Safe Asset Migration*

Chase P. Ross†

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Abstract

Post-crisis reforms changed the location of safe asset production. I propose a pair of tests to identify who issues safe assets and which safe asset issuers opportunistically time issuance when the price of safe assets is high. The Federal Home Loan Bank (FHLB) system is a newly crucial safe asset producer. FHLB debt issuance is an important determinant of the price of safe assets, and FHLB debt issuance responds to day-to-day fluctuations in the demand for safe assets—measured via the convenience yield. FHLBs issue more after an unexpected increase in the convenience yield and an unexpectedly large FHLB issue decreases the convenience yield. The FHLBs' ability to produce safe assets depends on their implicit government backing, a potential source of concern for future policymakers.

1 Introduction

The US financial system produces money in the form of "safe assets." Money provides a store of value and a transaction medium: essential ingredients of a well-functioning financial system. What qualifies as money is a question of what is safe, but which assets are safe change over time. This paper measures how issuers' safe asset production abilities change over time by examining the link between candidate safe asset issuance and the price of safe assets as measured by the convenience yield.

A safe asset is an asset that is information-insensitive, thereby facilitating the security's use as a store of value and a medium for transactions. Safe assets require government guarantees (e.g., Treasurys or agency debt) or collateral (e.g., mortgage-backed securities). Information-insensitive assets are the most efficient transaction media because they give agents the lowest

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†Yale University. Email: `chase.ross@yale.edu`.

incentive to acquire private information. Uninformed agents can comfortably trade information-insensitive assets without concern for adverse selection.

I classify safe asset issuers along two dimensions: first, what happens to the price of safe assets after a candidate safe asset issuer produces more debt? The subsequent price of safe assets should fall after a safe asset issuer creates more safe assets. Second, does the safe asset issuer opportunistically time their issuance when the price of safe assets is high? I find that the Federal Home Loan Bank (FHLB) system is a newly crucial component in safe asset production: the price of safe assets falls after FHLBs' issuance, and the FHLBs opportunistically time their issuance when the price of safe assets is high. Post-crisis, no other potential safe asset issuer displays both characteristics.

We need to know what is safe and how it changes because it is painful when safe assets become unsafe. The recent financial crisis is a prime example. When investors began questioning the collateral underlying their safe assets—repurchase agreements (repo) collateralized by asset-backed securities (ABS), for example—the safe asset production machine broke down; markets and institutions which depended on safe assets followed shortly after that. Just as economists diligently monitor the size of the economy and construct the national accounts, they should also monitor the production of safe assets.

The most obvious safe assets are US Treasurys and debt from similarly positioned sovereigns. Bernanke et al. (2011) and Pozsar (2011) show global appetite for safe assets grew in lockstep with cash pools like pensions, endowments, corporations, and sovereign wealth funds. Safe asset demand also increased because safe assets are valuable collateral, particularly for repo, a widely used form of collateralized financing. Sometimes there are not enough safe assets, and sometimes safe assets become unsafe: Greek sovereign debt and asset-backed commercial paper (ABCP) both lost their safe asset status at points in the past decade.

When there are not enough Treasurys, cash pools push into agency debt from government-sponsored enterprises (GSEs), including Fannie Mae, Freddie Mac, and the FHLB system. Unlike the US Treasury, the agencies have profit motives but retain an implicit guarantee from the US taxpayer. In 2008, the implicit guarantee for Fannie and Freddie became explicit after the government placed them into conservatorship.

This paper adds to the safe asset literature in three ways: first, I propose a pair of tests to identify who issues safe assets and which safe asset issuers opportunistically time issuance when the price of safe assets is high. Second, I propose a new proxy of the demand for safe assets using the magnitude of Treasury auction tails. I combine the auction tails measure with existing measures of the convenience yield—the OIS-Tbill and GCF-Tbill spreads—to proxy the price of safe assets. I perform the empirical tests using these measures of the convenience yield.

Third, I document the changing role that agency issuers occupy in the production of safe assets. My discussion focuses on the effect of the changes in the regulatory landscape—the conservatorship of the GSEs in 2008, Basel III, and the 2016 money-market mutual fund reforms—and how the changes created a boom in FHLB short-term debt and the relative decline of Fannie Mae and Freddie Mac as important safe asset issuers.

I find the convenience yield responds to FHLB issuance on a day-to-day basis. Since the money-market reforms announced in 2014 and implemented in 2016, FHLB short-maturity issuance drives the convenience yield down; pre-crisis, FHLB issuance had no such effect. Explicitly, a one standard deviation increase in FHLB issuance of $4.7 billion reduces the following day's convenience yield between 0.3 and 0.4 basis points after the money-market fund reforms. The effect is a significant reduction given the seasonally adjusted convenience yield measures average roughly 2.5 basis points.

I also find that the FHLBs—and many other private safe asset issuers—issue debt opportunistically to time fluctuations in the convenience yield and thereby earn the convenience yield. A one standard deviation increase in the seasonally adjusted convenience yield of 14 basis points leads to an increase in FHLB issuance of about $275 million with 4-week to 26-week maturity. Other candidate safe asset issuers behave similarly: ABCP ($200 million) and Freddie Mac ($130 to $160 million) and non-financial CP ($170 million) also display timing behavior.

This paper builds on two threads of the incipient safe asset literature: the first strand studies how the supply of safe assets changes over time. Gorton et al. (2012) document the changing composition of safe assets since the 1970s, shifting from traditional safe assets (bank deposits) to private safe assets (ABS and repo).

The paper also builds on a series of papers that study the incentives for private safe asset producers to satisfy growing safe asset demand. Krishnamurthy and Vissing-Jorgensen (2012) show a scarcity of safe assets relative to GDP—measured by US Treasurys (USTs) outstanding—push the spread between USTs and highly rated corporate bonds higher as investors place a premium on the safety and liquidity uniquely provided by USTs. Gorton (2010), Stein (2012), Sunderam (2015) and Xie (2012) discuss the incentives of private safe asset producers to create short-term money-like liabilities when the demand for money is high, which they empirically confirm in ABCP and ABS markets.

2 Literature Review

There is a well-developed literature on the role of safe assets in an economy. Gorton and Pennacchi (1990) explain that banks exist to create safe debt for use as an information-insensitive medium of exchange. Dang et al. (2015) show that information-insensitive assets are the most efficient transaction media because they give agents the lowest incentive to acquire private information. Therefore, uninformed agents can comfortably trade information-insensitive assets without concern for adverse selection—concern the counterparty has produced private information on the asset. Dang et al. (2017) show banks are optimally opaque to keep their debt trading at par, and thereby keep their debt useful for conducting transactions.

Pozsar (2011) and Bernanke et al. (2011) empirically document the increased demand for safe assets. As the demand for safe assets increased over time, the private sector stepped into the gap to produce private safe assets to help meet the growing demand. Private safe assets can include repo, commercial paper, and some forms of securitized debt. Gorton et al. (2012) find a constant safe asset share relative to the size of the economy over time. However, the composition of safe assets has shifted largely toward privately produced safe assets, reflecting the gradual transition from traditional banking to shadow banking.

Safe assets earn the "convenience yield." As the supply and demand for safe assets fluctuate, the relative price of safe assets varies as well. The price of safe assets is related to the convenience yield, which is the non-pecuniary return to securities that are useful in providing liquidity or safety. Issuers of safe assets can earn the convenience yield: Gourinchas and Rey (2005) show that the annualized difference between the return on assets and the return paid on liabilities for the US in aggregate—an exporter of safe assets—exceeds 2%. The US engages in a massive carry trade; the US finances higher-yielding assets by issuing safe debt, and since the debt is information-insensitive, it earns the convenience yield. Nadauld and Weisbach (2012) show a similar phenomenon at the corporate issuer level: loans that can be securitized cost 17 basis points less to the borrower because highly rated securitizations are private safe assets and earn the convenience yield. Xie (2012) shows that private securitizations are sold into the market when the convenience yield is high, on a day-to-day basis.

Krishnamurthy et al. (2016) show Treasurys are safe because a large amount of Treasury debt outstanding relative to the alternatives leaves investors "nowhere else to go." Krishnamurthy et al. (2019) present a model of safe asset determination: fundamentals of a sovereign issuer and the size of outstanding debt determine which bonds are safe, but the equilibrium depends on whether the demand for safe assets is high or low.

Safe assets play an important role in financial crises and bank runs, as described in Gorton (2016). Historical safe assets include free banknotes backed by state bonds, chartered banknotes backed by loan portfolios, national banknotes backed by Treasurys, and national bank demand deposits backed by bank assets and the creditworthiness of a specific person. Modern private safe assets can include commercial paper, ABS, repos, and money-market funds. Modern safe assets also include agency debt, the focus of this paper.

Money and short-term debt are socially useful creations: everyday life depends on the routine use of almost riskless claims. Bank money and short-term claims are vulnerable to runs precisely because these claims are useful despite being *almost* riskless. As the supply of genuinely safe assets (Treasurys) diminishes relative to the size of the economy, financial vulnerabilities can build when private safe assets turn out riskier than expected in bad times. Stein (2012) and Carlson et al. (2016) examine the monetary policy and financial stability implications of safe asset supply and demand.

Several papers measure the empirical shortage of safe debt by examining trends in the price of safe assets as measured via the convenience yield. Krishnamurthy and Vissing-Jorgensen (2012) show a scarcity of USTs relative to GDP pushes spreads between USTs and highly rated corporate bonds higher as investors place a premium on the safety and liquidity uniquely provided by USTs. Gorton and Muir (2015) show that more repo fails occur when the convenience yield is high. Laarits and Gorton (2018) show the contraction of post-crisis safe asset supply using the GCF-Tbill convenience yield measure. Jiang et al. (2018) show the Treasury basis measures the foreign convenience yield because dollar exchange rates embed foreign investors' expectation of the convenience yield.

Researchers have recently focused on the FHLBs. The first papers to discuss the FHLBs in their current context are Flannery and Frame (2006) and Ashcraft et al. (2010). The latter showed the FHLBs acted as a lender of "next-to-last-resort" during the financial crisis. They show FHLBs' members often preferred to borrow from the FHLBs rather than via the Federal Reserve's stigmatized discount window. Anadu and Baklanova (2017), Gissler and Narajabad (2017a), Gissler and Narajabad (2017b), and Gissler and Narajabad (2017c) show the effect of the money-market mutual fund reforms on flows to FHLBs and the FHLBs' increased reliance on the short-term financing provided by money-market funds.

Gissler and Narajabad (2018) also document the expansion of FHLB short-term debt and show banks use FHLB borrowing as a substitute for deposit funding. Sundaresan and Xiao (2020) provide evidence that liquidity reforms decreased banks' production of short-term safe assets but increased their reliance on borrowing the FHLBs, as the FHLBs are not subject to liquidity regulations. Tarullo (2019) mentions the effect of money-market fund reforms on FHLBs, noting it as a concerning point for policymakers. The FHLB literature constitutes a collective handwringing: that there should be some consternation about where maturity transformation has moved after the crisis, and that the FHLB channel still ultimately depends on implicit government support.

This paper contributes to the literature by estimating the relationships between agency issuance and the price of safe assets to pin down which issuers help determine the price of safe assets, which issuers opportunistically issue in response to a high price of safe assets, and how these two phenomena have changed from pre-crisis to post-crisis.

3 Institutional Context

3.1 Agency Debt

Agency debt stands between USTs and privately produced safe assets on the pecking order of safe assets. Several federal agencies issue debt: the most critical agency issuers include the Federal Home Loan Banks (FHLBs), the Federal National Mortgage Association (FNMA or Fannie Mae), and the Federal Home Loan Mortgage Corporation (FHLMC or Freddie Mac). Other agencies also issue securities, including the Federal Farm Credit Bank System (FFCB), the Tennessee Valley Authority (TVA), and the Government National Mortgage Association (GNMA or Ginnie Mae). While the government guarantees Treasury debt with full faith and credit, most federal agencies' securities are not guaranteed. GNMA mortgage-backed securities carry an explicit guarantee backed by the full faith and credit of the US government; other agencies' debt only carries the implicit backing of the government. Total agency debt outstanding was approximately $1.9 trillion in Q3 2018.

Fannie, Freddie, and the FHLBs issue debt with a maturity of fewer than 12 months, and some issue overnight debt as well. Table 1 shows the outstanding amount of short-term debt from various agency issuers compared to Treasury bills. Pre-crisis, both Freddie and Fannie became relatively large issuers of short-term debt, together peaking at approximately $430 billion compared to a total of $1 trillion of Treasury bills outstanding.[1] Post-crisis, Fannie and Freddie debt outstanding fell to less than $100 billion, whereas the FHLB system surged past pre-crisis levels with outstanding of about $400 billion in 2019.

3.2 The Federal Home Loan Bank System

The Federal Home Loan Banks are a set of closely related but independent banks with the goal of financing housing-related assets to its members, which include banks, credit unions, thrifts, and some insurance companies. Flannery and Frame (2006) and Gissler and Narajabad (2017a, 2017b, 2017c) provide a detailed discussion of the FHLB system's history and operations.

[1] The dramatic increase in outstanding debt for Fannie, Freddie, the FHLBs and the Treasury in 2008 and 2009 is an artifact of actions during the financial crisis.

There are eleven FHLB banks across the country: there were twelve until recently, but the FHLB Seattle merged with FHLB Des Moines in 2015 after residual losses from the financial crisis. The FHLBs' member institutions own each FHLB, and the member institutions must reside within that FHLB's district. Large bank holding companies with operating subsidiaries spanning multiple FHLB districts, however, may belong to many FHLBs.[2] Owners of the FHLBs—the members—retain ownership in the FHLB in the form of six-month or five-year redeemable equity states. Voting rights are not proportional to equity capital: each shareholder has a single vote.[3]

A system-wide balance sheet is presented in Tables 2 and 3 which show the balance sheet in 2007 and 2018, respectively. At the peak in 2007, the entire system held about $1.3 trillion in assets, and in 2018 held approximately $1.1 trillion. Simple leverage in 2018 was 19, with a simple capital ratio (with no risk-weighting) of 5.2%.

This paper focuses on the liability side of the FHLBs. Investors consider FHLB debt safe for three reasons: first, the FHLBs overcollateralize loans to members; second, the "statutory super-senior lien" places FHLBs above all other creditors including the FDIC and Federal Reserve Banks; and third, FHLB debt carries an implicit government guarantee.[4]

FHLB debt carries an implicit government guarantee in part due to the FHLBs' unique legislatively-granted properties: FHLBs are exempt from federal, local and state taxes;[5] the Federal Reserve acts as the fiscal agent for the FHLBs; the FHLBs are considered a "federal instrumentality" and are therefore exempt from the bankruptcy code; the Treasury is allowed to purchase up to $4 billion of FHLB securities; and, regulators allow government money-market funds to purchase FHLB debt.

The FHLB Office of Finance's credit rating webpage includes a discussion of "Strong US Government Support," noting that FHLB debt issuance is subject to US Treasury approval, and that FHLB debt is eligible as collateral for public deposits and investment by national banks and thrifts. Moody's

[2]For example, Bank of America Rhode Island is a member at FHLB Boston, Bank of America California belongs to FHLB San Francisco, and Bank of America Oregon belongs to the FHLB Des Moines (which, in 2015, acquired FHLB Seattle and renamed it the FHLB Des Moines Western Office).

[3]Table A1 shows the number of FHLB members by institution type. The majority are depository institutions, of which commercial banks and credit unions are the largest groups. Insurance companies represented about 8% of total members in 2018. Figure A1 provides the share of commercial bank assets by district. The FHLBs of New York, Cincinnati, Des Moines, and Atlanta are the largest. The large fluctuations in Figure A1 are due to the shifting membership of the largest members. For example, the change in 2011 is Citibank N.A. moving from FHLB San Francisco bank to FHLB New York; the dip in 2012 is JP Morgan Chase Bank N.A. moving from the FHLB New York to FHLB Cincinnati.

[4]Although the super-lien applies to the collateral pledged to the Federal Reserve Banks by FHLB members, the Federal Reserve and FHLBs traditionally agree to preserve the Federal Reserve Banks' seniority position. (Gissler and Narajabad, 2017a).

[5]Despite the special tax treatment, the Financial Institutions Reform, Recovery and Enforcement Act of 1989 imposed system-wide assessments of approximately 25%.

rating of FHLB debt states "any rating actions on the US Government would likely result in all individual FHLBanks' long-term deposit ratings and the FHLBank System's long-term bond rating moving in step with any US sovereign rating action." Standard & Poor's rating notes the FHLBs are a "government-related entity with an almost certain likelihood of extraordinary government support." Combined, these unique characteristics of the FHLB system reinforce its implicit government guarantee.

FHLB liabilities—the focus of this paper—are debt issued by the FHLB system at a variety of maturities, from overnight to 30 years. Debt with a maturity fewer than one year are discount notes ("discos"), whereas debt with a maturity greater than one year are bonds. FHLBs issue debt via a consolidated obligation (CO) joint with all other FHLBs: if a single FHLB cannot pay its CO debt, then the lender has recourse to other FHLB branches. All CO debt is issued centrally by the FHLB Office of Finance, and lenders do not know to which FHLB bank they are specifically lending. For this reason, all FHLBs pay the same rate on their CO debt. In 2018, roughly 40%, $400 billion, of the aggregate FHLB system's liabilities were discount notes with maturities fewer than one year, whereas 60%, about $600 billion, were consolidated obligation bonds.

Figure 1 shows the progression of outstanding FHLB debt. Maturities fewer than six months, but excluding overnight, grew from approximately $50 billion the early 2000s, dramatically spiking to $250 billion as the FHLB system ramped up its efforts to act as lender of "next-to-last" resort, then collapsed in 2008 due to Fannie and Freddie related GSE fatigue. FHLB debt surged post-crisis, moving to a peak of almost $300 billion, although falling from that high through 2018.

There are two types of FHLB assets: advances and investments. Advances are loans to its member institutions, representing 70% of FHLB assets. The FHLBs offer these loans at various rates and structures, and each bank sets the rates and haircuts of its advances. The advances are subject to the statutory super-lien. FHLB investments represent 30% of assets, and focus primarily on housing-related assets (agency and private-label mortgage-backed securities) but include other categories including repo, Federal Funds sold,[6] and commercial paper.[7]

The FHLBs perform regular bank services, although their customers are different from a traditional bank. They borrow at short maturities from

[6]Post-crisis, the FHLB system is a significant player in the Federal Funds market. FHLBs do not earn interest on their reserve accounts at the Federal Reserve because they are a GSE; they instead lend in the Federal Funds market to (mostly) foreign banks who can earn interest on excess reserves (IOER) from the Federal Reserve. The foreign banks effectively arbitrage the spread between IOER and the Fed funds rate, which has averaged about ten basis points since the crisis ended.

[7]Tables A2 and A3 and Figure A2 provide information on the types of collateral the FHLBs accept in their advances, the haircuts for the collateral, and the concentration of advances to the largest members.

creditors—including money-market funds, which will be discussed later in the paper—and they lend the proceeds to members in the form of longer-term advances and also invest in other investment securities. The maturity distribution of advances is important: as of 2018, about 50% of advances have maturities fewer than 1 year, 40% 1 to 5 years, and the remainder greater than 5 years. FHLBs are in the traditional bank business of maturity transformation.

3.3 FHLBs' Systemic Importance

Can an FHLB fail? It is not unimaginable. Gissler and Narajabad (2017c) discuss the question extensively. There are three candidate mechanisms: losses in the advances book, losses in the investment portfolio, or failure to roll over financing. It is unlikely that losses in the advances book pose material risk given the haircuts and super-senior lien FHLBs' hold on collateral. Losses in the investment portfolio represent a potential worry spot, but investments are generally a small share of assets. The FHLBs' underlying business of borrowing short and lending via advances involves significant maturity transformation, and FHLBs may have trouble funding their assets if they lost the ability to issue debt regularly and cheaply. Indeed, in 2008 the FHLBs' creditors pulled back from FHLB debt as they were "guilty by association" with other government agencies—Fannie and Freddie.

The unlikely failure of an FHLB would be particularly concerning since many FHLBs advances go to members without access to the discount window, so members without access to wholesale funding markets would struggle. Ashcraft et al. (2010) describe the FHLB system's role as a lender of "next-to-last" resort, as many banks and thrifts relied on advances from the FHLB system rather than going to the Federal Reserve's traditional lender-of-last-resort facility: the stigmatized discount window.

Additionally, the members own the FHLBs, and so write-downs of FHLB equity would translate to losses at banks—an important difference between the FHLBs compared to Fannie and Freddie, which were public companies. In September 2008, Citi, JP Morgan, Bank of America, and Wells Fargo held $12.4 billion of FHLB equity, and reporting at the time suggested banks considered writing down the value of the equity. (Buhl, 2009). For comparison, the same four banks received $100 billion in public capital injections in the Capital Purchase Program of October 2008. The four largest shareholders in 2019 include JP Morgan, Wells Fargo, PNC, and Metlife (an insurance company). Combined, the top ten shareholders in Q3 2019 hold $8.8 billion of FHLB equity.

One episode is worth mentioning: capital levels at both FHLB Seattle and FHLB Chicago fell from roughly 5% pre-crisis to less than 1% in 2008 as their investment portfolios, composed in part of private-label MBS, sustained losses. FHLBs have two choices to shore up capital levels: they can retain earnings or they can raise capital if more members join their branch. The main mechanism to increase capital levels is via retained earnings since the latter choice is largely out of the FHLBs' control. The FHLB Chicago retained earnings and recovered from its portfolio losses. FHLB Seattle, however, struggled to retain earnings as Washington Mutual simultaneously withdrew both its capital and its business from the bank. After six years of struggling to raise capital, FHLB Seattle merged with FHLB Des Moines. Gissler and Narajabad (2017c) provides additional discussion of this episode.

3.4 Post-Crisis Reforms

Two post-crisis reforms in financial regulations have changed the relative position of the FHLB system in money-markets and have elevated FHLB debt as a new critical safe asset producer. The two recent changes in the money-market structure are Basel III and the money-market mutual fund reforms. I now briefly describe the critical components of these reforms as they related to the FHLBs.

Money-Market Mutual Fund Reforms In the aftermath of the Reserve Primary Fund breaking the buck in September 2008 and the Treasury's subsequent money-market fund guarantee, financial regulators sought to limit the systemic risk of money-market mutual funds (MMFs). The SEC implemented reforms in late 2016 which required funds to report floating net asset values (NAV) unless the fund imposed gates and fees or invested only in government securities. The gate structure allows the fund to temporarily prevent investors' redemptions to cash in times of stress and would (in principle) limit a run from the money fund. Liquidity fees work toward a similar goal by charging a withdrawal fee to slow a run and prevent the money-market fund from fire-selling assets to satisfy panicky redemptions. Retail and government funds can keep $1 NAVs, but institutional funds must have floating NAVs unless they invest in government securities or impose gates and fees.

As discussed in Anadu and Baklanova (2017), the effect of the reform has been a marked shift from prime funds, which invest primarily in commercial paper, toward government funds, since government funds have a fixed $1 NAV but no gates or fees. MMF investors clearly prefer the fixed $1 NAV and the option to run in bad times over the comparatively higher yield offered by prime funds.

FHLB debt is eligible for purchase from government funds, along with Treasurys and other agency securities. Pre-reform, prime funds had $1.7 trillion in assets compared to government funds' assets of less than $1 trillion, as shown in Figure 2. Figure 3 shows the magnitude of the shift caused by the money-market fund reforms, with almost $1.5 trillion—nearly 90% of prime funds' pre-reform assets—moving from prime funds to government funds. As government funds have absorbed this massive inflow, they expanded purchases of government securities, particularly of FHLB debt.

Gissler and Narajabad (2017b) show that the weighted average rate on FHLB debt is ten basis points lower than that of prime money funds after the money fund reforms. Thus, some banks prefer intermediation via FHLB advances rather than commercial paper issuance to money-market funds. Indeed, Figure 4, compiled by Gissler and Narajabad (2017b), shows that the share of MMF assets in FHLB debt has increased from 10% to nearly 40% from 2012 to 2017 and that MMFs hold more than half of FHLB debt.

Basel III Basel III's Liquid Coverage Ratio (LQR) requires that banks hold 30 days equivalent of net cash outflows in high-quality liquid assets (HQLAs), among many other changes. HQLAs must offset any liability with maturity shorter than 30 days. A bank faces the choice of increasing the number of HQLAs they have to cover 30 days of outflows or otherwise push their liabilities' tenor beyond 30 days. The overall effect increases the cost for banks to borrow short. For this reason, banks are less motivated to expand their balance sheet by producing commercial paper and performing matched book repo, which are vital sources of marginal private safe assets.

Gissler and Narajabad (2017b) describe a second, related, effect of Basel III: "collateral upgrading." Large commercial banks increasingly rely on FHLB advances instead of commercial paper because FHLBs provide cheaper financing via collateral upgrading. A simple example: the bank posts a less-liquid asset, like a whole mortgage loan, as collateral for an FHLB advance. The bank then uses the cash proceeds of the FHLB advance to purchase HQLAs. So long as the advance has a maturity greater than 30 days, the bank has increased its LQR.

4 Changing Sources of Safe Assets

A useful way to show the changing sources of safe assets in the post-crisis world is to enumerate the most important paths for cash to flow from cash pools to the ultimate cash user, either on deposit at the Federal Reserve or as use in leverage provision for speculators. I summarize the paths in Figure 5 via a series of asset/liability T-charts; the figure is the most critical figure in the paper, which shows how FHLBs, MMFs, broker-dealers (BDs), and banks intermediate cash flows.

Pozsar (2017) classifies cash pools into two types: "passive" and "active." Active cash pools take serious two mandates "do not lose" and "make money;" the active pools include actively managed corporate treasuries or hedge funds. Passive pools—pensions, many corporate treasuries—focus on the "do not lose" mandate and use convenient financial products for cash management.

It is helpful to walk through each path listed in Figure 5 with a brief description:

1. Pre-Crisis Path 1: Passive cash pools use prime money-market funds, and the money-market fund uses the cash proceeds to purchase bank certificates of deposit or commercial paper of various flavors. Banks hence use the MMFs as a source of funding.

2. Pre-Crisis Path 2: Passive cash pools use prime money-market funds, which in turn conducts tri-party repo with their broker-dealer; the broker-dealer uses the repo as the liability side of its matched booked repo book and passes the funding on to its levered clients, like hedge funds, which in turn use the cash proceeds to speculate.

3. Pre-Crisis Path 3: Active cash pools speculate across Tbills, bilateral repo, and FX swaps; the last two of which end up as a liability to a broker-dealer which then intermediates the flows on toward fast money investors.

The most important parts of this most important figure are the green balance sheet items: these represent *private safe asset production.* The basic function of banks is to produce an information-insensitive liability that is useful as a transaction medium and store of value, just as described in Gorton and Pennacchi (1990). The production of information insensitivity assets in this figure takes the form of banks' commercial paper, tri-party, and bilateral repo. The passive cash pools are not performing serious information production (i.e., credit or market risk analysis) on the collateral or counterparty in these transactions. They may not even have the ability to do so. Instead, passive cash pools use the products because they are information-insensitive and thus are simple to use. Describing how these green line-items have relocated in the financial system is the main focus of this paper.

The post-crisis paths correspond to their pre-crisis equivalents, but now reflect the various changes caused by new financial regulations. There is also a new path, Post-Crisis Path 4, which is a result of the Federal Reserve's new monetary policy framework.

1. Post-Crisis Path 1: Passive cash pools use government money-market funds instead of prime funds due to the gates and fees requirement of the money-market reforms; the government money-market fund uses the cash proceeds to purchase, among other things, FHLB debt; FHLBs use this funding to provide advances to banks, which in turn use the advances as a source of funding. *Government* MMF*s and*

FHLBs *have replaced prime* MMFs*; and—just like prime* MMFs *before the reforms—government* MMFs *and* FHLBs *ultimately fund banks.*

2. Post-Crisis Path 2: Passive cash pools use government money-market funds, which in turn enter into tri-party repo with their BDs; the BD uses the repo as the liability side of its matched booked repo book and passes the funding on to its levered clients, like hedge funds, which in turn use the cash proceeds to speculate. This path is unchanged from its pre-crisis equivalent, except that it is more expensive for the BD to expand its balance sheet and so the transaction is less appealing, ceteris paribus, to the MMF.

3. Post-Crisis Path 3: Active cash pools speculate across Tbills, bilateral repo, and FX swaps; the last two of which end up as a liability to a BD which then intermediates the flows toward fast money investors. Again, this path is unchanged from its pre-crisis equivalent except that it is more expensive for the BD to expand its balance sheet.

4. Post-Crisis Path 4: Passive cash pools use government money-market funds, which can sidestep their BD counterparties and directly use the Federal Reserve's repo facility. This transaction was not available pre-crisis due to changes in the Federal Reserve's monetary policy implementation. The transaction is, all else equal, not preferred by money funds because tri-party repo is relationship-based, and therefore MMFs would prefer to intermediate via their traditional counterparties. (Pozsar, 2017).

The orange and red boxes in post-crisis path two through four show the precise links which are more expensive–or otherwise disfavored—and therefore limits that path's relative importance. Contrast the colored boxes on the bottom of the figure with where private safe assets are produced, shown in green. The reforms severely diminished tri-party repo, bilateral repo, and commercial paper. Post-crisis, FHLB debt plays a new and crucially important role in private safe asset production.

Government money funds do not only buy FHLB debt: they buy Treasurys, other agencies' debt, and engage in repo backed by government debt. However, FHLB debt has experienced the most substantial growth in volume. Additionally, the majority of agency debt—namely Fannie and Freddie—do not use their debt issuance proceeds to finance banks, or do so only indirectly, as Fannie and Freddie guarantee mortgages rather than provide advances to banks.

Table 4 shows the changing role of the FHLBs compared against Fannie and Freddie by showing the debt outstanding by tenor by agency. Pre-crisis in 2007, Fannie and Freddie had debt outstanding of approximately \$1.5 trillion compared to FHLB debt of \$1 trillion. In 2017, Fannie and Freddie debt outstanding fell more than 60% to $632 billion, with more significant drops in short-term debt. FHLBs, however, issue approximately the same amount, having doubled short-term issuance while reducing long-term debt. Producing safe assets is profitable so long as one can time the convenience yield and use the proceeds to invest in higher-yielding assets. The overall amount of debt outstanding and the creation of short-term agency debt point in the direction of the FHLBs ramping up safe asset production.

One way to see the changing position of the FHLBs in the money-market is to examine the window-dressing pattern in their debt. At month-ends, private safe asset producers (banks, BDs) pay down repo, commercial paper, and other short-term liabilities to lower their reported leverage ratios. This reduction in the supply of private safe assets means that cash-pools must search elsewhere for short-term stores of value for their cash. After the reforms, the FHLBs absorbed a larger share of these month-end flows, which is evident when comparing the difference between the average non-month-end and month-end rate the FHLBs pay on overnight discount notes. If there is no search for safety at month-ends flowing to FHLBs, I would expect this spread to be zero. The spread noticeably jumps as month-end FHLB overnight discount note yields are pushed down as much as 30 basis points by flows from cash-pools seeking safety beginning in 2016, as shown in Figure 6.

5 Data

The Federal Reserve provides commercial paper data. Price data on when-issued securities is from GovPX. Repo, overnight indexed swap, benchmark Treasury, swap, exchange, and interbank offered rates are from Bloomberg. Issuance and rate data on FHLB discount notes are from the FHLB Office of Finance. Freddie discount note and reference bill data is from Freddie Mac. Issuance for agencies longer than one-year maturity and corporate bond issuance is from Mergent Fixed Income Securities Database. Markit provides credit default swap data. CRSP provides equity and Treasury return data. ABS data is from the Asset-Backed Alert Database. The Treasury's website provides Treasury issuance data.

6 The Convenience Yield

Correctly measuring the price of safe assets, as reflected by the convenience yield, is key to analyzing the issuance patterns of safe asset producers. I consider two benchmark definitions of the convenience yield, and I use both throughout the remaining empirical analysis. To test the validity of these measures I enumerate expectations for the behavior of the convenience yield based on straightforward comparative statics in the supply and demand for safe assets, and then check that each behavior is confirmed empirically with the two proposed measures of the convenience yield.

Measuring the convenience yield is an effort of finding two instruments in which the only difference is their "money-ness" or "collateral-ability." For this reason, the short leg should be a Treasury rate, as Treasurys can both be "spent" as money and are also useful as collateral. The challenge of measuring the convenience yield is finding another instrument that is highly liquid and nearly risk-free but cannot be spent or used as collateral like Treasurys. The literature has used three measures of the convenience yield, all based on yield spreads:

$$\text{ConYield}_t^{\text{OIS}} \equiv \text{OIS}_t^{3m} - \text{Tbill}_t^{3m} \tag{1}$$

$$\text{ConYield}_t^{\text{GCF}} \equiv \text{GCF}_t^{3m} - \text{Tbill}_t^{3m} \tag{2}$$

$$\text{ConYield}_t^{AAA} \equiv \text{Aaa Long Maturity}_t - \text{UST Long Maturity}_t \tag{3}$$

Sunderam (2015) measures the convenience yield using Definition 1, which is the spread between similar maturity Tbills and the overnight indexed swap (OIS) rate. The OIS rate is the market-determined fixed rate at which investors can swap the daily fluctuating effective Federal Funds rate for a single fixed-term rate. Duffie and Stein (2015) provide details on the mechanics of the swap. The OIS rate reflects the market's expectation for the average effective Federal Funds rate over the maturity of the swap, responding both to fluctuations in the Federal Funds markets from reserve scarcity and also fluctuations due to changes in the Federal Reserve monetary policy stance. The OIS is somewhat biased due to risk aversion to changes in interest rates, but this is a small matter for short maturity contracts. Finally, while OIS transactions are collateralized to limit counterparty risk, the underlying reference rate—the effective Federal Funds rate—is itself unsecured.

The appeal of Definition 1 as a measure of the convenience yield is that only one leg moves around as the supply of Treasurys fluctuates, and OIS instruments cannot be spent or easily used as collateral for other transactions or otherwise rehypothecated. Therefore, fluctuations in the relative appeal of Treasurys—after stripping out the level of interest rates embedded in the OIS rate—drive variations in the spread. The main disadvantage to the measure—other than the small risk aversion bias mentioned above—is that the OIS market is small, standing at about $15 billion notional in dollar terms in 2016. Despite this, I will use Definition 1 as one of the two benchmark measures of the convenience yield.

Definition 2 presents the second benchmark measure of convenience yield used in this analysis. The measure, proposed by Xie (2012), uses the reference rate for general collateral repo, which is the general collateral financing (GCF) repo rate. General collateral is a broad classification of securities that are eligible for use as collateral in general collateral repo transactions. I focus on the Treasury GCF in this paper. The eligible collateral in these GCF repos are Treasurys, and therefore credit risk is negligible; collateralization by Treasurys, with a haircut, also negates counterparty risk.

GCF is not as useful as money as Tbills. It is difficult, but not impossible, to rehypothecate GCF repo, and only large institutions can do so. Since the rate is for general Treasury collateral, the aggregate supply and demand for Treasurys affect the GCF rate. Both legs of the spread fluctuate as the demand and supply of Treasurys vary. Nevertheless, the difference in the yield of the GCF repo rate and the Tbill rate largely reflects differences in moneyness, given the minimal counterparty and credit risk. The measure is an attractive complement to the OIS measure given the long time-series history and size of the market: the gross value of GCF repo stood at $700 billion in Q4 2018 and data is available back to 1991. GCF rates are reported as bids and asks, effectively the rates for repo (borrowing) and reverse repo (lending), and I use the average of the two rates as the GCF measure.

For completeness, Definition 3 gives a third measure of the convenience yield used by Krishnamurthy and Vissing-Jorgensen (2012). The measure is useful due to its long time-series. There are myriad differences between long-term US Treasurys and highly rated corporate bonds, only one of which is the degree of moneyness. Therefore, this paper does not use the spread.

Combined, Definition 1 and Definition 2 measure similar phenomena, albeit in different institutional contexts. Table 5 presents summary statistics for the three spreads. In the post-crisis era, $\text{ConYield}_t^{\text{GCF}}$ trades 8 basis points higher than $\text{ConYield}_t^{\text{OIS}}$. A brief discussion of how GCF and OIS trade relative to each other is helpful: in general, GCF should trade below OIS because GCF is secured and OIS is a reference rate for an unsecured rate insofar as effective Fed Funds is unsecured. Flight-to-quality and supply or demand factors for new issue Treasurys will affect GCF but not OIS, as the OIS rate is a form of the market's expectation for interest rates over the life of the swap. If $\text{GCF}_t^{3m} > \text{OIS}_t^{3m}$ likely reasons include the oversupply of Treasury securities or the relative constraint on banks' balance sheets: for example, the reference repo rate traded above the Fed Funds rate during the Savings and Loan crisis.

Table 6 provides the correlation matrix for the three measures in the post-crisis era. The two benchmark measures are closely correlated with a correlation coefficient of 0.54, and somewhat lower correlations between the two benchmark measures and the AAA measure.

The convenience yield has significant seasonality as the demand for safe assets ebbs and flows predictably throughout the year. For example, window-dressing by banks increases the convenience yield at month-ends and quarter-ends. I will seasonally adjust the convenience yield in the following way: I run a rolling regression window over the previous five years (excluding the current day) in which I regress the two measures of convenience yield on week-of-year, day-of-week, month-end, and quarter-end dummies to estimate the seasonal component of the convenience yield. I exclude the crisis period from June 2007 to July 2009 in the rolling estimation as I am only interested in normal seasonal variation in the convenience yield. I then produce the seasonally adjusted convenience yield by subtracting the seasonal component:

$$\text{ConYield}_t^{SA} = \text{ConYield}_t^{NSA} - \text{SeasonalComponent}_t \tag{4}$$

6.1 The Convenience Yield and the Price of Safe Assets

Since the convenience yield reflects the price of safe assets, comparative statics around the supply and demand for safe assets generate straightforward predictions about the behavior of the convenience yield. I summarize these predictions in Table 7, and I check that both benchmark measures of the convenience yield satisfy these a priori predictions.

Ceteris paribus, when the supply of safe assets increases, the convenience yield should decrease; when the supply of safe assets decreases, the convenience yield should increase. The logic produces four predictions for the convenience yield. I now discuss each in turn.

First, when there are more Treasurys outstanding, the convenience yield should be lower, and when the Treasury issues more debt, the convenience yield should fall. Table 8 presents the results for these two predictions, using both the OIS-Tbill and GCF-Tbill spread. The regression excludes a period from 2008 to 2011 when the Treasury conducted the Supplemental Financing Program (SFP) because the Treasury issued bills to drain reserves from the financial system to assist the Federal Reserve's interest rate policy. In regular times, the Treasury does not explicitly issue debt due to money-market conditions, but the SFP is the exception. The regressions confirm our comparative statics prediction.

Second, window-dressing at financial institutions reduces the amount of private safe assets in the economy—in particular, as banks reduce leverage by paying down liabilities like commercial paper and repo—so the convenience yield should increase. Munyan (2015) shows, for example, that non-U.S. banks with relatively low capital ratios remove an average of $170 billion, or 10% of the entire market, from the tri-party repo market before quarter-ends to window-dress. I expect the convenience yield measures to spike at quarter-ends. I run the following regressions:

$$\text{OIS}_t^{3m} - \text{Tbill}_t^{3m} = \alpha + \beta \mathbb{I}_{\text{Quarter-End}} + \theta_t + \varepsilon_t \tag{5}$$

$$\text{GCF}_t^{3m} - \text{Tbill}_t^{3m} = \alpha + \beta \mathbb{I}_{\text{Quarter-End}} + \theta_t + \varepsilon_t \tag{6}$$

in which the dummy is equal to one if the date is in the last week of a quarter-end in March, June, September or December and zero otherwise, and θ_t are year fixed-effects. I run the regression on both the entire time-series available and the sample excluding the crisis. The results are reported in Table 9. The magnitudes show the importance of window-dressing: relative to an average spread of 6 basis points (14 basis points) for the OIS (GCF) measure of the convenience yield, the measure is 1.7 to 2.5 (3.6 to 4.0) basis points higher at quarter-end. The results confirm the intuition that the two benchmark measures of the convenience yield are higher at quarter-ends, consistent with my prediction.

Third, banks produce fewer safe assets like commercial paper and repo in periods in which banks are relatively more constrained—as measured by bank-intermediated arbitrages identified by Boyarchenko et al. (2018)—and the convenience yield should increase. When banks are not constrained and can lever up or down as desired, the bank-intermediated arbitrage identities should be zero. When the arbitrage identities are large in magnitude, banks are constrained and relatively less able to expand their balance sheet to produce private safe assets. Empirically, I test this by checking the convenience yield measures' correlations with the bank-intermediated covered interest parity (CIP) arbitrages.

I calculate the covered interest parity violations (relative to the dollar) of G10 currencies at the one-week, one-month, and three-month tenor using both OIS discounting and the respective national inter-bank offered rate (IBOR), as in Du et al. (2018). The calculation results in six buckets of CIP violations: three tenors times two discounting methods. I use daily data beginning in 1998. I next take the absolute value of each violation, since the arbitrage identity should be zero and larger deviations from zero indicate frictions in the bank-arbitrageur channel. I then extract the first four principal components from each of the six buckets of CIP violations. I choose the first four principal components as the first four explain between 85% and 90% of the variation across each bucket. The goal of this aggregation process is to capture the intuition that substantial CIP violations, in absolute terms, across many currencies occur when the intermediary sector is constrained: if the CIP violation is large for a single currency, it may instead capture a specific, idiosyncratic effect.

I check the pairwise correlations of both convenience yield measures with each of these six aggregated CIP measures, shown in Table 10. The correlations are uniformly positive and significant, with the exception of OIS with the 1-week and 3-month IBOR-discounted violations, neither of which are significantly negative. The aggregation process is not sensitive to small changes: using more or fewer principal components, normalizing each CIP violation to standardized volatilities, or using subsamples of the time-series does not meaningfully change the correlations. Broadly, this confirms my intuition that the convenience yield, a proxy for the price of safe assets, is higher when banks are constrained, as measured by the magnitude of CIP violations.

The final prediction of the comparative statics exercise is to check that the price of safe assets is, on average, higher in the post-reform time sample than the pre-crisis sample as the combination of regulatory reforms have made it more expensive for intermediaries to expand their balance sheets. I confirm the prediction empirically by comparing the average convenience yield, seasonally adjusted or not, before and after regulators started phasing-in Basel III. My analysis is consistent with the finding of Laarits and Gorton (2018), aptly titled "Collateral Damage." I find that the convenience yield measures are uniformly higher after the phase-in arrangements for Basel III implementation, which ramped up in 2015.[8]

I now discuss predictions based on the demand curve for safe assets. Ceteris paribus, when the demand for safe assets increases, the convenience yield should increase; and when the demand for safe assets decreases, the convenience yield should decrease. I walk through the two predictions for the convenience yield based on changes in demand for safe assets.

First, safe assets are valuable as a transaction medium because they are information-insensitive. Dang et al. (2015) shows that information-insensitive assets are the most efficient transaction medium because they give agents the lowest incentive to acquire private information. Therefore, uninformed agents can comfortably trade information-insensitive assets with less concern about adverse selection; namely, that the counterparty has produced private information on the asset and is only willing to sell lemons. Dang et al. (2015) additionally show that financial crises are information events. In this line of thinking, Chousakos et al. (2018) show the amount of private information in the economy measured via the cross-sectional variance in equity returns varies over time, and that increased private information production predicts financial crises.

This logic generates the following empirical prediction: when private information production is high, the risk of adverse selection is also high, and investors will bid the price of safe assets up because safe assets are a refuge for the uninformed. An example makes this explicit: suppose a money-market fund engages in repo with a bank counterparty, which is collateralized by a basket of asset-backed securities. Suppose now the economy switches to a high private information production regime. The money-market fund may be fearful that its bank counterparty has produced information on the ABS collateral and is using the money fund to finance

[8] LQR phase-in started in 2015, while counter-cyclical buffers ramped up beginning in 2016. Additionally, CET1 minimums started increasing in 2013 from 3.5% to 4.5% by 2015. Broadly, Basel III increased capital requirements ramped up through the entire period from 2013 to 2019, along the dimensions of total capital requirements, redefinitions of risk-weights, and rulemaking for the supplementary leverage ratio and net stable funding ratio.

its lowest quality collateral. Since the money-market fund does not have the expertise nor time (most repos are fewer than seven days maturity) to value the ABS (i.e., to produce private information on the ABS), the fund exits the repo agreement and moves the balance to Treasurys. Hence, as private information production in the economy picks up, the convenience yield should increase as well.

I measure information production in two ways: first, I use the daily cross-sectional standard deviation in equity returns as proposed by Chousakos et al. (2018). Second, I use the daily cross-sectional standard deviation of changes in 5-year credit default swap spreads on senior unsecured debt for AAA to BBB rated debt. I test the prediction by confirming the uniformly positive and significant correlation between the information measures and the two benchmark convenience yield measures, which I show in Table 11.

6.2 Issuance

I detrend all issuance series using a similar process as Xie (2012). I log each issuance series and then apply a one-sided Hodrick-Prescott filter with λ selected to reflect the daily nature of the data. The process separates the trend from short-run deviations using only historical data; by construction, the one-sided filter does not use future information. I then subtract the long-term trend from the total logged issuance number to produce the detrended issuance number:

$$\log(\text{Issuance})_{\text{Detrended},t} = \log(\text{Issuance})_t - \log(\text{Issuance})_{\text{HP-Filter Trend},t} \quad (7)$$

The goal for this process is to measure when an issuer issues more or less than suggested by the recent past. As a check, I also confirm that a piecewise linear regression produces similar detrended issuance series.

7 Empirical Strategy and Results

This paper tests two related questions: first, does safe asset issuance help explain fluctuations in the convenience yield? Second, do safe asset issuers time their issuance in part to earn the convenience yield— that is, do issuers engage in so-called “opportunistic issuance”? I first answer these questions using FHLB issuance. I also analyze whether other agencies and private safe asset producers have a similar impact on the convenience yield and exhibit opportunistic issuance behavior, and how these issuers’ behaviors have changed over time.

It is challenging to analyze the long-term relationship of fluctuations in the convenience yield and private safe asset issuance; instead, I focus on daily fluctuations. Using daily data has two advantages: first, the time-series of FHLB and other agency issuance is only available back to the mid-1990s, so daily data allows for more observations. Second, this paper's focus on short-term deviations in issuance and the convenience yield help control for changes in the underlying macroeconomic landscape, which are unlikely to change meaningfully from day to day.

7.1 Benchmark Test 1: The Convenience Yield Responds to FHLB Issuance

First, I examine how the convenience yield responds to FHLB issuance, i.e., whether $\text{ConYield}_t^{SA} = f(\text{Issuance}_t)$ in the post-reform regime. I use the timing of the independent and dependent variables purposefully; I want to rule out the possibility that convenience yield and FHLB issuance are jointly determined. Because issuance decisions are made before the market close, and the convenience yield is measured at market close, the issuance decision occurs first. Therefore, the convenience yield on day t cannot affect the issuance decision on day t because it is not yet known. Importantly, the detrended issuance is known at date t.

I run the following regression:

$$\Delta\text{ConYield}_t = \alpha + \beta \log(\text{FHLB}_t)_{\text{Detrended}} + \theta_t + \varepsilon_t \tag{8}$$

where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. The dependent variable is changes in the convenience yield—both seasonally adjusted and not—and the independent variable is the detrended FHLB issuance time-series of 4-week to 26-week discount notes. I use data from the post-reform period from July 2014 to February 2020, reflecting the period after which the money-market reforms had been announced. I show the result in Table 12. Columns (1) and (2) show the results when I measure the convenience yield with the OIS-Tbill measure, and columns (3) and (4) show the results with the GCF-Tbill measure. Across the two measures of convenience yield the coefficient on issuance is significant and negative. The result suggests that FHLB debt is a safe asset, as an increase in FHLB debt issuance reduces the price of safe assets.

A one standard deviation increase in the FHLB issuance of $4.7 billion lowers the seasonally adjusted convenience yield by 0.3 to 0.4 basis points using the OIS measure for the smaller estimate and the GCF measure for the larger estimate, using betas shown in columns (1) and (3) of Table 12. The effect is a significant reduction given the average seasonally adjusted GCF and OIS convenience yield measures are 2.2 basis points and 2.9 basis points, respectively. In other words, a standard deviation increase in FHLB issuance lowers the convenience yield by about 10% to 18%.

Additional Evidence for Benchmark Test 1 I first show there is no common variation between the convenience yield and debt issuance more generally. I show the convenience yield does not fall following corporate bond or low rated commercial paper issuance. The result captures the idea that these two security types are comparatively risky assets and not private safe assets, so an unusually large issuance should not affect the convenience yield. Table 13 shows the result from running the benchmark test but changing the independent variable from FHLB issuance to corporate bonds and low rated A2/P2 non-financial commercial paper. As expected, the coefficient on detrended issuance is insignificantly different from zero, although the coefficient of corporate bonds and the GCF is, if anything, marginally positive and significant—the opposite of a safe asset producer whose issuance drives the convenience yield lower. The lack of a negative and significant relationship across both securities and both measures of the convenience yield confirms the intuition that there is no common variation between the convenience yield and debt issuance generally.

A second test is to run a horserace between how FHLB issuance affects the convenience yield compared to other candidate safe assets, shown in Table 14. This test rules out the possibility that FHLBs issue debt simultaneously with some other safe asset, which would spuriously make FHLB debt appear to decrease the convenience yield. I run benchmark test 1 but now as a horserace of FHLB issuance and several other candidates to confirm FHLB issuance is the correct focus. I run the regression on FHLB issuance and also include as controls: AA-rated (top-rated) asset-backed, financial, and non-financial commercial paper with maturity fewer than four days; total commercial paper with maturity fewer than four days, corporate bonds, asset-backed securities, private-label mortgage-backed securities, and collateralized debt obligations. The standard detrending process described previously is applied to each issuance series. Table 14 presents the results from this regression, using the GCF measure of the convenience yield in panel A, and the OIS measure in panel B. When comparing FHLB issuance against these measures, the relationship between FHLB issuance and convenience yield is unchanged, as can be seen by skimming along the top row and noting the always negative and significant relationship between FHLB issuance and the convenience yield, even after controlling for several other issuers. The only exception is the horserace against PLMBS and ABS—the coefficient is negative, as expected, but not significantly. This likely due to the comparatively smaller sample.

A third check is to check the result holds for Treasurys: when the Treasury issues, the convenience yield should fall since an increase in the supply of safe assets should subsequently drive down the price of safe assets. This result was already presented in the discussion about the comparative statics of the convenience yield and presented in Table 8. The table shows that the convenience yield is lower when there are more USTs outstanding, and also that the convenience yield falls with UST issuance.

Overall, I have shown that the convenience yield responds in ways we expect with regards to risky asset production (corporate bonds and low rated commercial paper), other candidates for private safe asset producers (Fannie, Freddie, commercial paper, and flavors of ABS), and public safe asset production (Treasurys). These tests show the vital role of FHLB issuance in explaining variation in convenience yield.

Migration in Convenience-Yield-Determiners Benchmark test 1 shows FHLB issuance helps determine the convenience yield in the post-MMF-reform period. I now consider how the convenience-yield-determining power of the FHLBs and similar debt-issuing government agencies have changed from pre-crisis to post-reforms. In summary, I find that FHLB issuance has a more significant effect on the convenience yield in the post-reform period and that the convenience yield effect is unique to the FHLBS, neither Fannie nor Freddie debt—of any maturity—have a meaningful effect on the convenience yield, either pre-crisis or post-crisis.

First, I run benchmark test 1 on the FHLB issuance over four regimes: pre-crisis, crisis, pre-reform, and post-reform. Pre-crisis is before June 2007, the crisis is June 2007 to June 2009, the pre-reform period is July 2009 to July 2014, and the post-reform period is July 2014 to February 2020, reflecting the period after which the SEC announced the money-market reforms.

I show the results in Table 15. In the pre-crisis period, FHLB issuance does not have the negative relationship between issuance and the convenience yield. In contrast, the post-reform period FHLB issuance has a significantly negative effect on the convenience yield. This result shows the new position of FHLBs as a result of the changing post-crisis regulatory regime, which has made FHLBs large suppliers of safe assets to money-market funds; something that was not the case pre-crisis. The crisis period is included for completeness, but the issuance behavior of the FHLB was markedly different during the crisis than outside the crisis. For most of the crisis period, the FHLB system acted as the "lender of next-to-last resort" as described by Ashcraft et al. (2010). During this unusual period, the convenience yield was high and the balance sheet of the FHLB system expanded by its balance sheet via advances to members—financed by increasing debt issuance—by roughly 50%.

Second, I run benchmark test 1 using interactions in a combined model rather than as a split-sample regression corresponding to the four regimes. To perform this test, I use the following specification:

$$\begin{aligned}\Delta \text{ConYield}_t^{SA} &= \alpha + \beta_1 \log(\text{FHLB}_t)_{\text{Detrended}} \\ &+ \sum_i \beta_i \log(\text{FHLB}_t)_{\text{Detrended}} \times \mathbb{I}_{\text{Regime}^i} + \mathbb{I}_{\text{Regime}^i} + \theta_t + \varepsilon_t \quad (9)\end{aligned}$$

where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects and $i = 1, 2, 3$ corresponds to indicator variables for the crisis, pre-reform, and post-reform periods, and the regression is run relative to the pre-crisis baseline with the detrended issuance series. The marginal effect of FHLB issuance in each period from this specification are provided in Table 16 and plotted in Figure 7 which uniformly shows the convenience yield falls after issuance of 4-week to 26-week maturity debt from FHLBs in the post-reform period and in no other period. The marginal effects clearly show migration in safe asset production to the FHLBs post-reform.

I now return to the original split sample version of the benchmark test and run the specification separately on each of the agency issuers to test if they display an effect on the convenience yield. I present the results of these individual split sample regressions in Table 17, with Panel A showing the results when using the OIS-Tbill measure and Panel B with the GCF-Tbill measure. The expectation for a safe asset producer is a significantly negative coefficient on the issuance variable, and migration occurs when the coefficient flips sign or loses significance. Figure 8 plots the effect of a standard deviation increase in issuance using the regression results presented in Table 17. After a standard deviation increase in FHLB issuance, the convenience yield falls between 0.3 and 0.4 basis points; the effect of Fannie and Freddie issuance is not significantly different from zero. The FHLBs post-reforms are the only agency issuer to affect the convenience yield.

7.2 Benchmark Test 2: Opportunistic Issuance

The second benchmark test examines whether the FHLBs issue opportunistically in response to variations in the convenience yield, i.e., whether $\text{Issuance}_t = f(\text{ConYield}_{t-1}, \text{Seasonal Component}_t)$. The FHLB issues discount notes depending on its own funding needs but is responsive to "reverse inquiry" in which FHLB debt buyers contact the FHLB and ask it to sell new debt. Whether or not the issuance is via reverse inquiry does not change the ability of the FHLB to opportunistically issue: the FHLB can both use the price of safe assets and the amount of reverse inquiry to determine the best time to issue.

I use the timing of the independent and dependent variables carefully to ensure the explanatory variable—the convenience yield—is not determined simultaneously with the issuance decision. To help identify the effect, I use Xie (2012)'s methodology of using the seasonal component of the convenience yield as an exogenous independent variable. Seasonality is useful because it is exogenous to issuers (i.e., it would be impossible for the issuance at date t to affect the seasonal component estimated for date t from the existing data) and seasonality is predictable to issuers.

Issuers can time the convenience yield in two ways: first, by anticipating fluctuations in the convenience yield due to seasonality (e.g., window-dressing) or second, by noticing that the level of the seasonally adjusted convenience yield has been high in the previous day. In this setup, I test the following specification:

$$\begin{aligned}\log(\text{Issuance}_t)_{\text{Detrended}} = \alpha &+ \beta_1 \text{SeasonalComponent}_t \\ &+ \beta_2 \text{ConYield}^{SA}_{t-1} + \theta_t + \varepsilon_t\end{aligned} \tag{10}$$

in which I predict the $\text{SeasonalComponent}_t$ out-of-sample, I detrend issuance as described above, and θ_t are controls for day-of-week, quarter-end, month-end, and year fixed-effects.[9] I report the results in Table 18. I measure the convenience yield via the two definitions, and the dependent variable is detrended issuance of FHLB discount notes with 4-weeks to 26-weeks in maturity. The main result shown in columns (1) and (2), using the seasonally adjusted convenience yield measures, show that FHLBs issue more debt when the previous day's convenience yield is higher. The empirical evidence does not support FHLBs timing the seasonal predictability of the convenience yield, but rather time issuance based on the seasonally adjusted convenience yield.

The magnitude is important. When the seasonally adjusted convenience yield is one standard deviation higher, amounting to 11 (14) basis points, the FHLB system issues an incremental \$389 million (\$274 million) as estimated using the OIS-Tbill (GCF-Tbill) convenience yield measure betas shown in Table 18.

Alternative Benchmark Test 2: When-Issued Market Using "tails" and "throughs" from Treasury auctions to measure innovations in safe asset demand allows testing FHLB opportunistic issuance without relying on the benchmark definitions of the convenience yield. When the Treasury announces an auction, dealers start trading that specific security on the same day in the WI market. WI transactions settle on the issue date of the auctioned security (i.e., not on the auction date). For example, if the Treasury announces a bill auction on Thursday morning, then the auction results are announced Monday afternoon, with settlement later that week. The WI market allows trading of the security before the security is physically available. When the stop-out yield in the Treasury auction exceeds the yield on the WI security, the auction is termed a "tail," which indicates weak demand for the Treasury. Likewise, when the stop-out yield in the auction falls below the yield on the WI security, the auction is termed a "through," which indicates strong demand for the Treasury. Mercer et al.

[9] By construction, the controls contain future information. I confirm the results using a rolling regression with only backward-looking controls to ensure the results are robust to excluding the future information contained in the controls.

(2013) provides additional details on the WI market.

Traders in the WI market can speculate and therefore have profit motives to forecast tails and throughs correctly. For example, an investor who thinks the WI yield is too low—meaning Treasury demand will be weaker than is priced in the WI security—can "play for a tail" by selling the WI short while covering the short by placing a competitive bid at a yield higher than on the WI security. The covering leg must carry a yield sufficiently low—below the stop-out yield—since covering with a too-high yield bid will leave the investor with a naked short position in the WI (Treasurys are not allocated to investors submitting bids which are too high). Similar, but reversed, logic applies for speculating on a "through" auction.

Tails and throughs provide a discrete method to measure unexpected Treasury demand. Tails and throughs proxy the unexpected demand for safe assets because speculators have incentives to forecast Treasury demand correctly and because Treasury typically fixes the size of the offering. If the demand for safe assets is higher than expectations, we would expect a through in the auction; if the demand is low, then we should expect a tail.

I test FHLB issuance around tails and throughs in Treasury bill auctions. I measure the tail as the percent difference between the yield in the WI market 1 minute before the Treasury announces the results at 1:00 PM and the subsequent yield on the actual Treasury at 1:30 PM:

$$\text{Tail}_t = \frac{\text{Yield}_{1:30\text{PM},t} - \text{Yield}_{12:59\text{PM},t}}{\text{Yield}_{12:59\text{PM},t}} \tag{11}$$

Thus, $\text{Tail}_t > 0$ indicates a tail and $\text{Tail}_t < 0$ indicates a through.

I test FHLB opportunistic issuance by running the following regression:

$$\log(\text{Issuance})_t = \alpha + \beta_1 \text{Tail}_{t-1} + \theta_t + \varepsilon_t \tag{12}$$

I expect demand for safe assets is lower and FHLBs will issue less when the Treasury auction tailed the previous day. The test examines opportunistic issuance based on the demand for safe assets but measured via Treasury tails rather than the convenience yield measures. I report the results of running the regression in Table 19. I report the main result in the first two columns, which shows that β_1 in the above specification is negative and significant, matching intuition. Columns (3) and (4) show the same result holds after adding additional controls for the seasonality of the convenience yield.

Additional Evidence for Benchmark Test 2 It is important to show there is no typical common variation in debt market issuance and money-markets to confirm the specification of benchmark test 2. I now perform three robustness tests.

First, I test whether comparatively riskier issuers—corporate bond issuers and A2/P2 non-financial commercial paper—opportunistically time the convenience yield. Since FHLBs produce private safe assets, I have argued that they will want to issue these assets when the price of safe assets is high. However, corporate bonds and low rated commercial paper are not as useful as safe assets. Therefore, I expect there is no timing of the convenience yield by these issuers. Table 20 reruns the regression given in equation 10 but replaces FHLB issuance. Columns (1) and (2) show corporate bond issuance does not exhibit opportunistic issuance behavior—there is no evidence of corporate issuers timing the seasonally adjusted convenience yield, and if anything corporate bond issuer issue more when the seasonal component is lower. Similar results hold for A2/P2 non-financial commercial paper. These results are inconsistent with the traits of safe assets.

A second test is to check whether the Treasury issues opportunistically. There are two reasons to believe it does not. First—and most importantly—the Treasury pre-announces the time and size of its auctions. Second, the Treasury follows a longstanding custom of not opportunistically issuing debt despite Treasury's objective to minimize debt costs. For this reason, I run the benchmark test 2 specification with Treasury issuance as the dependent variable and expect that the coefficient on $\text{ConYield}_{t-1}^{SA}$ is not significantly different from zero. Columns (5) through (8) in Table 20 report the results from repeating the regression in equation 10. I exclude a period in which the Treasury issued debt explicitly in response to adverse money-market conditions as part of the supplemental financing program, a program in which the Treasury issued debt to drain reserves from the banking system and therefore allow the Federal Reserve better control of its policy rate. Table 20 shows the Treasury does not time its issues based on the previous day's convenience yield for either measure of the convenience yield. Overall, the results confirm the prior that the Treasury, unlike FHLBs, does not opportunistically issue debt to time the convenience yield.

A third check is to use Treasurys outstanding as an instrument for the convenience yield, as shown in Table 21. As discussed in Xie (2012), the convenience yield fluctuates as the Treasury issues and redeems Treasury debt. A large increase of Treasurys outstanding will crowd out other safe assets like FHLBs, and the FHLBs will issue less. I now perform the following two-step regression: first, I show an increase in detrended log Treasurys outstanding lowers the convenience yield in the first stage regression:

$$\text{ConYield}_t^{NSA} = \alpha + \beta \log(\text{UST Outstanding}_{t-1})_{\text{Detrended}} + \varepsilon_t \qquad (13)$$

The first stage regression results are shown in columns (1) and (3) using the GCF and OIS measures of the convenience yield, respectively. I use Treasury issuance as an instrument to predict the convenience yield as shown in the above specification and then show the FHLBs are indeed crowded out by Treasury issuance, which I present in

$$\log(\text{FHLB}_t)_{\text{Detrended}} = \alpha + \beta \widehat{\text{ConYield}}_{t-1}^{NSA} + \varepsilon_t \tag{14}$$

in which $\widehat{\text{ConYield}}_{t-1}^{NSA}$ is the first stage estimate of the convenience yield from Treasurys outstanding. Columns (2) and (4) show the second stage regression results in Table 21: when the convenience yield is higher—due to fewer Treasurys outstanding—then FHLBs issue more. Importantly, FHLBs exhibit "gap-filling" behavior with issuance in that FHLB issuance is lower when bill issuance the day before is larger: I present the result in columns (5) of Table 21.

To summarize, I have presented five pieces of additional evidence for opportunistic issuance. First, FHLBs issue less when demand for Treasury debt is low as measured via auction tails in the WI market. Second, issuers of risky assets do not time the convenience yield. Third, Treasury issuance does not time the convenience yield. Fourth, FHLBs issue more when using Treasurys outstanding as an instrument to estimate the convenience yield. Finally, FHLBs exhibit "gap-filling" behavior—they issue more when the Treasury issues less. Each of these tests matches intuition and confirm the behavior of FHLBs as safe asset producers who time the convenience yield.

Who Else Opportunistically Issuances? Benchmark test 2 shows that the FHLBs opportunistically time issuance based on the convenience yield in the previous day, which has been the case for the entire sample and not only after the money-market reforms. Who else opportunistically times the convenience yield? I now run benchmark test 2 on other agency and candidate private safe asset issuers to examine their opportunistic issuance behavior, and report the results in Table 22. As discussed before, there are two possible ways to time the convenience yield: either based on $\text{SeasonalComponent}_t$ or $\text{ConYield}_{t-1}^{SA}$. The issuance series include Freddie discount notes (excluding overnight); Freddie reference bills; Fannie bond issuance greater than one year; Federal Farm Credit Bank issuance greater than one year; one to four-day maturity highly rated ABCP, financial CP, and non-financial CP; and collateralized debt obligations.

The test shows the following facts: first, that both types of Freddie discount notes, ABCP, and non-financial CP time the seasonal component of the convenience yield using at least one measure of the convenience yield. Second, the following issuers time $\text{ConYield}_{t-1}^{SA}$: Freddie, non-financial CP, and CDOs. ABCP issuance times the $\text{SeasonalComponent}_t$, consistent with Sunderam (2015). Notably, financial commercial paper does not time issuance: this is unsurprising since window-dressing constrains financials precisely when the convenience yield is high (e.g., at quarter-ends during window-dressing), and so financials cannot opportunistically issue.

Figure 9 plots the economic magnitude of the timing behavior using the estimated β_2 from Table 22: it shows the effect of a standard deviation increase in the convenience yield on issuance. FHLB discount notes increase issuance by roughly $300 million to $400 million across the two convenience yield measures. ABCP ($200 million) and Freddie ($130 to $160 million) and non-financial CP ($170 million) also display timing behavior, for example, with the GCF measure. The effect with the OIS measure is generally smaller and less significant, except for FHLBs and ABCP. The non-timing behavior of financial commercial paper appears again in the last bar, likely for the reasons related to window-dressing discussed previously.

8 Vector Autoregression

I now present a vector autoregression to analyze the persistence and the interaction between the convenience yield and agency debt outstanding. Recall, benchmark result 1 showed that the convenience yield falls after FHLB debt issuance post-reforms, and benchmark result 2 showed that many safe asset producers time issuance when the convenience yield is high through the full sample. A vector autoregression model allows me to analyze the interaction of the two series (issuance and the convenience yield), the persistence of the effect, and to test for Granger causality.

Let o_t be the outstanding debt at time t, cy_t be the convenience yield—as measured by the OIS-Tbill or GCF-Tbill spread, and sc_t be the seasonal component of the convenience yield. I estimate a VAR of the form

$$\begin{bmatrix} o_t \\ cy_t \end{bmatrix} = \boldsymbol{a_0} + \boldsymbol{A_1} \begin{bmatrix} o_{t-1} \\ cy_{t-1} \end{bmatrix} + \cdots + \boldsymbol{A_{t-k}} \begin{bmatrix} o_{t-k} \\ cy_{t-k} \end{bmatrix} + \boldsymbol{\Gamma_t} sc_t + \begin{bmatrix} \varepsilon_{o,t} \\ \varepsilon_{cy,t} \end{bmatrix} \tag{15}$$

where $\boldsymbol{a_0}$ is a vector of intercept terms, $\boldsymbol{A_1}, \ldots, \boldsymbol{A_{t-k}}$ are 2×2 matrices of coefficients estimated from the lags of the outstanding and convenience yield variables, and $\boldsymbol{\Gamma_t}$ are coefficients on the exogenous seasonal component control, sc_t. I select the lags k using Akaike's information criterion. I estimate the VAR six times: for both convenience yield spreads—the GCF-Tbill and also the OIS-Tbill spreads—across each of three periods: pre-crisis, post-reform, and full sample excluding crisis.

I perform a pairwise Granger causality test to analyze whether lags of cy Granger-causes o_t (and vice versa) in the sense that lags of cy help predict o_t. The pairwise Granger causality test regresses o_t on its lags and the lags of cy and uses a Wald test to check if the coefficients on lags of cy are jointly zero. The null hypothesis is that the coefficients on the lags are jointly zero, and I say that a variable Granger-causes another if I reject the null. I report the results in Table 23. I now discuss the results in the context of benchmark test 1 and test 2.

First, benchmark test 1 found that FHLB issuance drove down the convenience yield post-reforms, but not pre-crisis: that is, safe asset production migrated to the FHLBs post-reforms. The VAR confirms a similar result by finding that log(FHLB outstanding) Granger-causes the GCF-Tbill and OIS-Tbill spreads post-reforms at the 5% and 1% level, respectively, but not pre-crisis. This is shown in the bottom two rows of the table.

Second, benchmark test 2 found that FHLB issuance opportunistically timed the convenience yield in the full sample, excluding the crisis. The VAR confirms this result: log(FHLB outstanding) is Granger-caused by both convenience yield spreads in the full sample but is robust at the 10% level when estimating the model in just the pre-crisis or post-reform sample separately.

The VAR lets us analyze the persistence of the effects over many days and weeks, not just within a day or the next. I plot the impulse response functions in Figures 10 and 11, using the OIS and GCF measures, respectively. The VAR equivalent of benchmark test 1 is shown in the left and middle panel on the top row of each figure: the effect of an impulse to log(FHLB outstanding) lowers the convenience yield post-reforms, but not pre-reforms. An impulse to the OIS measure lowers the convenience yield by almost 4 bps cumulatively over the following 30 trading days; the GCF is somewhat smaller. For both measures, the pre-crisis and post-reform periods have plainly different shapes of the impulse response on the convenience yield—this is migration.

The VAR equivalent of benchmark test 2, of opportunistic issuance, is shown in the bottom right panel of each figure. The panels show the effect of an impulse in the convenience yield on subsequent log(FHLB outstanding). The effect is large, positive, persistent, and similar when looking across all three panels: confirming the intuition that opportunistic issuance is not new post-crisis but has been a characteristic from pre-crisis to post-reforms.

9 Conclusion

This paper aims to show three related facts: first, that various financial reforms in the wake of the financial crisis have made the FHLBs major issuers of safe assets. Second, the fluctuations in FHLB issuance post-reform help explain variation in the convenience yield on a day-to-day basis. Third, the FHLBs issue debt opportunistically to time fluctuations in the convenience yield, allowing them to earn the convenience yield; Freddie and ABCP also exhibit clear timing behavior. The results suggest that safe asset production has migrated toward the FHLBs.

There are two systemic risk implications of this paper's analysis. First, FHLBs' opportunistic issuance is socially valuable because they are a marginal producer of safe assets. However, what happens if they cannot issue this marginal safe debt? Second, the FHLBs engage in a carry trade: they can borrow at low rates because of the implicit government guarantee and invest the proceeds into higher-yielding advances and investments. But this carry trade is risky given the magnitude of maturity transformation performed by the FHLBs system. The fallout from a failure of the FHLBs—albeit unlikely—would be unlike that of Fannie and Freddie because the FHLBs are an important source of financing to banks and because the banks hold equity positions in the FHLBs.

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10 Figures

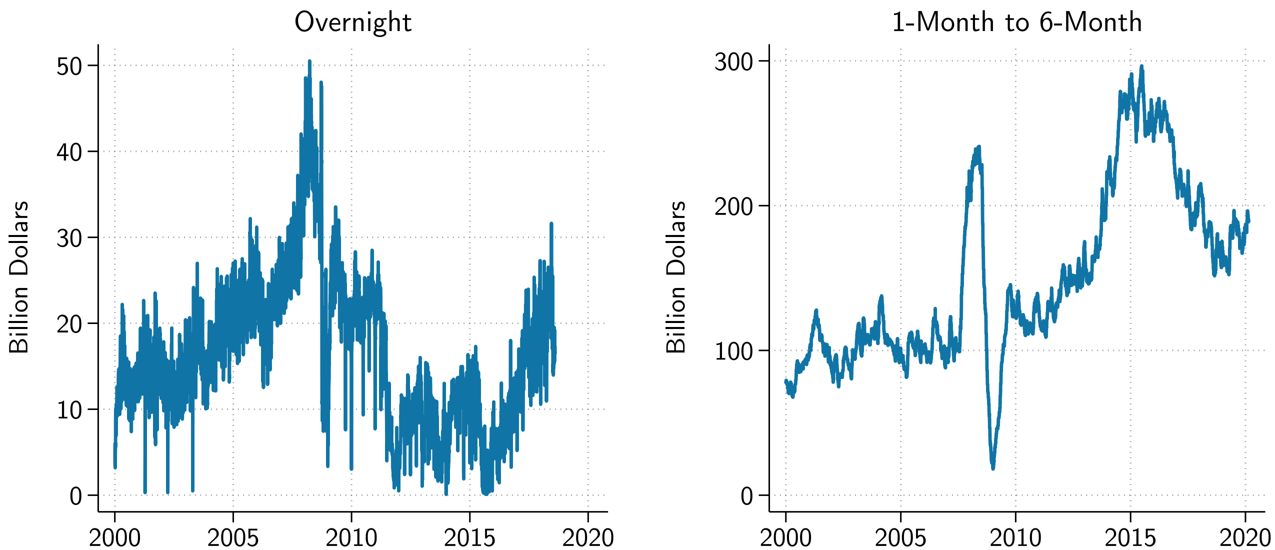

Figure 1: FHLB Discount Notes Outstanding. Source: FHLB Office of Finance

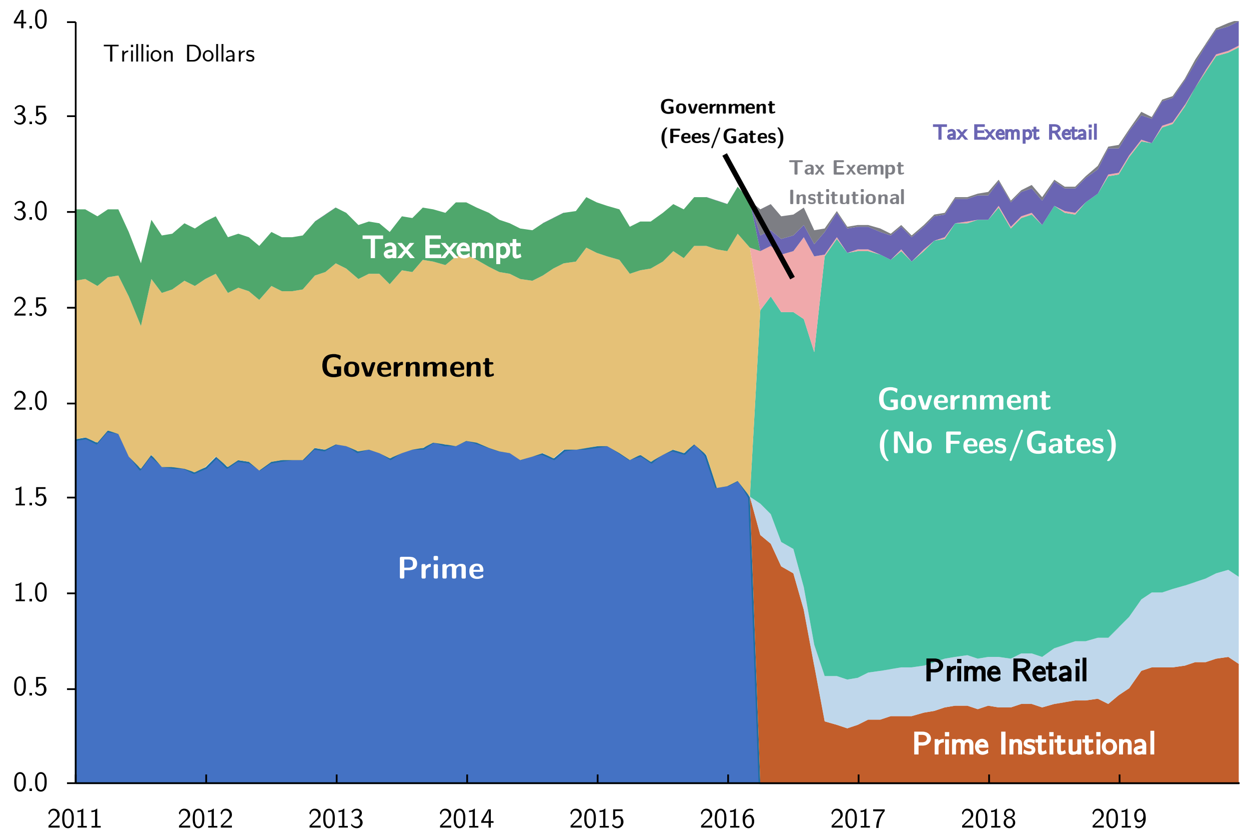

Figure 2: Money-market fund Landscape. Source: Office of Financial Research US money-market fund monitor

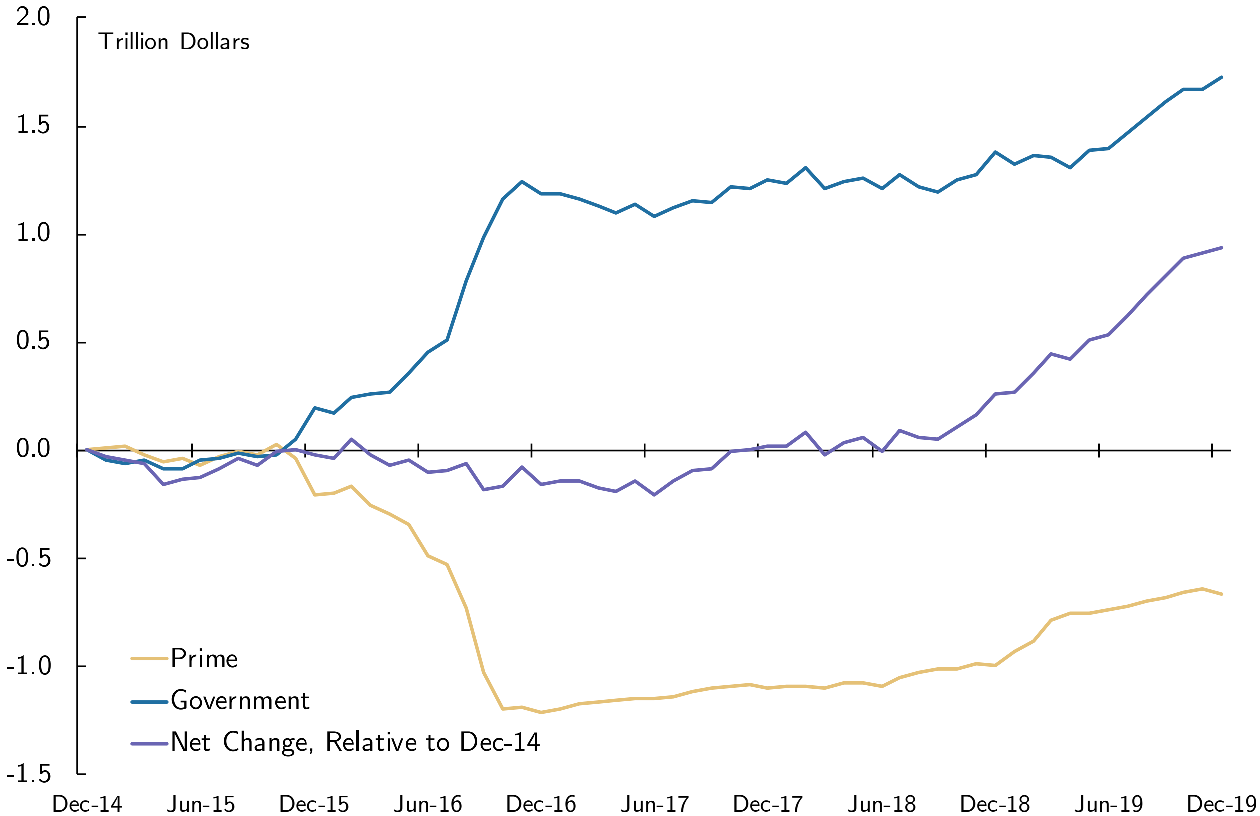

Figure 3: Reform Moved Assets from Prime to Government Funds. Source: Office of Financial Research US money-market fund monitor

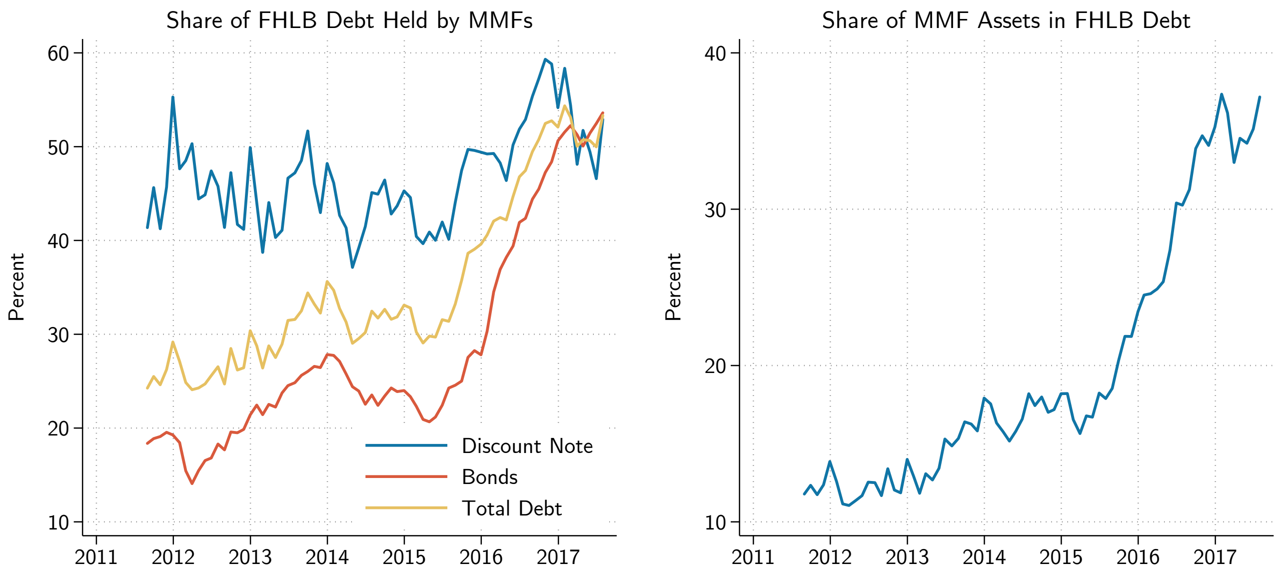

Figure 4: FHLB Debt and money-market funds. Source: Gissler and Narajabad (2017b)

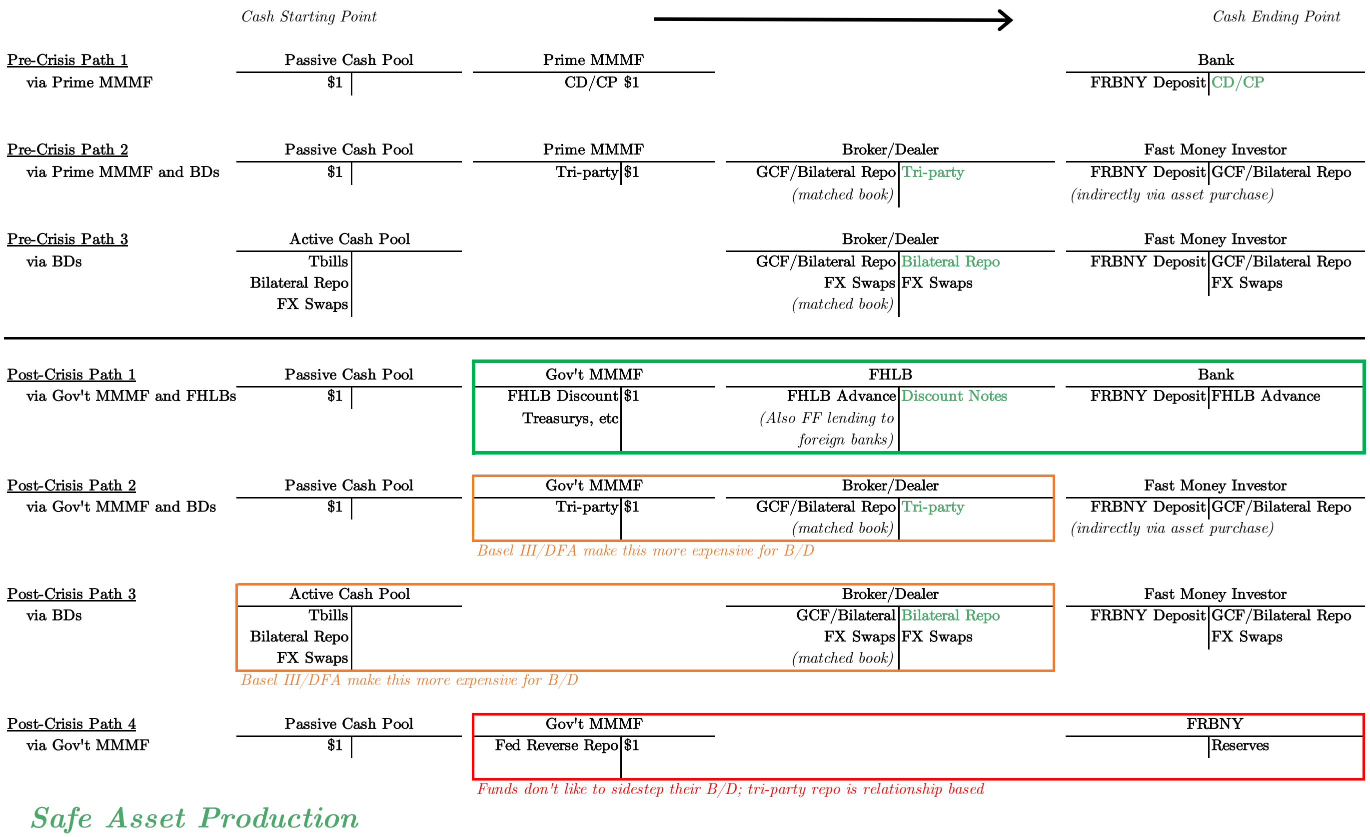

Figure 5: Changing Sources of Safe Assets. Source: Modified from Pozsar (2017)

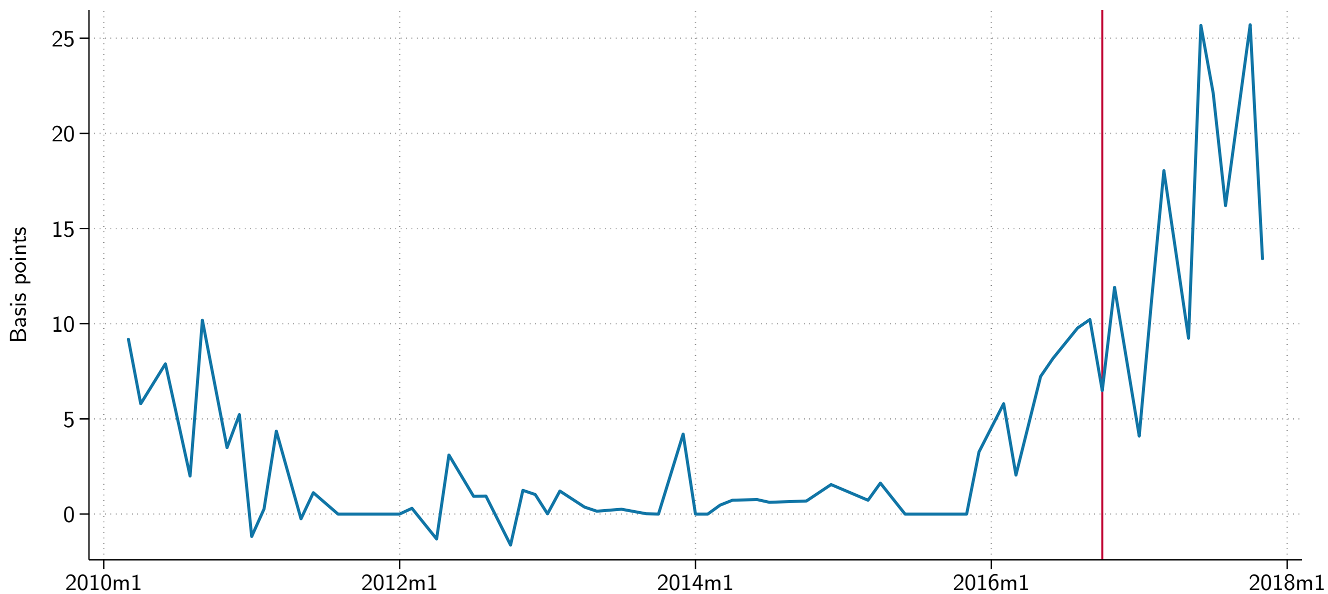

Figure 6: Money Market Reforms Pushed Month-End Flows to FHLBs. Figure plots the difference between intra-month and month-end rates for overnight FHLB discount notes.

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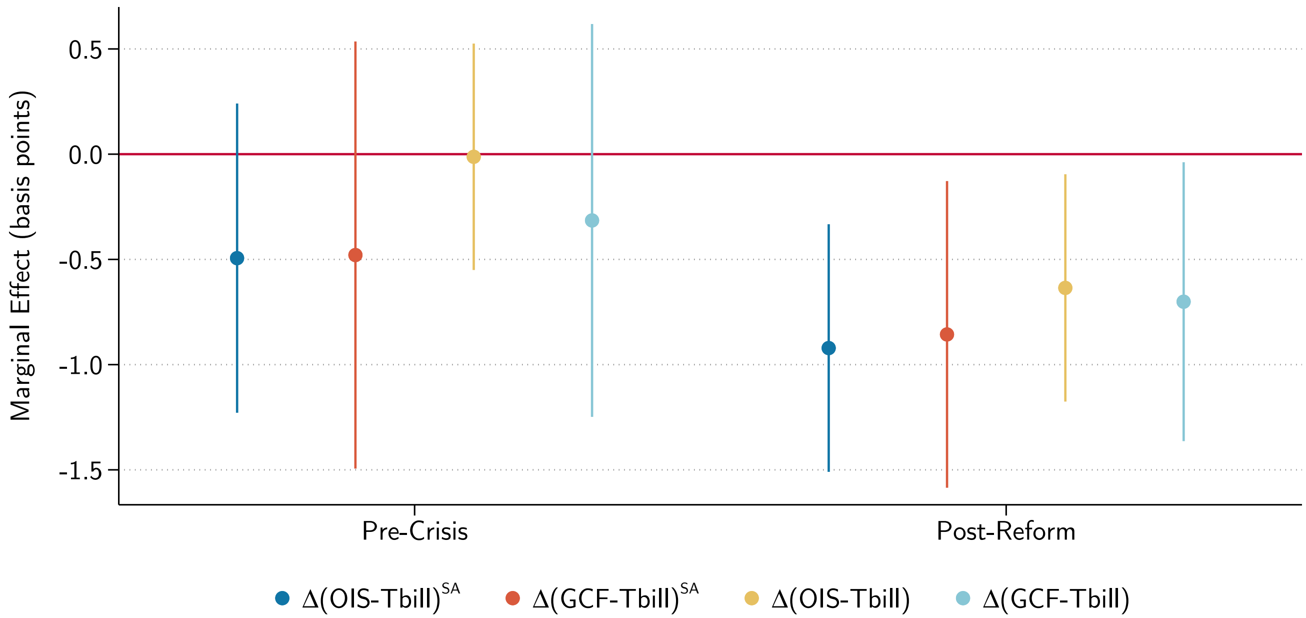

Figure 7: Migration in Benchmark Test 1: Marginal Effect of FHLB Issuance. Plot gives the marginal effect of FHLB issuance on changes in the convenience yield from regression reported in Table 16: $\Delta \text{ConYield}_t^{SA} = \alpha + \beta_1 \log(\text{FHLB}_t)_{\text{Detrended}} + \sum_i \beta_i \log(\text{FHLB}_t)_{\text{Detrended}} \times \mathbb{I}_{\text{Regime}^i} + \mathbb{I}_{\text{Regime}^i} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Dependent variable is changes in the convenience yield, in basis points, as measured by changes in the OIS-Tbill and GCF-Tbill spreads, both seasonally adjusted (SA) and not. Seasonal adjustment from preceding 5-year rolling window, excluding the crisis period. Issuance is calculated from the detrended series of log FHLB discount note issuance of maturities 4-weeks to 26-weeks. Pre-crisis is before June 2007, crisis is June 2007 to June 2009, pre-reform is July 2009 to July 2014, and post-reform is July 2014 to February 2020, reflecting the period after which the money-market reforms had been announced. Error bars represent 95% confidence intervals.

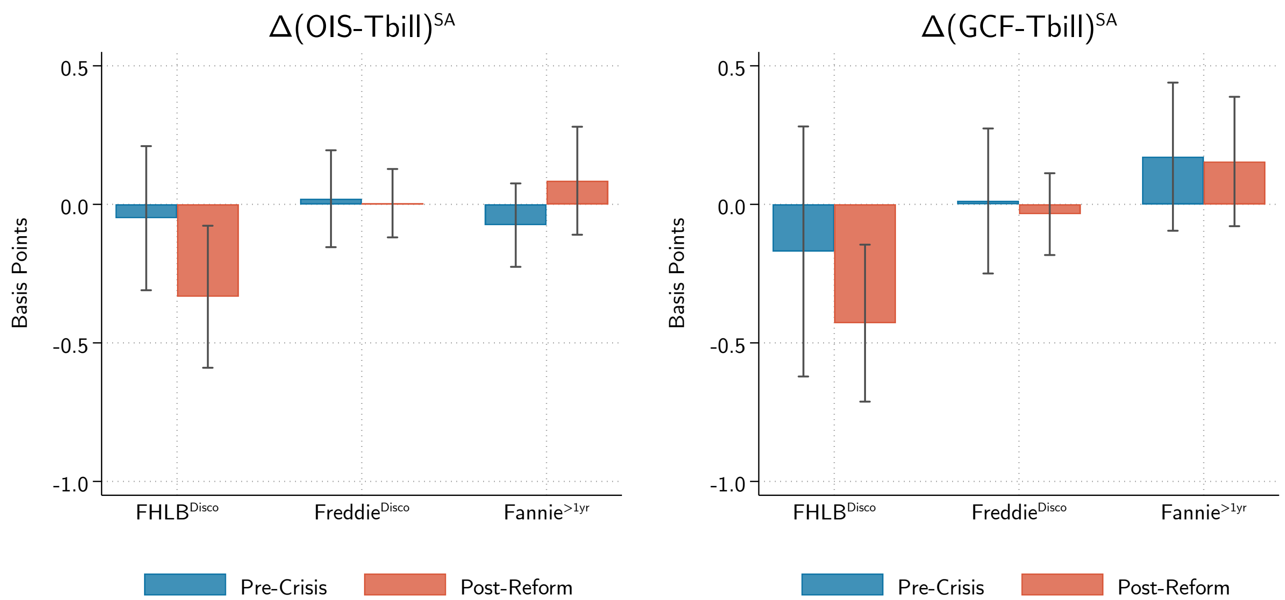

Figure 8: Issuance Impact on Convenience Yield. Bar graphs plot the effect of a one standard deviation increase in detrended issuance on the conveience yield estimated from the following regression: $\Delta \text{ConYield}_t = \alpha + \beta \log(\text{Issuance}_t)_{\text{Detrended}} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. The results for this regression are reported in Table 17. Error bars represent 95% confidence intervals. Regression run at the daily level. Dependent variable is seasonally adjusted convenience yield, measured via the OIS-Tbill or GCF-Tbill spread, corresponding to definitions 1 and 2. Issuance is calculated from the detrended series. Freddie discos are discount notes that are not overnight. FHLB disco are discount notes have maturities 4-weeks to 26-weeks. Fannie$^{>1\text{yr}}$ are issuances with greater than 1-year in maturity.

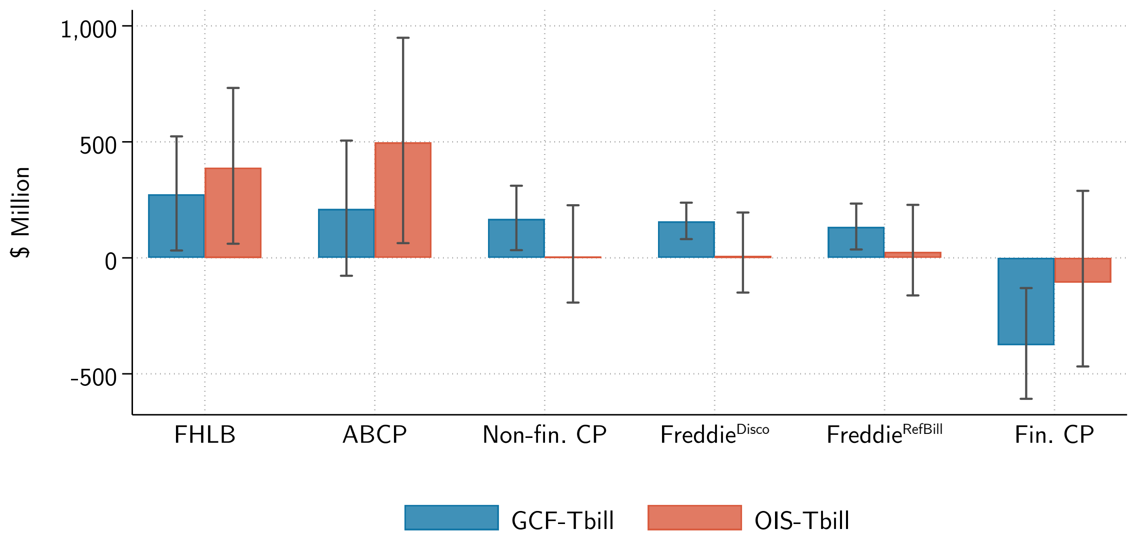

Figure 9: Who Times Issuance? Effect of Elevated Convenience Yield on Issuance. Plots show the effect on issuance when the convenience yield is one standard deviation higher using β_2 coefficient shown in Table 22 from running benchmark test 2 regression across the full sample: $\log(\text{Issuance}_t)_{\text{Detrended}} = \alpha + \beta_1 \text{SeasonalComponent}_t + \beta_2 \text{ConYield}_{t-1}^{SA} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Dependent variable is seasonally adjusted convenience yield, measured either via the OIS-Tbill or GCF Tbill measure, which correspond to definitions 1 and 2. Independent variable is the issuance of the indicated series which is calculated from the detrended log of the issuance series. FHLB are discount notes with 4-week to 26-week maturities, ABCP is AA (highly rated) asset-backed commercial paper with maturities 1 day to 4 days, Non-fin. CP is AA-rated non-financial commercial paper, Freddie^{Disco} and $\text{Freddie}^{RefBill}$ refers to Freddie discount notes excluding overnight and reference bills, and Fin. CP is AA-rated financial commercial paper issuance with maturities 1 day to 4 days. Error bars represent 95% confidence intervals.

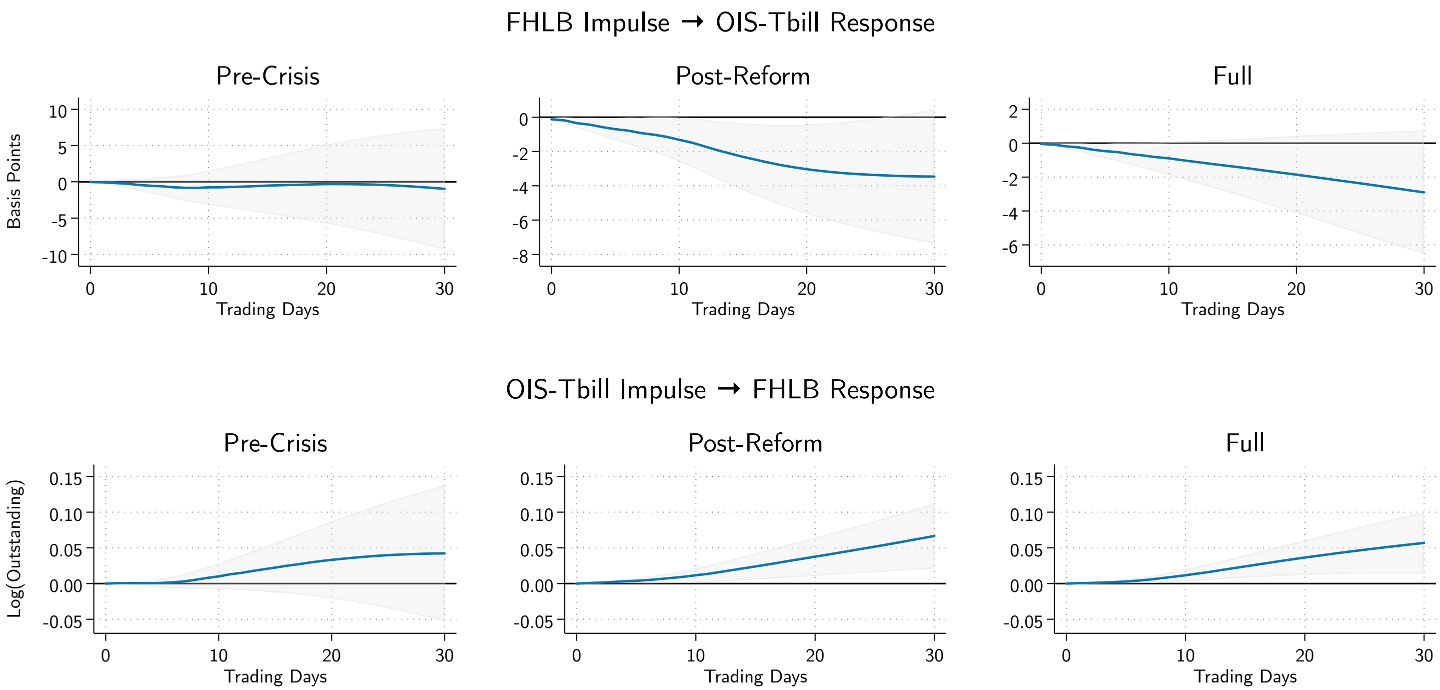

Figure 10: Impulse Response Function: OIS Measure. Plots show cumulative orthogonalized impulse response functions estimated from a vector autoregression model including the OIS-Tbill spread and the log level of FHLB 4-week to 26-week discount notes outstanding. Each column shows the model estimated in different samples: pre-crisis, post-reforms, and the full ex-crisis sample.

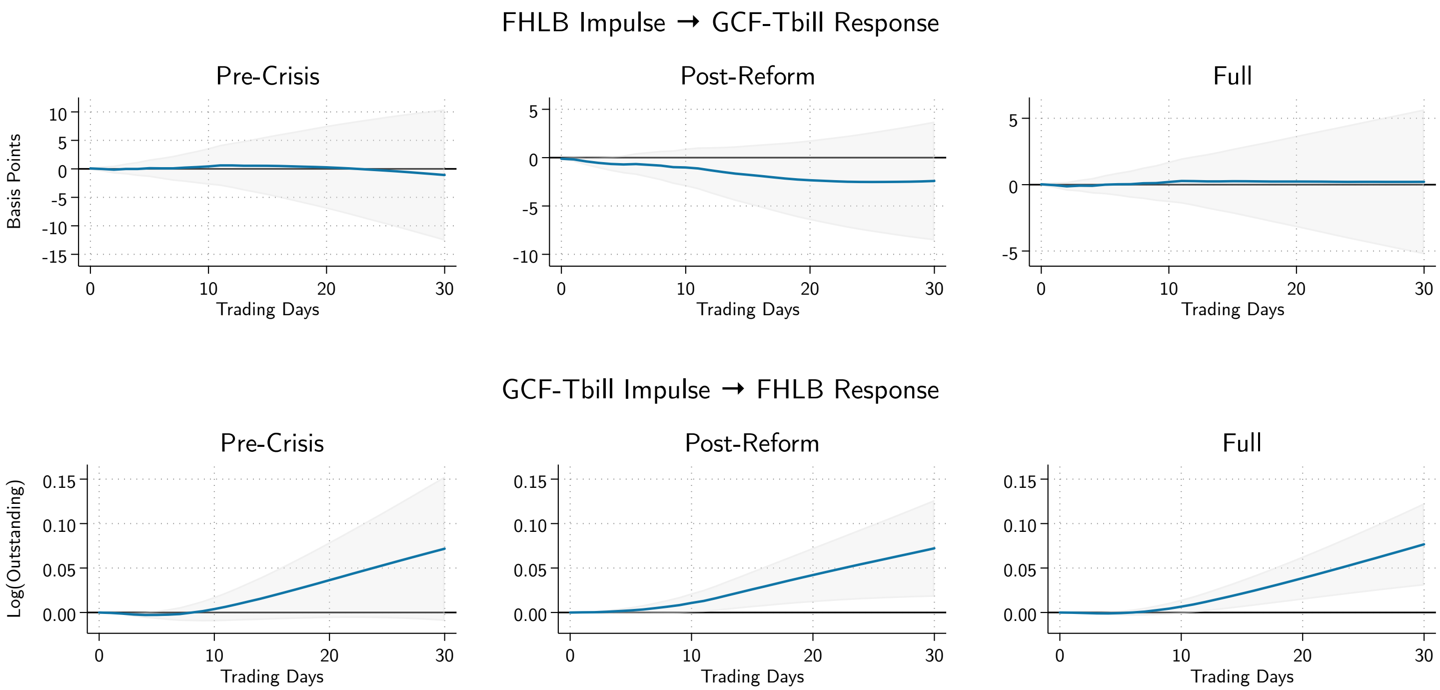

Figure 11: Impulse Response Function: GCF Measure. Plots show cumulative orthogonalized impulse response functions estimated from a vector autoregression model including the GCF-Tbill spread and the log level of FHLB 4-week to 26-week discount notes outstanding. Each column shows the model estimated in different samples: pre-crisis, post-reforms, and the full ex-crisis sample.

11 Tables

Year	FHLBs	Freddie	Fannie	Farm Cred.	Farmer Mac	TVA	Treasury Bills
2006	158.1	167.4	168.6	17.8	3.3	2.6	940.8
2007	378.4	197.6	234.2	19.7	0.7	1.6	999.5
2008	441.1	330.9	332.5	16.1	0.9	2.4	1,861.2
2009	198.6	238.3	200.6	11.6	1.9	1.1	1,793.5
2010	194.5	197.2	152.0	19.2	3.4	0.2	1,772.5
2011	190.2	161.4	146.8	13.6	4.1	0.8	1,520.5
2012	216.3	117.9	105.3	14.6	5.0	1.0	1,629.0
2013	293.3	141.8	72.3	18.6	5.0	1.8	1,592.0
2014	362.4	134.7	105.0	27.0	5.5	1.1	1,457.9
2015	494.3	113.6	71.1	32.3	5.0	1.5	1,514.0
2016	410.1	71.5	35.0	29.6	3.8	2.0	1,818.0
2017	392.0	73.2	33.4	25.6	1.7	2.7	1,955.9
2018	425.1	68.7	28.3	19.2	1.2	1.2	2,340.0
2019	389.2	94.5	35.9	17.8	2.2	0.9	2,416.9

Table 1: Short-Term Sovereign Safe Debt Outstanding ($ billions). Agency numbers include all maturities $\leq$1 year. 2019 value is 2019Q3. Source: Sifma, US Treasury.

Assets ($ billions)		Liabilities ($ billions)	
Advances	875.1	Consolidated Bonds	802.6
Held-to-maturity securities	151.2	Consolidated Discos	376.3
Mortgages loans held in portfolio	91.6	Deposits	22.1
Fed funds sold	85.8	Derivative Liabilities	5.3
Interest bearing securities	48.2	Repo	1.5
Trading securities	6.8	Mandatorily redeemable capital stock	1.1
Available-for-sale securities	5.8	Total	1,220.9
Reverse repo	0.8		
Cash	0.3		
Total	1,274.5	Loss absorbing capital	50.3
Memo:			
GSE MBS	55.1	Leverage	25.4×
Private-Label MBS	88.0	Capital Ratio	3.94%
Total Investments	298.7		

Table 2: Consolidated FHLB Balance Sheet, Year-End 2007

Assets ($ billions)		Liabilities ($ billions)	
Advances	706.0	Consolidated Bonds	613.5
Held-to-maturity securities	80.3	Consolidated Discos	402.8
Mortgages loans held in portfolio	60.1	Deposits	8.2
Fed funds sold	72.7	Derivative Liabilities	0.4
Interest bearing securities	13.6	Other	5.7
Trading securities	13.4	Mandatorily redeemable capital stock	1.1
Available-for-sale securities	80.3	Total	1,220.9
Reverse repo/Securities Lending	45.3		
Cash/Deposits	14.4		
Total	1,098.3	Capital + Retained Earnings	57.6
Memo:			
GSE Obligations	19.6	Leverage	19.1×
Private-Label MBS	7.0	Capital Ratio	5.24%
GSE MBS	135.3		
Total Investments	318.3		

Table 3: Consolidated FHLB Balance Sheet, 2018 Q3

$ billions		2007	2017	Percent Change
Freddie Mac	Overnight		1.0	
	Short-term excl. o/n	159.5	44.7	-71.3
	Long-term	362.8	162.3	-55.3
	Other	254.6	98.7	-61.2
	Total	776.9	306.7	-60.5
Fannie Mae	Short-term	161.7	33.3	-79.4
	Long-term	605.1	291.4	-51.8
	Total	766.9	324.7	-57.7
FHLB	Overnight	28.2	17.1	-39.4
	Short-term, excl. o/n	188.6	386.8	105.1
	Long-term	806.0	615.2	-23.7
	Total	1,022.8	1,019.1	-0.4

Table 4: Agency Debt Outstanding: 2007 vs. 2017

		basis points			
	N	Mean	σ	Min	Max
AAA Long Maturity$_t$ − UST Long Maturity$_t$	2,661	29	39	-65	92
$\text{OIS}_t^{3m} - \text{Tbill}_t^{3m}$	2,662	6	6	-17	28
$\text{GCF}_t^{3m} - \text{Tbill}_t^{3m}$	2,656	14	8	-11	46

Table 5: Summary Statistics: Convenience Yield Measures. Data is from the post-crisis period from July 2009 to February 2020. UST is US Treasury. AAA Long Maturity yield is the ICE BofAML US Corporate AAA effective yield. Tbill is the 3-month constant-maturity yield. OIS is the 3-month overnight indexed swap, and GCF is the Treasury general collateral financing repurchase agreement 3-month rate.

	AAA-UST	OIS-Tbill	GCF-Tbill
AAA Long Maturity$_t$ − UST Long Maturity$_t$	1.00		
$\text{OIS}_t^{3m} - \text{Tbill}_t^{3m}$	0.17	1.00	
$\text{GCF}_t^{3m} - \text{Tbill}_t^{3m}$	0.50	0.54	1.00

Table 6: Correlation: Convenience Yield Measures. Data is from the post-crisis period from July 2009 to February 2020. UST is US Treasury. AAA Long Maturity yield is the ICE BofAML US Corporate AAA effective yield. Tbill is the 3-month constant-maturity yield. OIS is the 3-month overnight indexed swap, and GCF is the Treasury general collateral financing repurchase agreement 3-month rate.

Curve	Change	ConYield Prediction	Empirical Proxy
SUPPLY	Supply of Safe Assets ↑	↓	Treasury issuance
	Window Dressing ↑	↑	quarter-ends
	Bank constraints ↑	↑	covered interest parity
	Bank constraints ↑	↑	reform implementation
DEMAND	Information production ↑	↑	cross-sectional σ(Equity Returns)
	Information production ↑	↑	cross-sectional $\sigma\,[\Delta(\text{CDS Spreads})]$

Table 7: A priori predictions for convenience yield behavior

	(1) GCF-Tbill	(2) Δ(GCF-Tbill)	(3) OIS-Tbill	(4) Δ(OIS-Tbill)
UST Outstanding$_t$	-152.757***		-73.956***	
	(-7.90)		(-3.38)	
UST Issuance$_t$		-0.317**		-0.227**
		(-3.09)		(-3.02)
Constant	14.801***	-0.166	14.407***	-0.067
	(21.61)	(-1.39)	(11.38)	(-0.72)
Observations	6069	1269	3511	801
Adjusted R^2	0.09	0.01	0.02	0.01
Sample	Exclude SFP	Exclude SFP	Exclude SFP	Exclude SFP

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Convenience Yield and US Treasurys. $\text{ConYield}_t^{NSA} = \alpha + \beta \log(\text{UST})_{t-1} + \varepsilon_t$. UST is US Treasurys. Regression run at the daily level. Dependent variable is convenience yield, in basis points, with no seasonal adjustment, measured either via the OIS-Tbill or the GCF-Tbill spread. Independent variable is the detrended series for US Treasurys outstanding and issuance. Sample excludes the Supplemental Financing Program period from September 2008 to August 2011. T-statistics are reported in parentheses using Newey-West standard errors with a maximum of 20 lags.

	(1) OIS-Tbill	(2) OIS-Tbill	(3) GCF-Tbill	(4) GCF-Tbill
Quarter-End	1.66***	2.48***	3.60***	3.99***
	(5.18)	(3.88)	(7.47)	(6.67)
Constant	0.76	0.58	18.34***	18.31***
	(1.30)	(0.89)	(19.39)	(19.31)
Observations	4035	4557	6604	7117
Adjusted R^2	0.77	0.63	0.50	0.49
Exclude Crisis	Yes	No	Yes	No
Year Fixed-Effects	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: Convenience Yield Robustness Test: Quarter-End Dummy Regression. Regression specification: $\text{ConYield}_t^{NSA} = \alpha + \beta_1 \mathbb{I}_{\text{Quarter-End}} + \theta_t + \varepsilon_t$ where θ_t are year fixed-effects. Dependent variable is convenience yield, in basis points, with no seasonal adjustment, measured either via the OIS-Tbill or the d GCF-Tbill spread. Quarter-end dummy is equal to one if the date is in the last week of a quarter-end in March, June, September or December and zero otherwise. T-statistics are reported in parentheses using robust standard errors. *, **, and *** denote significance at the 5%, 1%, and 0.1% levels respectively.

	OIS – Tbill	GCF – Tbill	1W/OIS	1W/IBOR	1M/OIS	1M/IBOR	3M/OIS	3M/IBOR
OIS – Tbill	1.00							
GCF – Tbill	0.75***	1.00						
1W/OIS	0.11***	0.25***	1.00					
1W/IBOR	-0.02	0.16***	0.97***	1.00				
1M/OIS	0.24***	0.50***	0.57***	0.56***	1.00			
1M/IBOR	0.06***	0.28***	0.57***	0.63***	0.82***	1.00		
3M/OIS	0.21***	0.50***	0.40***	0.44***	0.90***	0.65***	1.00	
3M/IBOR	0.01	0.23***	0.33***	0.47***	0.67***	0.80***	0.71***	1.00

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: Pairwise Correlation Between Benchmark Convenience Yield Measures and Covered Interest Parity Violations. Each covered interest parity series is the first four principal components of the absolute value of the basis parity violation relative to the dollar from 1998 to 2018, measured at a daily level, and discounted either at OIS or the respective country's interbank offered rate. Series include Australian dollar (AUD), Canadian dollar (CAD), Swiss franc (CHF), Danish krone (DKK), Euro (EUR), Pound sterling (GBP), Japanese yen (JPY), New Zealand dollar (NZD), and Swedish krona (SEK). 1-Week series does not include CHF as the data is not available. *, **, and *** denote significance at the 5%, 1%, and 0.1% levels respectively.

	OIS − Tbill	GCF − Tbill	Equity Vol	CDS Vol
OIS − Tbill	1.00			
GCF − Tbill	0.75***	1.00		
Equity Vol	0.10***	0.29***	1.00	
CDS Vol	0.22***	0.33***	0.58***	1.00

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11: Pairwise Correlations between Benchmark Convenience Yield Measures and Information Production Measures Cross-Sectional Standard Deviation of Equities and CDS. Cross-sectional volatility for stocks, Equity Vol, is proposed in Chousakos et al. (2018) and is calculated from the cross sectional volatility of daily CRSP returns following sample selection of Asness et al. (2013). In particular, the sample excludes: financials, real estate, insurance companies; stocks with share codes that are not ordinary common stocks; stocks with a price less than $1 at the beginning of a month; stocks without at least 12 months of return history; and stocks that are not in the top 90% of market value when ranked by market value. The purpose of this selection is to produce a sample of stocks that are the most liquid and easily traded. The credit default swap measure, CDS Vol, is the cross-sectional standard deviation in the daily change in 5-year swap spreads across specific contracts. Daily data is provided by Markit and the sample includes contracts with the following attributes:USD-denominated; North American reference entity, senior unsecured tier, ratings between AAA and BBB.

	(1) Δ(OIS-Tbill)$_t^{SA}$	(2) Δ(OIS-Tbill)$_t$	(3) Δ(GCF-Tbill)$_t^{SA}$	(4) Δ(GCF-Tbill)$_t$
FHLB$_t$	-0.86*	-0.71*	-1.11**	-0.94**
	(-2.56)	(-2.20)	(-2.97)	(-2.85)
Constant	-2.92	-3.25	-0.25	-2.34
	(-1.12)	(-1.66)	(-0.14)	(-1.25)
Observations	583	583	580	580
Adjusted R^2	0.13	0.07	0.06	0.03
Controls	Yes	Yes	Yes	Yes
Sample	Post-Reform	Post-Reform	Post-Reform	Post-Reform

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 12: Benchmark Test 1 Main Result: FHLB Issuance Drives the Convenience Yield. $\Delta\text{ConYield}_t = \alpha + \beta \log(\text{FHLB}_t)_{\text{Detrended}} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Dependent variable is changes in the convenience yield, in basis points, as measured by changes in the OIS-Tbill and GCF-Tbill spreads, both seasonally adjusted (SA) and not. Seasonal adjustment from preceding 5-year rolling window, excluding the crisis period. Issuance is calculated from the detrended series of log FHLB discount note issuance of maturities 4-weeks to 26-weeks. Post-reform sample is July 2014 to February 2020, reflecting the period after which the money-market reforms had been announced. T-statistics are reported in parentheses using Newey-West standard errors with a maximum of 20 lags.

	(1) Δ(OIS-Tbill)$_t^{SA}$	(2) Δ(GCF-Tbill)$_t^{SA}$	(3) Δ(OIS-Tbill)$_t^{SA}$	(4) Δ(GCF-Tbill)$_t^{SA}$
Corporate Bonds$_t$	0.07	0.10		
	(1.61)	(1.94)		
A2/P2 Non-Fin. CP$_t$			0.12	0.11
			(0.78)	(0.79)
Constant	-0.73**	-1.07***	-0.72**	-1.09***
	(-2.85)	(-4.58)	(-2.81)	(-4.76)
Observations	1257	1253	1393	1387
Adjusted R^2	0.05	0.06	0.05	0.06
Controls	Yes	Yes	Yes	Yes
Sample	Post-Reform	Post-Reform	Post-Reform	Post-Reform

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13: Benchmark Test 1 Robustness Test: Corporate Bond and A2/P2 Commercial paper Issuance Does Not Drive the Convenience Yield. $\Delta \text{ConYield}_t = \alpha + \beta \log(\text{Issuance}_t)_{\text{Detrended}} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Dependent variable is changes in the convenience yield, in basis points, as measured by changes in the seasonally adjusted (SA) OIS-Tbill and GCF-Tbill spreads. Seasonal adjustment from preceding 5-year rolling window, excluding the crisis period. Issuance is calculated from the detrended log issuance series of corporate bonds and A2/P2 (i.e., the lowest-rated) non-financial commercial paper with less than 4 days maturity. Post-reform sample is July 2014 to February 2020, reflecting the period after which the money-market reforms had been announced. T-statistics are reported in parentheses using Newey-West standard errors with a maximum of 20 lags.

	(1) Δ(GCF-Tbill)$_t^{SA}$	(2) Δ(GCF-Tbill)$_t^{SA}$	(3) Δ(GCF-Tbill)$_t^{SA}$	(4) Δ(GCF-Tbill)$_t^{SA}$	(5) Δ(GCF-Tbill)$_t^{SA}$	(6) Δ(GCF-Tbill)$_t^{SA}$	(7) Δ(GCF-Tbill)$_t^{SA}$	(8) Δ(GCF-Tbill)$_t^{SA}$	(9) Δ(GCF-Tbill)$_t^{SA}$
FHLB$_t$	-1.11**	-1.08**	-1.11**	-1.10**	-1.14**	-1.08*	-1.22*	-0.40	-0.98
	(-2.76)	(-2.77)	(-2.73)	(-2.69)	(-2.68)	(-2.58)	(-2.56)	(-0.59)	(-1.53)
ABCP$_t$		0.67							
		(1.37)							
Fin. CP$_t$			0.01						
			(0.04)						
Non-Fin. CP$_t$				-0.06					
				(-0.38)					
Total CP$_t$					0.50				
					(0.45)				
Corp. Bonds$_t$						0.12			
						(1.16)			
ABS$_t$							0.00		
							(0.03)		
PLMBS$_t$								0.23	
								(0.57)	
CDO$_t$									0.33
									(1.19)
Constant	-0.25	-0.22	-0.26	-0.16	-0.32	0.00	1.86***	0.50	1.64***
	(-0.12)	(-0.11)	(-0.12)	(-0.08)	(-0.15)	(0.00)	(9.16)	(0.74)	(5.28)
Observations	580	580	580	579	580	523	385	95	260
Adjusted R^2	0.06	0.06	0.05	0.05	0.05	0.07	0.07	-0.00	0.06
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	Post-Reform	Post-Reform	Post-Reform	Post-Reform	Post-Reform	Post-Reform	Post-Reform	Post-Reform	Post-Reform

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 14: Benchmark Test 1 Robustness Test: FHLB Horseraces, Panel A. $\Delta\text{ConYield}_t = \alpha + \beta \log(\text{Issuance}_t)_{\text{Detrended}} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Dependent variable is changes in the convenience yield, in basis points, as measured by changes in the seasonally adjusted (SA) GCF-Tbill spread. Seasonal adjustment from preceding 5-year rolling window, excluding the crisis period. Issuance is calculated from the detrended log issuance series: FHLB is 4-week to 26-week maturity discos; ABCP, Fin. CP, and Non-fin. CP refer to flavors of AA rated (top-rated) commercial paper with less than 4 days maturity, asset-backed, financial, non-financial; Total CP is all commercial paper with less than 4 day maturity; corporate bonds is all corporate bonds in the Mergent Fixed-Income database; ABS refers to the sum of USD securitized asset-backed issuance of public SEC-registered ABS, private/rule 144A ABS, private-label MBS, CDO, and ABS/MBS sold primarily outside the US; CDO are collateralized debt obligations; and PLMBS refer to private-label mortgage-backed securities that are SEC-registered with first-lien residential loans including jumbo and Alt-A mortgages. Post-reform sample is July 2014 to February 2020, reflecting the period after which the money-market reforms had been announced. T-statistics are reported in parentheses using robust standard errors.

	(1) Δ(OIS-Tbill)$_t^{SA}$	(2) Δ(OIS-Tbill)$_t^{SA}$	(3) Δ(OIS-Tbill)$_t^{SA}$	(4) Δ(OIS-Tbill)$_t^{SA}$	(5) Δ(OIS-Tbill)$_t^{SA}$	(6) Δ(OIS-Tbill)$_t^{SA}$	(7) Δ(OIS-Tbill)$_t^{SA}$	(8) Δ(OIS-Tbill)$_t^{SA}$	(9) Δ(OIS-Tbill)$_t^{SA}$
FHLB$_t$	-0.86**	-0.84*	-0.93**	-0.84*	-0.94**	-0.97**	-0.80*	-0.24	-0.45
	(-2.61)	(-2.57)	(-2.85)	(-2.52)	(-2.72)	(-2.65)	(-2.50)	(-0.44)	(-1.12)
ABCP$_t$		0.54							
		(1.16)							
Fin. CP$_t$			0.28*						
			(2.48)						
Non-Fin. CP$_t$				-0.14					
				(-1.51)					
Total CP$_t$					1.12				
					(1.46)				
Corp. Bonds$_t$						0.13			
						(1.35)			
ABS$_t$							-0.07		
							(-0.71)		
PLMBS$_t$								-0.00	
								(-0.02)	
CDO$_t$									0.31
									(1.60)
Constant	-2.92	-2.90	-3.07	-2.67	-3.01	-2.50	2.28***	-0.42	2.02***
	(-1.08)	(-1.10)	(-1.13)	(-1.01)	(-1.15)	(-0.97)	(16.69)	(-0.85)	(10.59)
Observations	583	583	583	582	583	525	386	95	261
Adjusted R^2	0.13	0.13	0.14	0.13	0.14	0.14	0.10	0.17	0.10
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	Post-Reform	Post-Reform	Post-Reform	Post-Reform	Post-Reform	Post-Reform	Post-Reform	Post-Reform	Post-Reform

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Benchmark Test 1 Robustness Test: FHLB Horseraces, Panel B. $\Delta\text{ConYield}_t = \alpha + \beta \log(\text{Issuance}_t)_{\text{Detrended}} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Dependent variable is changes in the convenience yield, in basis points, as measured by changes in the seasonally adjusted (SA) OIS-Tbill spread. Seasonal adjustment from preceding 5-year rolling window, excluding the crisis period. Issuance is calculated from the detrended log issuance series: FHLB is 4-week to 26-week maturity discos; ABCP, Fin. CP, and Non-fin. CP refer to flavors of AA rated (top-rated) commercial paper with less than 4 days maturity, asset-backed, financial, non-financial; Total CP is all commercial paper with less than 4 day maturity; corporate bonds is all corporate bonds in the Mergent Fixed-Income database; ABS refers to the sum of USD securitized asset-backed issuance of public SEC-registered ABS, private/rule 144A ABS, private-label MBS, CDO, and ABS/MBS sold primarily outside the US; CDO are collateralized debt obligations; and PLMBS refer to private-label mortgage-backed securities that are SEC-registered with first-lien residential loans including jumbo and Alt-A mortgages. Post-reform sample is July 2014 to February 2020, reflecting the period after which the money-market reforms had been announced T-statistics are reported in parentheses using robust standard errors.

	(1) Δ(OIS-Tbill)$_t^{SA}$	(2) Δ(GCF-Tbill)$_t^{SA}$	(3) Δ(OIS-Tbill)$_t^{SA}$	(4) Δ(GCF-Tbill)$_t^{SA}$	(5) Δ(OIS-Tbill)$_t^{SA}$	(6) Δ(GCF-Tbill)$_t^{SA}$	(7) Δ(OIS-Tbill)$_t^{SA}$	(8) Δ(GCF-Tbill)$_t^{SA}$
FHLB$_t$	-0.12	-0.41	0.04	-0.70	-0.49*	-0.24	-0.86*	-1.11**
	(-0.38)	(-0.74)	(0.04)	(-0.67)	(-1.98)	(-0.76)	(-2.56)	(-2.97)
Constant	1.19	0.80	-16.16*	-16.17***	-2.30**	-0.65	-2.92	-0.25
	(1.85)	(0.32)	(-2.35)	(-4.44)	(-2.69)	(-0.57)	(-1.12)	(-0.14)
Observations	469	857	215	210	527	525	583	580
Adjusted R^2	0.14	0.02	0.01	-0.01	0.16	0.01	0.13	0.06
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	Pre-Crisis	Pre-Crisis	Crisis	Crisis	Pre-Reform	Pre-Reform	Post-Reform	Post-Reform

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 15: Migration in Benchmark Test 1: FHLB Issuance Drives Convenience Yield Post-Crisis, Not Pre-Crisis. $\Delta\text{ConYield}_t = \alpha + \beta \log(\text{FHLB}_t)_{\text{Detrended}} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Dependent variable is changes in the convenience yield, in basis points, as measured by changes in the seasonally adjusted (SA) OIS-Tbill and GCF-Tbill spreads. Seasonal adjustment from preceding 5-year rolling window, excluding the crisis period. Issuance is calculated from the detrended series of log FHLB discount note issuance of maturities 4-weeks to 26-weeks. Pre-crisis is before June 2007, crisis is June 2007 to June 2009, pre-reform is July 2009 to July 2014, and post-reform is July 2014 to February 2020, reflecting the period after which the money-market reforms had been announced. T-statistics are reported in parentheses using Newey-West standard errors with a maximum of 20 lags.

	(1) Δ(OIS-Tbill)^{SA}	(2) Δ(GCF-Tbill)^{SA}	(3) Δ(OIS-Tbill)	(4) Δ(GCF-Tbill)
Pre-Crisis	-0.49	-0.48	-0.01	-0.31
	(-1.32)	(-0.93)	(-0.05)	(-0.66)
Crisis	0.09	-0.82	0.00	-0.79
	(0.06)	(-0.54)	(0.00)	(-0.54)
Pre-Reform	-0.40	-0.34	-0.18	-0.21
	(-1.31)	(-0.98)	(-0.69)	(-0.67)
Post-Reform	-0.92**	-0.86*	-0.64*	-0.70*
	(-3.07)	(-2.30)	(-2.31)	(-2.07)
Observations	1794	2172	1898	2172

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 16: Migration in Benchmark Test 1: Pre-Crisis to Post-Reforms Migration to FHLBs. Table gives the marginal effect of FHLB issuance on changes in the convenience yield estimated from $\Delta \text{ConYield}_t^{SA} = \alpha + \beta_1 \log(\text{FHLB}_t)_{\text{Detrended}} + \sum_i \beta_i \log(\text{FHLB}_t)_{\text{Detrended}} \times \mathbb{I}_{\text{Regime}^i} + \mathbb{I}_{\text{Regime}^i} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Marginal effects are plotted in Figure 7. Regression run at the daily level. Dependent variable is changes in the convenience yield, in basis points, as measured by changes in the seasonally adjusted (SA) OIS-Tbill and GCF-Tbill spreads. Seasonal adjustment from preceding 5-year rolling window, excluding the crisis period. Issuance is calculated from the detrended series of log FHLB discount note issuance of maturities 4-weeks to 26-weeks. Pre-crisis is before June 2007, crisis is June 2007 to June 2009, pre-reform is July 2009 to July 2014, and post-reform is July 2014 to February 2020, reflecting the period after which the money-market reforms had been announced. T-statistics are reported in parentheses using robust standard errors.

Panel A: OIS-Tbill Measure of Convenience Yield

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$i =$	FHLB^{Disco}		Freddie^{ON}		Freddie^{Disco}		$\text{Freddie}^{>1yr}$		$\text{Fannie}^{>1yr}$	
Regime	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Issuance^i	-0.12	-0.86*	0.07	0.00	0.02	0.00	-0.07	-0.01	-0.06	0.05
	(-0.38)	(-2.56)	(0.99)	(0.04)	(0.23)	(0.07)	(-1.31)	(-0.30)	(-0.98)	(0.86)
N	469	583	726	1196	1116	1369	997	985	1048	457
Adj. R^2	0.14	0.13	0.09	0.05	0.09	0.05	0.08	0.05	0.07	0.07
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: GCF-Tbill Measure of Convenience Yield

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
$i =$	FHLB^{Disco}		Freddie^{ON}		Freddie^{Disco}		$\text{Freddie}^{>1yr}$		$\text{Fannie}^{>1yr}$	
Regime	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Issuance^i	-0.41	-1.11**	0.07	-0.10	0.01	-0.02	0.01	-0.07	0.13	0.09
	(-0.74)	(-2.97)	(0.87)	(-0.68)	(0.09)	(-0.47)	(0.11)	(-1.34)	(1.26)	(1.30)
N	857	580	2380	1191	2903	1364	2928	984	3006	456
Adj. R^2	0.02	0.06	0.00	0.06	0.01	0.06	0.01	0.07	0.00	0.08
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 17: Migration in Benchmark Test 1: Migration to FHLBs. $\Delta\text{ConYield}_t = \alpha + \beta \log(\text{Issuance}_t)_{\text{Detrended}} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Dependent variable is changes in the convenience yield, in basis points, as measured by changes in the OIS-Tbill and GCF-Tbill spreads seasonally adjusted from preceding 5-year rolling window, excluding the crisis period. Issuance is calculated from the detrended series of log issuance of: FHLB discount notes maturities 4-weeks to 26-weeks, Freddie overnight discount notes, Freddie discount notes excluding overnight, Freddie debt with greater than 1-year maturity, and Fannie debt with greater than 1-year maturity. Pre-crisis is before June 2007 and post-reform is July 2014 to February 2020, reflecting the period after which the money-market reforms had been announced. T-statistics are reported in parentheses using Newey-West standard errors with a maximum of 20 lags.

	(1)	(2)	(3)	(4)
$\text{ConYield}_{t-1}^{OIS,SA}$	0.0050*			
	(2.33)			
$\text{SeasonalComponent}_{t}^{OIS}$	0.0077		0.0036	
	(1.95)		(0.80)	
$\text{ConYield}_{t-1}^{GCF,SA}$		0.0027*		
		(2.22)		
$\text{SeasonalComponent}_{t}^{GCF}$		0.0006		-0.0019
		(0.25)		(-0.87)
OIS-Tbill_t			0.0039	
			(1.75)	
GCF-Tbill_t				0.0027*
				(2.09)
Constant	-0.4718*	-0.2965	-0.4727*	-0.3069
	(-2.53)	(-1.81)	(-2.57)	(-1.86)
Observations	1579	1970	1579	1970
Adjusted R^2	0.29	0.26	0.29	0.26
Sample	Ex-Crisis	Ex-Crisis	Ex-Crisis	Ex-Crisis
Controls	Yes	Yes	Yes	Yes

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 18: Benchmark Test 2 Main Result: FHLB Issuance Responds to Convenience Yield the Day Before. $\log(\text{Issuance}_t)_{\text{Detrended}} = \alpha + \beta_1 \text{SeasonalComponent}_t + \beta_2 \text{ConYield}_{t-1}^{SA} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Dependent variable is issuance calculated from the detrended series for FHLB issuance of discount notes with 4-week to 26-week maturity debt. Seasonal adjustment of convenience yield from preceding 5-year rolling window, excluding the crisis period. T-statistics are reported in parentheses using Newey-West standard errors with a maximum of 20 lags.

	(1)	(2)	(3)	(4)
Tail_{t-1}	-0.1101***	-0.0988***	-0.0959**	-0.0942**
	(-3.43)	(-3.37)	(-3.28)	(-3.26)
$\text{ConYield}_{t-1}^{GCF,SA}$			0.0015	
			(0.92)	
$\text{SeasonalComponent}_{t}^{GCF}$			-0.0051	
			(-1.04)	
$\text{ConYield}_{t-1}^{OIS,SA}$				0.0062*
				(2.08)
$\text{SeasonalComponent}_{t}^{OIS}$				-0.0079
				(-0.60)
Constant	-0.0762**	0.0234	0.1647	-0.0749
	(-3.09)	(0.19)	(1.01)	(-1.15)
Observations	389	389	381	247
Adjusted R^2	0.09	0.12	0.12	0.17
YearFE	None	Year	Year	Year
Sample	GovPX	GovPX	GovPX	GovPX

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 19: Benchmark Test 2 Alternative Specification: FHLB Issuance Responds to Treasury Demand the Day Before as Measured by Tails. $\log(\text{Issuance}_t)_{\text{Detrended}} = \alpha + \beta_1 \text{Tail}_{t-1} + \theta_t + \varepsilon_t$. Regression run at the daily level. Dependent variable is issuance calculated from the detrended series for FHLB issuance of discount notes with 4-week to 26-week maturity debt. The independent variable, Tail_{t-1}, which is the percent change between yields implied 1 minute before auction and yields realized 30 minutes after the Treasury bill auction. A positive value for Tail_{t-1} means yields increased after auction indicating lower Treasury bill demand than anticipated in the when-issued market. $\text{ConYield}_{t-1}^{SA}$ is the seasonally adjusted convenience yield, measured either via the OIS-Tbill or the GCF-Tbill measure, which correspond to definitions 1 and 2, respectively. Seasonal adjustment from preceding 5-year rolling window, excluding the crisis period. Tails are calculated from 1991 to 2008 due to data constraints. T-statistics are reported in parentheses using robust standard errors. *, **, and *** denote significance at the 5%, 1%, and 0.1% levels respectively.

	(1) Corp. Bonds$_t$	(2) Corp. Bonds$_t$	(3) A2/P2 Non-Fin. CP$_t$	(4) A2/P2 Non-Fin. CP$_t$	(5) Tbill$_t$	(6) Tbill$_t$	(7) UST$_t$	(8) UST$_t$
$\text{ConYield}_{t-1}^{OIS,SA}$	0.0031		0.0037		-0.0002		0.0003	
	(0.49)		(1.86)		(-0.04)		(0.06)	
$\text{SeasonalComponent}_t^{OIS}$	0.0039		0.0003		-0.0672*		-0.0470*	
	(0.51)		(0.14)		(-2.46)		(-2.43)	
$\text{ConYield}_{t-1}^{GCF,SA}$		-0.0008		-0.0039***		0.0006		0.0015
		(-0.37)		(-3.40)		(0.13)		(0.39)
$\text{SeasonalComponent}_t^{GCF}$		-0.0185***		-0.0088***		-0.0063		-0.0064
		(-4.89)		(-3.79)		(-0.65)		(-0.82)
Constant	0.0406	0.4327*	0.0610	0.2766***	1.6707***	2.1081***	1.3605***	1.5504***
	(0.17)	(2.46)	(1.21)	(3.91)	(3.76)	(8.01)	(5.56)	(9.84)
Observations	3632	6174	3781	4227	535	897	814	1278
Adjusted R^2	0.11	0.11	0.39	0.38	0.05	0.11	0.14	0.20
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	Ex-Crisis	Ex-Crisis	Ex-Crisis	Ex-Crisis	Ex-SFP	Ex-SFP	Ex-SFP	Ex-SFP

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 20: Additional Evidence for Benchmark Test 2: Corporate Bonds and Treasurys. $\log(\text{Issuance}_t)_{\text{Detrended}} = \alpha + \beta_1 \text{SeasonalComponent}_t + \beta_2 \text{ConYield}_{t-1}^{SA} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Seasonal adjustment from preceding 5-year rolling window, excluding the crisis period. Issuance is calculated from the detrending process described above. The corporate bond and commercial paper sample excludes the crisis period and the Treasury sample excludes the time the supplemental financing program was in effect, from September 2008 to August 2011. T-statistics are reported in parentheses using Newey-West standard errors with a maximum of 20 lags.

	(1) First Stage (GCF)	(2) Second Stage	(3) First Stage (OIS)	(4) Second Stage	(5) $FHLB_t$
UST_{t-1}	-115.1***		-76.45***		-1.875***
	(-6.69)		(-3.72)		(-4.59)
GCF−Tbill		0.0160***			
		(3.99)			
OIS−Tbill				0.0215**	
				(2.68)	
Constant	15.15***	-0.282***	13.33***	-0.333**	-0.0399**
	(17.83)	(-4.39)	(10.92)	(-3.14)	(-2.62)
N	1849	1849	1560	1560	1860
F-stat 1st Stage		44.71		13.87	

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 21: Additional Evidence for Benchmark Test 2: Treasury Issuance Shock. Regression in columns (2) and (4) is $\log(\text{FHLB}_t)_{\text{Detrended}} = \alpha + \beta \widehat{\text{ConYield}}^{NSA}_{t-1} + \varepsilon_t$, where $\widehat{\text{ConYield}}^{NSA}_{t-1}$ is estimated in the first stage by regressing the OIS-Tbill or GCF-Tbill spread on the detrended Treasury outstanding series: $\text{ConYield}^{NSA}_t = \alpha + \beta \log(\text{UST Outstanding}_{t-1})_{\text{Detrended}} + \varepsilon_t$, which is shown in columns (1) and (3). Excludes supplemental financing program period from September 2008 to August 2011. Issuance is calculated from the detrended series of log FHLB discount note issuance of maturities 4-weeks to 26-weeks. T-statistics are reported in parentheses using Newey-West standard errors with a maximum of 20 lags.

Panel A: Agency Debt

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Freddie^{Disco}		$\text{Freddie}^{RefBill}$		$\text{Fannie}^{>1yr}$		$\text{FFCB}^{>1yr}$	
	OIS-Tbill	GCF-Tbill	OIS-Tbill	GCF-Tbill	OIS-Tbill	GCF-Tbill	OIS-Tbill	GCF-Tbill
$\text{SeasonalComponent}_t$	0.001	0.010***	0.001	0.004**	0.001	-0.003	0.002	0.003
	(0.10)	(4.19)	(0.26)	(2.71)	(0.11)	(-1.39)	(0.56)	(1.41)
$\text{ConYield}_{t-1}^{SA}$	0.005	0.013**	-0.004	0.005	-0.023**	-0.017***	0.006	0.002
	(0.52)	(2.71)	(-0.87)	(1.58)	(-2.66)	(-3.80)	(1.09)	(0.60)
Constant	0.911***	0.691***	0.324**	0.040	0.663***	1.072***	0.961***	0.542*
	(6.16)	(3.66)	(3.21)	(0.44)	(4.88)	(8.37)	(12.86)	(2.12)
Observations	3733	5533	969	1249	2484	4461	3271	4659
Adjusted R^2	0.19	0.20	0.37	0.35	0.11	0.09	0.07	0.06
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Private Safe Assets

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	ABCP		Fin. CP		Non-Fin. CP		CDO	
	OIS-Tbill	GCF-Tbill	OIS-Tbill	GCF-Tbill	OIS-Tbill	GCF-Tbill	OIS-Tbill	GCF-Tbill
$\text{SeasonalComponent}_t$	0.004*	0.001	-0.002	-0.007**	0.000	0.006*	0.012	0.000
	(2.25)	(1.43)	(-0.55)	(-2.95)	(0.05)	(2.47)	(1.95)	(0.10)
$\text{ConYield}_{t-1}^{SA}$	-0.006*	0.001	-0.002	-0.016***	0.012	0.012*	0.002	0.010*
	(-2.05)	(0.53)	(-0.32)	(-3.37)	(1.72)	(2.52)	(0.25)	(2.25)
Constant	0.269***	0.002	-0.040	0.440***	0.712***	0.148	-0.205	-0.205
	(13.93)	(0.04)	(-1.22)	(3.39)	(7.77)	(1.15)	(-1.13)	(-0.85)
Observations	3780	4226	3731	4177	3776	4222	1878	2649
Adjusted R^2	0.59	0.55	0.56	0.57	0.31	0.30	0.12	0.09
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 22: Who Times Issuance: Non-FHLB Agencies and Commercial Paper Issuers. $\log(\text{Issuance}_t)_{\text{Detrended}} = \alpha + \beta_1 \text{SeasonalComponent}_t + \beta_2 \text{ConYield}_{t-1}^{SA} + \theta_t + \varepsilon_t$ where θ_t represents controls including: day-of-week, quarter-end, month-end, and year fixed-effects. Regression run at the daily level. Seasonal adjustment from preceding 5-year rolling window, excluding the crisis period. Issuance is calculated from the detrended logged series: Freddie^{Disco} refers to Freddie discount notes (excluding overnight); $\text{Freddie}^{RefBill}$ are Freddie reference bills; Fannie is bond issues with maturity greater than 1 year; FFCB to Federal Farm Credit Banks bond issues with greater than 1 year maturity; ABCP, financial, and non-financial refers to highly-rated commercial paper issuance with maturities 1 day to 4 days; and CDO are collateralized debt obligations. T-statistics are reported in parentheses using Newey-West standard errors with a maximum of 20 lags.

		Prob > χ^2		
Equation	Excluded	Pre-Crisis	Post-Reform	Full ex-GFC
log(FHLB Outstanding)	GCF-Tbill	0.024	0.067	0.000
log(FHLB Outstanding)	OIS-Tbill	0.098	0.048	0.019
GCF-Tbill	log(FHLB Outstanding)	0.310	0.032	0.150
OIS-Tbill	log(FHLB Outstanding)	0.544	0.009	0.054

Table 23: Granger Causality. Table presents the results from running pairwise Granger causality Wald tests after estimating the vector autoregression in equation 8. The pairwise Granger causality test regresses y_t (shown in column "Equation") on its own lags and the lags of x_t (shown in column "Excluded") and uses a Wald test to check if the coefficients on lags of x_t are jointly 0. The null hypothesis is that the coefficients on the lags are jointly 0: a variable Granger-causes another if we reject the null.

12 Appendix

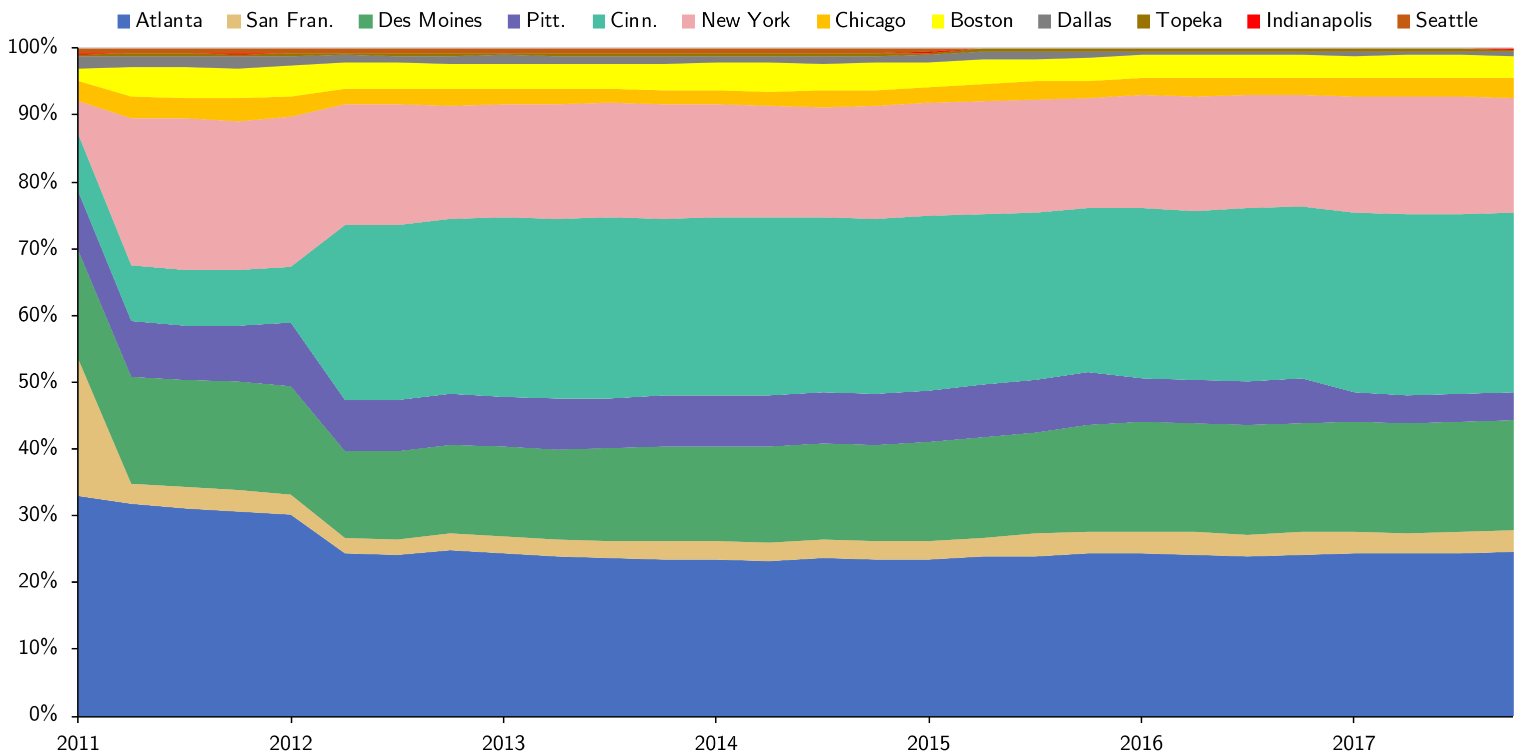

Figure A1: Share of Total Commercial Bank Assets by District. Source: FHLB and Federal Reserve. Only includes commercial banks matched in WRDS and does not include non-commercial-bank members.

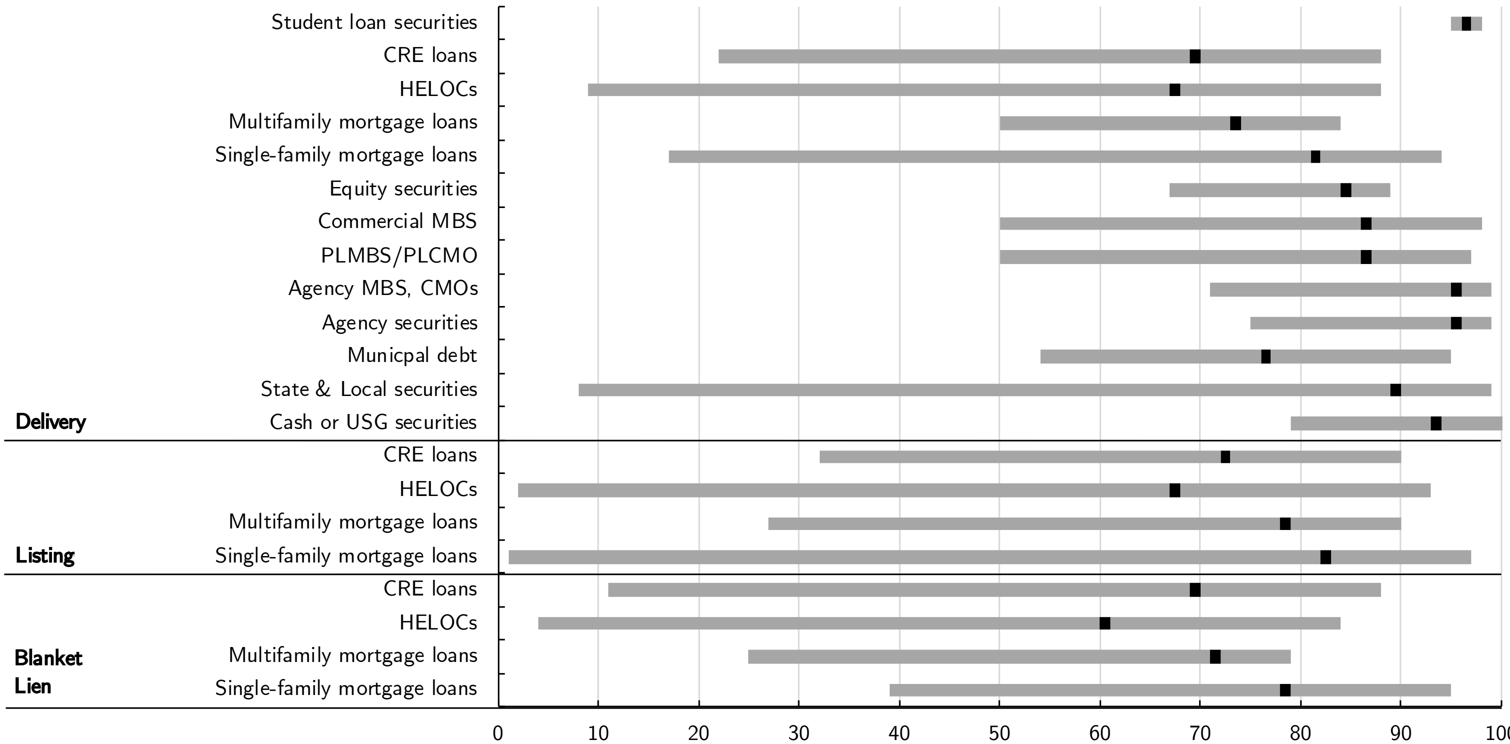

Figure A2: Advance Haircuts, Q4 2017. Source: 2017 FHLB Office of Finance Collateral Q&A.

Member Type	Charter	Q4 2009	Q2 2018
Commercial Bank	State	4,496	3,504
Credit Union	Federal	516	735
	State	488	734
Insurance Company	N/A	207	419
Savings Bank	Federal	437	0
	State	395	331
Savings Association	Federal	0	316
	State	0	52
Savings and Loan	Federal	227	0
	State	73	0
CDFI	N/A	0	52

Table A1: Total Number of FHLB Members by Institution Type

Collateral Type	Blanket %	Listing %	Delivery %	Total %	Blanket $ bil	Listing $ bil	Delivery $ bil	Total $ bil
Single family mortgage	43.5	68.4	2.2	51.6	484	885	6	1,375
CRE loans	33.7	11.3	12.4	20.8	376	146	32	554
Multifamily loans	6.4	12.2	4.9	9.1	71	158	12	241
HELOCs	7.9	7.1	0.0	6.8	88	92	0	180
Agency MBS, CMOs			48.0	4.6			122	122
Agency Securities			7.5	0.7			19	19
U.S. obligations			6.5	0.6			16	16
CMBS			6.3	0.6			16	16
PLMBS/PLCMO			2.2	0.2			6	6
Other	8.5	1.0	9.9	5.0	95	13	25	133
Total	100	100	100	100	1,114	1,294	254	2,662

Table A2: Advance Collateral

$ billion	**Large Borrowers**	**All Others**	**Large Share**
Advances Outstanding (principal)	527	209	72%
Other Credit Products	79	69	54%
Collateral Outstanding	1,583	1,080	59%
Average Haircut	33%	19%	

Table A3: Concentration of Advances. Note: Large borrowers defined as borrowers with $\geq$ \$1 billion of advances outstanding.