The Demand and Supply of Convenience Assets

Arvind Krishnamurthy *
Stanford Graduate School of Business

Yiming Ma†‡
Columbia Business School

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*Corresponding Author. Finance Group, Stanford Graduate School of Business, 655 Knight Way, Stanford, CA 94305. E-mail: akris@stanford.edu.

†Finance Division, Columbia Business School, 665W 130th St, New York, NY 10027. E-mail: ym2701@columbia.edu.

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Abstract

Safe and liquid assets ("convenience assets") are used to make payments, meet unexpected consumption shocks, and facilitate financial transactions. The value of these convenience services is captured by the convenience yield, which is determined by the aggregate demand and supply of convenience assets. U.S. Treasurys are a prime example of a convenience asset, while bank and non-bank financial institutions also produce claims with varying degrees of safety and liquidity. Repos are safe and liquid securities created from tranching a long-term bond into a risky equity claim and a debt repo claim. Banks and bond mutual funds create liquid assets by pooling across investors' idiosyncratic liquidity risk. Finally, packaging securities into a composite, as in mortgage-backed securities, also creates liquid and safe assets. Private-sector creation of convenience assets involves a number of challenges, including leverage constraints and panic runs. We discuss how to measure convenience yields, convenience-asset creation by the private sector, and the equilibrium determination of convenience yields.

Keywords: liquidity premium, safety premium, convenience yield, safe assets, liquidity transformation, Treasurys, bank deposits, non-bank financial institutions, panic runs

1 Introduction

Safe and liquid assets are integral to the functioning of an economy. A variety of agents use these assets as payment instruments. Investors desire liquid assets to meet unexpected transaction and portfolio needs. Banks and other sophisticated financial institutions use liquid assets to facilitate payments, as safe collateral for loans and derivative contracts, and to maintain sufficient liquidity so that they are able to make risky loans or offer credit lines to firms. Importantly, the set of safe and liquid assets serve a dual purpose, both as a financial investment and as input to the productive activities of an economy. Because safe and liquid assets serve this dual purpose, investors pay a premium – the convenience yield – to own the asset.

Suppose $m_{t,t+1}$ is the pricing kernel used by investors at time t to discount payoffs at $t+1$. The price of an asset that is valued only as a financial investment satisfies,

$$P_t = E_t\left[m_{t,t+1}P_{t+1}\right], \tag{1}$$

where P_{t+1} is next period's asset price and P_t is the current period's price. On the other hand, suppose the asset is used as an input to other activities, which we capture in reduced form as generating a flow of services measured as $v_t P_t$. Then, the price of this asset satisfies,

$$P_t = P_t v_t + E_t\left[m_{t,t+1}P_{t+1}\right] \quad \Rightarrow \quad 1 = v_t + E_t\left[m_{t,t+1}\frac{P_{t+1}}{P_t}\right]. \tag{2}$$

We refer to the service flow v_t as a convenience yield. Higher v_t drives up the prices of safe and liquid assets and lowers their expected return $\left(E_t\left[\frac{P_{t+1}}{P_t}\right]\right)$ in equilibrium.

The clearest example of the existence of this convenience yield comes from examining U.S. Treasurys. Figure 1a is from Krishnamurthy & Vissing-Jorgensen (2012) and plots the spread in yields between long-term AAA corporate bonds and Treasury bonds against the total stock of privately held U.S. Treasury bonds, divided by GDP, using annual data from 1919 to 2008. The spread reflects credit risk ($Risk_t$), as the corporate bond is riskier than the Treasury bond, and can reflect the convenience services the Treasury bond offers. Thus,

$$S_t^{AAA-Treas} = Risk_t \; + \; v_t. \tag{3}$$

If we further posit that v_t is decreasing in the total quantity of convenience assets held by investors, then the figure traces out the convenience-demand function, v_t, akin to a money-demand function. Krishnamurthy & Vissing-Jorgensen (2012) infer from this relation that the average convenience yield on Treasury debt relative to corporate debt over their sample is 75 basis points.

The private sector has also attempted to produce safe and liquid assets in various ways. The most significant example of a privately produced asset that carries convenience yields is short-term debt issued by financial institutions, including banks. Figure 1b is from Krishnamurthy & Vissing-Jorgensen (2015) and plots the quantity outstanding of short-term financial sector debt against the supply of government safe assets, using annual data from 1874 to 2014. The figure illustrates that financial sector debt is a substitute for government debt: less government debt increases the convenience yield on safe and liquid assets (left panel) and induces the banking sector to take advantage of the higher convenience yield by increasing their issuance of bank debt (right panel).

Leading up to the 2008 financial crisis, there was an expansion of activities that transformed loans into liquid claims, including asset-backed commercial paper (ABCP), asset-backed securities (ABS), and mortgage-backed securities (MBS). See Dang et al. (2020) for a detailed review. More recently, non-bank financial institutions have been increasingly active in transforming illiquid assets into more liquid claims. Bond mutual funds issue fund shares that are demandable on a daily basis, while exchange-traded funds (ETFs) issue shares that are tradeable on liquid exchange markets. Institutional prime money market funds (MMFs) allow daily redemptions at a floating net asset value (NAV) like bond mutual funds, while government MMFs promise a more stable NAV at $1.

The safety and liquidity of privately produced assets vary over time. Even for insured and regulated banks, there are periods of strains when deposits are no longer a liquid and safe asset. Recent examples include the 2008 financial crisis and the 2023 U.S. regional banking crisis. Non-bank liquidity transformation has also experienced significant disruptions, including MMFs "breaking the buck" in September 2008 and runs on bond mutual funds in March 2020. Thus, the notion of liquidity and safety for privately produced assets is relative and time-varying.

This article is an introduction to theory and measurement around convenience assets that can be understood by anyone who has completed the first year of graduate-level work in finance and economics. It is not a comprehensive survey of the area. For complementary treatments of the issues we cover see Gorton (2017), Caballero et al. (2017), Diamond (2020), Dang et al. (2020), Gorton & Ordonez (2022). The next section explains the economic forces that shapes the private sector's ability to create convenience assets. Section 3 explains how the convenience yield has been measured in the literature and how to interpret different measures. We also clarify a conceptual point around terminology: why we use the word "convenience yield" rather than liquidity, safety or collateral premium. Section 4 reviews estimates on the demand for convenience assets. Section 5 reviews work on measuring the suppliers of convenience assets.

2 The Production of Convenience Assets and its Challenges

The evidence in Figure 1a concerns government bonds. In this section, we discuss how the private sector creates safe and/or liquid assets.[1] Financial intermediaries tranche claims into inside equity and debt, enhancing the liquidity of debt claims. We describe how intermediaries also issue claims to pool investors' idiosyncratic liquidity shocks and generate liquidity. In practice, intermediaries provide liquidity in this manner through both demandable equity and demandable debt. Finally, we describe how liquidity provision can occur through pooling securities into a traded bundle.

2.1 Tranching

Gorton & Pennacchi (1990) present a model where an issuer tranches the cash-flow from an asset into a risky equity claim and a low-risk debt claim. When some investors have private information regarding the asset's cash-flows, doing so minimizes adverse selection in the retrading of the debt claim in the secondary market.[2] That is, the trading of the debt claim is less subject to the trading motives of privately informed investors, and hence retrading the debt claim suffers a smaller lemons cost than retrading the equity claim. DeMarzo & Duffie (1999) offer a related analysis in which an issuer with private information about cash-flows issues a debt claim against these cash-flows to minimize the lemons cost when raising funds in the primary market. Both papers develop the idea that the benefit of tranching is that the debt claim is minimally information sensitive so trading the claim in the primary or

[1] We do not address the fiscal and monetary challenges of governments in creating safe assets. He et al. (2016), Farhi & Maggiori (2018), Chen et al. (2022) and Coppola et al. (2023) study this issue.

[2] Dang et al. (2017) further argue that the opacity of banks ensures that information about bank assets remains hidden, preserving symmetry of information across depositors.

secondary market reduces lemons-costs and maximizes liquidity.

Treasury-backed repo is an example of tranching to create a safe debt instrument. The borrower issues debt of D_t against the collateral of long-term Treasury bonds at the current market value of P_t. The amount of debt is $D_t < P_t$, with the "haircut" defined as $P_t - D_t$. With a sufficiently high haircut, the lender owns a safe debt claim, over-collateralized by Treasurys. The claim is information-insensitive in the sense that its payoff depends minimally on the factors that drive the value of the Treasurys at $t+1$, P_{t+1}. The borrower retains the equity claim, which will be worth $P_{t+1} - D_t(1+r_t)$ at $t+1$, with r_t as the repo interest rate. The owner of the Treasury-backed repo, such as a MMF, need not have any information about the factors that drive the value of long-term Treasury bonds. For the investor in the Treasury-backed repo, the repo is a safe and adverse-selection-free investment in the sense of DeMarzo & Duffie (1999).

Finally, the convenience services stemming from the safe Treasury repo cause r_t to fall, relative to a non-convenience benchmark at rate r_t^{NC}, so that $r_t = r_t^{NC} - v_t$. Consider the financial payoff at $t+1$ to the owner of the Treasury collateral ("equity holder") that issues D_t of repo debt against the collateral at r_t. The owner invests the proceeds of D_t from the repo borrowing at a non-convenience rate at r_t^{NC} giving,

$$P_{t+1} + D_t(r_t^{NC} - r_t) = P_{t+1} + D_t v_t. \tag{4}$$

We note that the term $D_t v_t$ looks similar to the convenience service flow in Equation (2), although here it is a financial payoff to the owner of the Treasury collateral. The price an investor will pay to purchase the Treasury collateral at date t is,

$$E_t[m_{t,t+1}(P_{t+1} + D_t v_t)] = E_t[m_{t,t+1} P_{t+1}] + E_t[m_{t,t+1}] D_t v_t \tag{5}$$

A higher v_t increases the discounted payoff from owning Treasury collateral and issuing debt that provides convenience services. As a result, the Treasury collateral becomes more valuable, which drives up P_t in equilibrium (Duffie, 1996, Krishnamurthy, 2002). A long-term Treasury bond that is good collateral in the repo market will have a high price, even if the bond itself does not offer convenience services to an investor. When interpreting Figure 1a, it is important to recognize that the relation may not capture convenience services of the long-term Treasury bond, but rather convenience services from the repo that is secured by the long-term Treasury bond.[3]

Another example of the creation of safe and liquid debt via tranching can be found in the 17th and 18th century Bank of Amsterdam. The bank introduced a ledger currency known as the florin. Florins were usable for payments through account transfers at the bank, making them a liquid asset. Additionally, the florin traded at a premium compared to the local Dutch coin, the guilder, which thereby reflected a convenience yield. To create a florin deposit, an investor would deposit a coin at the bank and receive some quantity of florin, at a haircut to the value of the coin, and a "receipt" which could be used in conjunction with the florin to redeem the underlying coin. Haircuts would vary depending on the underlying coin (many coins of varying metallic content circulated in medieval Europe). Quinn & Roberds (2023) describe this arrangement and the development of the florin. The receipt is analogous to the equity claim on the collateral (the coin), while the florin deposit is the debt claim. Once created, the florin deposit could be traded easily, in part because its value was minimally informationally sensitive to the value of the underlying coin.

In both of these cases of tranching, there are costs/limits to the creation of the safe/liquid debt claims. The first limit is the aggregate quantity of usable collateral. Figure 1a illustrates this point. Suppose that the convenience value to agents v_t is decreasing in the quantity of convenience assets. Then, since the amount of Treasury-backed repo is limited by the total quantity of Treasurys, shifts in that quantity lead to changes in the convenience yield. A second limit is the institutional setting behind contract enforcement. In the context of Amsterdam, the implicit commitment of the city of Amsterdam to not seize the coin of the Bank was important in ensuring the safety of the florin. This commitment failed in the latter part of the 18th century due to fiscal needs of an ongoing war, leading to the demise of the Bank of Amsterdam. A third limit is the risk-bearing capacity of safe asset creators. The payoff in Equation (5) is risky, as a leveraged position in risky Treasury collateral. If the risk-bearing capacity of leveraged investors is low, which may occur if intermediary capital is low, as in models of intermediary asset pricing (He & Krishnamurthy, 2013), then the supply of safe debt issued against risky collateral will fall.[4]

[3] In the U.S., agency MBS are another form of collateral commonly used in the repo market. These assets also command a convenience yield as shown by He & Song (2022).

[4] More formally, the leveraged investor needs to fund $P_t - D_t$ in (5). Suppose that this comes from investor's capital at a shadow cost of capital of $r_t^{NC} + \lambda_t$. Then, the payoff to the equity holder is $P_{t+1} - P_t(1 + r_t^{NC} + \lambda_t) + D_t v_t$, which falls as λ_t rises. Additionally, if the leveraged investor has reduced risk capacity in the sense that $m_{t,t+1}$ assigns higher prices to worse payoff states, then the discounted value of the leveraged investor's equity payoff falls. Both factors will reduce the leverage investor's willingness to own collateral against issuing repo debt, and hence reduce tranching in equilibrium.

2.2 Pooling of Investors' Liquidity Risk

In Diamond & Dybvig (1983), banks hold long-term investment projects and issue demandable deposit contracts to investors that offer them liquidity. Real investment projects mature in the long run and are costly to liquidate in the short run. Investors face idiosyncratic liquidity needs, whereby they may need to consume in the short run. Without an intermediary, each investor needs to liquidate her long-term project at a cost if needing to consume early. An intermediary pools investment in the long-term project, holding some resources for the investors who need to consume in the short run. Collectively, more of the long-term project can be held to maturity without incurring liquidation costs. Therefore, the pooling of idiosyncratic liquidity risk allows for the creation of liquidity for investors. Bank deposit contracts are liquid in the sense that investors can use them to obtain resources immediately.

As noted in Diamond & Dybvig (1983), offering liquidity via demandable debt gives rise to the potential for coordination failure: If a depositor believes that other depositors will withdraw funds early, it is optimal for her to withdraw early while the bank can still honor the deposit promise. Otherwise, if all other depositors withdraw, assets are liquidated at a discount, the bank defaults, and the value of debt is reduced for any remaining depositors below the promised value.[5]

In practice, banks create debt that is liquid, traded in a manner that is free of adverse selection, and used as payment instruments. However, there are limits on banks' ability to create debt. If a bank issues too much debt against ownership of illiquid assets, then the bank is subject to run risk. Regulated banks have access to the central bank's discount window as well as government deposit insurance that mitigates this risk. But these government guarantees are often incomplete to mitigate moral hazard concerns. For example, Dávila & Goldstein (2023) characterize an optimal deposit insurance limit that trades off the benefits from reducing run risk against the moral hazard costs. The presence of uninsured deposits still subjects banks to run risk (Egan et al., 2017, Jiang et al., 2024). Government insurance is also coupled with regulatory requirements to hold sufficient central bank reserves and other high-quality liquid assets. Additionally, illiquid assets are also typically risky assets that create the risk of insolvency. If bank capital is low, binding bank capital requirements may limit leverage and thereby limit the creation of liquid debt.

[5]Goldstein & Pauzner (2005) show that such panic-based bank runs may arise when underlying fundamentals (i.e., the value of bank assets) are weak. In theory, panic runs can be eliminated with deposit insurance. In practice, the risk of bank runs remains as deposit insurance is incomplete and non-deposit funding is not explicitly insured.

There exist other non-bank financial institutions that create liquidity by pooling investors' liquidity risks, but do so via issuance of equity-like claims rather than the debt claims of the Diamond & Dybvig (1983) model. Open-ended bond mutual funds issue equity contracts that are demandable at the end of the day and backed by a pooled portfolio of illiquid assets such as corporate bonds. Demandable fund equity can provide liquidity similar to bank deposits when investors are subject to idiosyncratic liquidity risks. On the other hand, as discussed in Section 2.1, debt claims may be more liquid than equity because they are less informationally sensitive. In practice, only bank debt is used by a wide set of agents to make payments.

Demandable equity, like bank debt, may be subject to runs. The details of the contract design of demandable equity can influence the risk of runs and, thus, the capacity for non-banks to provide liquidity to investors. Bond mutual fund shares pay the end-of-day NAV, which reflects the market value of the assets that remain in the fund's portfolio at the end of each day. This end-of-day NAV is contingent on the fundamental value of the portfolio assets. However, it does not directly reflect the externalities imposed by redeeming investors on the remaining investors' payoffs (Chen et al., 2010, Goldstein et al., 2017). For example, funds may delay the sale of illiquid assets to the days following a given redemption because of illiquidity in the underlying bond markets. Investors then have an incentive to redeem from the fund before the sales depress the share value, i.e., there is a first-mover advantage. Even if funds have enough cash to meet redemptions in a given period, rebuilding cash buffers in future periods involves the costly sale of more illiquid securities (Zeng, 2017). The fact that the end-of-day NAV does not reflect these possibilities, while investor behavior does, can explain why bond mutual funds remain subject to panic-based outflows in practice, such as in March 2020 (Haddad et al., 2021, Falato et al., 2021, Ma et al., 2022b).

The vulnerability of demandable equity contracts to panic runs is also evident from the experience of MMFs. Although MMFs are constrained to hold assets of shorter maturities and higher ratings, some illiquidity remains, and the cost of liquidating assets at short notice is not negligible. That is why their fixed $1 NAV can lead to panic runs (Kacperczyk & Schnabl, 2013). However, even after the 2016 money market reform required institutional prime MMFs to float their NAVs as in an equity contract, they still experienced panic-driven outflows in March 2020 (Li et al., 2021). As in the case of mutual fund shares, floating NAVs incorporate changes in the fundamental values of portfolio assets, but they do not incorporate the costs of investor redemptions that are expected to be incurred in the future. Thus, runs on MMFs remain a possibility.

If fund equity were designed so that NAVs incorporate the externalities imposed by redeeming investors in a forward-looking way, then liquidity can be provided without panic runs. In particular, swing pricing at bond mutual funds allows the end-of-day NAV to be "swung down" to adjust for the future costs that same-day investor outflows will induce. Then, investors that redeem shares do not impose negative externalities on investors remaining in the fund. Although adjusting for future liquidation costs involves swinging down fund NAVs, the quantity of liquidity provision may not necessarily decrease. (Ma et al., 2022a) theoretically show that the reduction in panic-driven outflows allows funds to transform a larger share of illiquid assets into liquid claims. Indeed, Jin et al. (2022) find that following the introduction of swing pricing in the U.K., bond funds experienced smaller outflows and invested in a larger proportion of illiquid assets.[6]

Bond ETFs also provide liquid claims by pooling investors' liquidity risks. Different from open-ended bond mutual funds whose shares are demandable from the issuer at short notice, bond ETFs issue equity claims that are tradeable on secondary markets. An important factor in the liquidity of ETF shares in secondary markets is the presence of arbitrageurs called authorized participants (APs). In Koont et al. (2022), investors are subject to liquidation shocks, as in Diamond & Dybvig (1983), that lead them to sell ETF shares or unexpected savings shocks that lead them to buy ETF shares. When net selling pressure in secondary markets depresses the ETF share price, APs step in to buy underpriced shares, deliver them to the ETF issuer, and redeem a portion of the underlying securities to sell in the bond market. Similarly, when net buying pressure causes ETF shares to be overpriced, APs buy the underlying securities in the bond market, deliver them to the ETF issuer, and create new ETF shares to sell into the secondary market. APs thereby enhance the liquidity of ETF shares by reducing investors' price impact from trading ETF shares at short notice. The importance of AP arbitrage for ETFs alos implies that limits to AP arbitrage impede ETF liquidity provision. Limits to arbitrage are especially salient for bond ETFs whose underlying securities are more illiquid and whose APs tend to be dealer banks with balance sheet constraints (Pan & Zeng, 2017). In the extreme scenario where there is no AP arbitrage, ETFs turn into traditional closed-ended funds whose shares are widely understood to be

[6]To implement swing pricing, the fund manager needs to accurately estimate the future liquidation costs induced by same-day outflows. This may be challenging in practice where last-minute outflows and equilibrium liquidation costs are difficult to predict. Nevertheless, any contract design that incorporates externalities from outflows into fund equity values will reduce run risk.

illiquid.

2.3 Pooling of Securities

Liquidity can also be provided by pooling individual securities and issuing claims that trade against the pooled value of these securities. In Subrahmanyam (1991) and Gorton & Pennacchi (1993), investors with superior information about individual security payoffs can profit at the expense of less-informed investors subject to unexpected liquidity shocks. If individual securities are pooled to form a composite security, however, informed investors' advantage over less-informed investors is reduced and the latter are able to better manage their liquidity needs. Thus, packaging individual securities into an indexed composite provides liquidity through reducing adverse selection.

This economic idea is present in many of the examples we have discussed, from banks to bond mutual funds and ETFs. Another example that encapsulates this idea well is securitization. MBS and other asset-backed securities are claims against a pool of individual loans. This design leads asset-backed securities to be far more liquid than the individual underlying claims. See Vickery & Wright (2013) for evidence on liquidity from the to-be-announced (TBA) MBS market.

3 The Convenience Yield v_t

Investors demand convenience services – liquidity, collateral, and safety services – and bid up the price of convenience assets to reflect the convenience yield v_t. This section discusses the ways that the literature has measured the convenience yield from bond market spreads and as well the interpretation of these measures. We focus on measuring convenience services on low-risk debt claims rather than on equity claims because most existing research studies debt instruments.[7,8]

Before going to the measurement, there is an important conceptual point to highlight. There are many interest rates on low-risk securities, so that one could construct many com-

[7]It is challenging to measure the convenience yield on equity claims. Take fund equity as an example. We can write $E[R^e] + v = r^f + \text{risk premium} + \alpha$, where α is the manager's alpha and the rest of the terms are standard. Then, the convenience yield on fund equity is measured as $v = r^f + \text{risk-premium} + \alpha - E[R^e]$. Each of the terms on the right side (other than r^f) are extremely difficult to measure and the subject of a large literature in their own right. Thus, the measured convenience yield will carry more noise than signal.

[8]Di Tella et al. (2023) study the convenience yield on debt claims relative to equity, measuring the convenience yield on Treasurys relative to an implied zero-beta rate.

binations to generate numerous spreads. Which of these spread constructions is meaningful to measure convenience services? The key economics to keep in mind is that a given spread measures the convenience services of the asset to an agent who holds *both* assets A and B. For example, it is not meaningful to construct a spread between the repo rate on Treasury bonds and the interest rate on insured checking deposits at a small community bank. There is likely no agent who is holding this portfolio of assets.

3.1 Measurement

Consider two assets, A and B, with payoff at $t+1$ of F_{t+1}^A and F_{t+1}^B. Suppose these assets offer convenience services of $v_t^j = \beta^j P_t^j V_t$, for $j \in \{A, B\}$ to a set of agents. Here V_t reflects an aggregate, common, component of convenience values and β^j measures the quantity of convenience services provided by asset-j to the agents.

Then, from (2),

$$P_t^A - P_t^B = (\beta^A P_t^A - \beta^B P_t^B)V_t + E_t[m_{t,t+1}(F_{t+1}^A - F_{t+1}^B)]. \tag{6}$$

Let us take the case where asset A is a riskless bond with payoff $F_{t+1}^A = 1$ and asset B a risky bond with promised payoff of 1, but with payoffs of $F_{t+1}^B < 1$ in some default states. Then,

$$P_t^A - P_t^B = \underbrace{(\beta^A P_t^A - \beta^B P_t^B)V_t}_{\text{conv. yield}} + \underbrace{E_t[m_{t,t+1}(1 - F_{t+1}^B)]}_{\text{def. risk}}. \tag{7}$$

Krishnamurthy & Vissing-Jorgensen (2012) develop a multi-period version of this pricing model to derive (2), which decomposes the AAA-Treasury spread in Figure 1a as reflecting a convenience yield and default risk.

The maturities in the AAA-Treasury spread of Krishnamurthy & Vissing-Jorgensen (2012) are around 20 years, so the spread measures a convenience yield and corporate default risk on long-term bonds. Krishnamurthy & Vissing-Jorgensen (2012) also present data on the spread between commercial paper and Treasury bills, both of which mature in less than one year, to measure a convenience yield on short-term bonds. The commercial paper carries some default risk, so that the spread reflects both a convenience yield and default risk. Nagel (2016) presents data on the spread between 3-month general collateral repo and 3-month Treasury bills, where both instruments are default-free, as a measure of the convenience yield on short-term bonds. Jiang et al. (2021) construct the spread between the one-year government bond yields of G10 (non-US) countries, swapped into dollars based on foreign exchange forward prices, and the corresponding yield of the one-year U.S. Treasury bond. The construction of the spread is done in a manner to remove default risk.

3.2 Relative Convenience Services

Following equation (7), each of these spreads measure the convenience yield component $(\beta^A P_t^A - \beta^B P_t^B)V_t$. Only under the restriction that β^B for the AAA bond is equal to zero does the AAA-Treasury spread measure the convenience yield on long-term Treasury bonds. This restriction is unlikely to be true, however, when both assets are low-default risk assets. Krishnamurthy & Vissing-Jorgensen (2012) present evidence that AAA bonds also carry a convenience yield, so that $\beta^B > 0$. They also provide evidence that CCC bonds do not carry any convenience yields. The CCC-Treasury bond spread then contains the full convenience yield on Treasury bonds of $\beta^A V_t$, but will also have a sizeable default risk component.

This indicates a tradeoff in measuring convenience yields. On the one hand, a measure like the repo-Treasury bill spread will have no default risk, minimizing noise in the measurement. On the other hand, both $\beta^A, \beta^B > 0$ for this spread so that a researcher needs further data to measure the convenience yield on repo and Treasury bills separately. Jiang et al. (2021) estimate that the β^B for the G10-swapped bonds is about 0.90 and that β^A for Treasury bonds is 1 (a normalization). The G10-swapped/Treasury spread in their sample averages 22 basis points, indicating that the full convenience yield on the Treasury bond is 2.2%, and that the G10-swapped bond also contains a substantial convenience yield.[9]

Table 1 provides a non-exhaustive summary of convenience yield measures in the literature. We indicate whether the underlying bond spread is of long- or short- maturity. We also indicate if there is a risk component, such as default risk, in the spread. The table also presents the a qualitative assessment of the β^j of each bond in the spread.

[9]There are other clean measures of the convenience yield from default-free bonds. Van Binsbergen et al. (2022) and Diamond & Van Tassel (2023) present the spread between the box yield, constructed in a risk-free manner from options prices, and Treasury bill yields. Greenwood et al. (2015) present the spread between Treasury bills and an implied short-term Treasury yield that is fit based on the term structure of Treasury yields beyond one-year. These papers do not offer estimates of β^B to back out the separate convenience yields on the two assets underlying the spread. Mota (2023) constructs a spread measure that adjusts the corporate bond yield for default risk using CDS prices, and also shows that highly-rated corporate bonds offer convenience services.

3.3 What is "Convenience"?

We have used the word "convenience" throughout — a catchall word — rather than tying a given spread explicitly to liquidity, collateral, or safety services. This is intentional. A given spread can measure different convenience services for different agents. We noted earlier that long-term Treasury bonds serve an important role as collateral in the repo market and that the Treasury repo rates reflect a convenience yield (see equation (5)). In this case, the convenience yield on long-term Treasury bonds is due to the collateral services and the price of the long-term Treasury bond contains a collateral premium. However, consider another perspective. Treasury bonds are far more liquid than corporate bonds. Take a bond mutual fund that values maintaining a portion of its portfolio in liquid bonds to buffer against outflows. For this investor, the Treasury bond provides liquidity services that the corporate bond does not, and the spread is the price the investor pays for these liquidity services. The convenience yield reflects a liquidity premium. The same spread measure has two interpretations in this case, depending on the identity of the agent.

In general, decomposing a convenience yield into subcomponents of liquidity, collateral, or safety lacks a strong conceptual foundation. These components reflect services to different investors. In equilibrium, the convenience yield will equate the marginal convenience services of these different forms across investors so that a convenience yield measures all of these services rather than the sum of these services. It is conceptually correct to say that a bond mutual fund pays a liquidity premium to own Treasury bonds and a dealer bank pays a collateral premium to own the bonds.

4 Measuring the Demand for Convenience Assets

The convenience yield is determined by the demand and supply of convenience assets in equilibrium. In this section, we discuss the demand for convenience assets and how it can be determined in the data.

4.1 Identifying Investor Demand

Suppose that across investors, and the different services that convenience assets provide, there is a well-defined demand for convenience services,

$$v_t = V(Q_t/GDP_t; \xi_t). \tag{8}$$

Here Q_t is the aggregate quantity of convenience assets,

$$Q\left(Q_t^G, Q_t^P(v_t)\right). \tag{9}$$

Q_t^G is the quantity of government convenience assets (Treasury bonds) which we take to be exogenously determined by the government. Q_t^P is the quantity of private-sector assets, which we allow to be a function of the convenience yield. On this last point, if the benefit to an issuer of issuing convenience asset rises (v_t rises), we would expect the issuer to provide more convenience assets. The term ξ_t reflects time-varying shocks to the demand curve.

Figure 1a plots the relation between a convenience yield and the total quantity of Treasury bonds. See Krishnamurthy & Vissing-Jorgensen (2012) for further details and the regression underlying this figure. We noted in the introduction that the figure can be viewed as tracing out an investor convenience demand function. We now explain this interpretation in further detail.

Consider again the convenience yield spread between assets A and B in Equation (7), $(\beta^A P_t^A - \beta^B P_t^B)V_t$. For the moment, suppose that Q_t^P is small, so that,

$$ln\ Q_t \approx ln\ Q_t^G + \epsilon Q_t^P. \tag{10}$$

We are interested in estimating the parameters of the convenience demand function,

$$v(Q_t/GDP_t; \xi_t) = \alpha + \eta\ ln\ Q_t + \xi_t. \tag{11}$$

A regression of convenience yields on Q_t will provide a biased estimate of η since Q_t^P is a function of v_t. Instead, consider the first-stage regression of $ln\ Q_t$ on $ln\ Q_t^G$, and the second-stage regression of convenience on the fitted quantity. This regression will provide unbiased estimates of η under the identifying assumption that shifts in Q_t^G are uncorrelated with demand shifts that may drive variation in v_t. The regression equation in Figure 1a thus measures the convenience demand function $\eta(\beta^A P_t^A - \beta^B P_t^B)\ ln\ Q_t/GDP$.

Krishnamurthy & Vissing-Jorgensen (2012) use the total supply of Treasury bonds as an instrument to estimate $v(Q_t/GDP_t; \xi_t)$. To satisfy the exclusion restriction, variation in the supply of Treasury bonds must be orthogonal to shifts in demand for convenience assets (ξ_t). To the extent that both are driven by the business cycle, this exclusion restriction may fail. Greenwood et al. (2015) use calendar time as an instrument for the supply of Treasury bills.

The U.S. Treasury's financing needs have a strong seasonal pattern that is mirrored in their issuance of Treasury bills. Since calendar time is unlikely to correlate with shifts in demand, this is a valid instrument. Unfortunately, the empirical results from this instrument lie at the margin of being statistically significant. Li et al. (2023) use cross-sectional variation in the degree of deposit competition to estimate the extent to which Treasury supply differentially crowds out bank deposits across branches of the same bank. In this way, the estimation conditions out time-varying shocks that drive both Treasury supply and shifts in bank-level convenience demand. Better instruments can be valuable to this research.

4.2 Investor Demand for a Broader Convenience Aggregate

Krishnamurthy & Vissing-Jorgensen (2015) and Nagel (2016) show that the quantity of bank debt is a [partial] substitute for the convenience services provided to investors by Treasury bonds. Krishnamurthy & Li (2023), building on Nagel (2016), estimate investor demand for a convenience aggregate that include both government and private debt. In particular, they estimate:

$$Q_t = \left((1-\lambda_t)D_t^\rho + \lambda_t(Q_t^G)^\rho\right)^{\frac{1}{\rho}}. \tag{12}$$

where D_t is the real stock of commercial bank deposits, Q_t^G is the real value of Treasury bonds, ρ parameterizes the elasticity of substitution between these two convenience assets, and λ_t parameterizes the relative convenience of the two assets. Krishnamurthy & Li (2023) estimate (12) using data on quantities of Treasurys, bank debt, and convenience yields on Treasurys and bank debt. They use as instruments the total supply of Treasurys as well as the calendar instruments. They estimate a value of ρ around 0.65 and λ averaging 0.20. They also consider broader aggregates of private sector convenience assets that includes MMF shares, commercial paper, and repo.

Understanding the substitutability between different convenience assets has implications for the transmission of conventional and unconventional monetary policy. For unconventional monetary policy, the overall impact of central bank purchases of a given asset varies not only with its own demand but also with its substitutability with other assets and their respective demands. Krishnamurthy & Vissing-Jorgensen (2011) find that MBS purchases in the first round of Quantitative Easing (QE) after the 2008 financial crisis effectively lowered MBS yields and corporate bond yields, while the purchases of Treasurys in the second round of QE had a disproportionate effect on Treasury and agency bond yields relative to MBS and corporate bond yields. In response to the March 2020 turmoil, the announced purchase of investment-grade corporate bonds proved to be effective at lowering the yields on the directly targeted corporate bonds, while the announcement to further include "fallen angels" and high-yield ETFs had a much more broad-based impact on fixed-income markets (Haddad et al., 2021). While these papers discuss multiple factors at work, portfolio substitution is one of these factors, which can be understood better through estimates of investor demand for convenience assets. Drechsler et al. (2017) and Nagel (2016) show that conventional monetary policy, i.e. central bank actions that change the short-term interest rate, affect the quantity of convenience assets provided by the financial system. The changes in quantity will transmit to the prices of other convenience assets in a manner that depends on investor demand for different convenience assets.

4.3 Shifting Investor Demand

We have noted that decomposing v_t into sub-components of safety and liquidity lacks a clear conceptual foundation. On the other hand, asking how much v_t rises if the demand for convenience assets from liquidity-driven investors rises is well posed. The answer to this question helps to understand how different aspects of convenience drive variation in v_t.

To make progress on this question, we need to estimate institution-level demand curves for convenience assets rather than an aggregate demand as in (12). Krishnamurthy & Vissing-Jorgensen (2007) does this for Treasury bonds. Suppose that there are many holders of Treasury bonds, ranging from households to foreign central banks. We can write $V(Q_t/GDP_t;\xi_t) = \sum_i V^i(Q_t^i/GDP_t;\xi_t^i)$ across holder-i. Krishnamurthy & Vissing-Jorgensen (2007) estimate the convenience demand function for nine principle holders of Treasury debt. The approach follows our discussion: the total supply of Treasury debt is used as an instrument to estimate the demand for each Treasury holder. One of their findings is that foreign central banks are inelastic demanders of Treasury bonds. Since these demanders are primarily driven to hold Treasury bonds because of their superior liquidity, one can surmise that shifts in v_t due to shifts in foreign central bank demand are liquidity-driven shifts in v_t. There is more recent work on estimating disaggregate demand curves (Eren et al., 2023, Jansen et al., 2024).

5 Measuring Suppliers of Convenience Assets

As discussed in Section 2, beyond specific government assets like central bank reserves and Treasury bills, much of the convenience asset supply is financially engineered by bank and non-bank financial institutions. While these institutions supply convenience assets through tranching and pooling, they face distinct challenges in liquidity provision and operate under different regulatory frameworks.

This section tackles two issues. First, we present a measure of convenience supply by entity. The measure allows us to understand quantitatively which parts of the financial sector creates convenience assets. Second, we discuss the [limited] work that estimates the elasticity of supply of private sector convenience assets.

5.1 Measuring Private Sector Convenience Creation

Measuring private sector safe and liquid asset creation faces the following complication. Consider a hypothetical MMF that only invests in Treasury bills and issues daily redeemable MMF shares to investors against these holdings. The shares are safe and liquid and so from that perspective the MMF is creating convenience assets. But from another perspective, the underlying Treasury bills are already very liquid and safe so the contribution of the MMF to convenience creation is limited.

In this hypothetical case, if the supply of Treasury bills went to zero, the MMF would shut down. Likewise, if there was an increase in demand for convenience assets, while the quantity of fund shares would rise, this would transmit as an increase in demand for Treasury bills as well. If we instead focus on a net measure of liquidity creation, we can truly learn about how much each institution contributes to the creation of convenience assets and at what supply elasticity. In the MMF case, the amount of net liquidity creation would be very limited despite the large supply of liquid and safe money market fund shares.

At the other end of the spectrum of convenience creation are financial institutions that issue claims against a portfolio of illiquid assets. For instance, the shares of corporate bond mutual funds are likely less liquid and safe than the shares of MMFs, but corporate bond funds also hold less liquid assets than MMFs. Bond funds create claims that are demandable daily, backed by a portfolio of corporate bonds that are typically costly or infeasible for an investor to own directly. Commercial banks lie somewhere in between this spectrum with a fraction of their portfolio in highly illiquid assets like firm loans and another fraction in liquid assets such as central bank reserves and Treasurys. The deposit claims they issue are highly liquid.

Ma et al. (2022a) develop a framework to measure the extent of liquidity provision by financial institutions. Their approach relates to Berger & Bouwman (2009), Brunnermeier et al. (2013), Krishnamurthy & Vissing-Jorgensen (2015), and Bai et al. (2018), which measure liquidity creation by the banking sector. Importantly, their Liquidity Provision Index (LPI) can be applied to both debt-issuing intermediaries like banks and equity-issuing intermediaries like mutual funds and MMFs. The LPI measures how much an intermediary's contractual payment value exceeds the direct liquidation value of the underlying assets absent the intermediary.

The LPI computation requires three inputs: asset holdings, the liquidation costs of assets, and outflows. It first specifies the contract payment $c_i(\lambda_i, R)$ given investor outflows λ_i and economic fundamentals R for each institution i. For banks, depositors obtain the face value of debt unless the bank defaults and the proceeds are distributed proportionately. For fund equity, redeeming investors obtain the NAV if the liquidation value of the underlying assets is sufficient to meet redemptions. Otherwise, the fund is liquidated and investors obtain a proportionate share of the liquidation value. With swing pricing, redeeming investors obtain an adjusted NAV that incorporates liquidation costs based on the amount of outflows λ_i. Finally, the realized LPI is calculated as the percentage change between the contract payment from the intermediary and the liquidation value of the underlying portfolio. The direct liquidation value is

$$\sum_{j=1} y_{ij}\beta_j(R)(1-\phi_j), \tag{13}$$

where for y_{ij} units of the portfolio asset j with price $\beta_j(R)$, ϕ_j is the liquidation discount that investors would have obtained on their own without the intermediary. That is, for a given time period, the LPI for intermediary i measures its contribution to liquidity transformation and is defined by[10]

$$LPI_i = \frac{c_i(\lambda_i, R)}{\sum_{j=1} y_{ij}\beta_j(R)(1-\phi_j)} - 1. \tag{14}$$

Applying the LPI to bond mutual funds and banks, Ma et al. (2022a) find that both provide an economically significant amount of liquidity, with bond funds providing about one-eighth of the liquidity banks provide per dollar. This gap arises in part because bank deposits are debt contracts. As explained in Section 2.1, debt promises more stable prices than equity, which improves its liquidity to investors. Deposit insurance and implicit guarantees further help to reduce run risk and stabilize the contract value of deposits. The price stability of deposits allows banks to hold more illiquid assets to maturity than mutual funds so that

[10]This is a simplified version of the full specification of the LPI, please refer to Ma et al. (2022a) for details.

investors suffer higher liquidation costs ϕ_j without the bank than without the fund.

In comparison, the LPI of MMFs is smaller because the liquidation costs of its assets are low to begin with, limiting the capacity for liquidity provision. Further, after institutional prime MMFs switched from fixed to floating NAV due to the 2016 Money Market Reform, their liquidity provision declined by more than that of MMFs with fixed NAVs. This result is consistent with floating-value equity contracts providing a positive but smaller amount of liquidity than fixed-value debt contracts.

Note that in general, an increased holding of liquid asset buffers may or may not increase an institution's liquidity transformation. On the one hand, a higher proportion of liquid asset holdings improves the expected contract value $c_i(\lambda_i, R)$ by reducing the probability of panic runs. This is because the externalities imposed by redeeming investors on remaining investors are reduced when assets with a smaller liquidation discount are sold. This is why bond mutual funds investing in illiquid assets choose to hold more cash buffers (Chernenko & Sunderam, 2016).

On the other hand, higher liquid asset holdings reduce the intermediary's capacity to improve liquidity provision by lowering ϕ_j. For commercial banks, Ma et al. (2022a) show that the LPI has declined from 2011 to 2018 as their liquid asset holdings have increased following reserves injections by QE. This pattern suggests that on net, banks' increased holdings of liquid assets following QE constrained rather than enhanced their liquidity provision. The result may be different at non-banks, which do not have deposit insurance and are more dependent on their liquid asset buffers to maintain the liquidity of their issued claims.

5.2 Supply Elasticity

There is relatively less work on providing quantitative estimates of the supply elasticity of convenience assets. Krishnamurthy & Vissing-Jorgensen (2015) find that \$1 less of Treasury bonds leads the aggregate financial sector to issue approximately \$0.50 more convenience assets (Figure 1b). Krishnamurthy & Vissing-Jorgensen (2015)'s measure of the quantity of private convenience assets is called "net short-term debt" and is a simplified version of net liquidity creation. The measure takes the total convenience holdings of the financial sector, which is cross-holdings plus holdings of government convenience assets, and nets it against the total amount of short-term debt issued by the financial sector. The \$0.50 estimate can be combined with the price elasticity of demand to back out a supply elasticity.[11]

Estimates of the supply elasticity are valuable for a number of economic questions. The literature has noted that one benefit of increasing the supply of government bonds is to reduce the convenience yield and disincentivize the financial sector from producing runnable convenience assets. Increasing the supply of convenience assets by the government is optimal if the private sector does not internalize the financial stability costs of its liquidity creation (Stein, 2012). The elasticity of supply is also relevant for evaluating the impact of QE. Because reserves can only be held by banks which, in turn, issue deposits to investors, in response to QE that increases bank reserves, the supply of deposits will likely expand (Lopez-Salido & Vissing-Jorgensen, 2023). How much depends on the elasticity of supply. The literature has noted that banks may limit balance sheet growth and thereby reduce loan supply (Diamond et al., 2024) or allow their balance sheet to grow by expanding their deposit base (Acharya & Rajan, 2024). Understanding these effects is important for quantifying the full impact of QE.

The impact of the introduction of CBDC depends on the elasticity of banks' deposit supply. For a monopoly bank, the introduction of CBDC may lead to an increase in deposit rates and volumes by increasing the competition in deposit markets (Andolfatto, 2021). If deposit markets are perfectly competitive, there is no improvement in competition, and bank deposits are crowded out by renumerated CBDCs (Keister & Sanches, 2023). The extent to which deposits are crowded out by CBDCs therefore varies with the of level deposit competition and the supply function of bank deposits (Chiu et al., 2023, Whited et al., 2022).

The elasticity of bank supply may also be altered by developments in payment technologies. New payment systems, such as Brazil's Pix and India's UPI, allow depositors to instantly make payments. This improves the convenience of bank deposits, which shapes bank deposit supply. Nevertheless, the improved payment convenience of deposits arises from removing banks' ability to delay and net payments, which increases banks' demand for holding liquid asset buffers to meet unexpected payment shocks (Gonzalez et al., 2024). The increased use of deposits in payments can thereby constrain banks' capacity for liquidity

[11] Sunderam (2014) presents evidence that the private shadow banking system grew in response to increases in the demand for convenience assets ("money-like claims") in the pre-2008 period, likewise indicating a supply response. Kacperczyk et al. (2021) presents similar international evidence for CDs issued by safe banks. Mota (2023) shows that the firms issue more debt when the convenience yield on their debt rises. These papers identify a supply response and their settings could be used to estimate a supply elasticity.

transformation.

Stepping back, much more work is needed to understand the supply elasticities of non-bank financial institutions, including the liquidity-transforming institutions identified in the LPI. The interdependencies of the supply functions between different bank and non-bank institutions is also not well understood. These are promising avenues of future research.

6 Conclusion

Investors demand convenience assets to satisfy a variety of economic functions. These demands are satisfied by the supply of assets created by both the government and the private sector. We have outlined the theoretical rationale underlying these demand and supply functions. We have also reviewed the main findings from research to date and pointed to open research questions in this area.

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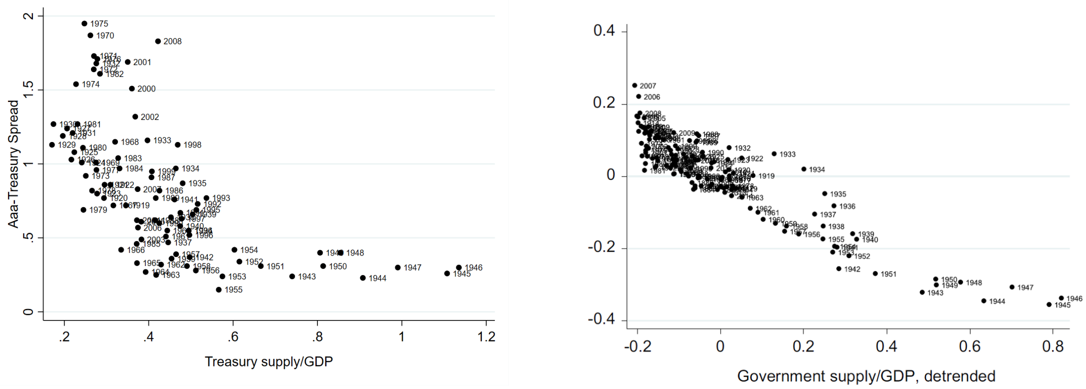
Figure 1: Government Debt, Corporate Bond Spread, and Financial Sector Debt



(a) Spread

(b) Quantity

Left panel plots U.S. Debt/GDP against the spread between AAA rated corporate bonds and Treasury bonds, measured in percentage, using annual data from 1919 to 2008. Right panel plots the total supply of government safe assets/GDP (detrended) against the total quantity of short-term financial sector debt/GDP (detrended), with annual data from 1874 to 2014. Source: Krishnamurthy & Vissing-Jorgensen (2012, 2015).

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Spread	Term	Risky	Relative Convenience
AAA–Treasury (Krishnamurthy & Vissing-Jorgensen, 2012)	Long	Yes	$\beta^{Treas} > \beta^{AAA} > 0$
BBB–AAA (Krishnamurthy & Vissing-Jorgensen, 2012)	Long	Yes	$\beta^{AAA} > \beta^{BBB} > 0$
Off-the-run–On-the-run Treasury (Krishnamurthy, 2002)	Long	Yes	$\beta^{On} > \beta^{Off} > 0$
AAA–Agency MBS (He & Song, 2022)	Long	Yes	$\beta^{MBS} > \beta^{AAA} > 0$
P2 CP – Treasury Bills (Krishnamurthy & Vissing-Jorgensen, 2012)	Short	Yes	$\beta^{Treas} > \beta^{CP} > 0$
Treasury Bills – Time&Savings Deposits (Krishnamurthy & Vissing-Jorgensen, 2012)	Short	No	$\beta^{Dep} > \beta^{Treas} > 0$
Repo– Treasury Bills (Nagel, 2016)	Short	No	$\beta^{Treas} > \beta^{repo} > 0$
Fitted Yield – Treasury Bills (Greenwood et al., 2015)	Short	No	$\beta^{Treas} > \beta^{Fitted} > 0$
Box- Treasury Bills (Van Binsbergen et al., 2022, Diamond & Van Tassel, 2023)	Short	No	$\beta^{Treas} > \beta^{Box} > 0$
Corp CDS Hedged – Treasury (Mota, 2023)	Long	No	$\beta^{Treas} > \beta^{Corp-Hedged} > 0$
G10 Hedged – Treasury (Jiang et al., 2021)	Long	No	$\beta^{Treas} > \beta^{G10-Hedged} > 0$
TIPS Hedged – Treasury (Fleckenstein et al., 2014)	Long	No	$\beta^{Treas} > \beta^{TIPS-Hedged} > 0$

Table 1: Convenience Yield Measures in the Literature