Internal and External Capital Markets of Large Banks*

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Abstract

We study the internal capital markets of large U.S. bank holding companies (BHCs). Within the BHC, commercial bank and broker-dealer divisions have different investment opportunities and actively share funding. We measure broker-dealer investment opportunities using arbitrage spreads and show that when spreads widen, the internal capital market transfers funding to the broker-dealer. However, the internal capital market is slow to respond to investment opportunities and the transfers are too small. These frictions cause liquidity to be partially segmented. As a result, division-specific liquidity prices the investment opportunities of that division.

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1 Introduction

A large body of research has shown that corporations are subject to sizable frictions in the internal allocation of capital across divisions and subsidiaries. Despite that, much of the intermediary asset pricing literature treats financial institutions as monoliths. Underlying this view there is the assumption that intermediaries have efficient internal capital markets which allow them to equalize the risk-adjusted marginal return to capital across their activities. As a result, if two markets share an intermediary, then risk-premia should be equated across these markets.

In this paper, we show that divisions within a financial intermediary are partially siloed and this causes dispersion in the marginal return to capital within an intermediary. We provide empirical evidence of internal and external capital market frictions for financial intermediaries. In both internal and external capital markets, capital is slow moving and insufficiently sensitive to investment opportunities. These frictions cause divisions of the same intermediary to be partially segmented. The liquidity directly held by a division determines the return on its own investment opportunities. By contrast, if financial intermediaries had frictionless internal capital markets, only the overall liquidity available to the intermediary would matter for asset prices.

We begin with a model of a division within a firm. The division face frictions to internal and external borrowing that violate Modigliani and Miller (1958). These frictions cause the division to be partially segmented from other divisions within the firm. Although the internal capital market transfers funding from opportunity-poor to opportunity-rich areas of the firm, differences in the marginal return to investment persist across divisions. In response to better investment opportunities, the division borrows more funding to invest more. This additional borrowing is an optimal mix of funding from the internal and external capital markets. The composition of borrowings reveals the relative convexity of funding frictions to internal and external markets. For instance, if in response to an increase in investment returns the division borrows more from the internal capital market than the external one, then the frictions are less convex for the internal capital market.

The model also makes additional predictions about the dynamics of risk premia when firms are internally siloed. First, risk premia may differ across divisions of the same firm. Therefore, even if two markets share a common financial intermediary, risk premia may not be integrated across these markets. Second, the distribution of liquid assets across divisions within an intermediary matters for division-specific risk premia. Divisions endowed with more liquidity invest more and earn a smaller marginal return on capital.

Next, we empirically test the predictions of the model. The financial intermediaries that we study are the U.S. global systemically important banks (GSIBs), which include Bank of America, Citigroup, Goldman Sachs, JP Morgan, Morgan Stanley, and Wells Fargo. As of 2022, the six U.S. GSIBs have $13.6 trillion in assets, which comprise 58 percent of the assets held by U.S. banks. We use a novel supervisory dataset that enables us to observe internal and external transactions of the subsidiaries of these banks at the daily frequency. We group each of the bank holding company subsidiaries into three divisions: the holding company, the commercial bank, and the dealer.

We focus mainly on unsecured wholesale funding because it is the marginal source of funding for the investment opportunities that we study. This excludes secured funding, which is primarily used for matchbook repo and to finance secured lending to clients (Carlson and Macchiavelli, 2020). Secured borrowing against Treasury collateral does not increase the liquidity of the dealer because cash and Treasuries are both money-like assets. However, unsecured borrowing raises additional funding that the dealer may use for its own investments.

Figure 1 depicts the external and internal capital market for unsecured wholesale funding among the three divisions of the bank. The bank holding company represents the consolidation of the holding company, the commercial bank, and the dealer. On average over our sample, the holding companies externally borrow $1.1 trillion of unsecured wholesale funding, the commercial banks $222 billion, and the dealers $356 billion. Internally, the holding companies net lend $114 billion of unsecured funding to the commercial banks and $454 billion to the dealers. Furthermore, commercial banks also net lend $400 billion of unsecured wholesale funding to their affiliated dealers. Unsecured wholesale funding is primarily long term debt (79 percent), but also includes short term notes and commercial paper. All told, dealers borrow $854 billion of unsecured funding internally and $356 billion externally.

To measure investment opportunities, we use arbitrage spreads for which dealers are active intermediaries. In particular, the U.S. dealers in our sample are active secured lenders against foreign sovereign debt collateral. They net lend $318 billion dollars against foreign sovereign debt collateral and hedge this exposure using foreign exchange (FX) derivatives. This trade earns the covered interest rate parity (CIP) spread and makes up 52 percent of their secured net lending. We directly observe the marginal return from engaging in CIP arbitrage, which is the return above the risk-free rate that the dealer earns from lending of U.S. dollars against foreign currency collateral with a currency hedge. We use variation in this arbitrage spread as a measure of changes to dealer investment opportunities.

Our first result is that internal capital markets are more responsive to changes in investment opportunities than external capital markets. In response to an exogenous shift in demand that raises the CIP arbitrage spread by 10 basis points (bps) over 1 month, dealers borrow $2.1 billion of unsecured funding from the internal capital market and $0.68 billion externally. Through the lens of our model, these estimates imply that the frictions to external capital markets are more convex than those of internal ones.

In response to additional internal borrowings by the dealer, the bank holding company does not expand its balance sheet. Instead, the holding company decreases its liquidity buffers to accommodate dealer demand for additional funding. The bank holding company is slow or unwilling to adjust the size of its balance sheet in response to dealer investment opportunities. This behavior is consistent with regulatory frictions that constrain the bank's balance sheet size for a given amount of equity capital.[1]

[1] See Boyarchenko et al. (2018) for a discussion of how dealer investments in arbitrage trades expand the bank's balance sheet and require additional equity capital to meet regulatory requirements, such as the

At higher frequencies, the internal and external capital markets are less responsive to changes in dealer investment opportunities. For a 10 bps increase in the spread over a 1-day horizon, the dealer raises $0.5 billion from the internal capital market, which is a quarter of what the dealer raises over a 1-month horizon. Furthermore, the external capital market is nearly insensitive to changes in dealer investment opportunities over a 1-day horizon. This implies that the convexity of capital market frictions relaxes over the investment horizon.

This finding suggests that the slow moving capital friction described by Duffie (2010) cannot be fully solved by expanding the boundaries of the bank. Internal capital market frictions are less convex, which mitigates the effect of financial constraints. However, the agency problems that slow down the responsiveness of external capital markets also permeate the internal capital market of banks.

If there is a positive correlation between dealer and commercial bank expected returns, then we would be underestimating the sensitivity of the internal capital market to changes in dealer investment opportunities. This assumption is difficult to test because the commercial bank primarily engages in risky lending, for which the expected marginal risk-adjusted return is unobservable. To address this concern, we use a demand shift in the FX market that is plausibly exogenous to commercial bank investment opportunities. Du et al. (2018) show that CIP arbitrage spreads widen at quarter-end, which coincides with foreign bank window-dressing incentives. Wallen (2022) documents that there is a negative supply shift by foreign banks in the foreign exchange derivatives market, which causes the quarter-end increase in the spread. We instrument for changes in arbitrage spreads using this quarter-end demand shift for U.S. dealers and estimate the transfer of unsecured funding. For a 10 bps increase in arbitrage spreads due to this quarter-end demand shift, the bank holding company internally transfers $3.7 billion of unsecured funding over a month. This estimate is larger than the OLS estimate, which is consistent with an unobservable positive correlation between commercial bank and dealer investment opportunities.

supplementary leverage ratio.

Our second result is that variation in dealer-specific liquidity affects the dealer's own marginal return on investment. We measure liquidity as the amount of high quality liquid assets (HQLA) held by the division.[2] We show that variation in the dealer's HQLA, not the bank holding company's, prices CIP arbitrage spreads. On average, a 1 standard deviation decrease in dealers' HQLA ($20.5 billion or 3.3 percent) is associated with a 5 bps increase in arbitrage spreads. This association is robust to controlling for the fraction of HQLA that is in excess of regulatory requirements and a decomposition of different types of HQLA depending on their moneyness.

We then provide additional evidence pointing to a causal liquidity effect. Dealer liquidity is potentially endogenous to investment opportunities: for example, dealers may hold additional liquidity in anticipation of wider CIP spreads at quarter-end. Therefore, we use the term structure of CIP arbitrage spreads to measure the surprise component of the quarter-end change in arbitrage spreads. We posit that the effect of division-specific liquidity on the unexpected change in arbitrage spreads should be stronger if the dealer accumulated less liquidity in the month prior to the quarter-end demand shift. We find evidence consistent with this hypothesis. In the month prior to quarter-end, if dealer liquidity decreased by 1 standard deviation ($18 billion), the effect of the quarter-end demand shift is on average 14 bps larger. This increase is economically large, about a third of the average quarter-end effect on spreads (45 bps). This effect is robust to controlling for the variation in bank holding company liquidity, which has an effect that is an order of magnitude smaller and marginally significant. The identifying assumption is that 1-month lagged variation in dealer HQLA is not endogenous to the unexpected size of the quarter-end demand shift.

So far, we have shown that internal and external capital markets respond to investment opportunities but do so slowly and imperfectly. We have rejected both null hypotheses of no internal capital markets and perfectly efficient ones. However, of interest is an estimate of

[2]Banks have a regulatory requirement to hold sufficient HQLA to meet near term obligations. HQLA is the weighted sum of liquid assets depending on their moneyness. Level 1 HQLA includes reserves and Treasuries, which are more liquid than Level 2 HQLA, which includes corporate bonds, mortgage backed securities, and more. See Appendix A variable definitions for more details.

how close the bank holding company's internal capital market is to perfect efficiency. We can estimate how much more sensitive the allocation of unsecured funding needs to be to the CIP arbitrage spread so that there is not an association with division-specific liquidity. Assuming the dealer saves any additional internal capital as HQLA, the bank holding company would need to internally transfer $4.07 billion more in response to a 1 basis point increase in the CIP arbitrage spread. This is 9 times more than what the bank holding company actually transfers. By this estimate, the bank holding company's internal capital market is far from perfectly efficient.

The inefficiency of the internal capital market to risk-free investment opportunities is likely a lower bound to that of risky investment opportunities. Risk-free arbitrage returns are directly observable, while there is uncertainty and disagreement about the expected returns for risky trades. Therefore, the frictions that impede the efficient flow of capital are likely to be more severe for risky trades. Furthermore, since we detect frictions even for observable risk-free investments, information asymmetry alone cannot explain the inefficiency of internal capital markets. Thus, agency frictions are likely to be an important factor. Indeed, frictions in the timely reallocation of budgets across desks and divisions are anecdotally relevant (Saita, 2010).

This paper aims to make two contributions. First, we contribute to the literature on internal capital markets by showing that bank holding companies have inefficient internal capital markets. The literature has mostly focused on non-financial corporations (e.g., Stein, 1997; Shin and Stulz, 1998), with a few exceptions discussed below. Borrowing methodologies used to assess external capital market frictions (e.g., Whited, 1992; Bond and Meghir, 1994), the internal capital market literature has documented that investment at the subsidiary level tends to be more correlated with the holding company's cash flow than its own, suggesting that non-financial corporations efficiently transfer resources internally. However, subsidiary investment is also correlated with factors that proxy for information asymmetry and agency frictions, such as social connections (Duchin and Sosyura, 2013). We contribute to this literature by showing that bank internal capital markets respond to investment opportunities, but the response is too slow and too little. The novelty is the transparency of our setting, namely that internal capital markets and investment opportunities are observable at a high frequency. This enables us to precisely quantify how inefficient the internal capital market is. The internal capital market is slow to respond, moving 4 times more at the monthly frequency than at the daily frequency in response to changes in investment opportunities. Furthermore, the internal capital market is at least 9 times too insensitive to investment opportunities.

Second, we contribute to the intermediary asset pricing literature by highlighting the importance of frictions within the intermediary and how arbitrage spreads are priced by the available liquidity of U.S. dealers. Intermediaries are not monoliths and frictions in their internal capital markets can help explain the partial segmentation of asset markets. Although large U.S. banks are active across asset markets, risk-free rates and risk premia differ across these markets. Siriwardane et al. (2022) shows that risk-free rates differ across foreign exchange, bond, and equity markets, and correlations in these arbitrage spreads are low. Duffie (2010) shows that risky assets exhibit predictable and short-lived price reversals in response to asset specific shocks. The partial segmentation that we observe in asset prices reflects the imperfections of the internal capital markets of financial intermediaries.

The intermediary asset pricing literature has used arbitrage spreads to infer a shadow cost to intermediation. This shadow cost has been described as a leverage constraint (He and Krishnamurthy, 2013; Ivashina et al., 2015) and a funding constraint (Andersen et al., 2019).[3] We show that the CIP arbitrage trade is a large fraction of U.S. dealers' net secured lending and that this spread is highly positively correlated with the HQLA of dealers, and nearly uncorrelated with the HQLA of the bank holding company. This suggests that the CIP arbitrage spread reflects the scarcity of liquidity available to the dealer.

More closely related to our work, Correa et al. (2022) show that exogenous fluctuations in reserves are associated with repo spreads and lending in foreign exchange markets, and

[3]For a more comprehensive coverage of the intermediary asset pricing literature, also see Adrian et al. (2014); He et al. (2017); He and Krishnamurthy (2018); Haddad and Muir (2021); Baron and Muir (2022).

suggests that internal repos connect the commercial bank to the broker-dealer. Suggestive of an internal capital market among commercial bank subsidiaries of the same bank holding company, Houston et al. (1997) show that subsidiary-level loan growth is more sensitive to cash flow and capital of the bank holding company than its own. We complement these papers by showing the complete internal capital market of large BHCs, including both secured and unsecured internal (as well as external) funding that flows from both the holding company and the commercial bank towards the broker-dealer, and then quantify which of these internal and external flows of funding are relevant for the pricing of arbitrage spreads.

The remainder of the paper is organized as follows. In section 2, we describe the data and the internal and external capital markets of bank holding companies. Section 3 introduces a model of a bank holding company facing frictions in both internal and external capital markets, and provides testable implications. In section 4, we empirically test the model's implications and estimate the efficiency of the bank holding company's internal capital market. Finally, section 5 concludes.

2 Data and Background

In this section we introduce the data and provide background on the internal capital market of U.S. bank holding companies. Specifically, we discuss how dealers raise secured and unsecured funding internally as well as externally, and how liquidity is stored across the bank holding company.

2.1 Data

We use confidential FR 2052a data collected by the Federal Reserve to assess the liquidity profile of Large Institution Supervision Coordinating Committee (LISCC) banks and monitor compliance with the Liquidity Coverage Ratio (LCR) rule. U.S. banks with $50 billion or more in total consolidated assets must report data for all of their domestic and international operations. Foreign Bank Organizations (FBOs) with U.S. assets of $50 billion or more must report data only for their consolidated U.S. operations. Starting in mid-2016, U.S. banks with $700 billion or more in total consolidated assets or $10 trillion or more in assets under custody and FBOs identified as LISCC firms have had to submit a report for each business day. Our sample includes the following U.S. bank holding companies for which we have data on their entire global operations: Bank of America, Citigroup, Goldman Sachs, JP Morgan, Morgan Stanley, and Wells Fargo.

Data are available at the daily level for subsidiaries of each bank holding company. We consolidate the data at the following divisions of the bank: the holding company, commercial bank, and broker-dealer levels. For example, on any given date and for each GSIB, we have the unsecured and secured borrowing and lending of the holding company, the commercial bank, the broker-dealer, and the overall bank holding company itself. Our sample period spans from January 1, 2017 to December 31, 2021. Each division reports several "tables" at the daily frequency, including its qualifying and non-qualifying liquid assets, its secured and unsecured borrowing, as well as its secured and unsecured lending. Within each table, the data are further disaggregated at the collateral class, currency denomination, and maturity.

In particular, we observe how much each division holds in qualifying assets of Level 1, 2A, and 2B, separately. Level 1 assets include central bank reserves, cash, and highly-rated sovereign bonds; Level 2A assets include agency debt and lower-rated sovereign bonds; and Level 2B assets include investment-grade bonds and publicly listed equities included in major indices. The currency denomination of each asset class is also available. An asset is qualifying if it meets certain liquidity requirements and is not encumbered, namely that no third party has a claim on it. For instance, an asset could be encumbered if it is pledged as collateral in a repo transaction.

Additionally, we observe how much each division borrows internally and externally in a secured or unsecured fashion, and at which maturity. Unsecured debt is broken down by instrument type (including retail deposits, brokered deposits, commercial paper, certificates of deposit), maturity, and whether it is internal or external. Secured borrowings, which include repo, securities lending, and customer shorts, are additionally broken down by collateral class. A similar breakdown is available for secured and unsecured lending. For more details on variable definitions, see Online Appendix Section C.

2.2 Internal and External Sources of Funding to Dealers

Dealers primarily carry inventories and provide leverage to clients. To take advantage of investment opportunities, they raise funding both internally (from the affiliated holding company and commercial bank) and externally from capital markets, including money markets and bond markets. Dealers provide leverage to clients in a collateralized fashion. To extend secured financing to their clients, dealers rely primarily on external secured funding in a process called rehypothecation, whereby the collateral backing the secured loans to clients is repledged in repo markets to raise the very same cash that is loaned to clients. Another important portion of the secured financing extended to clients comes from dealers' unsecured funding, both internal and external. Lastly, a smaller portion comes from internal secured markets in the form of internal repos from the affiliated commercial bank and holding company. For more information on the business model of dealers, see Online Appendix Section E. For dealers, the *net* sources of funding are unsecured markets, both internal and external, and internal secured markets. On the other hand, dealers are net lenders in external secured funding markets. We first discuss unsecured markets and then pivot to secured ones.

Figure 1 shows the internal and external unsecured capital markets that provide net funding to the dealers. The three divisions of the bank holding company are the holding company, the commercial bank, and the dealer. An arrow pointing from the commercial bank to the dealer represents an internal transfer from the commercial bank to the affiliated dealer, while an arrow pointing to the dealer from the outside represents the dealer borrowing from external markets. All three divisions borrow unsecured wholesale funding from external capital markets. The holding company net lends unsecured funding in the internal capital market to the commercial bank and the dealer. Furthermore, the commercial bank also net lends unsecured funding to the dealer.

Table 1 shows that our sample of bank holding companies fund themselves with $6.1 trillion of deposits and $1.66 trillion of unsecured wholesale funding. In aggregate, the dealers fund themselves with nearly zero deposits and $1.2 trillion of unsecured wholesale funding. The main wholesale unsecured liabilities of the bank holding company include long term debt, free credits, asset backed securities, certificates of deposit, short-term notes, interbank borrowing, and commercial paper.[4] Long term debt comprises 79 percent of unsecured funding for the bank holding company. In contrast, short-term notes are the primary source of unsecured internal capital for the dealer.

Turning to secured markets, Figure 2 shows that commercial banks and broker-dealers are large net lenders of secured funding to the external market, $129 and $661 billion, respectively. In aggregate, holding companies do not engage in external secured lending but net lend $99 billion of secured funding to the affiliated dealers and $4 billion to the affiliated commercial banks. Additionally, the commercial bank net lends $199 billion of secured funding to the affiliated dealer.

In aggregate, dealers in our sample raise $854 billion of internal unsecured funding, $356 billion of external unsecured funding, and $298 billion of internal secured funding. Secured funding tends to be more variable and we discuss it in more detail in the following section. There is a positive trend to external unsecured funding of the dealer, which increases by 66 percent over the sample period. In addition, there are periods of heightened internal capital market activity, such as during the Covid crisis (March 2020) when bank holding companies temporarily transfer about $150 billion to dealers.

Since most of the credit provided by dealers to clients is in the form of secured funding, secured markets represent a source of net lending for the dealers while unsecured ones (both

[4]Asset backed securities (ABS) are a type of secured funding, but they are grouped in the dataset with other sources of unsecured funding and the bank holding company is a net borrower against ABS, rather than a net lender.

external and internal) are a source of net funding. Broker-dealer's internal unsecured funding comprises the majority of its total net funding. Overall, the net funding raised by the dealers can be used to finance additional leverage for clients, build liquidity buffers, and take advantage of investment opportunities, including arbitrage spreads.

2.3 Dealers and Unsecured Funding

In Table 2, we estimate the sources of marginal changes to dealers' unsecured funding (BD Unsecured). These sources (y) include internal transfers from the holding company and the commercial bank, as well as external issuance by the dealer. To capture the importance of each source, we estimate the following time series regression:

$$\Delta y_t = \alpha + \beta \Delta \text{BD Unsecured}_t + \epsilon_t.$$

Variation in dealers' unsecured funding is primarily through internal rather than external capital markets. Internal sources are displayed in Panel A and external ones in Panel B. At the daily horizon, for a $1 increase in dealer unsecured funding, the holding company internally transfers $0.76, the commercial bank internally transfers $0.18, and the dealer externally raises $0.06. These proportions even out more over time: at the monthly horizon, the holding company internally transfers $0.54, the commercial bank transfers $0.35 and the dealer externally raises $0.11. This suggests that, from the point of view of the dealer, the external capital market is slower to adjust than the internal capital market. Furthermore, variation in unsecured funding of the dealer is primarily internal. For a $1 increase in dealer unsecured funding, the bank holding company as a whole externally raises $0.06 at the daily frequency and $0.02 at the monthly frequency (Panel B, columns 4 and 6). This rigidity in the balance sheet of bank holding companies suggests that leverage constraints may be of first-order importance for dealers' activities, as suggested by Boyarchenko et al. (2018). Indeed, to finance dealers net funding needs, much of the money comes from an internal reallocation of liquidity inside the bank holding company, with very little raised externally.

2.4 Dealers and Secured Funding

In addition to the reallocation of unsecured funding, divisions of the bank holding company raise external secured funding and lend it both internally and externally. We measure net secured lending as the net dollars lent in each collateral class. Banks borrow dollars against collateral through repo, customer shorts, and securities lending. They then lend dollars against collateral through margin loans, reverse repo, and securities borrowing. For a detailed description of each source and use of secured funding, see Online Appendix Section C. Specifically,

$$\begin{aligned}\text{Net Secured Lending} = &(\text{Reverse Repo} + \text{Margin Loans} + \text{Securities Borrowing}) \\ &- (\text{Repo} + \text{Customer Shorts} + \text{Securities Lending}).\end{aligned}$$

Secured transactions occurs against a variety of collateral types, including foreign sovereign debt, Treasuries, equities, corporate debt, agency debt, and mortgage backed securities.[5] Table 3 shows the net secured lending of the bank holding company and the broker-dealer, both external and internal. Over our sample period, dealers net lent $345 billion against foreign sovereign debt, $198 billion against Treasuries, and $121 billion against U.S. equities. The sum of their net external secured lending across asset categories is $661 billion. This external lending is partially funded through internal secured borrowing. On a collateralized basis, dealers borrowed $298 billion from the bank holding company, primarily against Treasuries ($96 billion) and MBS ($95 billion). The rest of their net secured lending is financed via external unsecured borrowings and internal unsecured transfers. The largest net secured lending position of the dealer is against foreign sovereign debt ($318 billion), which is an important part of how dealers take advantage of arbitrage spreads in foreign exchange markets, as we discuss later.

[5] For a detailed description of each collateral category, please see Online Appendix Section D.

2.5 Internal Allocation of High Quality Liquid Assets

Our sample of U.S. GSIBs hold $2.3 trillion of high quality liquid assets. HQLA includes reserves, Treasuries, and other safe assets which may be readily converted into cash. Figure 3 shows the HQLA held by dealers and commercial banks. A notable increase in the HQLA held by commercial banks occurred around the March 2020 Covid crisis. As flight-to-safety deposits accumulate at large U.S. banks, they are primarily kept as HQLA, while some are also transferred to the dealer via internal secured transactions.

On average, the dealer holds 15.4 percent of the bank holding company's HQLA, while the commercial bank and holding company hold the remaining 84.6 percent. The fraction of liquidity held at the dealer varies from 12 to 18 percent. The correlation between dealer HQLA and the HQLA held by the rest of the bank holding company is negative in monthly changes (-13 percent). Basel III requires both the commercial bank and the bank holding company to separately satisfy the minimum LCR requirement. As such, commercial banks must hold a minimum amount of HQLA, while any HQLA held specifically by the dealer does not necessarily serve a regulatory purpose. Instead, it is likely part of dealers' market making activities. For more details on the LCR, please see Online Appendix Section F. Bank holding companies carry a large buffer of $448 billion above and beyond the LCR minimum, representing a 24 percent buffer. These precautionary savings of the bank have similar economic motivations to those of cash holdings by firms (e.g., Opler et al., 1999; Almeida et al., 2014). The bank holds liquidity due to frictions in the external capital market and uncertainty about the bank's future demand for funding.

3 A Model of Financing Constraints with Internal and External Capital Markets

So far we have documented some new stylized facts about the internal and external capital markets for secured and unsecured funding, as well as the allocation of liquidity across the bank holding company. We now present a model of internal and external capital market frictions.

3.1 Framework

We model a division within a firm that chooses the level of investment to maximize profits and funds this investment from three different sources: *directly* held liquidity (w_D), *internal* capital market borrowing (w_N), and *external* capital market borrowing (w_E). The division has an investment opportunity, where the gross return on investment I is given by the production function $\alpha F(I)$, which is a smooth, strictly increasing and concave function, and α is a parameter that shifts the productivity of investment. For simplicity, we define the opportunity cost of directly held liquidity w_D as the cost of capital, which we normalize to 1. Furthermore, let the investment opportunity be sufficiently productive such that the division always wants to raise additional capital ($I > w_D$).

When the division seeks to raise funding from the internal or external capital market, there are information asymmetries and agency frictions. We model these frictions in reduced form as an additional cost of funding from the internal capital market $C^N(w_N)$, where w_N is the amount raised from the internal capital market, and similarly for the external capital market $C^E(w_E)$, where w_E is the amount raise from the external capital market. These frictions ($C^N(\cdot)$, $C^E(\cdot)$) are smooth functions that are weakly increasing and weakly convex. Let $C_1^N(0) = 0$ and $C_1^E(0) = 0$, such that the division will be at an interior point to internal and external capital market borrowing. The firm has a fixed supply of total funding W, which includes the directly held funds of the division w_D. Thus, for an interior solution to internal capital borrowing, we also assume that the firm has sufficient liquidity W such that the division does not want to borrow more from the internal capital market than the firm has ($w_N < W - w_D$). Denote the wedge to raising funding from outside the division as

$$C(w_N, w_E) = C^N(w_N) + C^E(w_E). \tag{1}$$

The problem of the division is to choose a level of investment and borrowing from the internal and external capital market so as to maximize

$$\max_{I \in \mathbb{R}_{\geq 0}, w_E, w_N} \alpha F(I) - I - C(w_N, w_E), \tag{2}$$
$$\text{subject to } I = w_D + w_N + w_E.$$

3.2 Analysis

The problem of the division may be split into two parts, (i) what mix of internal and external borrowing to fund a given level of investment and (ii) how much to invest. In the first part, for a given level of investment I, the division needs to raise $w_N + w_E = I - w_D$ to satisfy the budget constraint. Since the division is at an interior point for both internal and external funding, the optimal amount of internal funding ($w_N^\star(I)$) and external funding ($w_E^\star(I)$) minimizes equation (1):

$$C_1^N(w_N^\star(I)) = C_1^E(w_E^\star(I)). \tag{3}$$

The optimal mix of internal and external funding thus equates the marginal cost of each source of funding.

In the second part of the problem, the division chooses an optimal level of investment. The first order condition to the divisions problem expressed in equation (2) is

$$\alpha F_1(I) = 1 + C_1(w_N^\star(I), w_E^\star(I)).$$

Substituting the wedge to raising funding in equation (1) and the optimal composition of funding in equation (3), we have that

$$\alpha F_1(I) = 1 + C_1^N(w_N^\star(I)) = 1 + C_1^E(w_E^\star(I)). \tag{4}$$

From equation (4), we can obtain through implicit differentiation the effects of small changes in the productivity of investment (α) on investment:

$$\frac{dI}{d\alpha} = \frac{F_1}{C_{11}^N \frac{dw_N^\star}{dI} - \alpha F_{11}} = \frac{F_1}{C_{11}^E \frac{dw_E^\star}{dI} - \alpha F_{11}} \tag{5}$$

Furthermore, we have the effect of small changes in productivity of investment on funding from the internal capital market:

$$\frac{dw_N^\star}{d\alpha} = \frac{F_1 + \alpha F_{11} \frac{dI}{d\alpha}}{C_{11}^N} \tag{6}$$

and on funding from outside investors:

$$\frac{dw_E^\star}{d\alpha} = \frac{F_1 + \alpha F_{11} \frac{dI}{d\alpha}}{C_{11}^E}. \tag{7}$$

Substituting equation (5) into equation (6), we see that $\frac{dw_N^\star}{d\alpha} \geq 0$ and we may similarly derive that $\frac{dw_E^\star}{d\alpha} \geq 0$. We can then use equations (6) and (7) to obtain the following proposition:

Proposition 1. If $C_{11}^N(w_N^\star) \leq C_{11}^E(w_E^\star)$, then $\frac{dw_N^\star}{d\alpha} \geq \frac{dw_E^\star}{d\alpha}$. If a division within a firm has more convex external capital market frictions than internal ones, then in response to an increase in the productivity of investment, the division will borrow more from the internal capital market than the external one. In response to an increase in the productivity of investment, a division within a firm increases their borrowing more from the the capital market with less convex frictions.

This proposition forms the basis of our empirical test that the dealer raises more capital when the marginal investment opportunity improves and that where the dealer sources more of this capital is informative about the relative convexity of frictions. If in response to better investment opportunities, the dealer raises more funding from the internal capital market than the external one, then the friction to the marginal dollar of funding is relatively more severe for the external capital market.

Next, we focus on liquidity. The effect of the amount of liquidity held directly by the division on investment is

$$\frac{dI}{dw_D} = \frac{\frac{dw_N^\star}{dI} C_{11}^N}{\frac{dw_N^\star}{dI} C_{11}^N - \alpha F_{11}} = \frac{\frac{dw_E^\star}{dI} C_{11}^E}{\frac{dw_E^\star}{dI} C_{11}^E - \alpha F_{11}}$$

which is weakly positive and less than 1 because $C^N(\cdot)$ and $C^E(\cdot)$ are weakly convex and F is concave. The effect of liquidity held directly by the division on the division's marginal investment opportunity is

$$\frac{d\alpha F_1(I)}{dw_D} = -C_{11}^N \left(\frac{dw_N^\star}{dI} \left(1 - \frac{dI}{dw_D} \right) \right) = -C_{11}^E \left(\frac{dw_E^\star}{dI} \left(1 - \frac{dI}{dw_D} \right) \right),$$

which is weakly negative because C^N is weakly convex and $\left(\frac{dw_N^\star}{dI}\right)$ and $\left(1 - \frac{dI}{dw_D}\right)$ are positive, and this similarly holds for the external capital market. This leads us to the following proposition:

Proposition 2. If $C_{11}^N > 0$ and $C_{11}^E > 0$, then $\frac{d\alpha F_1(I)}{dw_D} < 0$. If there are convex internal and external capital market frictions, then more directly held funds will induce more investment and cause the marginal return on investment to decrease.

By contrast, for an increase in liquidity held by the firm (W), the effect on investment by a division is

$$\frac{dI}{dW} = 0$$

and the effect on the marginal return to investment is

$$\frac{d\alpha F_1(I)}{dW} = 0.$$

The intuition for this is that a division equates the marginal return on investment to the marginal cost of funding from the internal and external capital markets as shown in equation (4). Therefore, for a division at an interior point, there is no effect of a change in firm liquidity that does not also change the friction to borrowing from the internal capital market.

In Online Appendix Section D, we show that if the internal capital market is perfectly efficient, $C^N(\cdot) = 0$, then we have a special case where our model is equivalent to Kaplan and Zingales (1997), where what matters for investment is the aggregate liquidity of the firm W, not the liquidity held directly by the division, w_D.

This proposition forms the basis of our empirical test of whether there is an internal capital market friction. We control for the liquidity of the bank holding company and empirically test whether liquidity directly held by the dealer prices the marginal return to dealer investments. Only with an internal capital market friction would directly held liquidity by the dealer price the investment opportunities of the dealer.

Finally, if the external capital market is also perfectly efficient, such that $C(\cdot) = 0$, then investment is not sensitive to division or firm liquidity. If this were the case, we would expect to see that neither division nor firm liquidity prices the marginal return to dealer investments.

4 Empirical Results

4.1 Measuring Marginal Returns

A pervasive problem in testing the efficiency of internal capital markets is that risk-adjusted expected returns to investments are not directly observable, especially the marginal return. Fortunately, in our setting we observe arbitrage spreads that dealers can trade. In particular, dealers can take advantage of CIP arbitrage spreads by executing a series of transactions, including lending against foreign sovereign debt, which represent the largest net secured lending position of the dealers. Indeed, dealers are net lenders of $318 billion of funding against foreign sovereign debt collateral. Such position is very large compared to the $102 billion and $90 billion net secured lending against Treasury and domestic equity collateral, respectively, which represent the second and third largest dealers' net secured lending positions.

Specifically, the CIP arbitrage trade involves the spot exchange of dollars into foreign currency, lending foreign currency to earn the foreign risk-free rate, and hedging the currency mismatch by selling forward the foreign currency. This trade earns the CIP spread, namely a synthetic dollar risk-free rate that is higher than the cash dollar risk free rate. Du et al. (2018) further describes this trade and documents that there is a large and persistent CIP basis. Let $i_{\$,t,\tau}$ be the risk-free cash dollar borrowing rate for tenor τ. A risk-free synthetic dollar borrowing rate can be constructed from a foreign risk-free rate ($i_{c,t,\tau}$) and a foreign exchange hedge with a forward premium of $\rho_{c,t,\tau}$. The forward premium is the rate implied by foreign exchange hedges and can be decomposed as follows:

$$\overbrace{\rho_{c,t,\tau}}^{\text{Forward Premium}} = \overbrace{i_{\$,t,\tau} - i_{c,t,\tau}}^{\text{Interest Rate Spread}} + \overbrace{b_{c,t,\tau}}^{\text{Basis}}.$$

The basis tends to be positive ($b_{c,t,\tau} > 0$) for the euro (EUR) which accounts for most of the secured lending against foreign sovereign debt, representing a profitable CIP arbitrage trade.

Empirically, we measure the U.S. and foreign risk-free rates using 1-month overnight index swap rates and 1-month forward premia quoted in units of foreign currency c per U.S. dollar. The data come from Bloomberg and are described in further detail in Wallen (2022). We use the CIP arbitrage spread for the EUR as the measure of marginal returns to synthetic dollar lending against foreign sovereign debt. This spread is the empirical counterpart to the marginal return on investment ($\alpha F_1(I)$) in the model.

Measuring marginal expected risk-adjusted returns for the commercial bank is much more challenging. It is not obvious what the marginal expected risk-adjusted return is for a loan to a firm. However, this is important because it is the differential in the expected return between the dealer and the commercial bank that matters for the allocation of liquidity. Within the model, we derive internal and external capital market implications of changes in an investment opportunity for a division, while holding constant the investment opportunities of other divisions within the firm. Empirically, if investment opportunities are positively correlated across divisions, then we would underestimate the efficiency of the internal capital market by omitting variation in commercial bank investment opportunities. We address this challenge with two approaches.

First, we make the simplifying assumption that the commercial bank's marginal expected risk-adjusted return in excess of the risk-free rate is constant over our horizon of analysis (daily to monthly). Here we control for the most mechanical source of positive correlation: changes in the risk-free rate. We assume that the commercial bank's marginal investment opportunity earns a constant spread over the risk-free rate over our horizon of analysis (daily to monthly).

Second, we use demand shifts that are specific to dealer investment opportunities that are unlikely to be correlated with commercial bank investment opportunities. More precisely, we use the quarter-end increase in CIP arbitrage spreads due to foreign bank window dressing. Du et al. (2018) are first to document these quarter-end spikes to arbitrage spreads and attribute them to quarter-end regulatory constraints to foreign banks. Wallen (2022) shows that the degree to which European banks decrease their supply at quarter-end explains 26 to 42 percent of the variation in the quarter-end spikes to CIP arbitrage spreads. A negative supply shift for foreign banks causes a positive demand shift for US banks at quarter-end. The first column of Table 4 shows that a 1-month CIP trade that spans quarter-end earns an additional 45 bps compared to other months. The identifying assumption is that commercial banks do not also have better investment opportunities at quarter-end. This is plausible because US credit spreads do not increase at quarter-end.

4.2 Internal and External Capital for Dealer Investments

In our model dealers face frictions to raising capital from the internal and external capital markets. The relative severity of these frictions determine the fraction of marginal funding sourced from internal versus external capital markets. Proposition 1 explains that the dealer raises more capital from the market with less convex frictions.

Next, we analyze how dealers raise internal and external capital in response to changes in the CIP arbitrage spread by estimating the following time series regression:

$$\Delta\text{BD Borrowing}_t = \alpha + \beta\Delta\text{Arb Spread}_t + \epsilon_t, \tag{8}$$

where ΔBD Borrowing$_t$ is the change in aggregate borrowings by the US dealers in our sample and ΔArb Spread$_t$ is the change in the 1-month EUR CIP arbitrage spread. We estimate this for 1-day, 1-week, and 1-month horizons, and for the three sources of dealers' net borrowing: unsecured internal, unsecured external, and secured internal. Standard errors are robust to autocorrelation.

Table 4 shows the response of dealer borrowings to changes in arbitrage spreads. At the daily horizon, when arbitrage spreads widen by 10 bps, dealers borrow an additional \$0.54 billion of unsecured wholesale funding from the internal capital market (Panel A). This increases to \$1.6 billion at the weekly horizon and \$2.1 billion at the monthly horizon. The response is much more muted for external unsecured funding. For the same spread increase, externally sourced unsecured funding increases by nearly zero at the daily frequency, \$0.43 billion at the weekly frequency, and \$0.68 billion at the monthly frequency (Panel B, columns 1-4). Furthermore, the response is insignificant and nearly zero for secured internal funding (Panel C, columns 5-8).

At all horizons from daily to monthly, the dealer raises more capital from the internal market than the external one. Interpreted through the lens of our model, this implies that the external capital market friction is more convex than that of the internal market. At the monthly horizon, the external capital market friction is 3 times more convex than that of the internal market. This difference increases as the horizon shrinks and, at the daily frequency, the convexity of the external capital market friction is sufficiently large such that the dealer does not borrow any additional external funding in response to changes to investment opportunities.

For both internal and external unsecured funding, the responsiveness to investment opportunities increases with the horizon. For the internal capital market, the monthly flows are 1.3 times as large as that of the weekly flows and 3.9 times as large as that of the daily flows. For the external capital market, the monthly flows are 1.6 times as large as that of the weekly flows. At the daily frequency, external funds are completely insensitive to investment opportunities. In the context of our model, this implies that borrowing frictions are less convex over longer horizons. This finding is consistent with the stickiness in the process of allocating budgets across the various divisions and desks of a bank (Saita, 2010). Additionally, the lack of a response of secured internal funding to arbitrage spreads is consistent with secured borrowing not being the primary source of funding for CIP arbitrage activities. Consistently, Siriwardane et al. (2022) shows that balance sheet constraints and unsecured funding are important for pricing arbitrage spreads.

Next, we estimate equation (8) using an instrumental variable (IV) approach that relies on the quarter-end window-dressing behavior of foreign banks–and the associated shift in demand for U.S. banks' intermediation–as an instrument for variation in arbitrage spreads. The first-stage displayed in column 1 of Panel A indeed reveals that quarter-ends exhibit a 45 bps increase in 1-month arbitrage spreads. Importantly, this source of variation is independent from U.S. banks' balance sheet costs or willingness to intermediate FX markets, as it originates from the fact that foreign banks report the supplementary leverage ratio only at quarter-end snapshots. Column 5 of Panel A, as well as columns 4 and 8 of Panel B report the second-stage results. Broadly in line with the OLS coefficients, a widening of arbitrage spreads leads to a large increase in unsecured internal borrowings by dealers, a more modest increase in unsecured external borrowings, and no significant change in secured internal borrowings. The IV estimate of column 5, Panel A, is nearly twice as large as that of the OLS estimate from unconditional changes in arbitrage spreads in column 4. In response to CIP spreads widening at quarter-end, the US banks borrow and additional $17 billion in unsecured internal funding at quarter-end.[6] This negative OLS bias is consistent with there

[6]The $17 billion figure is obtained by multiplying the first-stage coefficient of 45.16 by the second-stage coefficient of 0.372.

being a positive correlation between commercial bank and dealer investment opportunities, as discussed in Section 4.1. While the sensitivity of unsecured internal funding to arbitrage spreads is the largest among the sources of net funding to the dealer, the magnitude of the effect is rather small, with

In sum, when dealers have better investment opportunities, they raise additional capital from the internal and external capital markets. Dealers raise capital in greater speed as well as quantity in the internal capital market than the external one. In the context of our model, this means that external capital market frictions are more convex than internal ones. In addition, longer horizons mitigate the convexity of these frictions, but only partially so.

Important for mapping our empirical tests to our model is the assumption that the CIP arbitrage spread is a good proxy for the marginal return to dealer investment ($\alpha F_1(I)$). Indeed, as discussed in Section 4.1, CIP arbitrage trades require raising unsecured funding from internal and external capital markets to deploy as secured lending against foreign sovereign debt collateral. We empirically test this assumption by estimating the association between dealer net secured lending against foreign sovereign debt and unsecured funding as follows:

$$\Delta \text{BD Foreign Sov Net Lending}_t = \alpha + \beta \Delta \text{BD Unsecured}_t + \epsilon_t,$$

where ΔBD Foreign Sov Net Lending$_t$ and ΔBD Unsecured$_t$ are dollar changes in aggregate broker-dealers' net secured lending against foreign sovereign debt collateral and unsecured funding, respectively.

Table 5 shows how dealers finance net secured lending against foreign sovereign collateral at different horizons. At the daily horizon, an additional $1 in unsecured funding is associated with an additional $0.07 in net secured lending against foreign sovereigns. This effect increases with the horizon, reaching $0.27 at the weekly horizon and $0.54 at the monthly horizon. When considering exogenous regulatory-driven variation around quarter-end, the effect increases to an additional $1.06 in dealer secured lending against foreign sovereigns for an additional $1 in dealer unsecured funding.

So far, we have rejected the null hypothesis of a perfectly *inefficient* internal capital market, namely an internal capital market that is insensitive to dealer investment opportunities. However, the sluggishness of the response suggests that the internal capital market is far from perfectly efficient.

4.3 Partially Segmented Internal Capital

An important feature of our model is the presence of frictions to internal capital markets. Proposition 2 explains that internal capital market frictions cause capital to be partially segmented: division-specific liquidity prices division-specific investment opportunities. By contrast, in a model with only an external capital market friction, such as Kaplan and Zingales (1997), the aggregate liquidity of the firm prices investment opportunities. Thus, we empirically test whether liquidity directly held by dealers prices dealer-specific investment opportunities, in particular CIP arbitrage spreads.

As described in Section 2.5, we measure the directly held liquidity of divisions as their high quality liquid assets or HQLA. Figure 4 plots the time series of dealer HQLA and 3-month EUR CIP arbitrage spreads: the correlation is 65 percent in levels and 41 percent in monthly changes. We use the 3-month spread to show that the association between dealer liquidity and arbitrage spreads is not driven by quarter-end spikes.

To test whether dealer liquidity prices its own investment opportunities, we estimate the following time series regression:

$$\text{Arb Spread}_t = \alpha + \beta \text{BD HQLA}_t + \gamma \text{BHC HQLA}_t + \epsilon_t,$$

where Arb Spread_t is the 3-month EUR CIP arbitrage spread, BD HQLA_t is the HQLA held by the dealer, and BHC HQLA_t is the HQLA of the bank holding company. We include the HQLA held by the bank holding company since under the null hypothesis of perfectly efficient internal capital markets, only bank holding company liquidity should matter.

Table 6 displays the results. The coefficient of dealer HQLA in column 1 indicates that a one standard deviation increase in the level of dealer HQLA ($20.5 billion or 3.3 percent) is associated with arbitrage spreads decreasing by 5 bps. The effect of changes in dealer HQLA is increasing in the horizon of the change, as shown in columns 3 to 5. At the daily frequency, the effect is small and insignificant. However, at the monthly frequency, a 1 percentage point increase in dealer HQLA ($6.1 billion of HQLA) decreases arbitrage spreads by 1.51 bps. Table B.1 shows that this association is also robust to controlling for either the fraction of bank holding company HQLA that is in excess of regulatory requirements or the individual components of HQLA.[7]

So far, we have shown evidence of a strong association between dealer liquidity and the return to dealer investment opportunities. To identify a causal relationship, we use the quarter-end demand shifts described in Section 4.1. Under the hypothesis that dealer liquidity matters for arbitrage spreads, the shift in demand for U.S. dealers' intermediation at quarter-end should lead to wider arbitrage spreads when dealers experience a decline in available liquidity, measured by lagged changes in dealer HQLA. To capture this interaction effect between quarter-end dynamics and dealer liquidity, we estimate the following time series regression:

$$\Delta \text{Arb Spread}_t = \alpha + \beta \text{QE}_t + \gamma \text{QE}_t \times \Delta \text{BD HQLA}_{t-1} + \epsilon_t, \tag{9}$$

where ΔArb Spread$_t$ is the 1-month EUR CIP arbitrage spread as in the first stage of the IV estimation reported in Table 4, QE$_t$ is an indicator variable for the quarter-end month and ΔBD HQLA$_{t-1}$ is the 1-month lagged change in dealer HQLA.

Table 7 shows that when dealer HQLA increases in the previous month, the quarter-end

[7]The concern is that of a potential measurement issue. Suppose that arbitrage spreads covary only with bank holding company liquidity, but dealer HQLA is a better measure of bank holding company liquidity. Then, we may find a spurious relationship between dealer HQLA and arbitrage spreads. This is unlikely to be driving the association because dealer HQLA is less liquid than that of the bank holding company on average. Dealer HQLA is comprised of more Level 2 assets, such as corporate bonds and mortgage backed securities, than bank holding company HQLA, which is primarily Level 1 assets (reserves and Treasuries). Dealer HQLA is 22 percent Level 2 assets, while bank holding company HQLA is 11 percent Level 2 assets.

shift in demand causes a smaller increase in arbitrage spread on average. For a 1 standard deviation increase in lagged dealer HQLA ($18 billion), the arbitrage spreads increase by 16 bps less in response to a quarter-end demand shift. The quarter-end increase in arbitrage spreads is about a third smaller when dealer HQLA increased by 1 standard deviation in the previous month. This effect is robust to the inclusion of 1-month lagged changes in bank holding company liquidity, excess liquidity, and the various HQLA components. It is variation in dealer liquidity, not bank holding company liquidity, that impacts the sensitivity of arbitrage spreads to demand shifts.

The identifying assumption is that 1-month lagged changes in dealer HQLA are exogenous to the quarter-end shift in demand. A potential threat to identification may arise if the dealer accumulates liquidity 1-month in advance of the predictable demand shift at quarter-end. To mitigate this concern, we remove the predictable component of quarter-end arbitrage spread changes. Specifically, we use the term structure of arbitrage spreads and the expectations hypothesis to measure the unpredictable component of the quarter-end arbitrage spread as follows:

$$\text{Arb Surprise}_{t,1M} = \text{Arb}_{t,1M} - \text{Arb}^{1M}_{t-1,1M},$$

where the first term is the current month (time t) CIP arbitrage spread and the second term is the previous month (time $t-1$) 1-month forward CIP arbitrage spread, where both have a tenor of 1-month. Following Du et al. (2023), we define the h-month forward CIP arbitrage spread with a tenor of 1-month to be

$$\text{Arb}^{h}_{t,1M} = (h+1)\text{Arb}_{t,1+h} - h\text{Arb}_{t,h}.$$

Using the surprise component of quarter-end changes in arbitrage spreads in estimating equation (9), we mitigate the endogeneity concerns that dealers may accumulate liquidity one month in advance of quarter-end in proportion to the expected shift in demand. As a validation that the surprise spread is not predictable in advance, we find that Arb $\text{Surprise}_{t,1M}$

does not significantly increase at quarter-end (column 1 of Table 8). While the surprise component is unpredictable, recall that arbitrage spreads increase by 45 bps on average at quarter-end, as shown in Table 4. Even when using the surprise component of arbitrage spreads in Table 8, we find that changes in the liquidity available to dealers ahead of the quarter-end demand shifts have a significant effect on arbitrage spreads. Moreover, the magnitude of the interaction effect (QE$\times\Delta$BD HQLA) is quantitatively similar whether we use changes in arbitrage spreads (Table 7) or changes in surprise spreads (Table 8) as the dependent variable.

In sum, we reject the null of a perfectly efficient internal capital market because it is dealer's liquidity, not bank holding company's, that prices arbitrage spreads. Division-specific liquidity matters for pricing division-specific investment opportunities. As emphasized in our model, internal capital market frictions are convex, which limits the immediate adjustment of capital to investment opportunities. This convexity results in directly held liquidity having a larger effect on short-lived investment opportunities. For a persistent increase in dealer investment opportunities, the internal capital market may gradually adjust over time.

We have shown that liquidity is partially segmented between the dealer and the bank holding company due to internal capital market frictions. Recall Table 4, where we find that the internal capital market is much more responsive to investment opportunities at the monthly frequency than the daily or weekly frequency. Thus, an important feature of these internal frictions is that they get relaxed over time. In other words, when the dealer experiences a negative liquidity shock, the bank holding company gradually supplies more liquidity to the dealer. Indeed, dealer liquidity is strongly mean reverting: for a $1 decrease in liquidity over 1 month, $0.7 is recovered over the next three months. In the language of our model, internal capital market frictions are less convex at longer horizons. We empirically test this hypothesis using the term structure of CIP arbitrage spreads.

Specifically, for each tenor of the CIP arbitrage spread (τ) spanning from 1 week to 12 months, we estimate the association between monthly changes in dealer liquidity and arbitrage spreads as follows:

$$\Delta \text{Arb Spread}_t^{\tau} = \alpha + \beta_\tau \Delta \text{BD HQLA}_t + \gamma_\tau \Delta \text{BHC HQLA}_t + \epsilon_t$$

Table 9 displays the results. A one percent decrease in dealer HQLA is associated with a 4.7 bps increase in the 2-week EUR CIP arbitrage spread, a 3.5 bps increase in the 1-month spread, and a 0.73 bps increase in the 12-month spread. Therefore, a monthly increase in dealer HQLA is associated with sizable reductions in arbitrage spreads at tenors shorter than one month. As the tenor increases beyond one month, the effect becomes smaller.

The decreasing effect of dealer liquidity on arbitrage spreads of longer tenors is consistent with a slow-moving internal capital market. At short horizons, a decline in dealer liquidity is not immediately offset by internal markets and therefore it has a significant effect on arbitrage spreads. However, as the dealer expects internal markets to replenish its liquidity over time, the same decline in dealer liquidity has more muted effects on arbitrage spreads of longer tenors.

4.4 Insufficient Internal Capital Market Flows

The partial segmentation of capital by division is the result of the insufficient sensitivity of internal capital markets to division-specific investment opportunities. When arbitrage spreads are large, the dealer receives more funding from the bank holding company but the transfer is insufficient, so the dealer also draws down on its own liquidity. Our model explains that with a fully efficient internal capital market, only the aggregate liquidity of the bank holding company should price investment opportunities. Therefore, we can compute how much more sensitive the internal capital market would need to be so that dealer liquidity does not price arbitrage spreads.

Suppose that the dealer saves each additional dollar of unsecured funding as HQLA. At the monthly frequency, the bank holding company would need to transfer an additional $4.07

billion of funding to the dealer in response to a 1 bps increase in the arbitrage spread. This requires internal capital markets to be 11 times more sensitive than they actually are.[8] If rescaled such that no internal capital market equals 0 and a perfectly efficient internal capital market equals 1, the estimated efficiency value of the existing internal capital market is 0.09. Therefore, the internal capital market is much closer to not existing than being perfectly efficient.

This partial equilibrium hypothetical efficiency estimate of 0.09 is a lower bound to how much more sensitive the internal capital market would need to be because of the assumption that the dealer saves all of the additional internal funding as HQLA. In equilibrium, the dealer would invest a fraction of the additional funding in the CIP trade. The amount of additional investment in the CIP trade depends on the customer elasticity of demand. This partial equilibrium hypothetical is only optimal if customer demand is perfectly inelastic. Wallen (2022) estimates customer demand on the other side of the CIP trade to be inelastic, but not perfectly so. This implies that the internal capital market is even further from perfectly efficient. Our estimate of the internal capital market efficiency of 0.09 is thus an upper bound.

With a more efficient internal capital market, the bank holding company would earn a larger return on its capital. Assuming that available liquidity held at the holding company or commercial bank earns the interest on reserves, then the marginal dollar transferred to the dealer would earn an additional 37 bps in the CIP trade.[9] Over our sample, this is a 33 percent increase in the rate earned on risk-free investments. Furthermore, without increasing the average amount of dollars transferred, the bank holding company could earn more by

[8] The dealer on average has \$615 billion of HQLA. For a 1 bps increase in arbitrage spreads, the estimates of Table 6 indicate that dealers should deploy $1/1.51 = 0.67$ percentage points in HQLA, which is equal to \$4.07 billion. In addition, the estimates of Table 4 suggest that, for a 1 bps increase in arbitrage spreads, dealer unsecured internal funding increases by \$0.372 billion (Panel A, column 5) and its unsecured external funding by \$0.065 billion. Subtracting the increase in unsecured external funding from the \$4.07 billion of liquidity needed, the dealer ought to receive an internal transfer of \$4 billion. However, it only receives \$0.372 billion. Therefore, internal unsecured funding transfers should be about 11 times (4/0.372) larger for dealer HQLA to not be sensitive to arbitrage spreads–which characterizes a fully efficient internal market outcome.

[9] This is the CIP spread relative to the interest on reserves spread (CIP basis - (interest on reserves - Fed Funds rate)).

making the transfers more sensitive to investment opportunities. Transferring an additional dollar to the dealer when the CIP spread is above median and one dollar less when the spread is below median would increase average returns by 26 bps.

4.5 Generalizability of Internal Capital Market Inefficiencies

So far we have shown that the internal capital market of the bank holding company is inefficiently sensitive to the investment opportunities of the dealer as measured by the CIP arbitrage spread. A natural question is whether this inefficiency is unique to this arbitrage spread or generalizes to other investment opportunities of the dealer.

In Online Appendix Section B, we show that the internal capital market is even more inefficient with respect to equity arbitrage spreads. We measure equity arbitrage spreads as the asset implied return in excess of the risk free rate to equity spot-futures. We use the average equity spot-futures spreads on the S&P500, Dow Jones, and Nasdaq indicies as measured in Siriwardane et al. (2022). Internal transfers of unsecured funding are insensitive to variation in the equity arbitrage spread (Table B.2). However, dealer liquidity decreases when the equity arbitrage spread increases (Table B.3). These findings suggest that dealers deploy liquidity to take advantage of the equity arbitrage spread without receiving internal funding, indicating a very inefficient internal capital market.

4.6 Regulatory Constraints to Internal Capital Markets

Regulation W permits commercial banks to engage in covered transactions with affiliated broker-dealers for up to 20 percent of the commercial bank capital. A covered transaction is an extension of credit or purchase of a security and commercial bank capital is the sum of their tier 1 and tier 2 capital.

Broker-dealers report their unutilized capacity for transfers in the FR2052a dataset. Appendix Figure A.2 shows the time series plot of unutilized capacity for internal capital market transactions between commercial banks and affiliated dealers. On average an additional

$90 billion could be transferred from commercial banks to dealers. This is 15 percent of the dealers' HQLA but only 5.3 percent of the commercial banks' HQLA. The Regulation W limit on these internal transfers is never binding in aggregate, with the minimum transfer capacity at $66 billion on July, 3rd 2019. In unreported results, we also show that these transfers are never binding for any one individual bank. Therefore, regulatory constraints are not close to binding for bank holding company internal capital transfers.

5 Conclusion

We observe internal capital market flows and investment opportunities of complex, large bank holding companies at high frequency. This provides for a high-powered test of the efficiency of bank internal capital markets and a precise quantification of how far the internal market is from perfectly efficient.

We document that the internal capital markets of bank holding companies are slow to respond to investment opportunities and the transfers are too small. We show that these frictions exist for simple, risk-free investment opportunities of the dealer and are likely more severe for risky investment opportunities for which there is greater information asymmetry. These internal frictions cause partial segmentation of funding within the bank holding company and can help explain the slow-moving capital phenomenon that is broadly observed in asset markets (Duffie, 2010). This suggests that the frictions to the integration of financial markets cannot be solved by expanding the boundaries of financial firms. The information asymmetry and agency frictions that underlie imperfect external capital markets extend within the bank holding company.

Since many financial institutions, such as hedge funds and asset managers, depend on broker-dealers for market making and funding, these internal capital market frictions are likely to generalize across bank intermediated markets. Even though the same set of bank holding companies serve as intermediaries across many markets, frictions to their internal capital markets may limit their ability to integrate these markets. This is consistent with evidence of low correlation between arbitrage spreads across markets and a partially segmented intermediary sector (Siriwardane et al., 2022).

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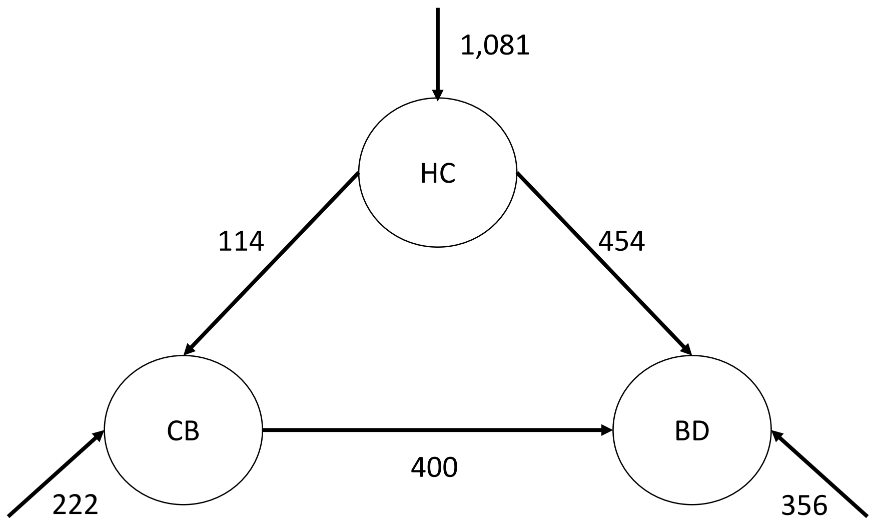
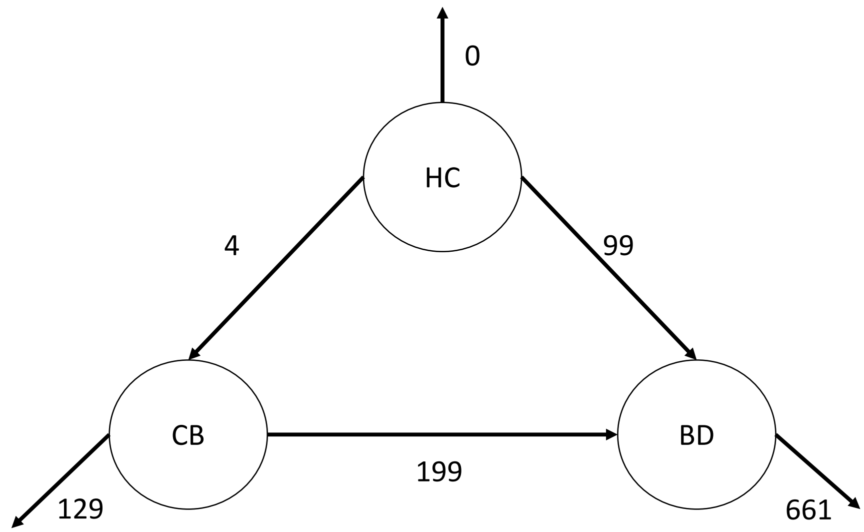
Figure 1: Internal and External Capital Market for Unsecured Wholesale Funding



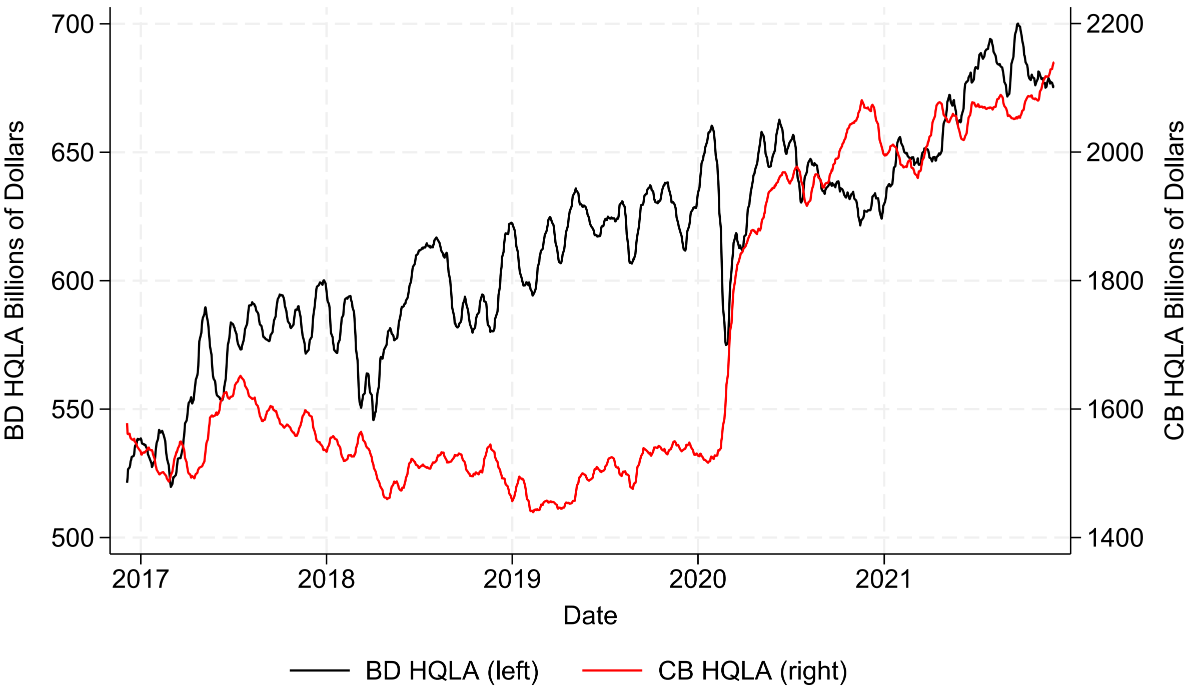
Notes : Figure 1 shows the internal and external capital market for unsecured wholesale borrowing and lending between the holding company (HC), commercial bank (CB), and broker dealer. On average, over our sample from January 3rd 2017 to December 31st 2021, the holding company borrows 1,081 billion dollars of unsecured wholesale funding externally and internally net lends 114 billion to the commercial bank and 454 to the broker dealer. The commercial bank borrows 222 billion externally, net lends 400 billion to the broker dealer, and net borrows 114 billion from the holding company. The broker dealer borrows 356 billion externally, net borrows 400 billion from the commercial bank and net borrows 454 billion from the holding company.

Figure 2: Internal and External Capital Market for Secured Funding



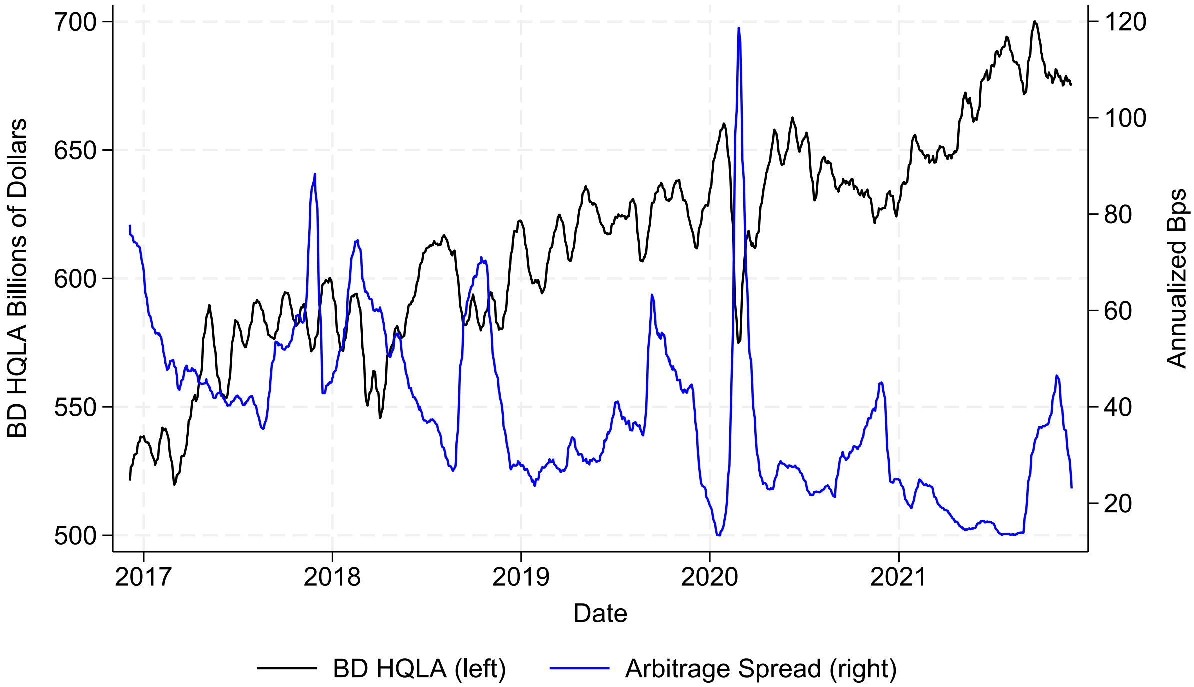
Notes : Figure 2 shows the internal and external capital market for secured borrowing and lending between the holding company (HC), commercial bank (CB), and broker dealer. On average, over our sample from January 3rd 2017 to December 31st 2021, the holding company does not secured borrow or lend with the external market, but the holding company in net secured lends 4 billion to the commercial bank and secured lends 99 billion to the broker dealer. The commercial bank in net secured lends 129 billion to the external capital market and secured lends 199 billion to the broker dealer and secured borrows 4 billion from the holding company. The broker dealer in net secured lends 661 to the external capital market and secured borrows 199 billion from the commercial bank and 99 billion from the holding company.

Figure 3: Broker Dealer and Commercial Bank Liquidity



Notes : Figure 3 shows the time series of high quality liquid assets (HQLA) held at the broker dealers and commercial banks for our 6 GSIB banks. The black line shows the sum of the HQLA held by the broker dealer divisions (left y-axis) and the red line shows the sum of the HQLA held by the commercial bank divisions and holding company (right y-axis). The plot is of 10-day moving averages of daily data that spans from January 1st 2017 to December 31st 2021.

Figure 4: Broker Dealer Liquidity and Arbitrage Spreads



Notes : Figure 4 shows the time series of liquidity held at the broker dealers for our 6 GSIB banks and the 3-month EUR USD CIP arbitrage spread. The black line shows the sum of the HQLA held by the broker dealer divisions and the blue line shows the average arbitrage spread. The plot is of a 10-day moving averages of daily data that spans from January 1st 2017 to December 31st 2021.

Table 1: Deposit and Unsecured Wholesale Funding

	BHC	BD External	BD Internal
Deposits	6082	7	-50
Unsecured Wholesale	1659	356	854
LT Debt	1316	154	243
Free Credits	108	108	0
ABS	82	49	15
CD	53	0	0
ST Notes	41	15	428
Interbank	27	2	4
CP	26	26	0
Other	6	3	163

Notes: Table 1 shows the average unsecured borrowing in billions for each type of instrument. Negative values are lending. The first column shows the external borrowing by the bank holding company; the second column shows the external borrowing by the broker dealer; the third column shows the internal borrowing by the broker dealer. The instruments include deposits and unsecured wholesale funding, which is further broken down into long term debt, free credits, asset backed securities (ABS), wholesale certificates of deposit (CD), short-term notes interbank lending, commercial paper (CP), and other.

Table 2: External and Internal Sources of BD Unsecured Wholesale Funding

A. Internal Capital Market

	Δ HC Unsecured Int			Δ CB Unsecured Int		
	Day	Week	Month	Day	Week	Month
Δ BD Unsecured Funding	-0.76***	-0.65***	-0.54***	-0.18***	-0.25***	-0.35***
	(0.03)	(0.04)	(0.06)	(0.03)	(0.04)	(0.06)
Adjusted R^2	0.72	0.66	0.57	0.16	0.23	0.35
N	1,251	1,247	1,232	1,251	1,247	1,232

B. External Capital Market

	Δ BD Unsecured Ext			Δ BHC Unsecured Ext		
	Day	Week	Month	Day	Week	Month
Δ BD Unsecured Funding	0.06***	0.10***	0.11***	0.06***	0.09***	0.02
	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.04)
Adjusted R^2	0.04	0.14	0.21	0.02	0.04	0.00
N	1,251	1,247	1,232	1,251	1,247	1,232

Notes: Table 2 shows the relationship between changes in broker dealer unsecured wholesale funding and its sources. Panel A shows that for a $1 increase in broker dealer unsecured wholesale funding over 1-month, the internal lending of the holding company increases by $0.54 and the internal lending of the commercial bank increases by $0.35. Similarly, Panel B shows that the external unsecured wholesale borrowing increases by $0.11 in response. These responses mechanically sum to $1. For a $1 increase in broker dealer unsecured wholesale funding over 1-month, the bank holding company borrows an additional $0.02 externally. This shows that the variation in unsecured broker dealer wholesale funding is primarily through the internal capital market. Standard errors are robust to autocorrelation to account for the daily data frequency and overlapping changes.

Table 3: Secured Net Lending

Collateral	BHC	BD External	BD Internal
Total	790	661	-298
Foreign Sovereign Debt	388	345	-27
Treasuries	215	198	-96
Domestic Equities	125	121	-31
Foreign Equities	43	43	-12
Other	26	13	-11
IG Corp Debt	15	9	-2
HY Corp Debt	12	6	-15
Loans	10	0	-0
Agencies	-6	-10	-3
GSE Debt	-8	-13	-5
MBS	-31	-51	-95

Notes: Table 3 shows the average secured lending in billions for each type of instrument. Negative values are secured borrowing. The first column shows the external secured lending by the bank holding company; the second column shows the external secured lending by the broker dealer; the third column shows the internal secured lending by the broker dealer.

Table 4: Broker Funding and Arbitrage Spreads

A. Internal Unsecured Wholesale Funding

	Δ Arb Spread	Δ BD Unsecured Internal			
	Month	Day	Week	Month	Month
Quarter-end	45.160***				
	(7.427)				
Δ Arb Spread		0.054*	0.160***	0.208**	0.372***
		(0.030)	(0.054)	(0.095)	(0.129)
Specification	OLS	OLS	OLS	OLS	IV
Adjusted R^2	0.25	0.00	0.03	0.07	
N	1,232	1,251	1,247	1,232	1,232

B. External Unsecured Wholesale Funding and Internal Secured Funding

	Δ BD Unsecured External				Δ BD Secured Internal			
	Day	Week	Month	Month	Day	Week	Month	Month
Δ Arb Spread	-0.000	0.043***	0.068***	0.065*	-0.044	-0.089	-0.080	0.226
	(0.010)	(0.015)	(0.023)	(0.033)	(0.064)	(0.079)	(0.072)	(0.238)
Specification	OLS	OLS	OLS	IV	OLS	OLS	OLS	IV
Adjusted R^2	0.00	0.03	0.11		0.00	0.00	0.00	
N	1,251	1,247	1,232	1,232	1,251	1,247	1,232	1,232

Notes: Table 4 shows the association between changes in arbitrage spreads and broker dealer sources of funding: unsecured internal, unsecured external, and secured internal. We use the 1-month EUR USD CIP arbitrage spread as our measure of broker dealer investment opportunities. Panel A column 1 shows that at quarter-end (an indicator variable equal to 1 for the 3rd month of every quarter), arbitrage spreads are on average 45 bps higher than otherwise. Columns 2-4 show that broker dealer internal unsecured funding increases in response to a contemporaneous increase in arbitrage spreads. At the monthly horizon, a 1 bps increase in arbitrage spreads is associated with broker dealer wholesale funding increasing by 0.208 billion dollars. Column 5 shows that a 1-bps increase in arbitrage spreads due to quarter-end is associated with a 0.372 billion dollar increase in unsecured wholesale funding. Panel B shows a weaker effect response for unsecured external funding and an insignificant response for secured internal funding. Standard errors are robust to autocorrelation to account for the daily data frequency and overlapping changes.

Table 5: Broker Dealer Unsecured Wholesale Funding and Secured Lending

	Δ BD Foreign Sov Net Lending			
	Day	Week	Month	Month
Δ BD Unsecured	0.07**	0.27**	0.54**	1.06**
	(0.04)	(0.13)	(0.27)	(0.52)
Specification	OLS	OLS	OLS	IV
Adjusted R^2	0.00	0.03	0.12	
N	1,251	1,247	1,232	1,232

Notes: Table 5 shows the association between secured lending against foreign sovereign debt and broker dealer unsecured wholesale funding. For a $1 increase in broker dealer unsecured funding over 1-month, secured lending associated with the CIP trade increases by $0.54. For increases in broker dealer unsecured funding associated with quarter-end, the effect increases to $1.06.

Table 6: Broker Dealer Liquidity and Arbitrage Spreads

	Arbitrage Spread		Δ Arbitrage Spread		
	Levels	Detrended	Daily	Weekly	Monthly
BD HQLA	-0.27***	-0.33***			
	(0.02)	(0.04)			
BHC HQLA	-0.00	-0.01***			
	(0.00)	(0.00)			
Δ BD HQLA			-0.14	-0.64**	-1.51**
			(0.11)	(0.25)	(0.62)
Δ BHC HQLA			-0.15	-0.75*	-0.25
			(0.15)	(0.39)	(0.93)
Adjusted R^2	0.42	0.16	0.00	0.06	0.12
N	1,252	1,252	1,251	1,247	1,232

Notes: Table 6 shows the relationship between arbitrage spreads and liquidity held at the broker dealer and bank holding company in levels, detrended levels, and changes at the daily, weekly, and monthly frequency. Controlling for bank holding company liquidity, when the level of broker dealer HQLA decreases by 1 percent, arbitrage spreads are on average 0.27 bps higher. When broker-dealer HQLA decreases by 1 percent ($6.15 billion) over 1-month, arbitrage spreads on average increase contemporaneously by 1.51 bps. By contrast, arbitrage spreads are only marginally negatively related to bank holding company liquidity. Table B.3 shows that this is robust to controlling for excess liquidity held at the bank holding company and splitting liquidity by type: Level 1 and Level 2.

Table 7: The Effect of Dealer Liquidity On Arbitrage Spreads

	Δ Arbitrage Spread				
	(1)	(2)	(3)	(4)	(5)
QE	45.16***	55.67***	56.99***	55.50***	53.21***
	(7.43)	(9.72)	(10.89)	(10.93)	(10.76)
QE × Δ BD HQLA (t-1)		-0.80***	-0.91**	-0.80**	-0.98**
		(0.29)	(0.42)	(0.35)	(0.44)
QE × Δ BHC HQLA (t-1)			0.07		
			(0.18)		
QE × Δ BHC Ex HQLA (t-1)				-0.01	
				(0.11)	
QE × Δ BHC Lvl1 HQLA (t-1)					-0.10
					(0.22)
QE × Δ BHC Lvl2 HQLA (t-1)					0.16
					(0.20)
Adjusted R^2	0.25	0.29	0.29	0.29	0.30
N	1,232	1,213	1,213	1,213	1,213

Notes: Table 7 shows the effect of 1-month lagged changes in dealer HQLA and bank holding company HQLA on how quarter-end shifts in demand impact arbitrage spreads. On average for the month prior to quarter-end, dealer HQLA increases by 13 billion. For the month prior to quarter-end, if there is a 1 standard deviation increase in broker dealer HQLA (18 billion), then the quarter-end demand shift increases arbitrage spreads by on average 16 bps less (18×-0.91, column 2). By contrast, variation in 1-month lagged bank holding company HQLA does not have a statistically significant impact on the sensitivity of arbitrage spreads to quarter-end demand shifts. Standard errors are robust to autocorrelation to account for the daily data frequency and overlapping changes.

Table 8: The Effect of Dealer Liquidity On Unexpected Variation in Arbitrage Spreads

	Δ Surprise Arbitrage Spread				
	(1)	(2)	(3)	(4)	(5)
QE	4.11	11.44*	14.16*	14.76*	10.60
	(5.02)	(6.90)	(7.69)	(7.89)	(7.06)
QE × Δ BD HQLA (t-1)		-0.58**	-0.79**	-0.70**	-0.86**
		(0.24)	(0.32)	(0.28)	(0.34)
QE × Δ BHC HQLA (t-1)			0.14		
			(0.14)		
QE × Δ BHC Ex HQLA (t-1)				0.10	
				(0.09)	
QE × Δ BHC Lvl1 HQLA (t-1)					-0.02
					(0.21)
QE × Δ BHC Lvl2 HQLA (t-1)					0.23
					(0.14)
Adjusted R^2	0.01	0.07	0.08	0.08	0.10
N	1,232	1,213	1,213	1,213	1,213

Notes: Table 8 shows the effect of 1-month lagged changes in dealer HQLA and bank holding company HQLA on how quarter-end shifts in demand impact surprises to arbitrage spreads. We measure surprises to arbitrage spread as the difference between realized and 1-month forward arbitrage spread. For the month prior to quarter-end, if there is a 1 standard deviation increase in broker dealer HQLA (18 billion), then the quarter-end demand shift increases arbitrage spreads by on average 14 bps less (18×-0.79, column 3). By contrast, variation in 1-month lagged bank holding company HQLA does not have a statistically significant impact on the sensitivity of arbitrage spreads to quarter-end demand shifts. Standard errors are robust to autocorrelation to account for the daily data frequency and overlapping changes.

Table 9: Broker Dealer Liquidity and Arbitrage Spreads at Different Tenors

	Δ Arbitrage Spread							
	1W	2W	3W	1M	2M	3M	6M	12M
Δ BD HQLA	-4.30***	-4.72***	-4.57***	-3.53**	-2.35***	-1.51**	-1.14**	-0.73***
	(0.91)	(1.15)	(1.37)	(1.50)	(0.88)	(0.62)	(0.44)	(0.28)
Δ BHC HQLA	-0.57	0.46	0.94	0.30	-0.66	-0.25	0.12	0.04
	(1.68)	(2.11)	(2.30)	(2.15)	(1.27)	(0.93)	(0.59)	(0.35)
Adjusted R^2	0.16	0.13	0.12	0.08	0.13	0.12	0.15	0.14
N	1,232	1,232	1,231	1,232	1,232	1,232	1,232	1,232

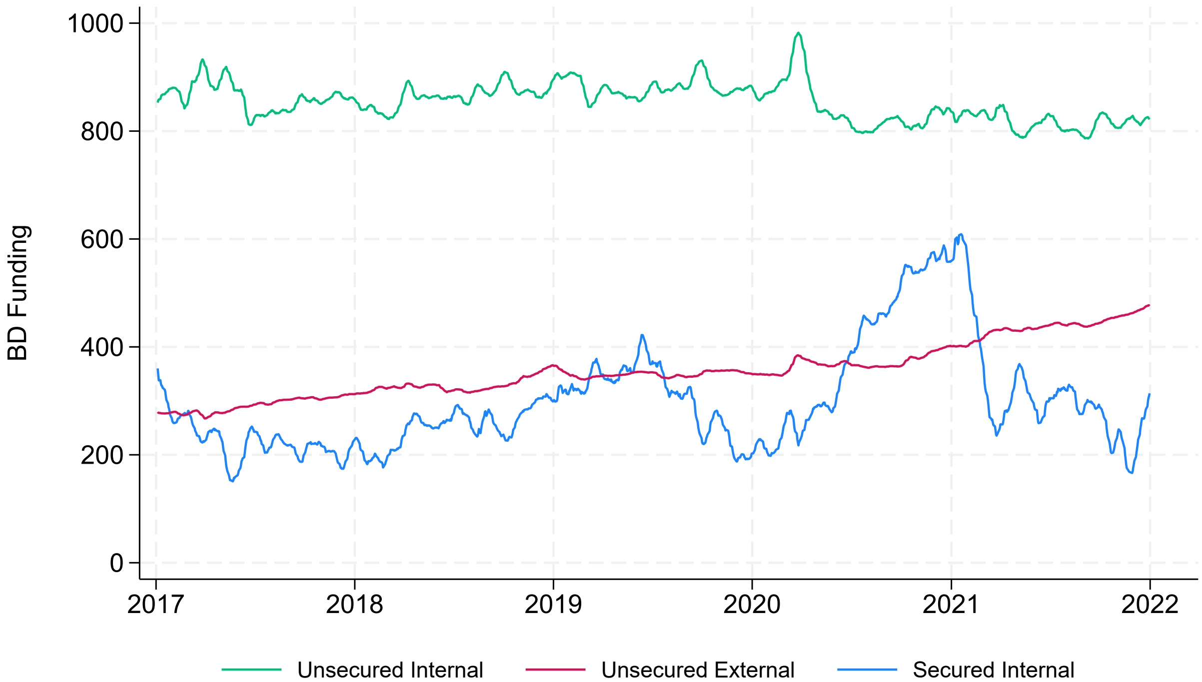
Notes: Table 9 shows the association between monthly percent changes in broker dealer and bank holding company HQLA and monthly changes in arbitrage spreads of tenors from 1-week to 12-months. For a 1 percent decrease in broker dealer HQLA over 1-month ($7.6 billion), the 1-week EUR USD CIP arbitrage spread increases by 4.30 bps and the 1-month spread increases by 3.53 bps and the 12-month spread increases by 0.73 bps. There is no such pattern for the association between bank holding company HQLA and arbitrage spreads. Standard errors are robust to autocorrelation to account for the daily data frequency and overlapping changes.

Online Appendix: Not For Publication

This appendix includes several sections of supplemental information. Appendices A and B present additional figures and tables, respectively, Appendix C contains definitions of all the variables used in the paper, Appendix D derives the equilibrium for a perfectly efficient internal capital market, and finally Appendix E describes a simplified broker-dealer business model.

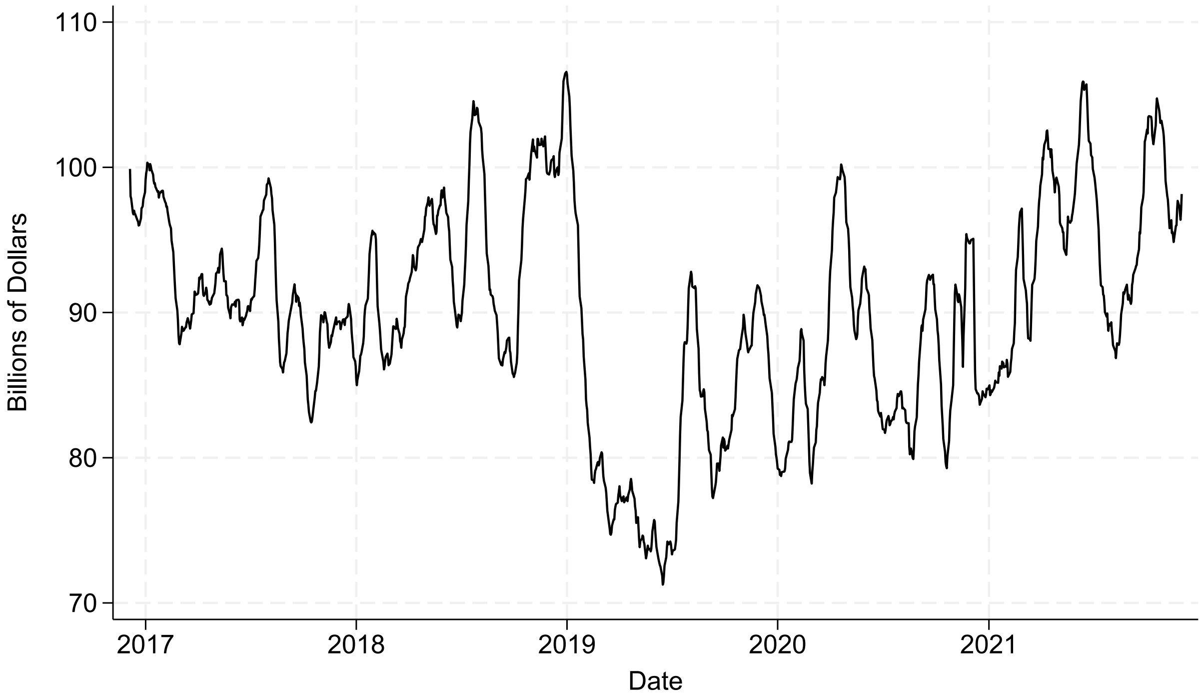
A Appendix Figures

Figure A.1: Broker Dealer Funding



Notes : Figure A.1 shows the time series of three components to broker dealer funding: internal unsecured wholesale borrowing, external unsecured wholesale borrowing, and internal secured borrowing. The broker dealer is a net lender of secured funding. The plot is of 10-day moving averages of daily data that spans from January 1st 2017 to December 31st 2021 and is the sum of the broker dealers for our 6 GSIB banks.

Figure A.2: Excess Capacity for Internal Transfers from the Commercial Bank to Broker-Dealers



Notes : Figure A.2 shows excess capacity for internal covered transactions between the commercial banks and affiliated commercial banks. The plot is of a 10-day moving averages of daily data that spans from January 1st 2017 to December 31st 2021. The correlation of excess capacity with dealer wholesale funding is 8 percent and with dealer HQLA is 8 percent.

B Appendix Tables

Table B.1: Broker Dealer Liquidity and Arbitrage Spreads Robustness

	Δ Arbitrage Spread		
	Daily	Weekly	Monthly
Δ BD HQLA	-0.12	-0.69***	-1.51**
	(0.10)	(0.25)	(0.60)
Δ BHC Excess HQLA	0.10**	-0.14	-0.22*
	(0.04)	(0.08)	(0.13)
Δ BHC Lvl 1	-0.24*	-0.15	0.38
	(0.14)	(0.27)	(0.71)
Δ BHC Lvl 2	-0.01	-0.02	0.08
	(0.01)	(0.03)	(0.06)
Adjusted R^2	0.01	0.05	0.13
N	1,251	1,247	1,232

Notes: Table B.1 shows that the association between dealer HQLA and arbitrage spreads is robust to controlling for the excess HQLA of the BHC and the components of HQLA of the BHC. The baseline specification is shown in Table 6.

Table B.2: Broker-Dealer Funding and Equity Arbitrage Spreads

A. Internal Unsecured Wholesale Funding

	Δ Arb Spread	Δ BD Wholesale Internal			
	Month	Day	Week	Month	Month
Quarter-end	5.769**				
	(2.890)				
Δ Arb Spread		-0.055	-0.051	0.211*	2.659*
		(0.110)	(0.105)	(0.111)	(1.460)
Specification	OLS	OLS	OLS	IV	
Adjusted R^2	0.02	-0.00	-0.00	0.02	
N	1,162	1,181	1,176	1,162	1,162

B. External Unsecured Wholesale Funding and Internal Secured Funding

	Δ BD Wholesale External				Δ BD Secured Internal			
	Day	Week	Month	Month	Day	Week	Month	Month
Δ Arb Spread	0.126***	0.013	0.056**	0.416	-0.360*	-0.120	-0.367**	1.360
	(0.038)	(0.030)	(0.028)	(0.324)	(0.213)	(0.155)	(0.147)	(2.028)
Specification	OLS	OLS	OLS	IV	OLS	OLS	OLS	IV
Adjusted R^2	0.02	0.00	0.02		0.00	0.00	0.02	
N	1,181	1,176	1,162	1,162	1,181	1,176	1,162	1,162

Notes: Table B.2 shows the association between changes in dealer funding and changes in equity arbitrage spreads. This mirrors Table 4.

Table B.3: Broker-Dealer Liquidity and Arbitrage Spreads

A. Controlling for BHC Liquidity

	Arbitrage Spread		Δ Arbitrage Spread		
	Levels	Detrended	Daily	Weekly	Monthly
BD HQLA	-0.36***	-0.23***			
	(0.02)	(0.04)			
BHC HQLA	0.04***	0.05***			
	(0.00)	(0.00)			
Δ BD HQLA			-0.12	-0.17	-1.68***
			(0.09)	(0.22)	(0.58)
Δ BHC HQLA			-0.05	0.48	1.80
			(0.13)	(0.59)	(1.49)
Adjusted R^2	0.14	0.11	0.00	0.00	0.08
N	1,211	1,211	1,181	1,176	1,162

B. Robustness

	Δ Arbitrage Spread		
	Daily	Weekly	Monthly
Δ BD HQLA	-0.10	-0.15	-1.62***
	(0.09)	(0.22)	(0.55)
Δ BHC Excess HQLA	0.07**	-0.00	-0.32*
	(0.04)	(0.11)	(0.18)
Δ BHC Lvl1	-0.21	0.35	2.11*
	(0.13)	(0.42)	(1.14)
Δ BHC Lvl2	-0.00	0.02	0.22**
	(0.02)	(0.04)	(0.11)
Adjusted R^2	0.01	0.00	0.09
N	1,181	1,176	1,162

Notes: Table B.3 shows the relationship between equity arbitrage spreads and liquidity held at the dealer and bank holding company in levels, detrended levels, and changes at the daily, weekly, and monthly frequency. This mirrors Table 6.

C Variable Definitions

Variable Name	**Description and Weight**
Selected HQLA:	
Level 1 Asset	Central Bank reserves, securities issued or unconditionally guaranteed by the full faith of the US government, certain foreign sovereign debt with zero risk weight (rated AA- and higher). *Weight: 100%. Source:* LCR Proposed Rule (Nov 29, 2013), §.21(b)(1), II.A.2.a, II.A.5.
Level 2A Asset	Securities guaranteed by a US government sponsored enterprise and securities guaranteed by a sovereign entity rated between A+ and A-. *Weight: 85%. Source:* LCR Proposed Rule (Nov 29, 2013), §.21(b)(2), II.A.2.b, II.A.5.
Level 2B Asset	Investment grade non-financial corporate bonds and municipal obligations, and publicly listed equities included in a major index and not issued by financial companies. *Weight: 50% . Source:* LCR Proposed Rule (Nov 29, 2013), §.21(b)(3), II.A.2.c, II.A.5.
Selected Outflows:	
Stable Retail Deposits	Retail deposit covered by deposit insurance. *Outflow rate: 3%. Source:* LCR Proposed Rule (Nov 29, 2013), §.32(a)(1), II.B.2.a.i.
Brokered Deposits	Brokered deposits maturing later than 30 days or covered by insurance; where less than the full amount is covered by insurance; brokered sweep deposits with less than the full amount covered by insurance; other brokered deposits maturing within 30 days. *Outflow rates: 10; 25; 40; 100%. Source:* LCR Proposed Rule (Nov 29, 2013), §.32(g), II.B.2.g.

Continued on next page

Table C.1 – *Continued from previous page*

Variable	**Description and Weight**
Unsecured Wholesale Funding	Wholesale funding not operational and not provided by financial company where the entire amount is covered by insurance; less than the full amount is covered by insurance; other unsecured wholesale funding. *Outflow rates: 20; 40; 100%. Source:* LCR Proposed Rule (Nov 29, 2013), §.32(h), II.B.2.h.
Secured Funding	Secured funding collateralized by Level 1 liquid assets; Level 2A liquid assets; Level 2B liquid assets and customer shorts covered by customer collateral that is not HQLA; non-HQLA collateral. *Outflow rates: 0; 15; 50; 100%. Source:* LCR Proposed Rule (Nov 29, 2013), §.32(j), II.B.2.j.
Selected Inflows:	
Retail Cash Inflow	Payments payable within 30 days from retail customers. *Inflow rate: 50%. Source:* LCR Proposed Rule (Nov 29, 2013), §33(c), II.B.3.c.
Unsecured Wholesale Cash Inflow	Unsecured wholesale cash inflow payable within 30 days from non-financial company: from financial company. *Inflow rates: 50; 100%. Source:* LCR Proposed Rule (Nov 29, 2013), §33(d), II.B.3.d.
Secured Lending	Secured lending collateralized by Level 1; Level 2A; Level 2B and margin loans collateralized by non-HQLA; non-HQLA collateral. *Inflow rates: 0; 15; 50; 100%. Source:* LCR Proposed Rule (Nov 29, 2013), §33(f), II.B.3.f.
Deposit and Unsecured Wholesale Funding:	
Deposits	This is deposits and reported under O.D in the FR 2052a dataset.

Continued on next page

Table C.1 – *Continued from previous page*

Variable	**Description and Weight**
Unsecured Wholesale	This is unsecured Wholesale funding and reported under O.W in the FR 2052a dataset.
Unsecured Funding	This is interchangably used for unsecured wholesale.
ABS	This is secured wholesale funding and reported under O.W.1 to O.W.7 in the FR 2052a dataset.
CP	This is commercial paper and reported under O.W.8 in the FR 2052a dataset.
Interbank	This is onshore and offshore interbank borrowing and reported under O.W.9 and O.W.10 in the FR 2052a dataset.
LT Debt	This is long term debt and reported under O.W.11 and O.W.12 in the FR 2052a dataset.
ST Notes	This is short term notes and reported under O.W.14 and O.W.15 in the FR 2052a dataset.
CD	This is wholesale certificates of deposit and reported under O.W.16 in the FR 2052a dataset.
Free credits	This is free credits and reported under O.W.18 in the FR 2052a dataset.
Other	This includes other unsecured wholesale borrowing (O.W.19) and also includes government guaranteed debt (O.W.13), credit line borrowing (O.W.17) and reported in the FR 2052a dataset.
Entity types:	
BHC	This is the consolidated entity for each of the bank holding companies of our sample.

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Table C.1 – *Continued from previous page*

Variable	Description and Weight
HC	This is the sum of all holding companies within each of the bank holding companies of our sample.
BD	This is the sum of all broker-dealers and other entities within each of the bank holding companies of our sample.
CB	This is the sum of the commercial banks (branches and other banks) for each of the bank holding companies of our sample.
External	This refers to transactions with an external counterparty.
Internal	This refers to transactions with an internal counterparty.
Secured Net Lending by collateral:	
Total	This is the net secured lending, which is the sum of all secured lending minus the sum of all secured borrowing. Secured lending is equal to margin lending (I.S.5) plus reverse repo (I.S.1) minus repo (O.S.1) plus securities borrowing (I.S.2) minus securities lending (O.S.2) minus customer shorts that are sourced from secured funding (O.S.7 and subproducts of customer long, external cash and non-cash transactions); this excludes firm longs which are not a source of funding).
Foreign Sovereign Debt	This is secured net lending (lending minus borrowing) for the collateral classes S-1, S-1-Q, S-2, S-2-Q, S-3, S-3-Q, S-4, S-4-Q as reported in the FR 2052a dataset.
Treasuries	This is secured net lending (lending minus borrowing) for the collateral classes A-1, and A-1-Q as reported in the FR 2052a dataset.

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Table C.1 – *Continued from previous page*

Variable	Description and Weight
Domestic Equities	This is secured net lending (lending minus borrowing) for the collateral classes E-1, E-1-Q, and E-3 as reported in the FR 2052a dataset.
Foreign Equities	This is secured net lending (lending minus borrowing) for the collateral classes E-2, E-2-Q, and E-4 as reported in the FR 2052a dataset.
Other	This is secured net lending (lending minus borrowing) for the collateral classes beginning with Y- and Z- as well as C-1, S-5, S-5-Q as reported in the FR 2052a dataset.
IG Corp Debt	This is secured net lending (lending minus borrowing) for the collateral classes beginning with IG as reported in the FR 2052a dataset.
HY Corp Debt	This is secured net lending (lending minus borrowing) for the collateral classes beginning with N in the FR 2052a dataset.
Loans	This is secured net lending (lending minus borrowing) for the collateral classes beginning with L in the FR 2052a dataset.
Agencies	This is secured net lending (lending minus borrowing) for the collateral classes A-2, A-2-Q, A-4, A-4-Q, A-5, A-5-Q in the FR 2052a dataset.
GSE Debt	This is secured net lending (lending minus borrowing) for the collateral classes G-1, G-1-Q, G-3, G-3-Q, and G-4 in the FR 2052a dataset.
MBS	This is secured net lending (lending minus borrowing) for the collateral classes A-3, A-3-Q, G-2, and G-2-Q in the FR 2052a dataset.
Arbitrage Spreads:	
Arb spread	This is the EUR USD CIP arbitrage spread which we compute for various tenors ranging from 1-week to 12-months. See section 3.1 for a detailed descriptions.

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Table C.1 – *Continued from previous page*

Variable	**Description and Weight**
Equity Arb Spread	This is the average of the SP500, Dow Jones, and Nasdaq 100 spot-futures arbitrage spread as described in Siriwardane et al. (2022).

D A Perfectly Efficient Internal Capital Market

In this appendix, we show that for a perfectly efficient internal capital market ($C^N(\cdot) = 0$),

$$\frac{dI}{dW} = \frac{C_{11}}{C_{11} - F_{11}}.$$

and holding firm liquidity W constant, changes in division specific liquidity does not change investment.

When there is no internal capital market friction, the wedge to raising funding from outside the division is

$$C(w_N, w_E) = C^E(w_E),$$

To minimize this cost, the division chooses the maximum w_N possible, which is constrained by the available funding of the firm ($w_N \leq W - W^D$). If this constraint is not binding, then the division only borrows from the internal capital market at the risk-adjusted required rate of return, which we normalize to 1. This division is not financially constrained and can reach the first best investment I such that

$$F_1(I) = 1.$$

For a division constrained by the internal funding of the firm, we have that $w_N = W - W^D$ and there is a need for external funding. Denote the amount of external funding raised as w_E. The division has W of funding from its direct holdings and the internal capital market. Therefore, the division's budget constraint is $I = w_E + W$.

The division's first order condition is

$$F_1(I) = 1 + C_1(I - W)$$

Thus, through implicit differentiation, we have that

$$\frac{dI}{dW} = \frac{C_{11}}{C_{11} - F_{11}}.$$

Division liquidity does not enter the first order condition for division investment, only firm liquidity. Therefore, holding firm liquidity W constant, changes in division specific liquidity does not change investment and therefore does not change the marginal return to investment.

E Dealer Business Model

Dealers generally use their balance sheet to intermediate both trades in securities and leverage. The following discussion of dealers' operations is reflected in their balance sheet, as displayed in Table E.1. Dealers carry inventories of securities for market making purposes and to store liquidity. Part of their inventories are funded in the repo market, where cash is raised against the pledge of those same securities as collateral. As such, securities funded in repo markets and other secured funding markets are encumbered (a third party has a claim on them) and thus do not qualify as HQLA. On the other hand, the securities that are funded by the dealer's own equity and unsecured debt are not encumbered and thus can count towards HQLA (as long as they satisfy additional liquidity requirements described in Appendix C). The unsecured debt used to purchase HQLA can be raised either externally (from money markets) or internally (from the affiliated commercial bank or the holding company). Regulation W limits the amount of internal transfers from the commercial bank to the dealer to 20 percent of the commercial bank's capital. No restriction applies to the amount of internal liquidity transferred from the holding company to the affiliated dealer.

Table E.1: Broker-Dealer Balance Sheet

Assets	Liabilities
High Quality Liquid Assets	Unsecured External Debt
Non-Qualifying Assets	Unsecured Internal Debt
Reverse Repo	Repo
Margin Loans	Customer Shorts
Securities Borrowing	Securities Lending
	Secured Internal Debt
	Equity

Notes: Table E.1 shows a stylized broker-dealer balance sheet.

Some of the inventories held by dealers may be part of an arbitrage trade if coupled with an associated derivative. For instance, a dealer may take advantage of an arbitrage spread by buying a bond in the cash market and taking an offsetting synthetic short position in a derivative that provides identical cash flows, thus pocketing the arbitrage spread. Similar connections between cash and derivatives occur when dealers take a synthetic short position in a stock (to accommodate a client synthetic long position) which they offset by taking a long position in the cash market, namely buying the same underlying stock. Such strategy is called delta hedging, which is often used by dealers since they aim to profit from intermediation spreads and not by taking risky directional bets.

Dealers also intermediate leverage. To provide leverage to hedge fund clients via reverse repos and margin loans, dealers pledge the collateral obtained from their clients back in the repo market. This process is called rehypothecation. The dealer raises secured funding from a money market lender and then turns around and provides that very same funding to the hedge fund client. Collateral flows in the opposite direction, from the hedge fund client to the money market lender via the dealer. Once the repo contract matures, cash and collateral flow back to their original position. The simplest such intermediation strategy is called matched-book repo, whereby the dealer enters into a repo and reverse repo of identical amount and maturity, and pledges the same collateral obtained from the reverse repo into the repo contract. The dealer profits from a differential repo spread and may also raise "net financing" by charging a higher haircut on the reverse repo than it is charged on the repo. Such net financing constitutes additional unencumbered liquidity available to the dealer.

Repos are used by dealers to raise cash against collateral. The cash lender can be a money market fund interested in lending cash on a secured basis (in which case the repo is called general collateral repo), or another asset manager interested in borrowing a specific security to short it. In the latter case, the asset manager provides cash collateral to the dealer against the borrowing of the security. This strategy is often implemented in the bilateral repo market and in the securities lending market. This type of intermediation is prevalent with the fixed income securities.

The intermediation of leverage in the equity market often takes a similar form. A client wanting to take a leveraged long position in a stock requests a margin loan from a dealer by pledging the stock as collateral. The dealer then funds the margin loan in one of two ways. It can pledge the same security as collateral in the equity repo market and securities lending market. Alternatively, the dealer can try to lend the same security to a client interested in taking a short position in the same stock. The latter strategy is quite common in equities and involves the funding of margin loans with customer shorts, also referred to as internalization.

F Regulatory Constraints

In this section we introduce the main regulations that apply to the U.S. GSIBs, with an emphasis on the Liquidity Coverage Ratio (LCR).

The LCR requires "covered companies" to hold enough high quality liquid assets (HQLA) to withstand a 30-day run. Covered companies are BHCs with $250 billion or more in total consolidated assets and their consolidated subsidiary depository institutions with more than $10 billion in assets. By the spirit of the rule, they should be able to raise enough cash by liquidating its stock of HQLA to fully accommodate the net cash outflow (Net Outflow) originating from a hypothetical 30-day run:

$$\text{LCR} \equiv \frac{\text{HQLA}}{\text{Net Outflow}} \geq 100\%.$$

Each asset a contributes to HQLA with weight ω_a, where higher-quality assets have higher weights: 100% for Level 1 assets; 85% for Level 2A assets; 50% for Level 2B; and 0% for any other assets. Level 1 assets consist of cash, central bank reserves, and debt fully guaranteed by a top-tier sovereign; Level 2A assets consist of agency mortgage-backed securities (MBS) and lower-grade sovereigns; and Level 2B assets include equities listed in major indexes and investment grade (IG) corporate bonds. Moreover, total Level 2 assets cannot make up more than 40% of HQLA and Level 2B no more than 15%. To be counted towards HQLA, assets need to be readily monetizable and unencumbered (not pledged as collateral in another transaction).

At the denominator of the LCR is Net Outflow, which equals cash outflows within 30 days minus cash inflows within 30 days plus a maturity mismatch add-on:

$$\begin{aligned} \textit{Maturity mismatch add on} = &\max\{0, \textit{Largest net cumulative maturity outflow}\} - \\ &\max\{0, \textit{Net day 30 cumulative maturity outflow}\}. \end{aligned}$$

The LCR does not allow a total offset of inflows and outflows, capping the maximum inflows to 75% of outflows. This maximum offset condition is never met in the data, however. Outflows and inflows within a 30-day window are computed by multiplying each instrument type i by a runoff (outflow or inflow) rate ρ_i. For instance, on the outflow side, stable and other retail deposits have outflow rates of 3 and 10%, respectively, while unsecured wholesale funding from financial customers maturing within 30 days has an outflow rate of 100%. Secured borrowing transactions that mature within 30 days have outflow rates broken down by collateral type that are equal to 100 minus the HQLA weight for the same asset class: 0% for Level 1 collateral; 15% for Level 2A; 50% for Level 2B; and 0% for all other collateral types. On the inflow side, payments due within 30 days from from retail and small business customers are assumed to have an inflow rate of 50% , while secured lending transactions maturing within 30 days have inflow rates by collateral that are identical to the respective outflow rates for the same collateral type.

In January 2016, the US implemented the Intermediate Holding Company (IHC) rule which required Foreign Banking Organizations (FBOs) operating in the US with more than $50 billion in global assets and with more than $50 billion in US non-branch assets to consolidate their non-branch activities into holding companies and be supervised by the Federal Reserve. One year later in January 2017, US banks subject to the LCR, including the IHCs of FBOs had to fully comply with the US implementation of the LCR, ending a gradual phase-in process that started in January 2015.

While a balance-sheet intensive activity such as raising retail deposits to invest in Level 1 assets greatly improves the LCR, any such activity is costly in terms of the leverage ratio. Differently from the LCR, the leverage ratio requires a BHC to maintain no less than 3% of total leverage exposure as Tier 1 capital, increased to 5% for the U.S. GSIBs, which happen to be the banks in our sample. The total leverage exposure is the sum of on-balance sheet asset exposures, including secured lending, derivative exposures, and off-balance sheet commitments. As such, the leverage ratio penalizes any activity that requires an expansion of the balance sheet, regardless of its risk. Thus, low-risk intermediation that takes up balance sheet space is especially penalized.

Finally, BHCs are also subject to three separate Basel III minimum capital ratios defined as the ratio of a certain measure of equity over risk-weighted assets (RWA).[10] In the case of capital ratios, balance sheet costs are proportional to the riskiness of the asset. As a result, intermediating zero risk-weight assets, such as Treasuries, involves no balance sheet cost (in terms of risk-based capital ratios).

Regulation W is a U.S. Federal Reserve System regulation that limits certain transactions between depository institutions, such as banks and their affiliates. It sets quantitative limits on covered transactions and requires collateral for certain transactions.1 The regulation applies to banks that are members of the Fed, insured state non-member banks, and insured savings associations. It was introduced to consolidate several decades of interpretations and rulemaking under Sections 23A and 23B of the Federal Reserve Act.1 No transaction with a single affiliate can exceed 10% of an institution's capital, and all affiliate transactions cannot exceed 20% of the institution's held capital.

[10]The minimum common equity tier 1 over RWA is 3.5%, tier 1 capital over RWA is 4.5% and total capital over RWA is 8%.