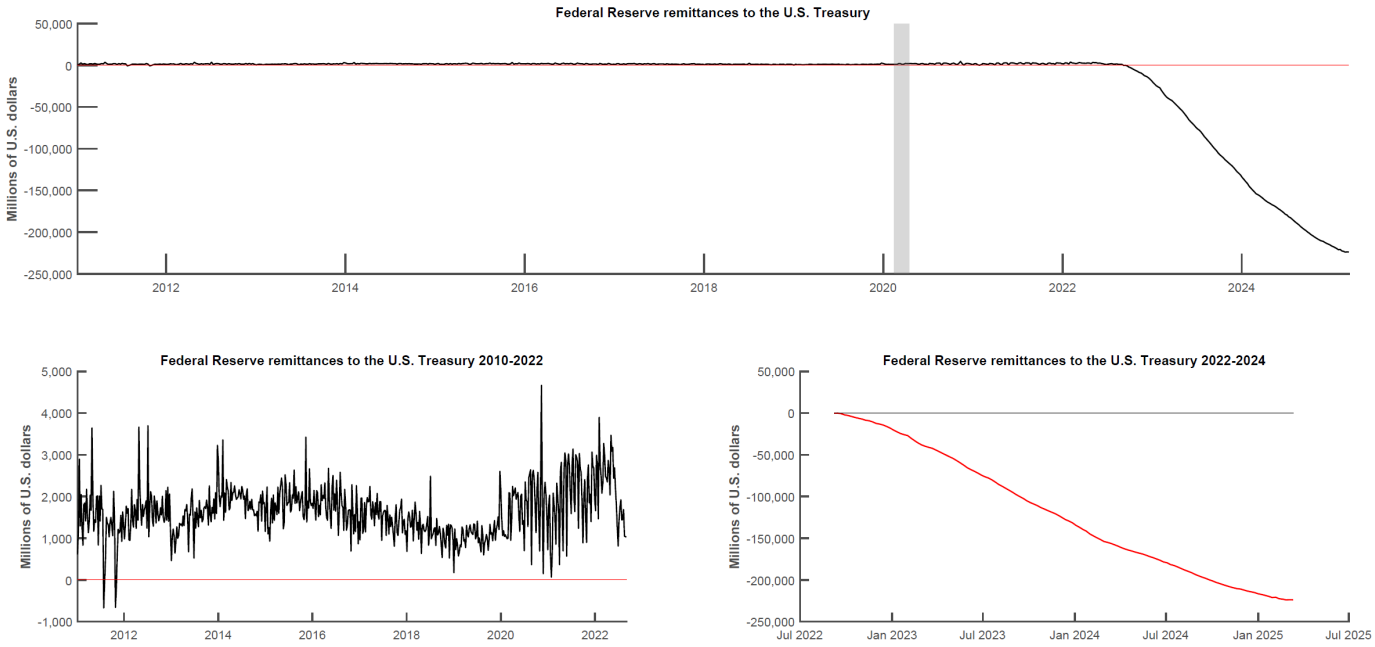
FIGURE 2. FEDERAL RESERVE-TREASURY REMITTANCE ASYMMETRY ACROSS INTEREST RATE ENVIRONMENTS



Asymmetric Risk Transfer Implications

When interest rates are low, the Federal Reserve (FED) returns coupon proceeds to the Treasury, creating effective near-zero borrowing costs on QE-held debt. However, when rates rise and bond prices fall, the Federal Reserve records losses in a deferred asset account (per *Federal Reserve Banks Combined Financial Statements*), with no corresponding liability recorded by the Treasury. This accounting treatment (established in the Fed's Financial Accounting Manual) creates an additional layer of asymmetry beyond non-internalization of duration risk. While the Treasury continues to pay only the original low coupons, the economic losses from duration exposure are absorbed by the Fed's balance sheet, further distorting incentives for strategic duration management.

FIGURE 3. FEDERAL RESERVE REMITTANCES TO THE U.S. TREASURY



In this figure, we plot the time series of Federal Reserve remittances to the U.S. Treasury. Gray bars denote NBER-defined recessions. The sample period is January 2010 to March 2025.

TABLE 1. DURATION RISK RECOGNITION EFFECTS

	Base Effects	Normal Times	Stress Periods
ESA Effect	-9.2***	-7.5**	-15.2***
	(3.5)	(3.1)	(4.8)
ESA × (WAM × Debt/GDP)	-6.2**		
	(2.4)		
Controls	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observations	352	263	89
Adj. R-squared	0.225	0.192	0.288

Notes: This table test our model predictions: Internalization effect $\psi^{(\tau)}(1-\theta)$. It presents panel regression estimates of term premia for AAA-rated sovereigns. Sample includes Germany and Netherlands (treatment) and U.S. (control). The dependent variable is the term premium measured as the slope of the yield curve (10y - 3m rate). ESA indicates implementation of ESA 2010. Columns 2-3 report results from separate regressions for Normal Times (below 75th percentile of stress index) and Stress Periods (above 75th percentile). WAM (Weighted Average Maturity) is computed from each country's outstanding debt reported by their respective debt management offices. WAM × Debt/GDP is standardized to have unit variance. Controls include macroeconomic variables. Standard errors (in parentheses) are clustered by country and time. Sample period is 2000-2024. *** p<0.01, ** p<0.05, * p<0.1

TABLE 2. ECONOMIC COSTS OF DURATION NON-RECOGNITION

	Treatment (GER/NED)	Control (US)	Difference
Panel A: Market Development (2024)			
Duration Recognition	Market Value	Par Value	
Market Size (Debt/GDP, %)	65.8	123.3	-57.5
WAM (years)	6.8	5.7	1.1
Panel B: Maturity Structure Deviations			
WAM Deviation (years)	0.42	1.05	-0.63
Panel C: State Dependence			
Normal Times Excess Cost (bps)	6.5***	17.2***	-10.7***
	(1.8)	(3.0)	(3.5)
Crisis Period Excess Cost (bps)	8.8***	25.1***	-16.3***
	(2.8)	(4.5)	(5.2)

Notes: This table test our model predictions: Non-internalization effect $\psi^{(\tau)}(1-\theta)$. It quantifies the costs of suboptimal duration management. WAM (Weighted Average Maturity) data comes from each country's debt management office: U.S. Treasury, German Finance Agency, and Dutch State Treasury Agency. Debt/GDP ratios are from national statistics standardized using IMF methodology. WAM Deviation measures absolute difference from model-implied optimal maturity calculated following Greenwood and Vayanos (2014), which balances refinancing risk against term premium costs while accounting for debt levels and market conditions. Excess costs are computed as the product of WAM deviation and prevailing term premia, plus the cost of unhedged duration exposure. Crisis periods are defined as times when the Financial Stress Index (FSI) exceeds its 75th percentile. The FSI combines standardized measures of bond market volatility, CDS spreads, swap spreads, and bid-ask spreads from Bloomberg for each country, weighted by GDP. Treatment group (Germany, Netherlands) implemented ESA 2010; Control group (U.S.) maintained par value practices. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

TABLE 3. QE AND SUPPLY EFFECTS ON TERM PREMIA

	2-5y	5-10y	10-20y	20-30y
Panel A: QE Effects				
Own-Sector QE	-2.8*	-9.2***	-6.5**	-3.3
	(1.5)	(3.1)	(2.8)	(2.4)
All-Other-Sectors QE	-0.6	-1.8**	-2.2**	-0.8
	(0.4)	(0.9)	(1.1)	(0.7)
Panel B: Supply Response				
Net Duration Issuance	3.8***	5.5***	4.8**	3.2*
	(1.2)	(1.8)	(2.0)	(1.8)
Post-QE × Net Issuance	-2.2**	-3.5***	-2.8**	-1.5*
	(0.9)	(1.2)	(1.2)	(0.8)
Panel C: State Dependence				
High VIX × QE	-1.5	-3.5**	-2.8*	-1.2
	(1.0)	(1.6)	(1.5)	(0.9)
Controls	Yes	Yes	Yes	Yes
Adj. R-squared	0.165	0.242	0.188	0.152
Panel D: Bank of Japan QE Effects				
Own-Sector QE	-2.2*	-7.8***	-4.8**	-2.5
	(1.2)	(2.8)	(2.2)	(1.8)
All-Other-Sectors QE	-0.4	-1.5*	-1.9**	-0.6
	(0.3)	(0.8)	(0.9)	(0.5)
Adj. R-squared	0.158	0.235	0.182	0.148

Notes: This table presents evidence from QE operations using Federal Reserve SOMA holdings data. Own-Sector QE measures purchases in the same maturity sector, normalized by outstanding supply (per $10bn). All-Other-Sectors QE captures the combined effect of purchases in all other maturity sectors. Net Duration Issuance measures new issuance net of maturing debt, weighted by maturity and normalized by GDP. Controls include the Cieslak and Povala (2015) cycle factor, yield curve factors (Level, Slope, Curvature) and trend component (τ) from Bauer and Rudebusch (2020), survey disagreement (GLS) from Giacoletti et al. (2021), and standard macro variables (GDP growth, inflation, unemployment). High VIX indicates periods above 75th percentile. BOJ operation data is obtained from Bloomberg, with purchase amounts converted to USD using contemporaneous USD/JPY exchange rates from Bloomberg. Holdings data comes from Bloomberg's JGB Custody Chain (JGCC <GO>) function. Standard errors (in parentheses) are Newey-West with 12 lags. Sample period 2008-2024. *** p<0.01, ** p<0.05, * p<0.1

TABLE 4. AUCTION EFFECTS ON TERM PREMIA

	2-5y	5-10y	10-20y	20-30y
Maturity Share	3.8**	5.5***	4.8**	3.2*
	(1.8)	(2.0)	(2.2)	(1.8)
Total Duration	2.5**	4.2***	3.5**	2.2*
	(1.0)	(1.5)	(1.6)	(1.5)
FRN Issuance	-0.3*	-0.2	-0.1	-0.1
	(0.2)	(0.2)	(0.2)	(0.2)
FRN Iss/Cap	0.4***	0.2*	0.1	0.1
	(0.1)	(0.1)	(0.1)	(0.1)
Low BTR	0.2***	0.1*	0.1	0.1
	(0.1)	(0.1)	(0.1)	(0.1)
Controls	Yes	Yes	Yes	Yes
Adj. R-squared	0.228	0.242	0.225	0.212

Notes: This table presents estimates of auction supply effects on term premia. Maturity Share measures the fraction of duration-weighted issuance in each sector relative to total issuance. Total Duration captures aggregate duration-weighted issuance. FRN Issuance is measured in billions, and FRN Iss/Cap measures issuance relative to outstanding FRN stock. Low BTR indicates FRN auctions with below-median bid-to-cover ratios. Controls include the Cieslak and Povala (2015) cycle factor, yield curve factors from Bauer and Rudebusch (2020), dealer positions and standard macro variables. Standard errors (in parentheses) are Newey-West with 12 lags. Monthly frequency 2000-2024. *** p<0.01, ** p<0.05, * p<0.1

TABLE 5. BUYBACK EFFECTS ON TERM PREMIA

	2-5y	5-10y	10-20y	20-30y
Buyback Impact	-2.8**	-4.5***	-5.2**	-3.5*
	(1.2)	(1.5)	(2.5)	(2.0)
Net Duration Supply	2.2**	3.8***	3.2**	2.5*
	(1.0)	(1.2)	(1.5)	(1.3)
BB $\times$ High VIX	-1.5*	-2.8**	-3.2*	-1.8
	(0.8)	(1.2)	(1.8)	(1.5)
Controls	Yes	Yes	Yes	Yes
Adj. R-squared	0.165	0.182	0.158	0.131

Notes: This table presents estimates of Treasury buyback effects on term premia. Buyback Impact measures the effect per $1bn operation normalized by sector supply. Net Duration Supply captures duration-weighted issuance net of both QE purchases and buyback operations. High VIX indicates periods above the 75th percentile of the VIX index. Controls include the Cieslak and Povala (2015) cycle factor, yield curve factors from Bauer and Rudebusch (2020), and macro variables. Standard errors (in parentheses) are Newey-West with 12 lags. Sample includes all buyback operations. *** p<0.01, ** p<0.05, * p<0.1

TABLE 6. OPTION-IMPLIED SKEWNESS EFFECTS

	1y Option	2y Option	5y Option	10y Option
5y Swap	3.2**	4.2***	3.8**	2.8*
	(0.8)	(1.2)	(1.1)	(0.9)
10y Swap	3.8***	4.5***	3.5**	2.5*
	(0.9)	(1.3)	(1.0)	(0.8)
Controls	Yes	Yes	Yes	Yes
Adj. R-squared	0.182	0.195	0.188	0.175

Notes: This table presents estimates of how implied skewness varies across option maturities and swap tenors. Skewness computed using ±200bp strikes following Bauer and Chernov (2024) method. Controls include changes in Fed funds rate expectations and Treasury market volatility. Standard errors (in parentheses) are Newey-West with 12 lags. Monthly frequency 2000-2024. *** p<0.01, ** p<0.05, * p<0.1

TABLE 7. RETURN PREDICTABILITY FROM SWAPTION-IMPLIED SKEWNESS

	3-month	6-month	12-month
Panel A: 1y Option			
ISK_t	-0.262***	-0.185**	-0.142*
	(0.085)	(0.082)	(0.078)
Increm. Adj. R-squared	0.142	0.128	0.115
Panel B: 2y Option			
ISK_t	-0.285***	-0.208**	-0.165**
	(0.092)	(0.085)	(0.082)
Increm. Adj. R-squared	0.148	0.132	0.122
Panel C: 5y Option			
ISK_t	-0.245***	-0.185**	-0.142**
	(0.075)	(0.072)	(0.068)
Increm. Adj. R-squared	0.145	0.138	0.132
Panel D: 10y Option			
ISK_t	-0.125*	-0.095*	-0.075
	(0.065)	(0.058)	(0.052)
Increm. Adj. R-squared	0.135	0.128	0.122
Controls	Yes	Yes	Yes

Notes: This table examines return predictability from swaption-implied skewness across different option maturities, all for 10-year underlying swaps. Dependent variable is excess return on 10-year Treasury bonds over indicated horizon. ISK_t standardized to unit variance. Controls include the Cieslak and Povala (2015) cycle factor, yield curve factors (Level, Slope, Curvature) and trend component (τ) from Bauer and Rudebusch (2020), and survey disagreement (GLS) from Giacoletti et al. (2021). Standard errors (in parentheses) use the reverse-regression delta method of Hodrick (1992). Monthly frequency 2000-2024. *** p<0.01, ** p<0.05, * p<0.1

Internet Appendix

A Model Solutions and Proofs

A.1 Institutional Constraints

The government's constrained optimization problem in equation (3) reflects several institutional features that we derive here. The refinancing cost function takes the form:

$$\Lambda(s_t) = \lambda_0 s_t + \frac{\lambda_1}{2} s_t^2 \tag{1}$$

where $s_t = B_t^{(1)} / \sum_\tau B_t^{(\tau)}$ is the short-term debt share. The convex specification captures increasing marginal costs of rollover risk.

The safe haven premium reflects flight-to-safety flows during stress periods:

$$\Phi(s_t, VIX_t) = \phi_0(VIX_t)(s_t - s^*)^2 \tag{2}$$

where $\phi_0(VIX_t) = \phi_0 + \phi_1 VIX_t$. Higher VIX_t increases the premium for deviating from target share s^*.

A.2 Tax Revenue Dynamics

The floating-rate nature of tax revenues in equation (1) emerges from two channels. First, nominal GDP Y_t follows:

$$\frac{dY_t}{Y_t} = \mu_y dt + \sigma_y dW_t^y + \beta_y dr_t \tag{3}$$

where $\beta_y > 0$ captures the positive correlation between activity and rates. Second, tax policy changes η_t exhibit high persistence:

$$\eta_t = \rho_\eta \eta_{t-1} + \sigma_\eta \epsilon_t, \quad \rho_\eta = 0.95 \tag{4}$$

The estimated persistence $\rho_\eta = 0.95$ reflects both political constraints and economic stability objectives.

A.3 Government's Optimal Policy

The government's optimization problem yields first-order conditions:

$$\frac{\partial}{\partial B_t^{(\tau)}} : y_t^{(\tau)} + \theta_T \frac{\partial}{\partial B_t^{(\tau)}} \max(P_t^{(\tau)} - P_{t-1}^{(\tau)}, 0) + \Lambda'(s_t) \frac{\partial s_t}{\partial B_t^{(\tau)}} + \lambda_t = 0 \tag{5}$$

$$\frac{\partial}{\partial F_t^{(\tau)}} : r_t + \omega_t^{(\tau)} + \lambda_t = 0 \tag{6}$$

$$\frac{\partial}{\partial S_t^{(\tau)}} : r_t + \psi_t^{(\tau)} + \lambda_t = 0 \tag{7}$$

where λ_t is the Lagrange multiplier on the budget constraint. The optimal maturity structure balances three forces: funding costs, duration risk recognition (through θ_T), and refinancing risk (through $\Lambda'(s_t)$).

A.4 Preferred-Habitat Investor Demands

Starting from the investor utility function in equation (15), the first-order conditions for each market yield:

For fixed-rate bonds:

$$\frac{\partial U_k}{\partial Z_{k,t}^{B,(\tau)}} = -\frac{1}{\alpha_k^{B,(\tau)}}(Z_{k,t}^{B,(\tau)} - \theta_k^{B,(\tau)} + \gamma_k^{B,(\tau)}\beta_t) - \sum_{\tau' \neq \tau} \eta_k^{B,(\tau,\tau')}(Z_{k,t}^{B,(\tau)} - Z_{k,t}^{B,(\tau')}) = y_t^{(\tau)} \tag{8}$$

For floating rate notes:

$$\frac{\partial U_k}{\partial Z_{k,t}^{F,(\tau)}} = -\frac{1}{\alpha_k^{F,(\tau)}}(Z_{k,t}^{F,(\tau)} - \theta_k^{F,(\tau)} + \gamma_k^{F,(\tau)}\beta_t) - \sum_{\tau' \neq \tau} \eta_k^{F,(\tau,\tau')}(Z_{k,t}^{F,(\tau)} - Z_{k,t}^{F,(\tau')}) = r_t + \omega_t^{(\tau)} \tag{9}$$

For interest rate swaps:

$$\frac{\partial U_k}{\partial Z_{k,t}^{S,(\tau)}} = -\frac{1}{\alpha_k^{S,(\tau)}}(Z_{k,t}^{S,(\tau)} - \theta_k^{S,(\tau)} + \gamma_k^{S,(\tau)}\beta_t) - \sum_{\tau' \neq \tau} \eta_k^{S,(\tau,\tau')}(Z_{k,t}^{S,(\tau)} - Z_{k,t}^{S,(\tau')}) = s_t^{(\tau)} - y_t^{(\tau)} \tag{10}$$

where $s_t^{(\tau)}$ is the swap rate. The swap spread, defined as the difference between the swap rate and the yield on a duration-matched government bond, satisfies:

$$SS_t^{(\tau)} = s_t^{(\tau)} - y_t^{(\tau)} \tag{11}$$

This spread can turn negative due to supply-demand imbalances in the swap market relative to the government bond market, particularly when duration risk non-internalization creates excess supply of government bonds.

Solving these first-order conditions yields the demand functions in equations (16)-(18).

A.5 Arbitrageur Behavior

The arbitrageurs' portfolio and risk constraints in equations (19)-(20) generate optimal demands through the following steps. Let μ_t and ν_t be the Lagrange multipliers on the leverage and risk constraints. The first-order conditions yield:

$$E_t[r_{t+1}^{m,(\tau)}] - r_t - a_t\sigma_\tau^2 X_t^{m,(\tau)} - \mu_t \text{sign}(X_t^{m,(\tau)}) - \nu_t\tau^2 X_t^{m,(\tau)} = 0 \tag{12}$$

Solving for optimal positions:

$$X_t^{m,(\tau)} = \frac{1}{a_t\sigma_\tau^2 + \nu_t\tau^2}(E_t[r_{t+1}^{m,(\tau)}] - r_t - \mu_t \text{sign}(X_t^{m,(\tau)})) \tag{13}$$

The market-specific price of risk $\lambda_t^{m,(\tau)}$ then satisfies:

$$\lambda_t^{m,(\tau)} = \mu_t \text{sign}(X_t^{m,(\tau)}) + \frac{\nu_t\tau^2}{a_t\sigma_\tau^2}(E_t[r_{t+1}^{m,(\tau)}] - r_t - \mu_t \text{sign}(X_t^{m,(\tau)})) \tag{14}$$

A.6 Market Clearing Solution

The market clearing conditions (22)-(24) determine equilibrium prices through the following steps. Substituting demand functions:

$$B_t^{(\tau)} = \sum_k [\theta_k^{B,(\tau)} - \alpha_k^{B,(\tau)} y_t^{(\tau)} - \sum_{\tau' \neq \tau} \eta_k^{B,(\tau,\tau')} y_t^{(\tau')} - \sum_{m \neq B} \xi_k^{(B,m)} p_t^{m,(\tau)} - \gamma_k^{B,(\tau)} \beta_t] + X_t^{B,(\tau)} + QE_t^{(\tau)} \tag{15}$$

Solving the market clearing equations simultaneously yields:

$$
\begin{aligned}
y_t^{(\tau)} = & \frac{1}{\sum_k \alpha_k^{B,(\tau)}} \Bigg[B_t^{(\tau)} - \sum_k \theta_k^{B,(\tau)} - X_t^{B,(\tau)} - QE_t^{(\tau)} \\
& + \sum_k \sum_{\tau' \neq \tau} \eta_k^{B,(\tau,\tau')} y_t^{(\tau')} + \sum_k \sum_{m \neq B} \xi_k^{(B,m)} p_t^{m,(\tau)} + \sum_k \gamma_k^{B,(\tau)} \beta_t \Bigg]
\end{aligned} \tag{16}
$$

Using the method of undetermined coefficients, we conjecture solutions of the form:

$$y_t^{(\tau)} = A_{(\tau)}^B + B_r^{(\tau)}(r_t - \bar{r}) + B_\beta^{(\tau)} \beta_t + B_u^{(\tau)} u_t \tag{17}$$

$$\omega_t^{(\tau)} = A_{(\tau)}^F + C_r^{(\tau)}(r_t - \bar{r}) + C_\beta^{(\tau)} \beta_t + C_u^{(\tau)} u_t \tag{18}$$

$$\psi_t^{(\tau)} = A_{(\tau)}^S + D_r^{(\tau)}(r_t - \bar{r}) + D_\beta^{(\tau)} \beta_t + D_u^{(\tau)} u_t \tag{19}$$

Substituting these conjectures and matching coefficients yields expressions for the constant terms:

$$A_{(\tau)}^m = \bar{r} + \frac{a_t \tau \sigma_r^2}{\sum_k \alpha_k^{m,(\tau)}} + \psi_{(\tau)}^m (1 - \theta_{coord}) + \xi_{(\tau)}^m + \phi_{(\tau)}^m \tag{20}$$

where:

$$\psi_{(\tau)}^m = \kappa^{(\tau)} \cdot a_t \cdot (B_t / Y_t) \tag{21}$$

$$\xi_{(\tau)}^m = \frac{\underline{B}^{(\tau)} - \sum_k \theta_k^{(\tau)}}{\bar{\alpha}^{(\tau)}(1 - HHI_t) + \frac{1}{a_t \sigma_\tau^2}} \tag{22}$$

$$\phi_{(\tau)}^m = \Lambda'(s_t) \frac{\partial s_t}{\partial B_t^{(\tau)}} + \eta^{(\tau)}(1 - F_t / \overline{F}^{(\tau)}) \tag{23}$$

B Proofs of Propositions

B.1 Proof of Proposition 1 (Duration Risk Transfer Premium)

The proof proceeds in three steps:

Step 1: From the government's first-order conditions:

$$E_t[y_{t+1}^{(\tau)}] - y_t^{(\tau)} \geq -\frac{1}{\tau}\psi^{(\tau)}(1 - \theta_{coord}) \tag{24}$$

This reflects asymmetric recognition of duration risk. To see this, note:

$$\frac{\partial P_{t+1}^{(\tau)}}{\partial B_t^{(\tau)}} = -\tau P_{t+1}^{(\tau)} \frac{\partial y_{t+1}^{(\tau)}}{\partial B_t^{(\tau)}} = -\tau P_{t+1}^{(\tau)} \psi^{(\tau)} \tag{25}$$

Step 2: From arbitrageur optimality:

$$E_t[y_{t+1}^{(\tau)}] - y_t^{(\tau)} = a_t \tau \sigma_r^2 X_t^{(\tau)} \tag{26}$$

This represents required compensation for bearing interest rate risk. Combining with Step 1:

$$a_t \tau \sigma_r^2 X_t^{(\tau)} \geq -\frac{1}{\tau}\psi^{(\tau)}(1 - \theta_{coord}) \tag{27}$$

Step 3: Market clearing requires:

$$X_t^{(\tau)} = \frac{B_t}{Y_t} \cdot \frac{Y_t}{\sum_k \alpha_k^{(\tau)}} - \frac{F_t^{(\tau)}}{\sum_k \alpha_k^{(\tau)}} \tag{28}$$

Combining this with Steps 1 and 2 yields:

$$\psi^{(\tau)} = \kappa\tau \cdot a_t \cdot (B_t/Y_t) \cdot (1 - F_t^{(\tau)}/B_t^{(\tau)}) \tag{29}$$

The comparative statics follow by differentiation:

$$\frac{\partial \psi^{(\tau)}}{\partial \tau} = \kappa a_t (B_t/Y_t)(1 - F_t^{(\tau)}/B_t^{(\tau)}) > 0 \tag{30}$$

$$\frac{\partial \psi^{(\tau)}}{\partial a_t} = \kappa \tau (B_t/Y_t)(1 - F_t^{(\tau)}/B_t^{(\tau)}) > 0 \tag{31}$$

$$\frac{\partial \psi^{(\tau)}}{\partial (B_t/Y_t)} = \kappa \tau a_t (1 - F_t^{(\tau)}/B_t^{(\tau)}) > 0 \tag{32}$$

B.2 Proof of Proposition 2 (Market Structure Effects)

When the minimum issuance constraint binds:

$$\underline{B}^{(\tau)} = \sum_k \left(\theta_k^{(\tau)} - \alpha_k^{(\tau)} \xi^{(\tau)} + u_{k,t}^{(\tau)} \right) + \frac{1}{a_t \sigma_\tau^2} \xi^{(\tau)} \tag{33}$$

The Herfindahl index affects price elasticity through:

$$\sum_k \alpha_k^{(\tau)} = \bar{\alpha}^{(\tau)} (1 - HHI_t) \tag{34}$$

Solving for $\xi^{(\tau)}$:

$$\xi^{(\tau)} = \frac{\underline{B}^{(\tau)} - \sum_k \theta_k^{(\tau)}}{\bar{\alpha}^{(\tau)} (1 - HHI_t) + \frac{1}{a_t \sigma_\tau^2}} \tag{35}$$

B.3 Proof of Proposition 3 (Coordination Failure Amplification)

The proof proceeds by analyzing the welfare effects of uncoordinated optimization.

Step 1: Define welfare under joint optimization where a social planner chooses both Treasury issuance and Fed QE:

$$\mathcal{W}^{Joint} = \max_{B_t^{(\tau)}, QE_t} \{ -\text{Borrowing Costs} - \text{Duration Risk Costs} - \text{Macro Losses} \} \tag{36}$$

The first-order condition for optimal coordination yields:

$$\frac{\partial \text{WAM}_t^{Joint}}{\partial QE_t} = -\kappa \tag{37}$$

where $\kappa > 0$ represents efficient duration offset.

Step 2: Under separate optimization, the Treasury's response to QE is:

$$\frac{\partial \text{WAM}_t^{Treasury}}{\partial QE_t} = -\theta_T \cdot \theta_F \cdot \kappa = -\theta_{coord} \cdot \kappa \tag{38}$$

Since $\theta_{coord} < 1$, we have $|\frac{\partial \text{WAM}_t^{Treasury}}{\partial QE_t}| < \kappa$, indicating insufficient offset.

Step 3: The welfare loss from coordination failure is:

$$\mathcal{W}^{Loss} = \int_{QE} \psi^{(\tau)}(1 - \theta_{coord}) \left(\kappa - \theta_{coord}\kappa\right) dQE_t \tag{39}$$

Taking the derivative:

$$\frac{\partial \mathcal{W}^{Loss}}{\partial QE_t} = \psi^{(\tau)}(1 - \theta_{coord})\kappa(1 - \theta_{coord}) > 0 \tag{40}$$

Since all terms are positive when $\theta_{coord} < 1$, welfare losses increase with QE when coordination fails.

B.4 Proof of Proposition 4 (State-Dependent Amplification)

We first prove the nonlinear response to market stress. From equation (28), the cross-partial derivative satisfies:

$$\frac{\partial^2 \mu_t^{(\tau)}}{\partial VIX_t \partial (B_t/Y_t)} = -\phi^{(\tau)}(1 - \theta_{coord}) \tag{41}$$

To establish $\phi^{(\tau)} > 0$, we show the three amplification channels:

First, arbitrageur risk aversion increases with VIX_t:

$$a_t = \bar{a} + \eta VIX_t, \quad \eta > 0 \tag{42}$$

Second, market concentration rises as participants withdraw:

$$HHI_t = \overline{HHI} + \gamma VIX_t, \quad \gamma > 0 \tag{43}$$

Third, refinancing concerns intensify:

$$\frac{\partial \Lambda'(s_t)}{\partial VIX_t} = \lambda_1 s_t \frac{\partial s_t}{\partial VIX_t} > 0 \tag{44}$$

Combining these effects establishes that $\phi^{(\tau)} > 0$, completing the proof.

B.5 Proof of Proposition 5 (Cross-Market Integration)

The proof proceeds in three steps:

Step 1: From market clearing in swap and bond markets:

$$s_t^{(\tau)} = \frac{1}{\sum_k \alpha_k^{S,(\tau)}} \left[S_t^{(\tau)} - \sum_k \theta_k^{S,(\tau)} + \sum_k \gamma_k^{S,(\tau)} \beta_t \right] \tag{45}$$

$$y_t^{(\tau)} = \frac{1}{\sum_k \alpha_k^{B,(\tau)}} \left[B_t^{(\tau)} - \sum_k \theta_k^{B,(\tau)} + \sum_k \gamma_k^{B,(\tau)} \beta_t \right] \tag{46}$$

Step 2: The swap spread $SS_t^{(\tau)} = s_t^{(\tau)} - y_t^{(\tau)}$ satisfies:

$$SS_t^{(\tau)} = \frac{\xi_k^{(B,S)}}{\sum_k \alpha_k^{S,(\tau)}} \cdot \frac{B_t^{(\tau)}}{Y_t} + \frac{1}{\bar{\alpha}^{(\tau)}} HHI_t + \frac{\partial a_t}{\partial VIX_t} \cdot \frac{\tau \sigma_r^2}{\sum_k \alpha_k^{(\tau)}} VIX_t \tag{47}$$

Step 3: The coefficients follow from market structure:

$$\nu^{(\tau)} = \frac{\xi_k^{(B,S)}}{\sum_k \alpha_k^{S,(\tau)}} > 0 \tag{48}$$

$$\lambda^{(\tau)} = \frac{1}{\bar{\alpha}^{(\tau)}} > 0 \tag{49}$$

$$\delta^{(\tau)} = \frac{\partial a_t}{\partial VIX_t} \cdot \frac{\tau \sigma_r^2}{\sum_k \alpha_k^{(\tau)}} > 0 \tag{50}$$

This establishes the swap spread decomposition $\mu_t^{(\tau)} = -\nu^{(\tau)}(1 - \theta_{coord})\frac{B_t}{Y_t} - \lambda^{(\tau)} HHI_t - \delta^{(\tau)} VIX_t$.

B.6 Proof of Proposition 6 (Asymmetric Price Impacts)

The proof follows from the interaction of duration risk non-internalization with market structure:

Step 1: From the government's first-order condition incorporating coordination failure:

$$\frac{\partial y_t^{(\tau)}}{\partial B_t^{(\tau)}} = \frac{1}{\sum_k \alpha_k^{(\tau)}} + \theta_{coord} \frac{\partial^2}{\partial (B_t^{(\tau)})^2} \max(P_t^{(\tau)} - P_{t-1}^{(\tau)}, 0) \tag{51}$$

Step 2: When rates decline ($r_t < r_{t-1}$):

$$\frac{\partial^2}{\partial (B_t^{(\tau)})^2} \max(P_t^{(\tau)} - P_{t-1}^{(\tau)}, 0) = \psi^{(\tau)}(1 - \theta_{coord}) \tag{52}$$

Step 3: Combining these results yields the asymmetric response:

$$\frac{\partial y_t^{(\tau)}}{\partial B_t^{(\tau)}} = \frac{1}{\sum_k \alpha_k^{(\tau)}} + \psi^{(\tau)}(1 - \theta_{coord}) \mathbf{1}_{r_t < r_{t-1}} \tag{53}$$

The sensitivity $\psi^{(\tau)}$ increases with maturity as shown in Proposition 1.