Identifying the Effects of Demand for Safe Assets

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March 16, 2024

Abstract

The Portfolio Balance Mechanism (PBM) posits that lowering the net supply of long-term Treasuries encourages the production of similar assets for preferred-habitat investors, potentially explaining Quantitative Easing's (QE) impact on the economy and the pre-2007-2008 crisis securitization spike. This paper identifies the PBM with the 2002 suspension of 30-year Treasury bond auctions, which led to significant increases in prices and issuance of safe, long-term collateralized-mortgage obligations (CMOs) to cater to the demand from habitat-preference investors. The heterogeneity of Treasuries and CMOs provides unusually clean identification of the PBM.

JEL classification: E41, E44, E51, E58, G11, G22, G23
Keywords: Limits to arbitrage, safe assets, preferred habitat, securitization, tranching, financial crisis

*We thank Zhiguo He, Eric Richert, Zhaogang Song, Athena Tsouderou, Dimitri Vayanos, Nancy Wallace, Xuan Wang, Sean Wilkoff and seminar participants at the 2023 AREUEA National Conference, 2023 FMA European Conference, 12^{th} Portuguese Finance Conference, 2024 Asia Meeting of the Econometric Society, South Central and Western Asia, 2023 CEAR-MRIC Behavioral Insurance Workshop, 11th HEC-McGill Winter Finance Workshop, and Rice University for helpful comments. We are particularly grateful for the comments and suggestions of Douglas McManus. Duarte (jefferson.duarte@rice.edu) and Umar (Tarik.Umar@rice.edu) are with the Jesse H. Jones School of Business at Rice University.

Bernanke (2010a) highlights that the Portfolio Balance Mechanism (PBM) may elucidate the influence of QE policies on the real economy. QE's acquisition of US Treasuries reduces their net supply, potentially prompting the creation of similar bonds to satisfy investors with a preference for safe, long-term bonds (referred to as "habitat preference"), which, in turn, could stimulate investments. Furthermore, the PBM suggests that purchases of long-term US Treasury bonds by Global Savings Glut (GSG) countries have diminished their net supply, leading to a significant increase in securitization to generate safe assets before the financial crisis.[1] Although the PBM provides a plausible explanation for the events leading up to the financial crisis and the effectiveness of QE, it encounters several obstacles. First, it is unclear whether securitization occurs to meet the demand for safe long-term assets because there are numerous potential substitutes for long-term Treasuries. For example, the prices of long-term foreign sovereign bonds have risen with QE and GSG purchases, suggesting that these foreign bonds serve as substitutes for Treasuries (e.g., Backus and Wright, 2007). Second, empirical evidence shows that the surge in securitization before the crisis was also driven by factors unrelated to the GSG, such as regulatory arbitrage and information frictions, casting doubt on the PBM's role in the pre-crisis securitization increase. Consequently, to identify whether the PBM can explain such a diverse set of important capital market phenomena, it is crucial to explore the effects of a singular external shock on the net supply of long-term Treasuries. This includes exploring its effects on the prices and availability of alternative long-term safe assets generated through securitization, namely Collateralized Mortgage Obligations (CMOs), the pricing of foreign sovereign bonds, and how investors adjust their portfolios by potentially reallocating to substitutes like foreign bonds and CMOs.

We formalize the PBM with a demand-driven model of the term premium and securitization. The model is an extension of the gap filling theory of Greenwood, Hanson, and Stein (2010) (GHS hereafter) and the quantity-driven model of the term premium of Greenwood, Hanson, and Stein (2010) (GHS hereafter), both of which rely on limits-to-arbitrage. In the absence of limits to arbitrage, the supply of long-term bonds by arbitrageurs is perfectly elastic, resulting in the insensitivity of safe asset prices to demand fluctuations (Vayanos and Vila, 2021, VV hereafter). Furthermore, securitization with tranching involves establishing

[1] Bernanke (2006, 2011) define the GSG countries as emerging economies and commodity producers.

rules for cash flow distribution from mortgage pools, and hence it does not add value in absence of frictions. However, in our model, limits to arbitrage render the supply of long-term safe assets by arbitrageurs not perfectly elastic and bestows value upon tranching. Specifically, we assume that there are domestic and foreign investors who prefer long-term safe bonds in their own currencies. We also assume the presence of an arbitrageur (the global bond investor in GHSS) that absorbs shocks related to the net supply for both US and foreign sovereign bonds. This arbitrageur, being risk-averse, requires a premium to arbitrage away the price disparities in long-term bonds caused by shocks to their net supply. As a result, the supply of US and foreign long-term bonds by the arbitrageur is not perfectly elastic. We add one further agent to our model, namely, a risk-averse mortgage dealer, that absorbs shocks to the net supply of US Treasury bonds by tranching the cash flows of mortgages into long-term agency-CMOs that are not subject to prepayment.[2] These agency-CMOs are called Planned Amortization Class (PAC). PACs are the most popular type of agency-CMOs and, by construction, have little exposure to prepayment risk.

The model presents three propositions directly linked to the PBM. First, a decrease to the net supply of Treasury bonds leads to a rise in the price of these bonds and their substitutes (i.e., PACs). Second, a decrease to the net supply of Treasury bonds leads to an increase to the volume of long-term PACs created by tranching to cater to the demand for long-term safe bonds from habitat-preference investors. Third, a negative shock to the net supply of Treasury bonds results in an increase in the price of foreign bonds even when preferred habitat investors do not use foreign bonds as substitutes for US Treasuries. Empirical support for these three propositions is essential to validate the portfolio balance mechanism.

We examine whether the three implications of the model are observed in the data with a single targeted shock — the suspension of 30-year Treasury bond auctions announced on October 31, 2001 and starting in 2002. On May 4, 2005, the Treasury announced the possible resumption of 30-year Treasury auctions, which, in fact, resumed in February 2006.

[2]Agency-CMOs are formed by tranching the cash flows from agency pass-throughs, which are pools of 30-year mortgages backed by credit guarantees from the agencies (Fannie Mae, Freddie Mac, and Ginnie Mae). The agency-CMO market is enormous. According to SIFMA, around 18% of the total outstanding agency mortgage-related securities between 2002 and 2018 consisted of CMOs. Prepayment risk is the primary concern for agency pass-throughs (He and Song, 2022). Tranching agency pass-throughs results in tranches with varying degrees of exposure to prepayment. Appendix A.1 describes the most relevant types of CMOs along with their creation process.

We analyze the prices of Treasuries, PACs, and foreign sovereign bonds. Additionally, we examine the extent to which preferred habitat investors, specifically life insurance companies (Greenwood and Vissing-Jorgensen, 2018), substitute Treasury purchases with newly issued PACs and long-term sovereign bonds.

We find strong support for the first proposition that the prices of long-term Treasury bonds and PACs increase with the excess demand for long-term safe bonds. Consistent with Bernanke, Reinhart, and Sack (2004), the difference between the return of the 30-year Treasury bond and the return of the 10-year note was 1.7% on the day the US government announced the suspension of the 30-year Treasury bond (October 31, 2001). More importantly, we also find a significant increase in the price of long-term PACs of 2.1% relative to the price of medium-term PACs. Together, these identified price effects indicate that arbitrageurs cannot freely create long-term bonds to satisfy shocks in the excess demand for long-term safe assets (VV), which is a necessary condition for the PBM.

We find strong support for the second proposition that a shock to the excess demand for long-term safe bonds results in a higher volume of long-term PACs issued by dealers to meet the demand from habitat investors. During the suspension, using a difference-in-difference analysis, we show that long-term PAC issuances increased significantly relative to the issuances of other types of long-term CMOs with prepayment risk. Furthermore, in a separate difference-in-differences analysis, we find that life insurers increased their purchases of newly issued long-term PACs relative to their purchases of medium-term PACs. In fact, the magnitude of the drop in Treasury bond purchases is comparable to the increase in long-term PAC purchases, suggesting a strong substitution. Consistent with the parallel trend assumption, we find similar trends in the purchases of long-term and medium-term PACs prior to the discontinuation and after the reopening of the regular 30-year Treasury bond auctions. In contrast, our findings indicate that life insurers did not increase their acquisitions of newly issued foreign sovereign bonds during the suspension period. This supports the notion that habitat-preference investors refrain from substituting bonds issued in different currencies.

Lastly, our results support the third proposition that an excess demand for Treasuries decreases yields on long-term sovereign bonds around the world even when preferred habitat investors do not use foreign bonds as substitutes for US Treasuries. In our extension of the GHSS model, the global arbitrageur issues domestic and foreign long-term bonds and invests at short-term interest rates to meet the excess demand from US and foreign habitat-preference investors. As a result, an increase in demand for US long-term bonds heightens the arbitrageur's exposure to fluctuations in US short-term interest rates. To offset this increased risk, the arbitrageur receives higher compensation through elevated prices for the foreign bonds they issue, particularly when the foreign short-term interest rate moves in tandem with the US short-term interest rate. As predicted by the model, we find that the yields on foreign 30-year bonds decreased significantly on the announcement of the suspension. Also, we find no evidence that life insurers increased their purchases of long-term sovereign bonds.

In addition, as the GHSS model predicts, the decrease is significantly stronger when the correlation between the short-term rate of the US and the foreign country is higher. For example, the effect of the announced suspension is stronger for Canada and Germany, whose short-term rates have higher correlations with the US rate, and only marginally significant for Japan, which has a weak correlation with the US short rate. Also, we take advantage of our single shock to a specific maturity in the US to provide evidence that shocks to the excess supply of long-term government bonds has spillover effects on the prices of US and foreign bonds of shorter maturities, as predicted by VV because of the presence of a global arbitrageur.

Our findings make a significant contribution to the securitization literature by providing direct evidence that tranching activity increases in response to increases in excess demand for specific assets. In the traditional securitization literature, tranching acts as a mechanism for securities suppliers to mitigate a 'lemons problem' when selling portfolios of illiquid assets (DeMarzo, 2005; Downing, Jaffee, and Wallace, 2009; Begley and Purnanandam, 2016). The reason for tranching we examine differs from this traditional view of securitization because it is driven by the demand for specific assets that cannot be created freely. Regulatory arbitrage is another reason for tranching. In this case, tranching is a mechanism to create highly rated securities with more benign capital requirements (Acharya, Schnabl, and Suarez, 2013; Stanton and Wallace, 2018; Cordell, Roberts, and Schwert, 2023). Differently from regulatory arbitrage, we examine the hypothesis that tranching happens to cater to the asset demand, which may be unrelated to regulatory arbitrage. Empirical evidence supporting the catering hypothesis remains limited. In fact, Gorton and Metrick (2013) remark, "There is no direct evidence that these demands for collateral led to increased asset-backed security supply." Our evidence lends empirical support to fundamental components of models of securitization in which intermediaries cater to investors' demand for specific types of assets (Gennaioli, Shleifer, and Vishny, 2012, 2013).

The literature addressing limits to arbitrage examines a wide array of subjects (e.g. Pontiff (1996) and Shleifer and Vishny (1997)). Our work augments the existing evidence that a limits-to-arbitrage framework in which risk-averse arbitrageurs absorb shocks to the excess demand for different securities (e.g., VV, Greenwood and Vayanos, 2010, 2014) helps explain a diverse and important collection of capital market phenomena. We achieve this by examining the various outcomes – such as the impact on prices of Treasury and foreign bonds as well as the issuance of and prices of PACs – resulting from a shock to the supply of a particular safe asset, namely 30-year Treasury bonds. Within the same limits-to-arbitrage framework, GHS demonstrate that corporations adjust their debt's maturity to cater to investors with habitat preferences. In our model, mortgage dealers play a role akin to that of corporations in GHS. We contribute to GHS because we document a direct switch from 30-year Treasury bonds to newly issued PACs in life insurers' portfolios, and hence we clearly identify the practice of catering to the habitat-preference investors. GHSS demonstrate that the same limits-to-arbitrage framework addresses a notable gap in the standard international macroeconomics model, which has struggled to explain why supply shocks affect foreign exchange rates. Our finding regarding the announcement effect on the prices of foreign long-term bonds supports the mechanism that their model proposes for the transmission of demand shocks across bonds issued by different countries. This mechanism is founded on the hypothesis that global arbitrageurs are key marginal investors in the sovereign bond market..

We contribute to the literature examining the pre-crisis increase in securitization and Quantitative Easing (QE).[3] Bernanke, Bertaut, DeMarco, and Kamin (2011) and Bertaut,

[3]Bauer and Neely (2014) and Neely (2015) explore the impact of QE on foreign bond yields, while D'Amico and King (2013) uses the large-scale asset purchases to examine VV theory. The decline in yields of both the 30-year Treasury and foreign bonds, triggered by the suspension of the 30-year Treasury bond auction shows that the observed price reactions extend beyond the scope of QE policies, highlighting broader supply and demand influences on prices.

DeMarco, Kamin, and Tryon (2012) show that the pre-crisis demand for safe US assets from foreign economies is paralleled by an increased issuance of AAA-rated private label securities.[4] In a contemporaneous working paper, Selgrad (2023) demonstrates that QE leads mutual funds to shift from Treasuries to corporate bonds. Our analysis reveals that habitat-preference investors, such as life insurers, transition from Treasuries to securities with similar maturity and credit quality (PACs) in response to a Treasury supply shock. While the shock we investigate differs from QE and the one posited in the GSG hypothesis, our examination provides a clear identification of the portfolio balance channel supporting its role in the pre-crisis growth in securitization and in QE.

The remainder of the paper is summarized below. Section 1 describes the model and its testable implications. Section 2 describes the data. Section 3 describes the empirical methodology and results. Section 4 concludes.

1 Model and Testable Implications

Our model expands on the framework presented in GHS, adapting it to a scenario with two countries and a mortgage dealer in one of the countries. As in GHS, we consider a three-period world. In the first period, the known short-term domestic (US) interest rate is r_1. The interest rate for the second period is r_2 with mean μ_r and variance σ_r^2. The foreign fixed income market mirrors the domestic market, with respective short-term rates and moments indicated by r_1^{ext}, r_2^{ext}, $\mu_{r^{ext}}$, and $\sigma^2_{r^{ext}}$. The correlation between domestic and foreign short-term interest rates is symbolized by ρ.

Both countries have preferred habitat investors. US preferred-habitat investors exhibit an inelastic demand for US bonds maturing at $t = 3$. The excess supply of bonds with maturity at $t = 3$ is represented by g, which is equal to the amount of bonds the US government issues minus the demand from inelastic preferred habitat investors. A similar dynamic is observed in the foreign market, where the excess supply for long-term bonds is g^{ext}.

The mortgage dealer can cater to the excess demand from US preferred habitat investors

[4] The tranching of pools of non-agency loans (also called private label) leads to tranches with different credit ratings. In contrast, tranching agency pass-throughs results in tranches with the same exposure to credit risk due to the credit guarantees in the collateral pass-throughs.

by issuing long-term bonds that cannot be prepaid and mature at $t = 3$ to finance the purchase of f dollars of mortgage pass-through securities. Specifically, homeowners borrow through fixed-rate mortgages with maturity at $t = 3$. Homeowners can prepay their mortgages at time $t = 2$ without a prepayment penalty. The mortgage rate is set in the pass-through market that is exogenous to the model. Preferred habitat investors do not invest in mortgage pass-throughs because of mortgage prepayment risk. Let M_I be the value at time $t = 3$ of the amount of interest paid between time $t = 1$ and $t = 3$ on \$1 of mortgage principal. M_I has mean μ_M and variance σ_M^2. Let P be the price at $t = 1$ of the bond maturing at $t = 3$. As a result, the return of one dollar invested by the mortgage dealer is $(1 + M_I - 1/P)$. The mortgage dealer maximizes the mean variance problem:

$$\max_f f(1 + \mu_M - \frac{1}{P}) - \frac{1}{2\theta} f^2 \sigma_M^2 \tag{1}$$

where θ is the risk tolerance of the mortgage dealer.

In our model, we refer to the long-term bonds sold by mortgage dealers as long-term PACs, due to their resemblance to actual PACs. PACs are agency-CMOs whose principal payments are predetermined, provided that prepayment speeds of the underlying pass-through remain within specified ranges. To mitigate the risk of prepayment variability, a PAC is created with a companion Support (SUP) tranche, absorbing a disproportionate share of underlying mortgage pass-through prepayment risk. Investors averse to prepayment risk, such as pension funds and life insurers, typically opt for PACs due to their stability and predictable cash flows.[5] Conversely, investors with a lower aversion to prepayment risk, such as hedge funds, are more inclined to invest in the SUP tranches (Fabozzi and Ramsey, 1999). In practice, dealers create agency CMO securities by selecting appropriate mortgage pass-through collateral and structuring a CMO that appeals to investors with varying levels of prepayment risk tolerance. In the model, the mortgage dealer assumes the prepayment risk associated with the mortgages financed through long-term PACs, thus emulating the roles typically played by dealers and hedge funds in the real world.[6]

[5]An excerpt from the Life USA Holding 1996 10-K states, "Government agency obligations are predominantly held in the form of PAC CMOs, the most conservative type of CMO issued. These CMOs are specifically structured to provide the highest degree of protection against swings in repayments caused primarily by changes in interest rates and have virtually no risk of default. These securities are well suited to fund the payment of the liabilities they support."

[6]Naturally, dealers also hold SUP tranches especially when they cannot sell them prior to CMO launch

Drawing parallels to Gourinchas, Ray, and Vayanos (2022) and GHSS, our model incorporates a yield curve arbitrageur adept at capitalizing on arbitrage opportunities within the yield curves of both countries. This term-structure arbitrageur addresses the excess demand for US long-term domestic bonds by selling long-term bonds at a price P and reallocating the proceeds at the short-term interest rate. Consequently, the excess return generated by this domestic yield-curve strategy is quantified as $rx_3 = [(1+r_1)(1+r_2) - 1/P]$. We assume that the arbitrageur sells \$$h$ worth of these long-term bonds. In a similar vein, the arbitrageur allocates h^{ext} to the foreign yield curve strategy with the return given by $rx_3^{ext} = [(1+r_1^{ext})(1+r_2^{ext}) - 1/P^{ext}]$. In line with the approach described in GHSS, let $\mathbf{h}'$ denote the vector representing the term-structure arbitrageur's holdings. Furthermore, the excess return for each of these strategies is encapsulated in the vector $\mathbf{rx}_3$. To determine the optimal holdings, the arbitrageurs engage in the following maximization problem:

$$\max_{\mathbf{h}} \mathbf{h'}E[\mathbf{rx}_3] - \frac{1}{2\lambda}\mathbf{h'}Var[\mathbf{rx}_3]\mathbf{h} \tag{2}$$

Here, λ signifies the arbitrageur's tolerance for risk, and $Var[\mathbf{rx}_3]$ is the covariance matrix of the excess returns of three arbitrageur's strategies.

The first-order conditions of the mortgage dealer and the arbitrageur's problem along with the market clearing conditions lead to the following expression for the expected return premium of the domestic long-term bond:

$$\frac{1}{P} - (1+r_1)(1+\mu_r) = \frac{\eta_f\eta_h}{\eta_f+\eta_h}g + \frac{\eta_f\eta_\rho}{\eta_f+\eta_h}g^{ext} \tag{3}$$

where $\eta_f = \sigma_M^2/\theta$ is the risk penalty inherent to the mortgage dealer's problem, $\eta_h = (1+r_1)^2\sigma_r^2/\lambda$ is the risk penalty of the domestic yield curve strategy, and $\eta_\rho = \rho\sigma_r\sigma_{r^{ext}}\left(1+r_1\right)\left(1+r_1^{ext}\right))/\lambda$ is the risk penalty related to the correlation of the returns of the international and domestic yield curve strategies. The amount of PAC issuance is:

$$f = -\frac{\eta_h}{\eta_f+\eta_h}g - \frac{\eta_\rho}{\eta_f+\eta_h}g^{ext} \tag{4}$$

and the expected return premium of the foreign long-term bond is:

$$\frac{1}{P^{ext}} - (1+r_1^{ext})(1+\mu_{r^{ext}}) = (\frac{\eta_f\eta_{h^{ext}} + \eta_h\eta_{h^{ext}} - \eta_\rho^2}{\eta_f+\eta_h})g^{ext} + \frac{\eta_f\eta_\rho}{\eta_f+\eta_h}g \tag{5}$$

settlement

where $\eta_h = (1 + r_1^{ext})^2 \sigma^2_{r^{ext}}/\lambda$ is the risk penalty of the foreign yield curve strategy.[7]

It is interesting to compare the solution in Equations 3 to 5 with the implications in GHS and GHSS. Similar to GHS, the price of the long-term bond in Equation 3 responds to shocks on its excess supply. This contrasts with models without any limits to arbitrage. For example, when the yield curve arbitrageur is risk neutral ($\eta_h = 0$ and $\eta_\rho = 0$) resulting in no limits to the yield curve arbitrage, the price of the long-term bond does not respond to shocks in g and g^{ext}. Echoing the model in GHSS, the price of foreign long-term bonds in Equation 5 is sensitive to fluctuations in the excess supply of US bonds (g) when η_ρ is different from zero. To understand the mechanism behind this relation, note that the global arbitrageur issues domestic and foreign long-term bonds and invests at short-term interest rates to meet the excess demand from US and foreign habitat-preference investors. Consequently, a variation in g impacts the arbitrageur's exposure to common fluctuations in both US and foreign short-term interest rates, thereby affecting the prices of US and foreign long-term bonds.

The model builds on GHS and GHSS by incorporating the role of the mortgage dealer. Notably, when the mortgage dealer is risk-neutral ($\eta_f = 0$), Equation 4 becomes $f = -g - (\eta_\rho/\eta_h)g^{ext}$. That is, the mortgage dealer issues enough PACs to both fully accommodate the excess demand for domestic long-term bonds and assume the global arbitrageur's risk related to fluctuations in the US short-term interest rates. Under these circumstances, the price of domestic long-term bonds, as outlined in Equation 3, is independent of their excess supply, which aligns with the expectation hypothesis. Furthermore, when $\eta_f = 0$, the price of long-term foreign bonds in Equation 3 is not affected by fluctuations in g. Conversely, as the mortgage dealer's risk aversion approaches infinity ($\eta_f \to \infty$), they cease to issue any long-term PACs ($f = 0$), rendering the prices of both US and foreign long-term bonds in Equations 3 and 5 symmetric, akin to the GHSS model.

In our model, as well as in reality, mortgage dealers are not bound by the same constraints that corporations encounter when determining their debt's maturity. In the GHS model,

[7] For simplicity and without loss of generality, we assume that prepayment is not priced in the pass-through market, which implies that $1 + \mu_I = (1 + r_1)(1 + \mu_r)$. Moreover, the term-structure arbitrageur also has access to the currency strategy, involving short-term borrowing in domestic currency and short-term lending in foreign currency. For details, see Appendix A.2.

corporations aim for a specific debt maturity, driven by various constraints related to their capital structure decisions (e.g., Harford, Klasa, and Maxwell, 2014). In contrast, the only constraints mortgage dealers face in our model relate to their risk aversion, paralleling the constraints that arbitrageurs confront. This framework aligns with the notion that catering to CMO buyers is the primary goal of dealers when structuring CMOs, which is supported by the iterative process of CMO design. Indeed, dealers typically present hypothetical structures and pricing for agency CMOs to assess market interest. If investor demand for a proposed structure is lacking, alternative structures are offered. This iterative process of proposal and adjustment continues until the agency-CMO's structure final date, at which point the exact collateral and cash flow distribution rules among tranches are established.

Equations 3 to 5 deliver the three propositions that we take to the data:

Proposition 1 *Equation 3 indicates that when neither the mortgage dealer nor the arbitrageur is risk-neutral ($\eta_f > 0$ and $\eta_h > 0$), the price of long-term government bonds and their substitutes, such as PACs, increases in response to negative excess supply shocks.*

Proposition 2 *Equation 4 indicates that the issuance of long-term PACs increases when the excess supply g decreases and the global arbitrageur is not risk neutral $\eta_h > 0$, fulfilling the additional demand from investors with a habitat preference, such as life insurers.*

Tranching is a blunt violation of the Modigliani and Miller (MM) proposition. Proposition 2 clarifies the MM condition that is violated to associate tranching with catering.[8] In fact, if there are no limits to the yield curve arbitrage, $\eta_h = \eta_\rho = 0$, and the yield curve arbitrageur completely absorbs shocks to the excess supply of long-term bonds ($f = 0$), then tranching does not add value and is not observed. On the contrary, where there are limits to arbitrage ($\eta_h > 0$), mortgage dealers help absorb negative shocks to the excess supply for long-term bonds by issuing long-term PACs.

Naturally, there is also good reason to believe that the agency-CMO structure solves a lemons problem as well. The fundamental risk of an agency mortgage is the prepayment risk of the borrower. Some borrowers promptly and "efficiently" exercise the prepayment

[8]CMOs are stucture as Real Estate Mortgage Investment Conduit (REMICs). This structure was created by the 1986 Tax Reform Act to avoid "double-taxation". That is, CMOs do not pay corporate taxes and hence taxation cannot be used as a justification for tranching (Gorton and Metrick, 2013).

option when interest rates fall, while others do not. Mortgage originators have better information than investors in general due to the institutional characteristics of the market. For instance, originators can gauge the likelihood of borrowers prepaying their mortgages due to selling their homes. They achieve this by employing a points-contract rate trade-off, encouraging mobile borrowers to opt for contracts with lower points and higher rates (Stanton and Wallace, 1998). The mortgages entering a pass-through pool are from only one lender's origination pipeline, so that the private information carries over to the pool of mortgages (Downing, Jaffee, and Wallace, 2009). Originators can benefit from selling their mortgage pass-throughs by tranching them to mitigate the 'lemons problem' with buyers. They do this by retaining the CMO tranches most susceptible to prepayment risk, rather than selling the entire pool directly (DeMarzo, 2005).

Examining Propositions 1 and 2 concurrently serves as a robust test to differentiate tranching as a form of catering from the alternative hypothesis that tranching is a strategy to overcome the 'lemons problem.' While the information frictions between originators and CMO buyers might account for an increase in tranching, it does not necessarily affect the price of safe assets, as indicated by Proposition 1. On the other hand, interpreting tranching as catering supports both Propositions 1 and 2.

Proposition 3 *Equation 5 indicates that when the mortgage dealer is not risk-neutral ($\eta_f > 0$), the arbitrageur is not risk-neutral, and the short-term interest rates of the two countries exhibit a positive correlation, ($\eta_\rho > 0$), the price of foreign long-term bonds rises with a decrease in the excess supply for US Treasuries (g).*

In the model, the price of foreign sovereign bonds responds to a shock in the net supply of US bonds, even if preferred habitat investors do not substitute US bonds with foreign sovereign bonds. We evaluate Proposition 3 to show that although the prices of many bonds may react to a shift in the net supply of US bonds, only a select few types of bonds act as substitutes for US Treasuries for investors with a preferred habitat.

Our empirical analysis explores the suspension of the 30-year Treasury bond auction from 2002 to 2005 as a shock to the supply of long-term bonds. We map the bond with maturity at $t = 3$ in our model to the real-world 30-year Treasury bond, deliberately excluding Treasury notes (times-to-maturity between 2 and 10 years) from our long-term bond category. This approach aids in cleanly identifying the effects described in Propositions 1 and 2 by exploring the difference in the effect of the auction suspension in the treated group (time-to-maturity above 10 years) and the control group (time-to-maturity less or equal to 10 years).

For example, although our model emphasizes long-term PAC securities, PACs in reality exhibit a spectrum of maturities. Commonly, PAC tranches are arranged in a sequential manner, with principal payments directed to each tranche until it is fully amortized before proceeding to the next. This leads to tranches having diverse average lifespans. Our empirical strategy explores these maturity variations in PACs to precisely identify the effects outlined in Propositions 1 and 2.

Furthermore, PACs are but one type of CMO. Sequential (SEQ) tranches, the second most prevalent type, exhibit a similar maturity sequence to PACs but carry prepayment risk, rendering them suboptimal substitutes for Treasury bonds. This diversity within CMOs facilitates the implementation of multiple controls and falsification tests. For instance, we explore whether the auction suspension resulted in a relative increase in issuances of long-term PACs compared to SEQs, and whether life insurers demonstrated a preference for acquiring newly issued long-term PACs over SEQs.[9]

2 Data

Our empirical analysis spans from 1998 to 2007, concluding in 2007 to ensure that our findings are not influenced by the financial crisis.

To examine Proposition 1, which predicts that a shock to the excess supply for Treasury bonds affects their prices and the prices of PACs, we gather data on US Treasury (UST) notes and bonds from the CRSP Treasury files. We gather data for all non-callable US Treasury bonds and notes issued between 1998 and 2007 from CRSP. CRSP data files contain information on each Treasury security, including the daily return, the total amount outstanding,

[9] Gabaix, Krishnamurthy, and Vigneron (2007) also explore the heterogeneity among agency-CMOs by analyzing the differential pricing of prepayment risk across interest-only (IO) and principal-only (PO) tranches. Specifically, they note that the value of POs increases with a higher likelihood of refinancing (and the opposite for IOs), thus indicating a direct (inverse) exposure to refinancing risk for POs (IOs). Unlike IOs and POs, PAC cash flows remain stable during refinancing waves, as the SUP tranche absorbs the prepayment risk.

and the maturity date.

Figure 1, Panel A shows the total amount of notes and bonds issued between 1998 and 2007. We divide all UST issuances into two categories based on the term of the Treasury securities: notes are medium-term (two to ten years to maturity), and bonds are long-term (with maturities greater than ten years). The issuance of notes increased during the event period from about $0.4 trillion in 2002 to $0.6 trillion in 2005. Bond issuance decreased from about $16 billion in 2001 to zero dollars between 2002 and 2005. About $26 billion worth of bonds were issued in 2006. Figure 1, Panel B shows the issuance of bonds relative to the total issuance of Treasury bonds and notes. In 2001, the issuance of bonds was about 6% of the total issuance of bonds plus notes. Between 2002 and 2005, there was no issuance of US Treasury bonds. Bond issuance increased to approximately 4% of the total issuance of bonds plus notes in 2006.[10]

[Insert Figure 1 Here]

To examine the returns of substitutes for long-term Treasuries, we gather the returns of various types of PACs from the ICE Bank of America - Merrill Lynch CMO Index database. These indexes are available from the ICE Index Platform in the last trading day of each month during our sample period.[11] We use the information about the constituents of the CMOP and CMPZ (very long-term PACs) indices.[12] Specifically, for each index, we have the market value, total return, OAS and effective duration of portfolios formed with the index constituents sorted by their effective durations. See Galdi, Goldblatt, and Zhang (2006) for details about these indexes.

To evaluate Proposition 2, which predicts an increase in the production of substitutes for long-term Treasuries to meet the demand of habitat investors, we assemble a comprehensive panel of all agency-CMOs issued between 1998 and 2007 by the Federal Home Loan Mortgage

[10]See `https://home.treasury.gov/news/press-releases/po749` and `https://home.treasury.gov/news/press-releases/js2420` for the announcement of the suspension and the announcement of the possible resumption of 30-year Treasury bond auctions.

[11]`https://www.ice.com/fixed-income-data-services/index-solutions/fixed-income-indices`

[12]A PAC tranche with minimal prepayment risk is issued along with a Support (SUP) tranche with high prepayment risk. The index of SUP tranche returns is CMSZ. Consistent with the fact that SUP tranches have more prepayment risk, Appendix Figure A4 shows that the yields on the SUP tranches are higher than those of the PAC tranches.

Company (FHLMC "Freddie Mac"), the Federal National Mortgage Association (FNMA "Fannie Mae"), and Government National Mortgage Association (GNMA "Ginnie-Mae"). The data related to FHLMC and FNMA CMOs are from Bloomberg and the data for GNMA CMOs are obtained from GNMA data disclosure web page.[13] The data consist of 3,106 individual CMO deals with 140,572 individual tranches. For each tranche, we have an exhaustive array of characteristics, including the CUSIP issue, size, and weighted average life (WAL) calculated at the time of issuance.

Using Bloomberg and GNMA classifications of the tranche types, we remove those CMOs that do not fall within the following three classes of tranche types: planned amortization class (PAC), support tranches (SUP), and sequential pay securities (SEQ). Our final database has 3,082 deals and 84,960 CMO tranches, all falling within these three classes of tranches.[14] Table 1 provides summary statistics for our CMO data.

[Insert Table 1 Here]

Table 1, Panel A presents descriptive statistics for CMO deals in our sample. Each deal has on average $1.8 billion in principal and 45 tranches. Table 1, Panel B shows descriptive statistics for the PAC and SUP tranches in the database. PACs and SUPs comprise the largest class of CMOs in the sample, with 59,453 tranches in this category out of the 84,960 tranches in our sample. Table 1, Panel C shows descriptive statistics for SEQs. These SEQs represent the second largest class of CMOs in the sample with 25,507 tranches.

In our empirical work, we take advantage of the average lives at the issuance of PACs and SEQs. Table 1, Panel B shows that the mean weighted average life of PACs and SUPs is 7.6 years with the first and third quartiles at 3.3 and 11.0 years, respectively. The weighted average life of SEQs is similar to that of PACs with a mean of 7.6 years.

To examine the purchases of agency-CMOs by investors, we gather data on life insurance companies' bond portfolios from the National Association of Insurance Commissioners (NAIC) database. Specifically, we use NAIC Schedule D - Part 1 data, which contain life

[13] https://www.ginniemae.gov/investors/investor_search_tools/Pages/default.aspx

[14] There are hundreds of CMO types in the data. We remove from our data CMOs such as floaters and hybrid CMOs (e.g. IO+PAC) that cannot clearly be assigned to the three classes mentioned above. These CMOs make up a much smaller fraction of the principal amount of CMOs in the data than PAC, SUP, and SEQ. Arcidiacono, Cordell, Davidson, and Levin (2013) describe the many different types of CMOs.

insurance companies' end-of-year bond holdings. These data contain information about the life insurer (e.g., AUM) and extensive information about bond holdings at the CUSIP level for individual life insurance companies. The initial NAIC data are from 1998 to 2007. We remove insurance companies that are not active and keep insurers in the top 500 of assets under management in 1999, which predates the shock. Although there are 1,347 insurers in the sample in 1999, the top 500 insurers control 99.1% of the fixed income assets or $1.4 trillion. This filter prevents the results from being affected by a large number of companies that have a small portfolio.[15] We keep insurers listed as active for a year. Because some holdings are non-US, we use the reported total assets under management of the insurer.[16]

To analyze how preferred-habitat investors responded to the interruption of Treasury bond auctions, we merge both our CRSP Treasury data and CMO data with the NAIC data by CUSIP. The result of this merging of three different data sources is a database with life insurance companies' holdings along with the characteristics of Treasury securities and CMOs in their portfolio. Using these data, we identify purchases by life insurance companies of newly issued Treasuries and CMOs. Each year, we then aggregate these purchases across the CUSIPs in a life insurer's portfolio to calculate the total changes in the life insurance company's holdings of medium- and long-term PACs and SEQs in the sample. Like with the Treasuries, we classify CMOs as medium-term (long-term) that have average lives at issuance of 2 to 10 years (more than 10 years). We use these purchases in Section 3 to analyze the impact of the elimination of the 30-year Treasury bond auction on the CMO holdings of life insurance companies.

Table 2 shows the summary statistics of these purchases by life insurance companies of various types of CMOs and Treasury securities. About 12% (992/8572) of the 8,572

[15] Appendix Figure A3 shows the number of life insurance companies by year in our sample. The number of insurers is exactly 500 in 1999 because we limited the sample to the top 500 insurers by AUM in 1999. The figure shows that the number of insurers decreases during the sample period to 372 insurers in 2007. This decrease of 25.6% is in line with the overall decrease in life insurers of 25.1% documented by the American Council of Life Insurers (ACLI, 2022). (Table 1.7 of the *Life Insurers Fact Book 2022* shows that the number of life insurers is 1347 in 1999 and 1009 in 2007, a 25.1% decrease.) Figure A3 also shows trends in the aggregate size of life insurers' fixed income portfolios during the sample period. In 1999, life insurers managed about $1.4 trillion, and in 2007, despite a decline in the number of life insurers in the sample, life insurers managed about $2.2 trillion.

[16] The structure of NAIC data varies annually, necessitating meticulous assembly of multiyear datasets. For example, the line numbers that reference the total assets under management vary from year to year.

insurer-year observations in the final sample include the purchase of newly issued long-term PACs. The mean purchase amount in a year for long-term PACs is $56 million. About 4% (308/8572) of the observations involve the purchase of a newly issued Treasury bond. The number of new Treasury bond purchases is low because there are no new issuances from 2002 to 2005 because of the suspension. Conditional on an insurer purchasing newly issued Treasury bonds in a given year, the mean purchase amount is $47 million per year. Lastly, approximately 10% of the observations involve the purchase of a long-term SEQ, and the average purchase amount is $47 million.

[Insert Table 2 Here]

To evaluate Proposition 3, which predicts that a shock to the excess demand for Treasuries affects the yields on foreign sovereign bonds because of a change in the risk of the global arbitrageur's portfolio, we follow GHSS and collect daily data on the zero coupon bond yield curves from the central banks of the five foreign countries with traded 30-year bonds at the time of the event (Canada, Eurozone, Great Britain, Switzerland, and Japan). To examine the alternative hypothesis, which is that the yields of foreign bonds change because life insurers are simply demanding more of these foreign safe, long-term bonds, we also examine life insurers' purchases of the national bonds issued by these five countries. We collected the universe of issuances by these countries during our sample period of 1998 to 2007 from Bloomberg.

3 Empirical Results

3.1 Treasury and PAC Prices on the Announcement of the Suspension of 30-Year Treasury Bond Auctions

Proposition 1 predicts that a negative shock to the excess supply of long-term Treasury bonds causes an increase in the prices of long-term Treasury bonds and long-term PACs. To examine this prediction, we investigate the daily returns of US Treasuries and monthly returns of PACs on October 31, 2001, which is when the US Treasury announced the suspension of 30-year Treasury bond auctions. We also examine their returns when the US Treasury announced the possible reversal of the suspension on May 4, 2005. Eventually, 30-year Treasury bond issuances resumed in February 2006.

Figure 2 panel A shows that the mean daily return of long-term 30-year Treasury bonds (time-to-maturity of 25-30 years) weighted by amount outstanding minus the daily weighted return of medium-term Treasury notes (with time-to-maturity from 9 to 10 years) was approximately 2.1% on October 31, 2001 when the Treasury announced the suspension of Treasury bond auctions, which is the largest positive daily return in the sample period 1998 to 2007.[17] This large announcement return is consistent with the results in Bernanke, Reinhart, and Sack (2004). The figure also shows that when the possible reversal of the suspension was announced on May 4, 2005, the returns of Treasury bonds relative to notes were approximately -1.2%. These returns are consistent with the limits to arbitrage mechanism in the model in one of the largest and most liquid markets for safe assets. The identified price movements suggest that arbitrageurs cannot freely absorb shocks in the excess supply of long-term safe assets (VV). In addition, the large effects of a single shock targeted at a specific US Treasury maturity enable us to examine cleanly the spillover effects on the prices and creation of substitute assets, the prices of other Treasury maturities and the prices of bonds in foreign countries.[18]

[Insert Figure 2 Here]

Table 3 evaluates the statistical significance of these market reactions. To do so, we calculate the distribution of the daily difference in the returns between 30-year Treasury bonds and 10-year notes in the period January 1, 1998 to August 30, 2001. This sample period precedes the announcement. Then, we compare the difference in returns on the announcement with the distribution of preceding returns, calculating a t-statistic. The t-statistic is 7.7 for US Treasury bonds on October 31, 2001 when the suspension is announced, and the t-statistic is -4.4 on May 4, 2005 when the possible reversal of the suspension is announced.

[17] We also show on the figure the largest negative return occurred on September 21, 2001, which is the day the markets opened after September 11, 2001 terrorist attacks.

[18] In the appendix, Figure A5 shows that Figure 2 holds for inflation protected TIPS, which helps rule out the inflation expectations changed with the announcement. Figure A6 shows that Figure 2 holds for swap rates.

[Insert Table 3 Here]

Figure 2 panel B shows that the announced suspension of the 30-year Treasury bond had spillover effects on the prices of shorter-duration Treasury securities. The duration of a newly issued 30-year Treasury bond at the time of the suspension is approximately 15 years. Interestingly, the returns of even bonds with a 2-year duration had significant positive returns on the announcement. The effect increases almost linearly with duration. In VV, the price of interest rate risk changes on the announcement of the suspension of 30-year Treasury bonds, and thus the effect on bond prices depends on the sensitivity to interest rate risk, which duration captures.

Now, we turn our attention to the prices of long-term PACs, around the announcement of the suspension. Table 3 shows the monthly difference in the value-weighted average return for agency PAC bonds with long effective duration (nine or more years) and medium duration (seven to eight years). The medium-term PAC bonds have a duration similar to that of the 10-year Treasury note.[19] The difference in monthly returns on the day of the announcement was 3.9% (t-statistic of 4.5). Figure 3 Panel A plots this difference in monthly returns for the sample period, showing that the price move in October 2001 was atypical.[20] Figure 3 Panel B shows that the effect on announcement of the suspension also increases with the duration of the PACs. Together, the large effect on the prices of PACs is consistent with the negative shock to the supply of Treasury bonds resulting in an increased demand for substitute safe assets by habitat investors, a resulting increase in the risk of the mortgage dealer's portfolio, and thus an increase in the price of the safe long-term bond.

[Insert Figure 3 Here]

3.2 CMO Issuances and Habitat Investors

We now examine Proposition 2, which predicts that a negative shock to the excess supply of Treasuries leads to an increase in the issuances of substitutes to fulfill the demand of

[19] In fact, on October 30, 2001, the 10-Year Treasury Note yield to maturity was 4.5% resulting in a duration of between seven and eight years.

[20] Figure A7 shows that the returns of the agency Support tranches do not change with the announcement of the suspension of the 30-year Treasury bond auctions.

habitat preference investors, such as life insurers. We first examine the purchase behavior of life insurers of newly issued CMOs using detailed holdings data. Then, we examine the aggregate issuances of long-term PACs relative to other CMO types during the suspension period.

Consistent with an increase in PAC prices resulting from a negative shock to the excess supply of long-term safe assets by habitat investors, we show that insurance companies increased the amount of long-term PACs in their portfolios during the period with no Treasury bond auctions (no-auction period). We estimate a difference-in-difference specification. The first difference is the change in the principal amount of newly issued medium- and long-term PACs purchased by life insurers during the suspension period, which started in 2002 and ended in 2005, relative to the non-suspension period. The second difference captures differences in this change in PAC holdings between long-term and medium-term PACs. To do so, we estimate the following specification:

$$\begin{aligned} \Delta PAC_{i,j,y} = {} & \beta_1 \times \mathbb{1}(\text{LT}_{i,j}) \\ & + \beta_2 \times \mathbb{1}(\text{No Auction}_y) \\ & + \beta_3 \times \mathbb{1}(\text{LT}_{i,j}) \times \mathbb{1}(\text{No Auction}_y) \\ & + \mu_j + \text{Controls}_{i,j,y} + \epsilon_{i,j,y}. \end{aligned} \tag{6}$$

The dependent variable is the amount of purchases of newly issued medium- or long-term PACs by the insurance company j in year y. We separately aggregate the purchases of medium- and long-term PACs, resulting in two observations (i) per year y for insurance company j. The volume of PACs purchased is in millions of dollars. We classify medium term PACs as those that the have a weighted average life between 2 and 10 years at the time of issuance and long-term PACs as those that have a weighted average life greater than 10 years at the the time of issuance. $\mathbb{1}(\text{LT})_{i,j}$ is an indicator variable equal to one for long-term PACs. $\mathbb{1}(\text{No Auction})_y$ is an indicator variable equal to one for all years starting in 2002, when the US Treasury suspended the bond auction, and ending in 2005, which is the year the US Treasury announced it would resume 30-year Treasury bond auctions in 2006. μ_j is a fixed effect for the insurance company that accounts for all fixed determinants of PAC investment activity by the insurance company j. Controls$_{i,j,y}$ include the amount of newly issued medium- or long-term SEQs i that the insurance company j purchased in year y, which accounts for common factors that account for agency CMO investment in general by insurance company j. We double cluster standard errors by insurer and year.

The key identifying assumption underlying our empirical strategy is that insurance companies' investments in long-term PACs and medium-term PACs would have had similar trends if the US Treasury had not suspended the 30-year bond auction. Figure 4 shows the difference in the amount purchased of newly issued medium- and long-term PACs by life insurers, controlling for the purchases of SEQs. It is clear that the purchases of the two types of PACs had similar activity prior to the suspension of Treasury bond auctions. After the suspension, purchases of long-term PACs increased significantly in 2002 and remained significantly higher through 2005. Purchases of long-term PACs relative to medium-term PACs returned to normal in 2006 when the US Treasury resumed Treasury bond auctions in February 2006.[21]

[Insert Figure 4 Here]

Table 4 shows the estimation results for equation 6. Examining column (2), the β_3 coefficient indicates that the average insurance company increased its long-term PAC purchases during the no-auction period by approximately $14.5 million dollars per year. This finding supports the prediction that securitization occurs, in part, to fill the gap and meet the excess demand for safe assets. Column (6) scales the purchases by the lagged AUM of the insurer, and the result becomes more statistically significant.[22]

[Insert Table 4 Here]

Life insurers may also have substituted their usual purchases of newly issued Treasury bonds with newly issued Treasury notes. Table 4 column (1) explores this substitution. We estimate a difference-in-difference specification in which the first difference is the change in the principal amount of newly issued Treasury notes and bonds purchased by life insurers

[21] Figure A9 shows that Figure 4 is robust to removing the 25 largest insurers by AUM in 1999.

[22] Table A2 repeats Table 4 removing the 25 largest insurers by AUM in 1999.

during the suspension period, which started in 2002 and ended in 2005, relative to the non-suspension period. The second difference captures differences in the change in purchases of bonds (long-term) and notes (medium-term). Column (1) shows that life insurers decrease Treasury bond purchases by $20.9 million and simultaneously increase their purchases of Treasury notes by approximately $15.8 million annually. This indicates that life insurance companies did not completely substitute their bond purchases with notes, resulting in an annual gap of about $5.1 million (20.9-15.8) during the suspension period.[23]

The increase in long-term PAC purchases of $14.5 million in column (2) constitutes about 69.4% of the drop in Treasury bond purchases of $20.9 million shown in column (1) and is similar in scale to the annual gap. Examining the quantities scaled by the size of the insurer, we find a similar magnitude. The increase in long-term PAC purchases relative to the insurer's AUM of 0.23 percentage points in column (6) constitutes about 31.5% of the decrease in Treasury bond purchases of 0.73 percentage points in column (5). Together, these results suggest a strong substitution between Treasury bonds and long-term agency PACs, which is consistent with the anecdotal evidence in Footnote 5.

Next, we perform a placebo test using SEQ purchases and sales by insurance companies. Naturally, insurance companies could use SEQs to invest in bonds with a long weighted average life at issuance. However, if they did, they would be exposed to the risk of prepayments, which could substantially shorten the weighted average life of their SEQs. Therefore, long-term PACs are close substitutes for long-term Treasury bonds, while SEQs are not. Accordingly, we show that insurance companies did not increase the amount of long-term SEQs in their portfolio during the period with no auction for Treasury bonds (no-auction period). To do so, we estimate a difference-in-differences specification similar to equation 6. The first difference is the change in the principal amount of medium and long-term SEQs in insurance company portfolios during the no-auction period which started in 2002 and finished in 2005. The second difference captures differences in this change in SEQs holdings during the no-auction period for long-term and medium-term PACs.

[23]Figure A10 plots a similar event time plot as Figure 4 but examines purchases of newly issued Treasury bonds and notes.

$$
\begin{aligned}
\Delta SEQ_{i,j,y} = {} & \beta_1 \times \mathbb{1}(\text{LT}_{i,j}) \\
& + \beta_2 \times \mathbb{1}(\text{No Auction}_y) \\
& + \beta_3 \times \mathbb{1}(\text{LT}_{i,j}) \times \mathbb{1}(\text{No Auction}_y) \\
& + \mu_j + \text{Controls}_{i,j,y} + \epsilon_{i,j,y}.
\end{aligned} \tag{7}
$$

The outcome variable (SEQ) is the volume of purchases or dispositions of SEQs by the insurance company j in year y. As in Equation 6, we aggregate the amount of medium-term and long-term CMOs, resulting in two observations (i) per year for each insurance company.

Table 4 columns (3) shows the estimation results for equation 7. The coefficient β_3 indicates that the insurance companies did not increase their long-term SEQ purchases during the no-auction period. Figure A11 shows no effect of the suspension on long-term SEQ CMO purchases by insurers. This finding supports the gap-filling reason for securitization.

Another possibility is that life insurers substitute towards long-term foreign government bonds, despite the currency exchange risk and other institutional differences. We explore insurers' purchases of medium-term and long-term foreign government bonds in columns (4) and (8). The results show no significant changes during the suspension period, and if anything, the estimate is negative rather than positive. This finding suggests that insurers as habitat investors do not move funds internationally in response to the suspension, and thus do not appear to deem foreign sovereign bonds as good substitutes for long-term US Treasuries.

Motivated by the significant price increase of long-term PACs on the announcement of the suspension and the strong substitution by insurers to long-term PACs, we examine whether the arbitrageur responded by issuing more long-term PACs. Figure 5 shows the number of long-term PAC and SEQ issuances by year. In the preperiod, the trends in the number of PAC and SEQ offerings are similar. However, the total number of issuances of long-term SEQs, which have a higher prepayment risk than PACs, increased less than the total number of issuance of long-term PACs between 2001 and 2003. Specifically, the number of PAC offerings increases between 2001 and 2003 from 723 offerings to 1,522 offerings, while the number of SEQ offerings is largely flat (592 offerings in 2001 and 608 offerings in 2003).

[Insert Figure 5 Here]

To examine the significance of these moves, we estimate the following panel regression:

$$\begin{aligned}\text{Issuances}_{i,y} = \beta_1 \times \mathbb{1}(\text{No Auction})_y + \beta_2 \times \mathbb{1}(\text{PAC})_i \\ + \beta_3 \times \mathbb{1}(\text{No Auction})_y \times \mathbb{1}(\text{PAC})_i + \epsilon_{i,y}.\end{aligned} \tag{8}$$

The outcome is either the total number of issuances of security i (PACs or Sequentials (SEQ)) in year y or the total amount of security i issued in year t. Because we aggregate separately for PACs and SEQs, the data have two observations per year. $\mathbb{1}(\text{PAC})_i$ is an indicator variable equal to one if the issued tranche type i is a PAC and equal to zero if the issued tranche type is a SEQ. The sample is limited to long-term tranches with a weighted average life that exceeds ten years at issuance. $\mathbb{1}(\text{No Auction})_y$ is an indicator equal to one for all years starting in 2002, when the US Treasury suspended the 30-year Treasury bond auctions, and ending in 2005, which is the year the Treasury announced that it would resume 30-year Treasury bond auctions in 2006.

[Insert Table 5 Here]

In column (1) of Table 5, the interaction term shows that the number of long-term PAC issuances increased on average for the entire suspension period (2002 to 2005) by about 425 per year relative to the long-term SEQ issuance. In column (2), the interaction term shows that long-term PAC issuance increased on average for the entire suspension period (2002 to 2005) by about $19.4 billion per year relative to long-term SEQ issuance. This increase is comparable to the drop in Treasury bond offerings per year of $16 billion shown in Figure 1. Note that in this analysis we cannot control for medium-term PAC issuance because, naturally, the creation of long-term PACs is mechanically tied to the creation of medium-term PACs because of the sequential structure of PACs (see Section A.1 and Figure A2).[24]

[24] We investigate the convenience premium of PACs with respect to long-term AAA corporate bonds following Krisnamurthy and Vissing-Jorgensen (2012). The convenience premium of PACs is the "option

3.3 Foreign Sovereign Bond Reactions

Proposition 3 predicts that a negative shock to the excess supply of US long-term bonds causes an increase in the prices of long-term foreign bonds. Moreover, the model predicts that the degree to which foreign bond prices change depends on the correlation between US and foreign sovereign bonds.

Consistent with Proposition 3, Figure 6 plots the 30-year zero coupon YTM over time for the five foreign countries with 30-year bonds trading at the time of suspension. The vertical red line marks the suspension date, and one can see that the YTM on 30-year bonds in the Eurozone, Canada, and the United Kingdom fell on announcement. The effect is visibly absent in Japan and Switzerland.

[Insert Figure 6 Here]

Table 6 shows the significance of these declines. We calculate the t-statistic in column (2) by comparing the effect on the announcement day to the distribution of daily changes in the YTM measure by country during the period January 1, 1998 to August 30, 2001 before the announcement of the suspension. We find that the most significant change is in Canada with a drop of 44 basis points (t-statistic -10.1), followed by the Eurozone (Germany) with a drop of 36 basis points (t-statistic -6.7) and Great Britain with a drop of 10 basis points (t-statistic -2.0). Japan and Switzerland have see no meaningful change. We find similar results in columns (3) and (4) when examining the change in the YTM of 30 year bonds less the change in the YTM of 10 year bonds.

[Insert Table 6 Here]

Furthermore, consistent with Proposition 3, column (5) of Table 6 shows that the significance of the effect appears to increase with the correlation of short rates between the

adjusted spread" (OAS) of long-term AAA corporate bonds less the OAS of long-term PAC bonds. The OAS is the difference between the yield of a security that pays fixed interest payments and the current US Treasury rates. Typically, Treasury yields proxy the risk-free rate. We find that the long-term PAC convenience premium increased during the suspension period. Figure A8 shows that there is little convenience premium in the preperiod and a pronounced increase upon announcement of the suspension. The convenience premium remained higher at approximately 50 basis points in 2002 and 2003. Table A1 shows that the higher convenience premium during the suspension period is highly statistically significant.

US and the foreign country. We proxy the correlation of short rates with the correlation of monthly changes in the 1-year YTM in the United States and the foreign country.[25] These findings show that a single shock to the excess supply of the 30-year US Treasury bond has spillover effects on the prices of foreign 30-year government bonds. The findings help address the critique by Greenspan (2005) and Backus and Wright (2007) of the global savings glut hypothesis, which asks how the increased demand for Treasuries from foreign countries can explain the low long-term rates around the world.

Lastly, we take advantage of our single shock to a specific maturity (the 30 year bond) to examine whether the announced suspension had spillover effects on the prices of foreign bonds of shorter maturities, as predicted by VV because of the presence of a global arbitrageur. By contrast, identifying spillover effects across maturities is more challenging to execute in a setting such as Quantitative Easing (QE) because in the QE setting, the shocks to bond supply are across the maturity spectrum and QE was happening concurrently in other countries. Using data from the central banks of the five foreign countries with 30 year bonds trading during the event period, we estimate the following regression:

$$\Delta YTM_{m,j} = \beta_1 \times \rho_j + \sum_{i=3,5,10,20,30} \beta_i \times \mathbb{1}(\text{maturity}_{m,j}{=}i) + \sum_{i=3,5,10,20,30} \gamma_i \times \rho_j \times \mathbb{1}(\text{maturity}_{m,j}{=}i) + \epsilon_{m,j}. \tag{9}$$

The outcome variable is the change on the day of the announcement in the zero coupon YTM of the bond with maturity m in the country j. ρ_j is the correlation of the monthly changes in the YTM of 1-year government bonds in country j with the changes in the YTM of 1-year government bonds in the US. β_i multiples an indicator for whether the YTM is of a bond with maturity m. The indicators are for maturities are 3, 5, 10, 20, and 30 years. The 1-year maturity is the omitted reference. γ_i multiples the interaction of ρ_j with these maturity indicators.

Table 7 column (1) shows, for the five countries with traded 30 year bonds, that the

[25] GHSS proxy the short rate with the yield of sovereign bonds with one year until maturity.

negative effect of the suspension of 30-year US Treasury bonds is significantly stronger for bonds with higher short rate correlations with the US. A one standard deviation increase in the short rate correlation is related to an 8bp larger drop in yields on announcement. Column (2) shows that the yields on bonds with maturities of 10 and 20 years also decreased significantly. The size of the effect appears to increase with the time to maturity of the bond. Relatedly, there appears to be no effect on short-term bonds with maturities of three or fewer years. The adjusted-R^2 of column (2) shows that when accounting for the maturity of bonds and the correlation of short rates, the regression model explains 62.4% of the variation in yields between countries and maturities on the day of suspension. More interestingly, in column (3), we interact the maturities with the short rate correlation and find that the effects are concentrated in the countries with higher short rate correlations. Also, importantly, the adjusted-R^2 increases to 85.6%, indicating that accounting for the interactions of maturity and short rate correlations is important to explain the cross-sectional variation in yield changes on the day of the announcement.

The fact that a big component of the shock to 30 year US bonds transmitted across maturities and countries, in line with the short rate correlations, is consistent with the VV framework and the presence of a global arbitrageur. In other words, we are seeing the shock on the 30 year US bond affecting the yields on 5 year bonds around the world (column 3). It is unlikely that habitat investors requiring 30 year safe assets are substituting towards 5 year bonds in other countries. In fact, as discussed previously, in Table 4 columns (4) and (8) we find no evidence of a major habitat investor shifting funds internationally. This fact is evidence against the alternative mechanism to the global arbitrageur, which is that habitat investors shift funds internationally, and their direct investments are why yields changed internationally. Altogether, these findings motivate future research that examines how models with a global arbitrageur can explain a diverse set of facts.

4 Conclusion

This paper provides evidence of limits to arbitrage in the vast markets for safe assets. This friction is fundamental to the portfolio balance mechanism proposed by Bernanke (2010b). We provide direct evidence that Treasury bond prices increased in response to a suspension of auctions in 2002. At the same time, the prices of foreign long-term bonds increased significantly, rationalizing the critique of the GSG hypothesis as a potential explanation for the Greenspan conundrum by Greenspan (2005) and Backus and Wright (2007). Most importantly, in response to the shock to the excess demand for safe assets, the prices and issuances of close substitutes also increased. Habitat investors, namely life insurers, reduced purchases of Treasury bonds during the suspension period and increased purchases of shorter-duration Treasury notes and the safest long-term agency CMOs. They did not purchase more long-term foreign government bonds. Our setting capitalizes on the suspension of Treasury bond auctions (and its reversal), as well as the heterogeneity in Treasuries and substitutes (Agency CMO tranche types) to provide unusually clean evidence of this mechanism.

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Figure 1: **Total amount of Treasury Notes and Bonds Issued by Year.** Panel A shows the total amount of Treasury notes and bonds issued by year. Treasury notes have a maturity of 1.98 to 10 years. Treasury bonds have a maturity of 10.1 or more years. Panel B shows the dollar amount of bonds issued per year as a fraction of the total amount of notes and bonds issued each year. No Treasury bonds were issued between 2002 and 2005.

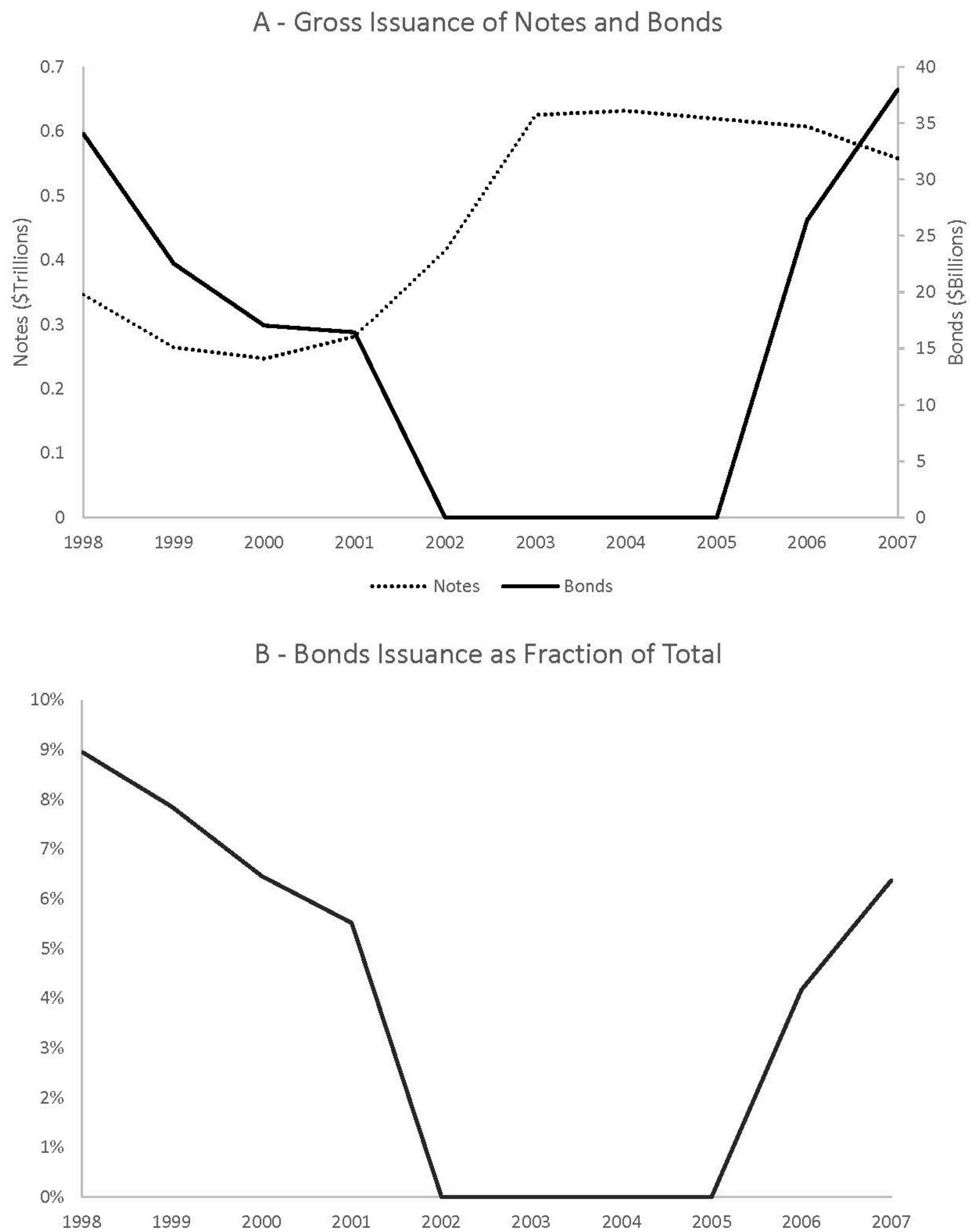
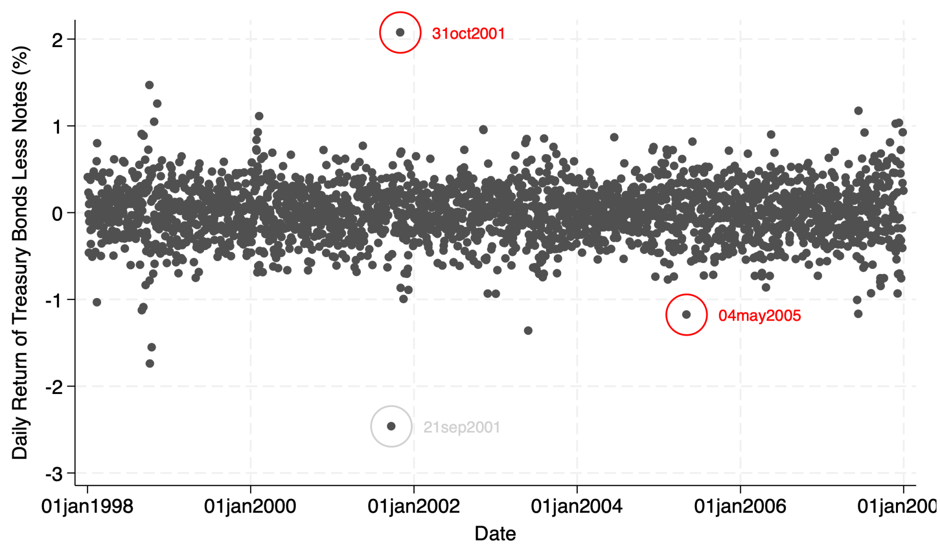
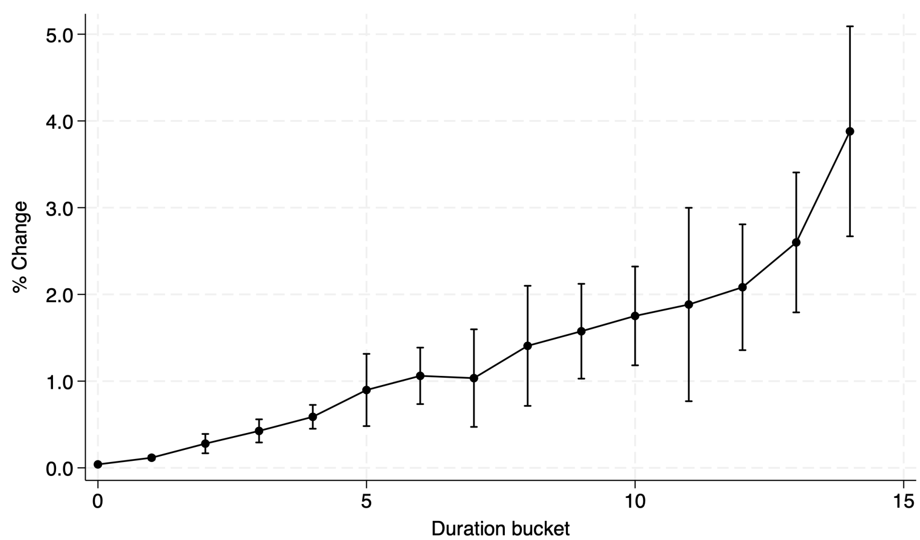


Figure 2: **Daily Treasury Returns and the Suspension.** Panel A shows the daily difference in the returns for Treasury bonds and the returns for Treasury notes. Daily returns for Treasuries are calculated as the price change plus accrued interest and paid interest, divided by the price of the previous day plus accrued interest (TDRETNUA). Treasury bonds have a maturity of 25 to 30 years. Treasury notes have a maturity of 9 to 10 years. We calculate the principal-weighted average of the daily returns of Treasury bonds and notes each day. We circled the data point on October 31, 2001, the day the Treasury announced the discontinuation of the 30-year Treasury bond auctions. We also circled the point at May 4, 2005, the day the Treasury announced the possible resumption of Treasury bond auctions. We also circled the point on September 21, 2001, the day the Treasury market reopened after the September 11, 2001 terrorist attacks. Panel B shows the value-weighted average of the Treasury returns by duration on the announcement of the suspension (October 31, 2001) and the possible resumption of Treasury bond auctions (May 4, 2005). 95% confidence intervals are provided.

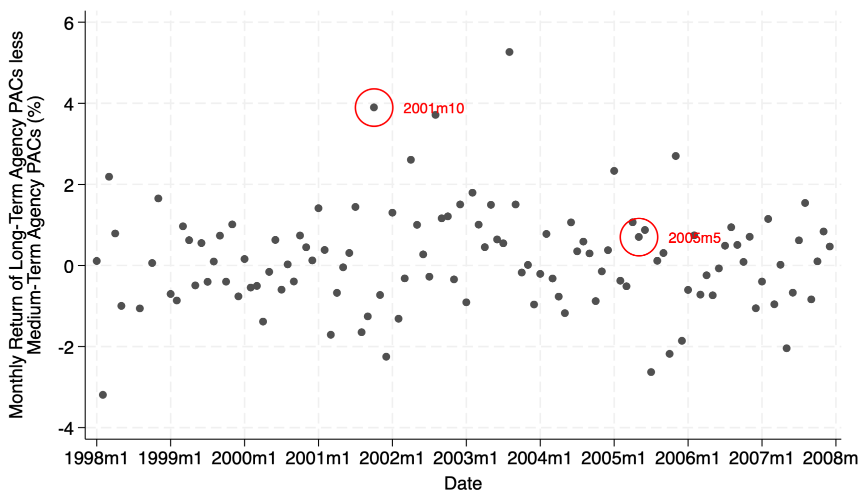


(a) Treasury Returns

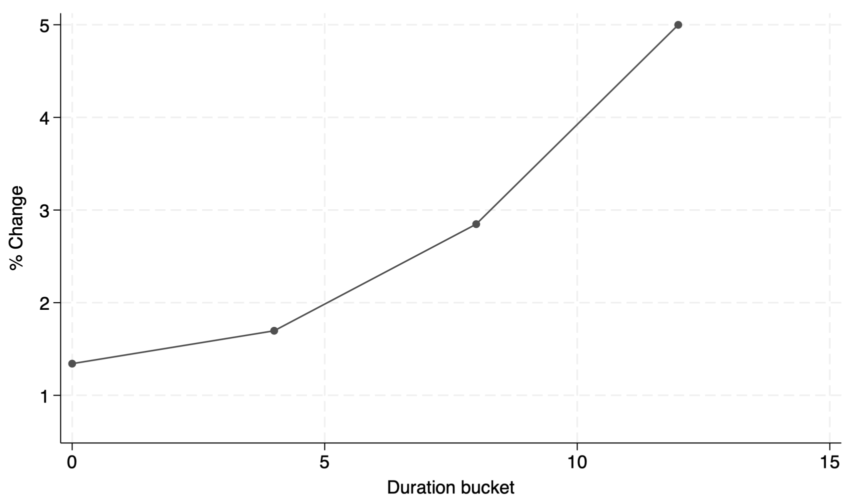


(b) Effect of Suspension on Treasury Returns by Duration

Figure 3: **Monthly PAC Returns and the Suspension.** This figure shows the monthly difference in the returns for long-term and medium-term agency PAC bonds. We use excess returns that adjust for differences in interest rate sensitivity, so that the returns reflect changes in the market value of managing prepayment risk. Long-duration PAC bonds have a duration of nine or more years, while medium-term PAC bonds have a duration between seven and eight years. The medium-term PAC bonds have a duration most similar to that of the 10-year Treasury Note during this period. We circled the month of October 2001 because on October 31, 2001, the Treasury announced the suspension of the 30-year Treasury bond auctions. We also circled May 2005 because on May 4, 2005, the Treasury announced the possible resumption of Treasury bond auctions. Panel B shows the value-weighted average of the PAC returns by duration on the announcement of the suspension (October 31, 2001). We cannot show confidence intervals because the underlying PAC returns are already grouped in the index, which is available by buckets based on duration.



(a) PAC Returns



(b) Effect of Suspension on PAC Returns by Duration

Figure 4: **Effect of Bond Auction Interruption on CMO and Treasury Purchases.** This figure shows that life insurers purchased more newly issued long-term PACs during the period without 30-year Treasury bond auctions relative to purchases of medium-term PACs. We aggregate the purchases of medium-term PACs and long-term PACs separately, resulting in two observations i per year y for each insurance company j. We scale these aggregate purchases by the lagged amount of assets under management of the insurer and multiply by 100. The plot shows the coefficients on the interactions of $\mathbb{1}(\text{Long-Term})_{i,j}$ with year dummies. $\mathbb{1}(\text{Long-Term})_{i,j}$ is an indicator variable equal to one if the transacted tranche type has more than ten years of weighted average life at origination. A control is the purchase of newly issued sequential tranches ($SEQ_{i,j,y}$). The specification includes an insurance company fixed effect to control for fixed differences across insurance companies and a fixed effect for the year. Thus, a 0.5 indicates that 0.5 percentage points more of an insurer's portfolio is allocated to long-term PACs. The vertical lines indicate the start of the suspension of 30-year Treasury bond auctions in 2002 and the year (2005) the Treasury announced it would resume Treasury bond auctions in 2006. We double cluster standard errors by year and insurer. We show the 90% confidence intervals. The specification is column (5) in Table 4.

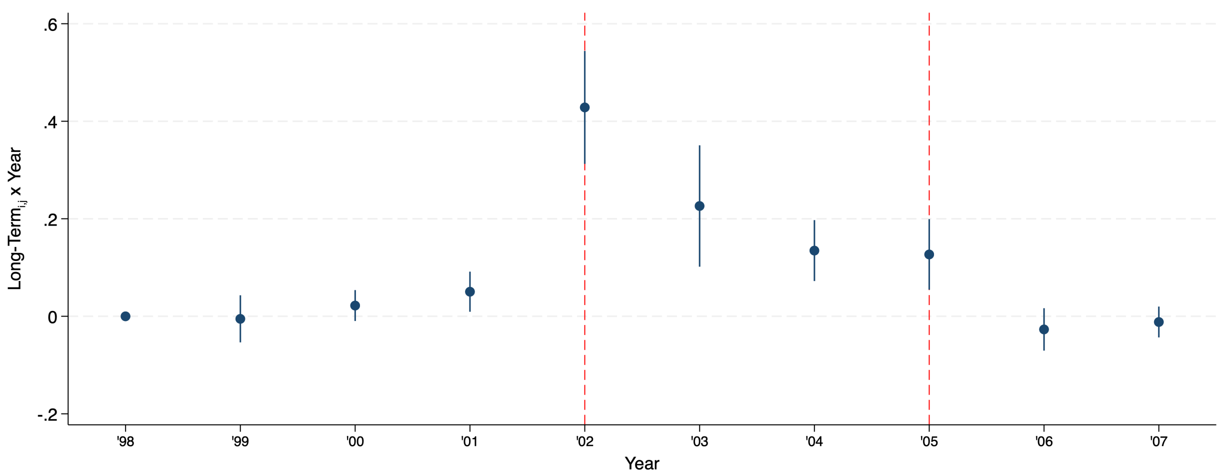


Figure 5: **Issuances of CMOs around the Suspension of Treasury Bond Auctions.** This figure shows the total number of CMO issuances with weighted average life above ten years between 1998 and 2007.

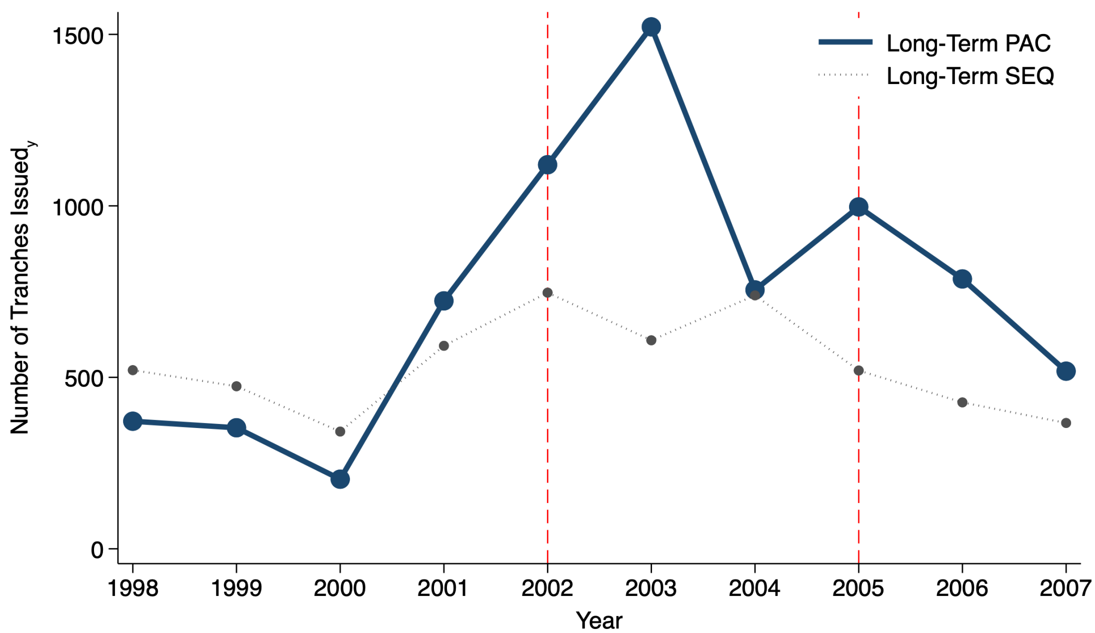


Figure 6: **Effect of the Suspension Announcement on the YTM of 30-Year Bonds in Foreign Countries.** This figure plots the YTM on traded 30-year bonds for the six countries around the announcement of the suspension on October 31, 2001 (marked with a red vertical line) with traded 30 year bonds.

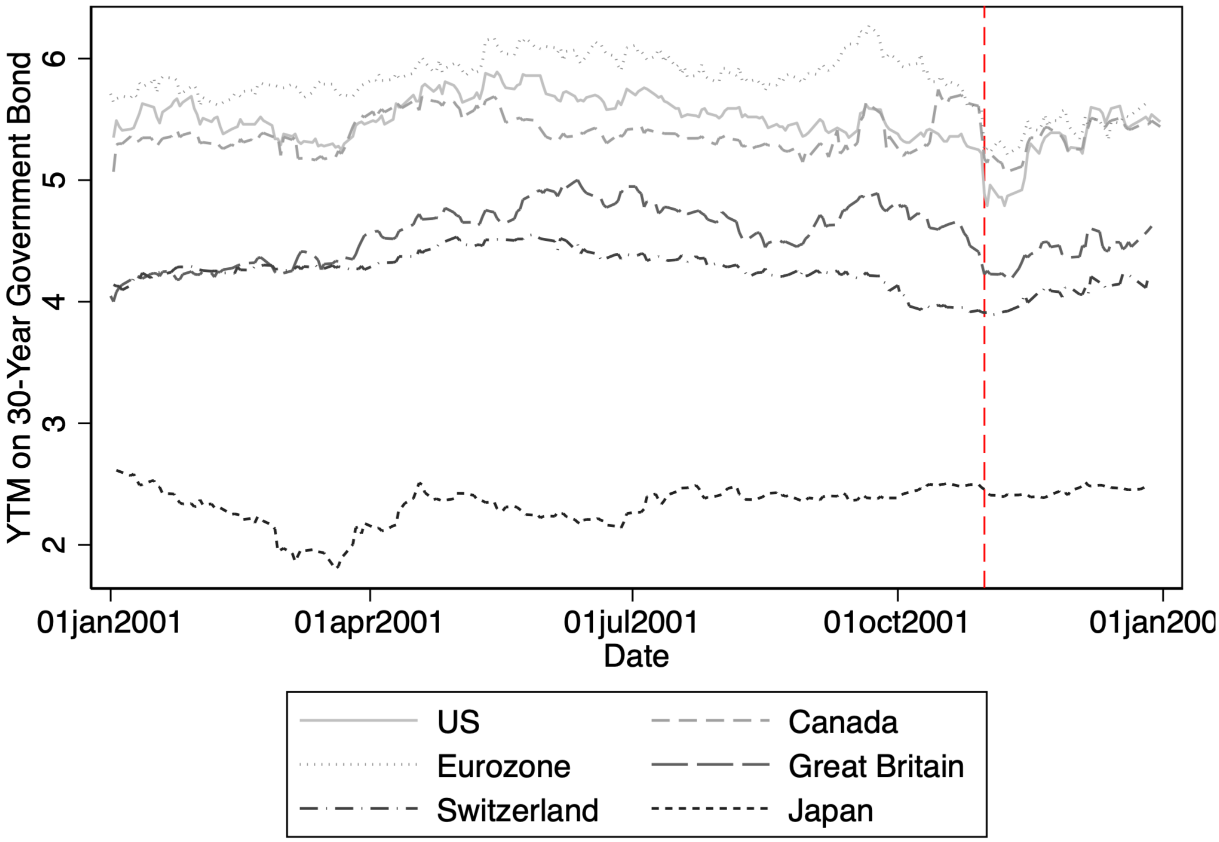


Table 1: **Summary Statistics.** This table summarizes CMO issuances from 1998 to 2007. Panel A describes the data by deal, combining all types of CMO tranche issuances, and Panel B and C break out the summary statistics by PAC/SUP and SEQ tranche types. Winsored at 1%.

	N	Mean	St. Dev.	Q1	Median	Q3
A - CMO Deal						
Total Issuance (Million $)	3082	1835	2449	497	1051	2192
Number of Tranches	3082	45	39	18	35	61
B - PAC/SUP Tranches						
Tranche Amount (Million $)	59453	47	63	8	25	57
Weighted Average Life at Issuance	59453	7.6	5.8	3.3	6.0	11.0
Tranches by Deal	2428	24	22	9	19	33
C - SEQ Tranches						
Tranche Amount (Million $)	25507	75	96	13	36	100
Weighted Average Life at Issuance	25507	7.6	5.2	3.6	5.3	10.9
Tranches by Deal	2227	11	12	4	8	15

Table 2: **Summary Statistics of Life Insurers' Purchases of Newly-Issued Treasuries and CMOs.** This table summarizes the annual purchases of newly issued Treasuries and CMOs in life insurers' portfolios from 1998 to 2007. The sample includes the 500 largest life insurers as of 1999. Medium-term bonds and CMOs have an average life between two and ten years. Long-term bonds have an average life of more than ten years. The estimates are in millions of dollars. We also show the size of the purchases as a percentage of the fixed income portfolio in the prior year. N reflects the number of firm-years with purchases of newly-issued bonds of the specified type. There are 8,572 firm-years in the final sample. For example, insurers purchased newly issued PACs in 11.6% (839/8,572) of firm years.

	PAC					
	N	Mean	St. Dev.	Q1	Median	Q3
Medium Term	839	35.0	89.3	3.6	9.6	26.0
Long Term	992	56.3	124.8	5.0	12.4	45.0
% Medium Term	839	1.4	2.1	0.3	0.8	1.7
% Long Term	992	1.8	2.6	0.3	0.9	2.2
	Treasury					
	N	Mean	St. Dev.	Q1	Median	Q3
Medium Term	1534	46.1	126	1.5	6.1	25.1
Long Term	308	47.4	125.5	2.0	7.0	23.4
% Medium Term	1534	1.8	3.0	0.1	0.6	1.9
% Long Term	308	0.8	1.9	0.1	0.3	0.8
	SEQ					
	N	Mean	St. Dev.	Q1	Median	Q3
Medium Term	807	33.0	72.1	3.3	9.6	25.6
Long Term	832	46.5	93.2	5.0	14.2	40.9
% Medium Term	807	1.0	1.7	0.2	0.5	1.1
% Long Term	832	1.4	2.0	0.3	0.7	1.6

Table 3: **The Suspension of Treasury Bond Auctions and the Returns of Treasury Bonds and PACs**

This table examines the returns on Treasury bonds and PACs when the US Treasury announced the suspension of 30-year Treasury bond auctions on October 31, 2001 at 10AM EST. Treasury returns are daily from CRSP, while PAC returns are monthly from the ICE Bank of America - Merrill Lynch CMO Indices available from the ICE Index platform. For Treasuries, the return is calculated as the price change plus accrued interest and paid interest, divided by the price of the previous day plus accrued interest (TDRETNUA in CRSP). Each day, we calculate the difference in returns for Treasury bonds and Treasury notes. We use the dollar-of-principal weighted average of returns for Treasury bonds maturing in 25 or more years and Treasury notes maturing in 9 to 10 years. We report the return on the announcement of the suspension in column (1) and the t-statistic of that change relative to the prior distribution in column (2). The prior distribution of returns is from January 1, 1998 to August 30, 2001. In columns (3) and (4), we report the return on the announcement of the possible reversal of the suspension and the corresponding t-statistic. For PACs, we use excess returns that adjust for differences in interest rate sensitivity, so that the returns reflect changes in the market value of managing prepayment risk. Each month, we calculate the monthly difference in the value-weighted average return for agency PAC bonds with long effective duration (nine or more years) and medium duration (seven to eight years). The medium-term PAC bonds have a duration similar to that of the 10-year Treasury note. We then calculate the dollar-of-outstanding-principal weighted average return of PACs by whether the PACs are long-term or not. ***, **, and * denote statistical significance at levels 1%, 5%, and 10%, respectively.

	Suspension Announced Oct 31, 2001		Possible Reversal Announced May 4, 2005	
Instrument	Effect (1)	t-stat (2)	Effect (3)	t-stat (4)
Treasury Returns (Daily)	2.08***	7.7	-1.17***	-4.4
PAC Returns (Monthly)	3.90***	4.5	0.70	0.83

Table 4: **Increase in the purchases of long-term PACs, relative to medium-term PACs, with the pausing of 30-year Treasury auctions.** This table shows that life insurers purchased more newly-issued long-term PACs in their portfolios during the period with no auction of 30-year Treasury bonds. In column (1), the dependent variable is the aggregate value of new medium-term and long-term Treasury (UST) purchases made by insurance company j in the fiscal year y. Specifically, we aggregate the purchases of newly issued medium-term Treasuries and newly issued long-term Treasuries separately, resulting in two observations i per year y for each insurance company j. Medium-term Treasuries are notes with time-to-maturity between 1.98 and 10.1 years at issuance, and long-term Treasuries are bonds with a time-to-maturity of more than 10.1 years. In column (2), we construct a similar outcome variable using the weighted-average life (WAL) of insurers' purchases of newly issued medium-term PACs and long-term PCs. We control for the purchase of newly issued sequential tranches in year y ($SEQ_{i,j,y}$). In column (3), the outcome variable is the total dollar amount of purchases (in millions) of newly-issued medium-term or long-term SEQs by the insurance company j in year y. In column (4), the outcome variable is the total dollar amount of purchases (in millions) of newly-issued medium-term and long-term foreign national bonds by the insurance company j in year y. In columns (5) to (8) we repeat columns (1) to (4) after scaling the variables by the dollar size of the insurer's fixed income portfolio at the end of the year $y-1$. $\mathbb{1}(\text{LT})_{i,j,y}$ is an indicator variable equal to one if the transacted tranche type has WAL greater than ten years at origination. $\mathbb{1}(\text{No Auction})_y$ is an indicator that equals one for all years starting in 2002, which is when the U.S. Treasury suspended the 30-year Treasury bond auctions, and ending in 2005, which is when the Treasury announced it would resume 30-year Treasury bond auctions in 2006. Each specification includes an insurance company fixed effect to control for fixed differences between insurance companies. We winsorize purchases at the 1% level. We double cluster standard errors by year and insurer. ***, ** and * denote statistical significance at the levels 1%, 5%, and 10%, respectively.

	$\text{UST}_{i,j,y}$	$\text{PACs}_{i,j,y}$	$\text{SEQs}_{i,j,y}$	$\text{FGB}_{i,j,y}$	$\frac{\text{UST}_{i,j,y}}{\text{AUM}_{j,y-1}}$	$\frac{\text{PAC}_{i,j,y}}{\text{AUM}_{j,y-1}}$	$\frac{\text{SEQ}_{i,j,y}}{\text{AUM}_{j,y-1}}$	$\frac{\text{FGB}_{i,j,y}}{\text{AUM}_{j,y-1}}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\mathbb{1}(\text{LT})_{i,j,y}$	-11.11***	-0.99	4.45**	-0.04	-0.52***	0.03	0.09**	-0.00
	(2.78)	(2.01)	(1.45)	(0.55)	(0.08)	(0.02)	(0.03)	(0.01)
$\mathbb{1}(\text{No Auction})_y$	15.77***	0.65	10.35**	-0.68	0.62***	0.25*	0.25***	-0.02
	(4.83)	(4.26)	(3.33)	(0.52)	(0.15)	(0.12)	(0.07)	(0.02)
$\mathbb{1}(\text{LT})_{i,j,y} \times \mathbb{1}(\text{No Auction})_y$	-20.86***	14.46*	-1.15	1.46	-0.71***	0.23**	0.02	0.01
	(4.90)	(7.66)	(3.30)	(1.11)	(0.14)	(0.08)	(0.06)	(0.01)
$\text{SEQs}_{i,j,y}$		0.89*						
		(0.46)						
$\frac{\text{SEQs}_{i,j,y}}{\text{AUM}_{j,y-1}} \times 100$						0.32***		
						(0.06)		
Constant	16.02***	1.45	2.32	1.56***	0.61***	0.13**	0.08***	0.03***
	(2.20)	(2.02)	(1.28)	(0.32)	(0.06)	(0.05)	(0.02)	(0.01)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
% Adjusted R^2	37.32	35.49	35.09	19.23	17.73	15.28	9.08	7.94
# Years	10	10	10	10	10	10	10	10
# Observations	8572	8572	8572	8572	8566	8566	8566	8566

Table 5: **Increase in long-term PAC issuances relative to long-term SEQ issuances with the suspension of 30-year Treasury auctions.** This table shows that dealers increased the number and amount of long-term PAC issuances during the period with no auctions of 30-year Treasury bonds. Specifically, the sample includes the total issuances of PACs and Sequentials (SEQ) by year y, resulting in two observations i per year. $\mathbb{1}(\text{PAC})_i$ is an indicator variable that equals one if the issued tranche type is a PAC and equals zero if the issued tranche type is a SEQ. The sample is limited to long-term tranches with a weighted average life that exceeds ten years at issuance. $\mathbb{1}(\text{No Auction})_y$ is an indicator that equals one for all years starting in 2002, which is when the U.S. Treasury suspended the 30-year Treasury bond auctions, and ending in 2005, which is when the Treasury announced it would resume 30-year Treasury bond auctions in 2006. ***, ** and * denote statistical significance at the levels 1%, 5%, and 10%, respectively.

	Number of Issuances$_{i,y}$ (1)	Amt. Issued$_{i,y}$ (Billions) (2)
$\mathbb{1}(\text{No Auction})_y$	183.83**	2.71
	(80.51)	(2.14)
PAC$_i$	-92.67	3.79
	(107.08)	(3.73)
$\mathbb{1}(\text{No Auction})_y \times \text{PAC}_i$	425.92**	19.42**
	(198.37)	(8.91)
Constant	556.67***	12.87***
	(50.40)	(1.41)
% Adjusted R^2	51.74	52.55
# Observations	20	20

Table 6: **Foreign Bond Yields and the Suspension of Treasury Bond Auctions**
This table examines whether foreign 30-year bond yields responded to the US Treasury's announced suspension of 30-year Treasury bond auctions on October 31, 2001 at 10AM EST. The sample is limited to countries with 30-year sovereign bonds that trade during the event period. Column (1) reports the change in the 30-year zero coupon bond yield for each country on the announcement day. Column (2) reports the t-statistic for the change, relative to the distribution of the measure from January 1, 1998 to August 30, 2001. Column (3) reports the change in the 30-year zero coupon bond yield less the change in the 10-year zero coupon bond yield for each country on the announcement day. Column (4) reports the t-statistic for the change, relative to the distribution of the measure from January 1, 1998 to August 30, 2001. We also show in column (5) the correlation between the monthly changes of 1-year yields in the US and the changes of 1-year yields in other countries from January 1, 1998 to August 30, 2001. ***, **, and * denote statistical significance at levels 1%, 5%, and 10%, respectively.

	Announcement Effect on 30YR YTM		Announcement Effect on 30-10YR YTM		Correlation of Short Rates
Country	Effect	t-stat	Effect	t-stat	ρ
	(1)	(2)	(3)	(4)	(5)
Canada	-0.44***	-10.1	-0.21***	-5.4	0.75
Eurozone (Germany)	-0.36***	-6.7	-0.21***	-3.3	0.59
Great Britain	-0.10**	-2.0	-0.01	-0.6	0.44
Switzerland	-0.00	-0.1	0.05	0.5	0.36
Japan	-0.02	-0.5	-0.02	-1.0	0.19

Table 7: **The Effect of Suspending 30-year US Treasury Bonds on Foreign Bond Yields by Maturity & Correlation**
This table investigates how the US Treasury's announcement to suspend 30-year Treasury bond auctions on October 31, 2001, at 10 AM EST influenced yields on foreign government bonds, and examines whether this effect differed based on the maturity of the foreign bonds and the correlation of the one-year short rate between the US and the foreign country. The outcome variable is the announcement day's daily change in the yield to maturity for each maturity in a foreign country's zero coupon bond yield curve. Bonds have maturities of 1, 3, 5, 10, 20, and 30 years. ρ is the correlation of the monthly changes in the YTM between the US and each foreign country. We limit the sample to the five foreign countries that have 30-year bonds during the event period in Table 6. We report heteroskedasticity robust standard errors. ***, **, and * denote statistical significance at levels 1%, 5%, and 10%, respectively.

	Δ_t YTM (%)		
	(1)	(2)	(3)
ρ	-0.41***	-0.41***	-0.09***
	(0.09)	(0.07)	(0.02)
maturity=3		-0.02	0.03
		(0.04)	(0.03)
maturity=5		-0.04	0.04
		(0.04)	(0.03)
maturity=10		-0.07**	0.07***
		(0.03)	(0.02)
maturity=20		-0.12**	0.14**
		(0.04)	(0.06)
maturity=30		-0.15**	0.21*
		(0.06)	(0.11)
maturity=3 × ρ			-0.11
			(0.08)
maturity=5 × ρ			-0.17**
			(0.08)
maturity=10 × ρ			-0.32***
			(0.03)
maturity=20 × ρ			-0.57***
			(0.10)
maturity=30 × ρ			-0.79***
			(0.17)
Constant	0.09***	0.16***	0.01
	(0.03)	(0.04)	(0.01)
% Adjusted R^2	45.93	62.40	85.56
# Observations	30	30	30

Internet Appendix to Identifying Demand Effects on the Prices and Creation of Safe Assets

This Internet Appendix contains supplementary analyses. These include the following:

1. Appendix A.1 contains institutional details about agency-CMOs
2. Appendix A.2 contains model details
3. Figure A1 shows the principal cash flows of a mortgage pass-through under different prepayment speeds
4. Figure A2 shows principal cash flows for sequentials and PACs
5. Figure A3 shows the number of life insurers and total AUM by year.
6. Figure A4 shows the yields on PAC and SUP bonds.
7. Figure A5 shows that Figure 2 holds for inflation protected TIPS.
8. Figure A6 shows that Figure 2 holds for swap rates.
9. Figure A7 shows that the returns of the agency Support tranches do not change with the announcement of the suspension of the 30-year Treasury bond auctions.
10. Figure A8 shows the PAC convenience premium relative to AAA corporate bonds during our sample period.
11. Figure A9 shows that Figure 4 is robust to removing the 25 largest insurers by AUM in 1999.
12. Figure A10 shows that Figure 4 is robust to scaling purchases by the insurer's lagged AUM.
13. Figure A11 shows no effect of the suspension on the purchases of long-term SEQ CMOs by insurers.

14. Table A1 examines the change in the PAC convenience premium around the suspension of 30-year Treasury Bond issuances.

15. Table A2 repeats Table 4 removing the 25 largest insurers by AUM in 1999.

A.1 Agency-CMOs

A Collateralized Mortgage Obligation (CMO) is a type of debt security that repackages and directs mortgage principal, interest, and prepayments to different security 'tranches' through a defined set of rules. Underlying agency-CMOs are agency pass-through securities, which provide the investor with a pro-rata share of the monthly mortgage payments from a pool of mortgages held in a trust created by one of the agencies. These are called pass-through securities as the monthly payments of principal, interest, and prepayments from the mortgage pool are "passed through" to the security holder. Pass-through securities are also called participation certificates (PCs). Most collateral for agency-CMOs is fixed-rate mortgage pass-through securities.

In CMOs, a tranche is one of several related securities offered as part of the same transaction. It uses a set of pre-specified rules to redirect cash flows from the underlying pool of mortgage assets to the different bond tranches. The risks and average life of the underlying mortgage collateral is not created or destroyed by structuring tranches. Instead, they are reallocated among the different tranches. For instance, the creation of tranches with more predictable cash flows necessitates the creation of tranches with less predictable cash flows. Similarly, the creation of tranches with a shorter average life than the underlying collateral necessitates the creation of tranches with a longer average life.

Prepayments have a significant effect on the cash flows of pass-through securities. Prepayment speeds are typically defined in terms of the Bond Market Association's prepayment speed standard (PSA).[26] The PSA standard is commonly used as a simple metric to build different prepayment speed scenarios. Recently originated mortgages are less likely to prepay than seasoned mortgages. This seasoning effect on prepayments is captured in the PSA standard. This standard assumes that the annualized principal prepayment rate of a pool of mortgages is equal to 0.2% for one-month old mortgages, increases by 0.2% every month until it reaches 6% for mortgages 30-months old, remaining constant at 6% until the mortgages are paid in full. Figure A1 shows the cash flows of a pass-through under three different PSA scenarios. In all three scenarios, the principal cash flows are at the maximum level when the underlying mortgage pool is 30-months old. This is a natural consequence of the

[26] See, for example, Duarte and McManus (2016)

PSA prepayment speeds. In addition, this creates the hump-shaped pattern that is common in all three scenarios. With 200% PSA, the principal cash flows of the underlying pool are much higher during the first 120 months of the mortgage pool, so the average life of the pool is shorter compared to that with 100% PSA. In contrast, in the 50% PSA scenario, the principal cash flows are spread more evenly over time. This results in an average life for the pool of mortgages that is longer than the one with 100% PSA due to the extension of the mortgage cash flows.

[Insert Figure A1 Here]

A.1.1 Agency-CMO tranche types

The most common agency-CMO tranche types are: Planned Amortization Class (PAC) and Sequential (SEQ) tranches.[27] Sequential (SEQ) tranches have a relatively simple design. In these structures, the first sequential tranche, frequently referred to as an 'A' tranche, receives all the principal payments until it has been paid off. In turn, the second sequential tranche, 'B,' receives all the principal payments until all the principal has been repaid to this tranche. This process continues until all tranches are paid off. Interest is received on the remaining tranche principal. This sequential structure creates tranches that differ in expected maturity. Panel A of Figure A2 shows the cash flows of four sequential tranches (A, B, C, and D) created from one mortgage pool. The cash flows of the mortgage pool in this figure are represented by the hump-shaped line at the top of the four areas. This line is based on the assumption that the prepayment speed of the mortgage pool is 150% PSA. The principal payments of this pool are directed first to the sequential A tranche, then to the B tranche and so forth until all of the mortgage principal is paid. The result is that bond A's weighted-average life is lower than that of bonds B, C, and D. Therefore, investors interested in buying bonds with a very long weighted average life may be interested in bond D. However, all of these sequential tranches are subject to prepayment risk. Indeed, when the prepayment speed of the underlying pool is much higher (lower) than 150% PSA, the weighted-average lives of bonds A, B, C, and D become shorter (longer) than those implied

[27] Interest-only (IO), principal-only (PO) as well as Floaters and inverse floaters are also common agency-CMOs but they are not as common as PAC and SEQs.

in Figure A2, Panel A.

[Insert Figure A2 Here]

By contrast, Planned Amortization Classes (PACs) are tranches whose principal payments are perfectly determined if prepayment speeds stay within certain bands, typically defined in terms of PSAs. Figure A2, Panel B shows the principal payments accruing to four PAC tranches if the prepayment speeds remain within the bands (in this example, from 100% to 250% PSA). The PAC tranches A, B, C, and D will receive principal payments determined by the minimum of the 100 and 250 PSA lines. Because of the relative certainty of cash flows, PAC tranches appeal to investors interested in bonds with low exposure to prepayment risk. For instance, tranche D in Panel B may be attractive to an investor interested in a long-term bond with low prepayment risk.

In order to create a long-term PAC (tranche D in Figure A2, Panel B), short-term PACs (tranches A, B, and C) are created. Analogously, a companion Support (SUP) tranche is created that takes on a disproportionate share of the prepayment risk. Because PAC tranches have lower principal payment volatility, the Support (SUP) tranche must have higher principal payment volatility. Accordingly, the SUP tranche promises a higher yield (See Figure A4). Mortgage hedge funds purchase the SUP tranche and hedge the prepayment risk with swaption contracts. In Panel B of Figure A2, should prepayment rates slow to 100% PSA, then the life of the SUP tranche would extend, receiving principal payments only after about 100 months (the intersection of the 250 and 100 PSA lines on top of tranche C) with these payments shown as the difference between the 100% and 250% PSA lines above the C and D PAC level principal payments. Alternatively, should prepayment rates rise to 250% PSA then the maturity of the SUP tranche would be curtailed, receiving all their principal payments within about 100 months (specifically the wedge of principal payments between the 250 PSA line and the PAC tranches A, B, and C). Because of additional prepayment risk, SUP-tranche investors are compensated by higher yields.

Tranche categories are not mutually exclusive. For example, a sequential tranche can be refined further into principal and interest tranches. It is also common to see different structures mixed within a group to satisfy more complex investor demands.

A.2 Model Details

Our model expands on the framework presented in GHS, adapting it to a scenario with two countries and a mortgage dealer in one of the countries. As in GHS, we consider a three-period world. In the first period, the known short-term domestic (US) interest rate is r_1. The interest rate for the second period is r_2 with mean μ_r and variance σ_r^2. The foreign fixed income market mirrors the domestic market, with respective short-term rates and moments indicated by r_1^{ext}, r_2^{ext}, $\mu_{r^{ext}}$, and $\sigma_{r^{ext}}^2$. The correlation between domestic and foreign short-term interest rates is symbolized by ρ.

Both countries have preferred habitat investors. US preferred-habitat investors exhibit an inelastic demand for US bonds maturing at $t = 3$. The excess supply of bonds with maturity at $t = 3$ is represented by g, which is equal to the amount of bonds the US government issues minus the demand from inelastic preferred habitat investors. A similar dynamic is observed in the foreign market, where the excess supply for long-term bonds is g^{ext}.

The mortgage dealer addresses the excess demand from U.S. preferred habitat investors for bonds maturing at time 3 by issuing Planned Amortization Class (PAC) securities. Specifically, the dealer acquires f dollars worth of mortgage pass-through securities, financed by bonds maturing at time $t = 3$.[28] These bonds, being devoid of prepayment risk, are akin to PACs. The mortgage dealer assumes the prepayment risk for the mortgages financed by these PACs, similar to how a hedge fund would retain a support tranche. The prepayment amount, denoted as (Π_2), is reinvested at the interest rate r_2, while the non-prepaid portion $(1 - \Pi_2)$ accrues interest at rate c. Consequently, the mortgage dealer's profit at time t_3, derived from financing mortgages with PACs, is calculated as $f \times (1 + M_I - 1/P)$, where P represents the price of the zero-coupon bond maturing at time 3. Here, $M_I = (1 - \Pi_2)c + (\Pi_2 + c)r_2$ signifies the value at time 3 of the interest paid on \$1 of mortgage principal from time 1 to 3. The term M_I has a mean of μ_M and a variance of σ_M^2. Accordingly, the mortgage dealer's wealth at time 3 is expressed as $W = f \times (1 + M_I - 1/P)$. The mortgage dealer's objective is to maximize the mean-variance utility of terminal wealth:

[28] For the sake of simplicity, our model does not incorporate short-selling constraints. That is, when the excess supply of bonds is positive ($g > 0$), mortgage dealers are allowed to short sell mortgage pass-throughs for investing in long-term bonds. Our primary focus, however, remains on scenarios where there is a negative excess supply for bonds.

$$\max_f E[W] - \frac{1}{2\theta}\sigma_W^2 \tag{10}$$

Here, θ symbolizes the mortgage dealer's risk tolerance. The primary condition for optimization yields $f = (1 + \mu_M - 1/P)/\eta_f$, with $\eta_f = \sigma_I^2/\theta$ representing the risk penalty inherent to the mortgage dealer's problem. For simplicity and without loss of generality, we assume that prepayment is not priced, $1 + \mu_M = (1 + \mu_r)(1 + r_1)$, leading to the following equation:[29]

$$f = \frac{(1 + r_1)(1 + \mu_r) - 1/P}{\eta_f} \tag{11}$$

Drawing parallels to Greenwood, Hanson, Stein, and Sunderam (2023), our model incorporates a yield curve arbitrageur adept in capitalizing on arbitrage opportunities within the yield curves of both countries. This term-structure arbitrageur addresses the excess demand for U.S. long-term domestic bonds by selling long-term bonds at a price P and reallocating the proceeds at the short-term interest rate. This approach is termed the domestic yield-curve strategy. Let's assume the arbitrageur sells $\$h$ worth of these long-term bonds. Consequently, the excess return generated by this domestic strategy is quantified as $rx_3 = [(1 + r_1)(1 + r_2) - 1/P]$. In a similar vein, the arbitrageur allocates h^{ext} to the foreign yield curve strategy with return given by $rx_3^{ext} = [(1 + r_1^{ext})(1 + r_2^{ext}) - 1/P^{ext}]$.

Moreover, the term-structure arbitrageur also has access to the currency strategy, involving short-term borrowing in domestic currency and short-term lending in foreign currency. The arbitrageur allocates h^q to this strategy with profitability: $rx_3^q = -Q_1(1 + r_1)(1 + r_2) + Q_3(1 + r_1^{ext})(1 + r_2^{ext})$, where Q_t is the dollar price of one unit of the foreign currency at t.

In line with the approach described in Greenwood, Hanson, Stein, and Sunderam (2023), let us denote $\mathbf{h} = [h, h^{ext}, h^q]'$ as the vector representing the term-structure arbitrageur's holdings in both the domestic and foreign yield-curve strategies, as well as in the currency strategy. Furthermore, the excess return for each of these strategies is encapsulated in the vector $\mathbf{rx}_3 = [rx_3, rx_3^{ext}, rx_3^q]'$. To determine the optimal holdings, the arbitrageurs engage in the following maximization problem:

[29] With priced prepayment, the constant terms in Equations 17 and 19 would differ, whereas the terms multiplying g and g^{ext} would stay the same. These latter terms are crucial for our empirical analysis.

$$\max_{\mathbf{h}} \mathbf{h'}E[\mathbf{rx}_3] - \frac{1}{2\lambda}\mathbf{h'}Var[\mathbf{rx}_3]\mathbf{h} \tag{12}$$

Here, λ signifies the arbitrageur's tolerance for risk, and $Var[\mathbf{rx}_3]$ is the covariance matrix of the excess returns of three arbitrageur's strategies:

$$Var[\mathbf{rx}_3] = \begin{bmatrix} \sigma_r^2 (r_1+1)^2 & \rho\sigma_r\sigma_{r^{ext}} (r_1+1)(r_1^{ext}+1) & Cov(rx_3^q, rx_3) \\ \rho\sigma_r\sigma_{r^{ext}} (r_1+1)(r_1^{ext}+1) & (\sigma_{r^{ext}})^2 (r_1^{ext}+1)^2 & Cov(rx_3^q, rx_3^{ext}) \\ Cov(rx_3^q, rx_3) & Cov(rx_3^q, rx_3^{ext}) & \sigma_Q^2 \end{bmatrix} \tag{13}$$

The first-order condition of this problem leads to the following:

$$E[\mathbf{rx}_3] = \frac{1}{\lambda}Var[\mathbf{rx}_3]\mathbf{h} \tag{14}$$

Consider the vector $\mathbf{g} = [g, g^{ext}, 0]'$, which encapsulates the excess supply: g for domestic bonds, g^{ext} for foreign bonds, and a zero value for the currency, reflecting our assumption of no excess supply for foreign currency for simplicity. The market equilibrium for domestic bonds is expressed by the equation $(f + h = -g)$, acknowledging that mortgage dealers supply f amount of PACs. Consequently, combining the first-order conditions of both the arbitrageur and mortgage dealer, along with the market equilibrium conditions, we arrive at the following equation:

$$E[\mathbf{rx}_3] = \frac{1}{\lambda}Var[\mathbf{rx}_3](-\mathbf{g} - \mathbf{f}) \tag{15}$$

Here, $\mathbf{f} = [f, 0, 0]'$ since the mortgage dealer only supplies CMOs in the domestic market. This equation is solved to determine the values of $1/P$, $1/P^{ext}$, and Q_1. To streamline the solution, we define a risk penalty matrix:

$$\frac{Var[\mathbf{rx}_3]}{\lambda} = \begin{bmatrix} \eta_h & \eta_\rho & \eta_{YQ} \\ \eta_\rho & \eta_{h^{ext}} & \eta_{Y^{ext}Q} \\ \eta_{YQ} & \eta_{Y^{ext}Q} & \eta_Q \end{bmatrix} \tag{16}$$

The yield of the domestic long-term bond is:

$$\frac{1}{P} - (1 + r_1)(1 + \mu_r) = \frac{\eta_f \eta_h}{\eta_f + \eta_h} g + \frac{\eta_f \eta_\rho}{\eta_f + \eta_h} g^{ext} \tag{17}$$

The yield of the foreign long-term bond is:

$$\frac{1}{P^{ext}} - (1 + r_1^{ext})(1 + \mu_{r^{ext}}) + (\frac{\eta_f \eta_{h^{ext}} + \eta_h \eta_{h^{ext}} - \eta_\rho^2}{\eta_f + \eta_h}) g^{ext} + \frac{\eta_f \eta_\rho}{\eta_f + \eta_h} g \tag{18}$$

The issuance amount of PACs, denoted as f, is given by:

$$f = -\frac{\eta_h}{\eta_f + \eta_h} g - \frac{\eta_\rho}{\eta_f + \eta_h} g^{ext} \tag{19}$$

From this solution, we deduce that:

$$\frac{\partial f}{\partial g} = -\frac{\eta_h}{\eta_f + \eta_h} \tag{20}$$

This value notably ranges between zero and one. Furthermore, the proportion of any increase in the excess demand for bonds, which is absorbed by the mortgage dealer, diminishes as her risk penalty ($\eta_f = \sigma_I^2/\theta$) increases. Conversely, it rises with an increase in the risk penalty of the yield-curve arbitrageur, $\eta_h = (1 + r_1)\sigma_r^2/\lambda$. In essence, the mortgage dealer accounts for $\partial f/\partial g$ of each increment in g, while the yield-curve arbitrageur accounts for the remaining $1 - \partial f/\partial g$. This concept is exemplified by the quantity of domestic long-term bonds issued by the arbitrageur (h):

$$h = -\frac{\eta_f}{\eta_f + \eta_h} g + \frac{\eta_\rho}{\eta_f + \eta_h} g^{ext} \tag{21}$$

The dollar price of one unit of the foreign currency is:

$$Q_1 = \frac{E[Q_3]\,(1 + r_1^{ext})\,(1 + \mu_{r^{ext}})}{(1 + r_1)(1 + \mu_r)} - \frac{\eta_{YQ}(\eta_\rho g^{ext} - \eta_f g)}{(\eta_f + \eta_h)(1 + r_1)(1 + \mu_r)} + \frac{\eta_{Y^{ext}Q} g^{ext}}{(1 + r_1)(1 + \mu_r)} \tag{22}$$

It is worth noting that Equation 22 shares similarities with the foreign exchange rate discussed in Greenwood, Hanson, Stein, and Sunderam (2023). Specifically, the first term on the right-hand side of Equation 22 is akin to the uncovered interest rate parity. Moreover, when mortgage dealers refrain from offering CMOs (considering the limit of the expression as η_f approaches infinity), $\eta_{Y^{ext}} = -\eta_Y$) the second term in Equation 22 becomes:

$$Q_1 = \frac{E[Q_3]\,(1 + r_1^{ext})\,(1 + \mu_{r^{ext}})}{(1 + r_1)(1 + \mu_r)} + \frac{\eta_{YQ}(g^{ext} - g)}{(1 + r_1)(1 + \mu_r)} \tag{23}$$

Figure A1: **Principal Cash Flows of a Mortgage Pass-through under Different Prepayment Speeds.** This figure shows the principal cash flows of a pass-through security with coupon rate 5% under different PSA scenarios. Principal amount at time zero is $100 million. WALA is the weighted average loan age (months) of the loans in the trust backing the mortgage participation certificate (PC). The PSA standard is commonly used as a simple metric to build different prepayment speed scenarios. The PSA standard takes into account the effect of mortgage seasoning on prepayment speeds. This standard assumes that the annual constant prepayment rate of a pool of mortgages is equal to 0.2% for one-month old mortgage loans, increases by 0.2% every month until it reaches 6% at 30 months, remaining constant at 6% until the mortgages are paid in full. The scenario called 100% PSA assumes that the PC has the same prepayment speed as the one given in the PSA standard. The scenario called 200% PSA assumes that the prepayment speed is given by two times the one in the PSA standard, and the 50% by 0.5.

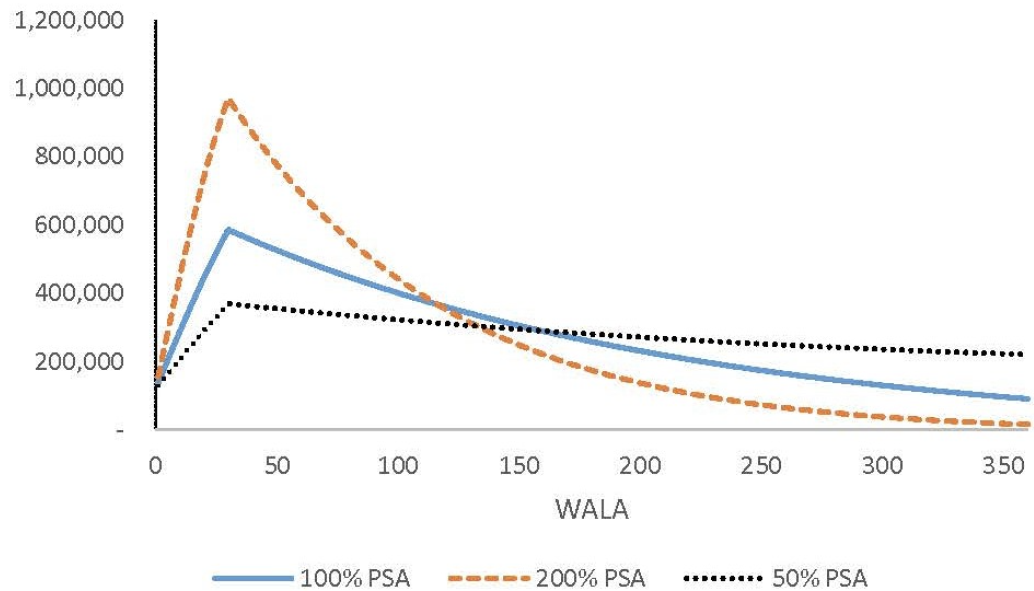


Figure A2: **Principal Cash Flows for Sequentials and PACs.** This figure shows the principal payments of Sequentials and PACs. Panel A displays the cash flows of four Sequentials (A, B, C, and D). The humped shaped line represents the principal cash flows over time of a passthrough with a $100 million dollars unpaid principal under the assumption that prepayment speed is 150% PSA. The lines above the four colored areas are the cash flows that the Sequentials A, B, C, and D receive in case this prepayment scenario realizes. Panel B displays the cash flows of four PACs (A, B, C, and D). In this example, if the underlying pool of mortgages have prepayments between 100 and 250 PSA, the PACs A, B, C, and D receive the principal amount represented by the line in the top of each colored area. The support (SUP) tranche receives the difference between the underlying pool payments and the PAC payments. If the underlying pool prepays at a speed below 100 PSA, the prepayments go in the order of tranches A, B, C, D, and SUP. If the underlying pool prepays at a speed above 250 PSA, once the SUP is extinguished, any payment above 250 PSA go in the order of PAC tranches A, B, C, and D.

Panel A - Principal cash flows for Sequentials

Panel B - Principal cash flows for PACs

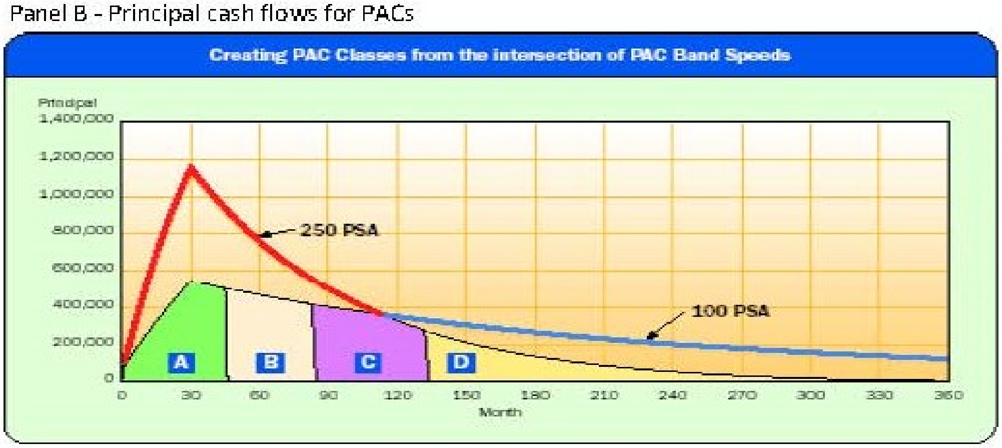


Figure A3: **Life Insurer AUM and Count by Year in the Sample.** We limit the sample to the top 500 life insurers in the U.S. according to the size of their fixed income portfolio at the end of 1999. We plot the aggregate AUM of these life insurers over the sample period from 1998 to 2007. We also plot the number of life insurers remaining in the sample by year. Note that the number of life insurers decreases during our sample period in line with national trends in life insurance. These trends are found in the American Council of Life Insurers *Life Insurers Fact Book 2022*, Table 1.7 (ACLI, 2022).

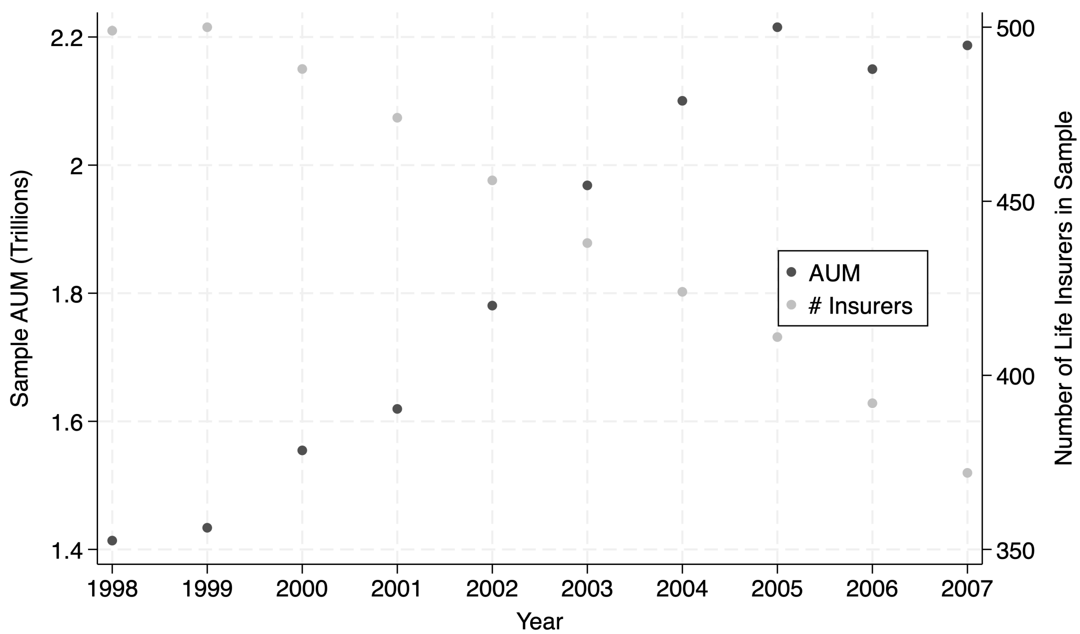


Figure A4: **Monthly Agency PAC vs SUP Tranche Yields.** This figure shows the monthly difference in the weighted average yield for agency PAC bonds and SUP bonds with long duration (more than eight years).

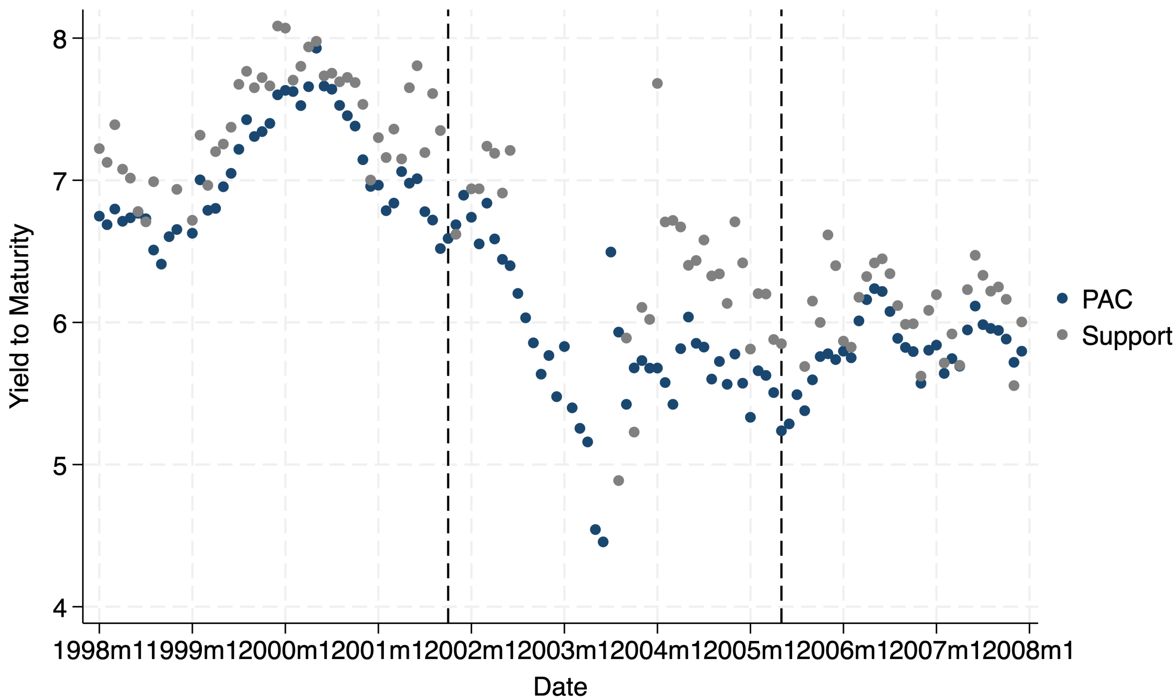


Figure A5: **Daily TIPS Returns.** This figure shows the daily difference in the returns for TIPS bonds and the returns for TIPS notes. Daily returns for TIPS are calculated as the price change plus accrued interest and paid interest, divided by the price of the previous day plus accrued interest (TDRETNUA). We use TIPS bonds with a maturity of 27 to 30 years. We compare the returns of TIPS bonds to the returns of TIPS notes with a maturity of 9 to 10 years. We calculate the principal-weighted average of the daily returns of TIPS bonds and notes each day. We circled the data point on October 31, 2001, the day the Treasury announced the discontinuation of the 30-year Treasury bond auctions. We also circled the point at May 4, 2005, the day the Treasury announced the possible resumption of Treasury bond auctions. Lastly, we circled the point on September 21, 2001, the day the Treasury market reopened after the September 11, 2001 terrorist attacks.

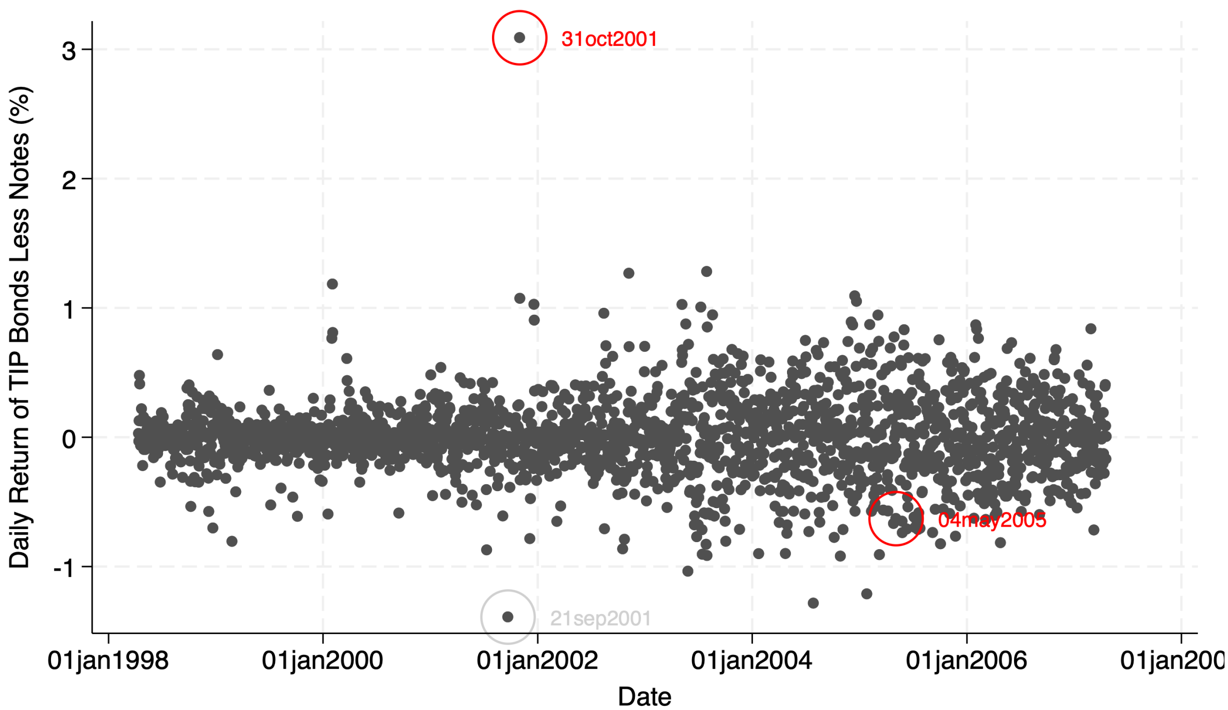


Figure A6: **Daily Changes in SWAP Rates.** This figure shows the daily change in the 30-year SWAP rate less than 10-year SWAP rate. Rate paid by fixed-rate payer on an interest rate swap with maturity of ten years. (Source: St. Louis Fed DSWP10). We circled the data point on October 31, 2001, the day the Treasury announced the discontinuation of the 30-year Treasury bond auctions. We also circled the point at May 4, 2005, the day the Treasury announced the possible resumption of Treasury bond auctions. Lastly, we circled the point on September 21, 2001, the day the Treasury market reopened after the September 11, 2001 terrorist attacks.

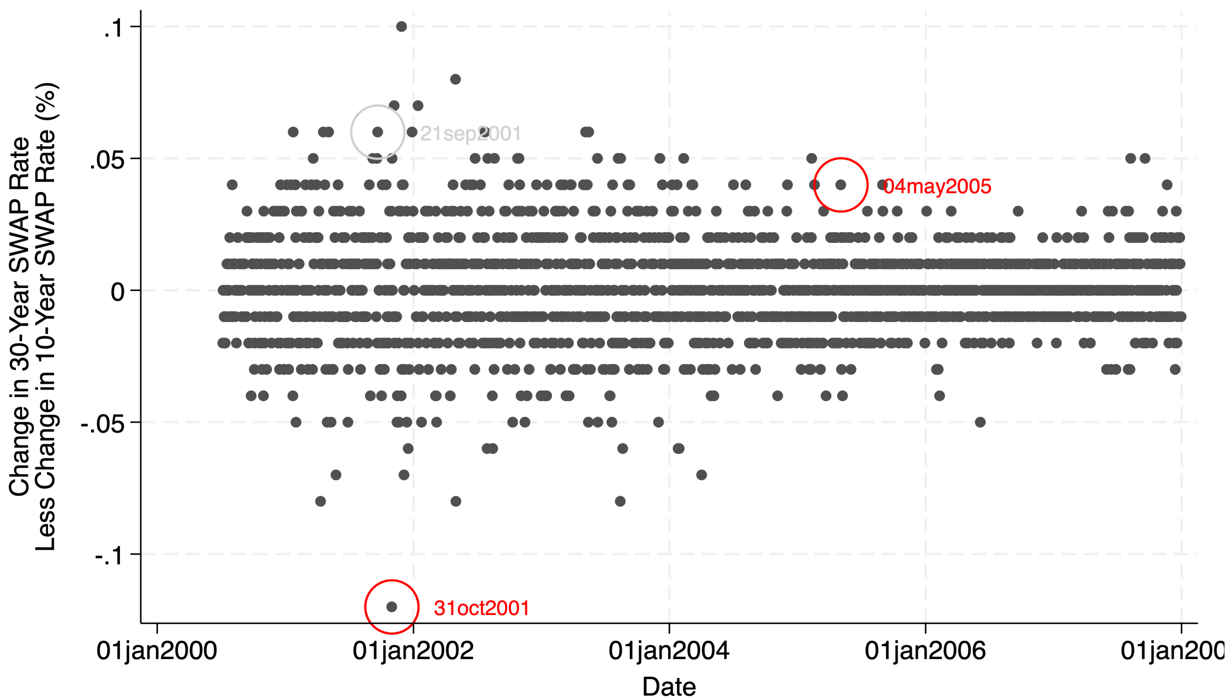


Figure A7: **Monthly Agency Support Tranche Returns.** This figure shows the monthly weighted average returns for agency Support (SUP) bonds. We circled the data point on October 31, 2001, the day the Treasury announced the discontinuation of the 30-year Treasury bond auctions. We also circled the point at May 4, 2005, the day the Treasury announced the possible resumption of Treasury bond auctions.

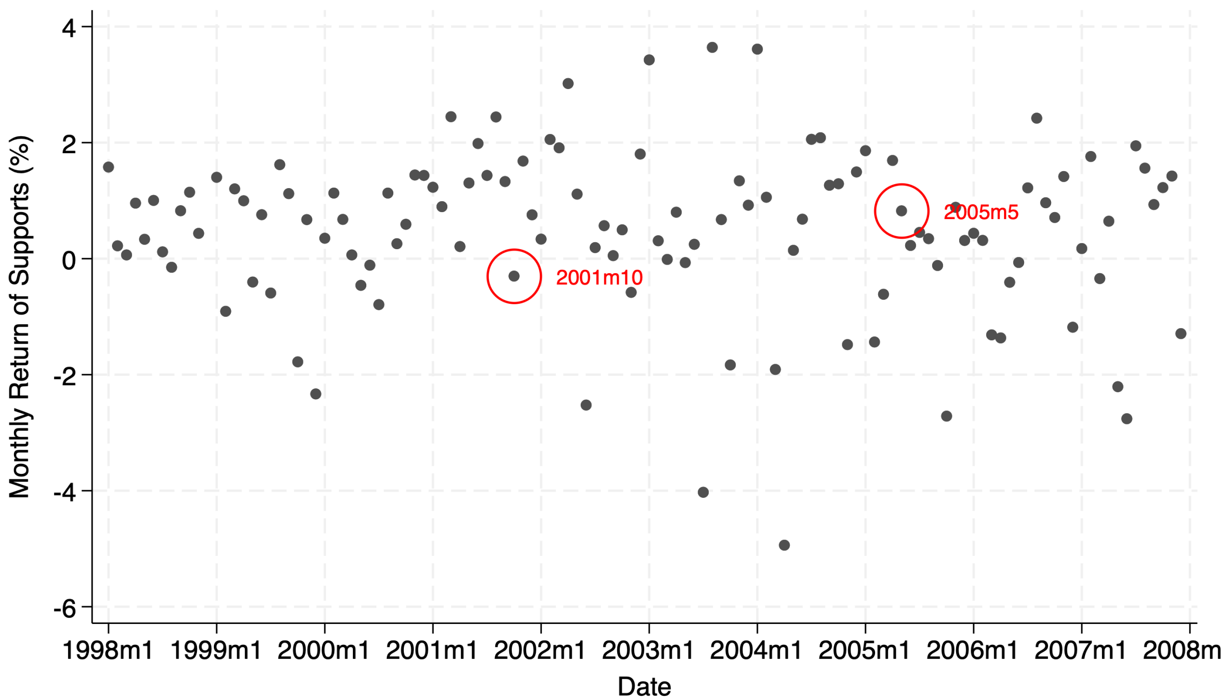


Figure A8: **PAC Convenience Premium.** This figure plots the convenience premium for long-term PACs with more than nine years of duration. The convenience premium is the OAS for AAA long-term corporates minus the OAS for long-term PACs. The option adjusted spread measures the difference in yield between a bond with an embedded option, such as an MBS or callables, and the yield on Treasuries. The long-term AAA corporate bond OAS comes from the ICE Index Platform (C8A1) and for the ICE BofA 15+ Year AAA US Corporate Index. The long-term PAC OAS is the OAS for PACs with a duration of eight or more years. The vertical dashed lines denote the start and end of the treatment period.

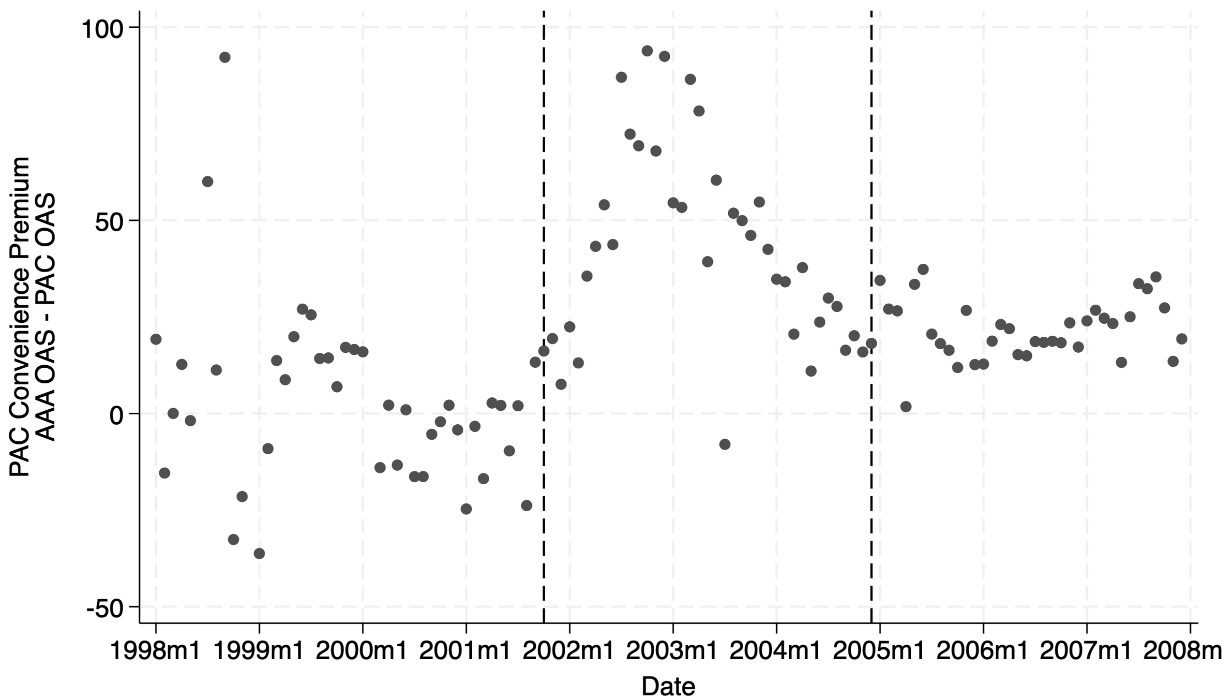


Figure A9: **Effect of Bond Auction Interruption on CMO Purchases (Removes Top 25 Insurers by AUM as of 1999).** This figure repeats Figure 4, removing the top 25 issuers by AUM as of 1999. This figure shows that life insurers purchased more newly issued long-term PACs during the period without 30-year Treasury bond auctions relative to purchases of medium-term PACs. We aggregate the purchases of medium-term PACs and long-term PACs separately, resulting in two observations i per year y for each insurance company j. We scale these aggregate purchases by the lagged amount of assets under management of the insurer and multiply by 100. The plot shows the coefficients on the interactions of $\mathbb{1}(\text{Long-Term})_{i,j}$ with year dummies. $\mathbb{1}(\text{Long-Term})_{i,j}$ is an indicator variable equal to one if the transacted tranche type has more than ten years of weighted average life at origination. A control is the purchase of newly issued sequential tranches ($SEQ_{i,j,y}$). The specification includes an insurance company fixed effect to control for fixed differences across insurance companies and a fixed effect for the year. Thus, a 0.5 indicates that 0.5 percentage points more of an insurer's portfolio is allocated to long-term PACs. The vertical lines indicate the start of the suspension of 30-year Treasury bond auctions in 2002 and the year (2005) the Treasury announced it would resume Treasury bond auctions in 2006. We double cluster standard errors by year and insurer. We show the 90% confidence intervals. The specification is column (5) in Table 4.

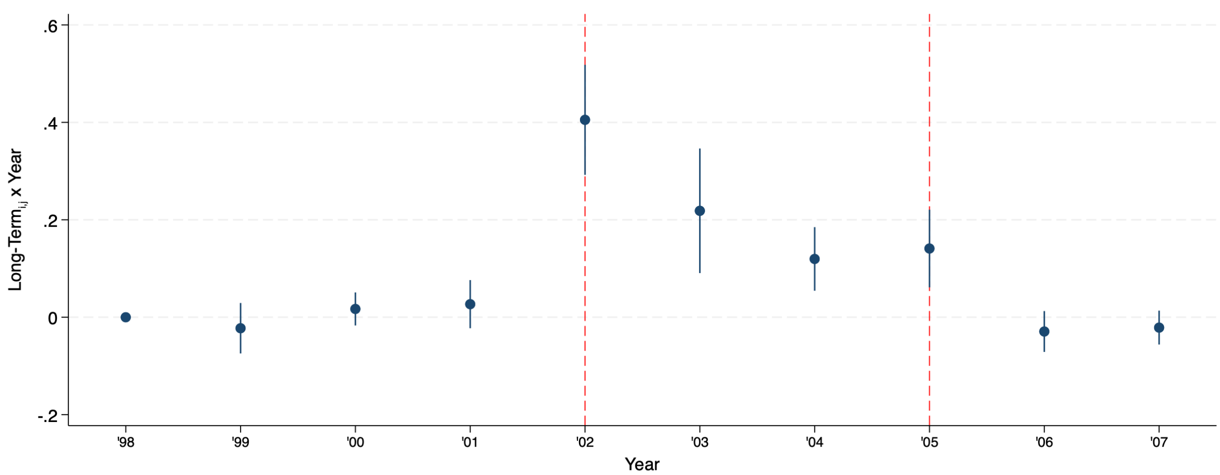


Figure A10: **Effect of Bond Auction Interruption on Treasury Purchases** This figure shows that life insurers (mechanically) decreased purchases of newly issued long-term Treasury bonds during the period without 30-year Treasury bond auctions relative to purchases of Treasury notes. We aggregate the purchases of Treasury notes and Treasury bonds separately, resulting in two observations i per year y for each insurance company j. We scale these aggregate purchases by the lagged amount of assets under management of the insurer and multiply by 100. The plot shows the coefficients on the interactions of $\mathbb{1}(\text{Long-Term})_{i,j}$ with year dummies. $\mathbb{1}(\text{Long-Term})_{i,j}$ is an indicator variable equal to one for newly issued Treasury bonds and equal to zero for newly issued Treasury notes with two to ten years to maturity. The specification includes an insurance company fixed effect to control for fixed differences across insurance companies and a fixed effect for the year. Thus, a 0.5 indicates that 0.5 percentage points more of an insurer's portfolio is allocated to Treasury bonds. The vertical lines indicate the start of the suspension of 30-year Treasury bond auctions in 2002 and the year (2005) the Treasury announced it would resume Treasury bond auctions in 2006. We double cluster standard errors by year and insurer. We show the 90% confidence intervals. The specification is column (4) in Table 4.

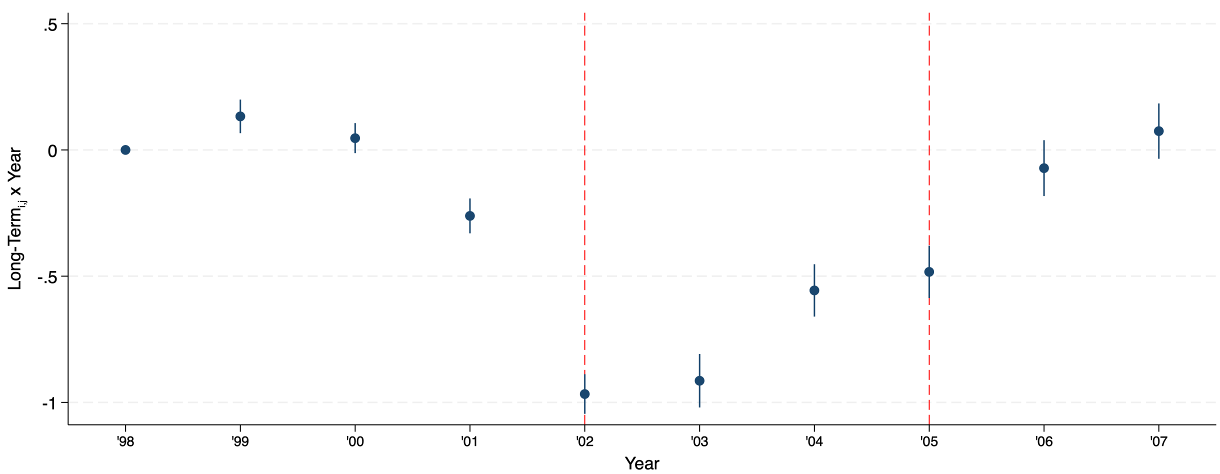


Figure A11: **Effect of Bond Auction Interruption on SEQ Purchases.** This figure shows that life insurers did not purchase more newly issued long-term SEQs during the period without 30-year Treasury bond auctions relative to purchases of medium-term SEQs. We aggregate the purchases of medium-term SEQs and long-term SEQs separately, resulting in two observations i per year y for each insurance company j. $\mathbb{1}(\text{Long-Term})_{i,j}$ is an indicator variable equal to one if the transacted tranche type has more than ten years of weighted average life at origination. The plot shows the coefficients on the interactions of $\mathbb{1}(\text{Long-Term})_{i,j}$ with year dummies. The specifications include an insurance company fixed effect to control for fixed differences across insurance companies and a fixed effect for the year. The vertical lines indicate the start of the suspension of 30-year Treasury bond auctions in 2002 and the year (2005) the Treasury announced it would resume Treasury bond auctions in 2006. We double cluster standard errors by year and insurer. We show the 90% confidence intervals.

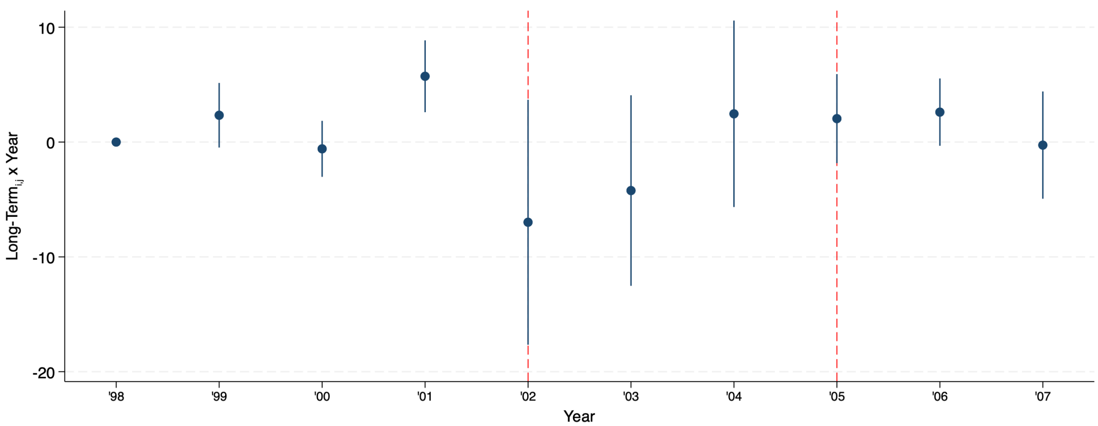


Figure A12: Purchases of Long-Term PACs versus Medium-Term PACs

Table A1: **The PAC Convenience Premium during the Suspension Period**
This table examines the monthly convenience premium for medium-term and long-term PACs around the suspension of 30-year Treasury bond issuances. The PAC convenience premium is the OAS for AAA long-term corporates minus the OAS for medium-term or long-term PACs. The option adjusted spread measures the difference in yield between a bond with an embedded option, such as an MBS or callables, and the yield on Treasuries. The long-term AAA corporate bond OAS comes from the ICE Index Platform (C8A1) and for the ICE BofA 15+ Year AAA US Corporate Index. The medium-term (long-term) PAC OAS is the OAS for PACs with a duration of five-to-seven (eight or more) years. ***, **, and * denote statistical significance at levels 1%, 5%, and 10%, respectively.

	PAC Convenience Premium		
	(1)	(2)	(3)
$\mathbb{1}$(No Auction)$_y$	26.15***	22.20***	23.67***
	(2.34)	(2.70)	(2.11)
$\mathbb{1}$(Long Term)	-4.06*	-7.27***	-7.27***
	(2.25)	(2.78)	(2.69)
$\mathbb{1}$(Long Term) $\times$ $\mathbb{1}$(No Auction)$_y$		7.91*	7.91**
		(4.65)	(3.75)
OAS AAA Corporate Bonds			0.38***
			(0.04)
Constant	16.73***	18.34***	-19.29***
	(1.60)	(1.66)	(4.53)
% Adjusted R^2	35.94	36.48	53.49
# Observations	236	236	236

Table A2: **Increase in the purchases of long-term PACs, relative to medium-term PACs, with the pausing of 30-year Treasury auctions. (Removes Top 25 Insurers by AUM as of 1999)** This table shows that life insurers purchased more newly-issued long-term PACs in their portfolios during the period with no auction of 30-year Treasury bonds. In column (1), the dependent variable is the aggregate value of new medium-term and long-term Treasury purchases made by insurance company j in the fiscal year y. Specifically, we aggregate the purchases of newly issued medium-term Treasuries and newly issued long-term Treasuries separately, resulting in two observations i per year y for each insurance company j. Medium-term Treasuries are notes with time-to-maturity between 1.98 and 10.1 years at issuance, and long-term Treasuries are bonds with a time-to-maturity of more than 10.1 years. In column (2), we construct a similar outcome variable using the weighted-average life (WAL) of insurers' purchases of newly issued medium-term PACs and long-term PCs. We control for the purchase of newly issued sequential tranches in year y ($SEQ_{i,j,y}$). In column (3), the outcome variable is the total dollar amount of purchases (in millions) of newly-issued medium-term or long-term SEQs by the insurance company j in year y. In columns (4) to (6) we repeat columns (1) to (3) after scaling variables by the dollar size of the insurer's fixed income portfolio at the end of the year $y-1$. $\mathbb{1}(\text{LT})_{i,j,y}$ is an indicator variable equal to one if the transacted tranche type has WAL greater than ten years origination. $\mathbb{1}(\text{No Auction})_y$ is an indicator that equals one for all years starting in 2002, which is when the U.S. Treasury suspended the 30-year Treasury bond auctions, and ending in 2005, which is when the Treasury announced it would resume 30-year Treasury bond auctions in 2006. Each specification includes an insurance company fixed effect to control for fixed differences between insurance companies. We double cluster standard errors by year and insurer. ***, ** and * denote statistical significance at the levels 1%, 5%, and 10%, respectively.

	$\text{UST}_{i,j,y}$	$\text{PACs}_{i,j,y}$	$\text{SEQs}_{i,j,y}$	$\frac{\text{UST}_{i,j,y}}{\text{AUM}_{j,y-1}}$	$\frac{\text{PAC}_{i,j,y}}{\text{AUM}_{j,y-1}}$	$\frac{\text{SEQ}_{i,j,y}}{\text{AUM}_{j,y-1}}$
	(1)	(2)	(3)			
$\mathbb{1}(\text{LT})_{i,j,y}$	-6.71***	0.43	1.68***	-0.54***	0.02	0.09**
	(1.18)	(0.46)	(0.46)	(0.08)	(0.02)	(0.03)
$\mathbb{1}(\text{No Auction})_y$	7.66***	2.48	4.79***	0.65***	0.26*	0.25***
	(1.79)	(1.45)	(1.15)	(0.15)	(0.13)	(0.07)
$\mathbb{1}(\text{LT})_{i,j,y} \times \mathbb{1}(\text{No Auction})_y$	-9.28***	6.72**	1.19	-0.73***	0.23**	0.03
	(1.56)	(2.17)	(1.44)	(0.14)	(0.08)	(0.07)
$\text{SEQs}_{i,j,y}$		0.45***				
		(0.10)				
$\frac{\text{SEQs}_{i,j,y}}{\text{AUM}_{j,y-1}} \times 100$					0.31***	
					(0.06)	
Constant	8.40***	1.95**	1.24**	0.63***	0.14**	0.08***
	(1.08)	(0.82)	(0.51)	(0.07)	(0.05)	(0.02)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
% Adjusted R^2	20.32	18.19	17.06	17.59	15.06	8.62
# Years	10	10	10	10	10	10
# Observations	8072	8072	8072	8066	8066	8066