

A Map of Collateral Uses and Flows

Andrea Aguiar

Morgan Stanley

andrea.aguiar@morganstanley.com

Dror Y. Kenett

Office of Financial Research

dror.kennett@ofr.treasury.gov

Richard Bookstaber

Regents of the University of California

rbookstaber@gmail.com

Thomas Wipf

Morgan Stanley

thomas.wipf@morganstanley.com

The Office of Financial Research (OFR) Working Paper Series allows members of the OFR staff and their coauthors to disseminate preliminary research findings in a format intended to generate discussion and critical comments. Papers in the OFR Working Paper Series are works in progress and subject to revision.

Views and opinions expressed are those of the authors and do not necessarily represent official positions or policy of the OFR or Treasury. Comments and suggestions for improvements are welcome and should be directed to the authors. OFR working papers may be quoted without additional permission.

A Map of Collateral Uses and Flows¹

Andrea Aguiar

Morgan Stanley

Richard Bookstaber

Office of the Chief Investment Officer, Regents of the University of California

Dror Y. Kenett

Office of Financial Research

Thomas Wipf

Morgan Stanley

May 26, 2016

Abstract

All flows of secured funding in the financial system are met by flows of collateral in the opposite direction. A network depicting secured funding flows thus implicitly reveals a network of collateral flows. Collateral can also be presented as its own network to show collateral arrangements with bilateral counterparties, triparty banks, and central counterparties; the purpose and incentives of collateral exchanges; and participants involved. We create a collateral map to show how this function of the financial system works, especially with secured funding and derivatives activity. This paper provides insights into the increased demand for collateral, the reduced capacity for banks to act as collateral intermediaries, and examples of risks and vulnerabilities in collateral flows.

Keywords:

Collateral, funding liquidity, central clearing, repo, derivatives, funding map, financial stability.

¹ Views and opinions are those of the authors and do not necessarily represent official positions or policy of the Office of Financial Research (OFR) or the U.S. Department of the Treasury. OFR working papers may be quoted without additional permission. This paper was produced while Richard Bookstaber was employed by the OFR and Thomas Wipf was a member of the OFR's Financial Research Advisory Committee. The paper benefited from helpful comments by Alexander Baier, Viktoria Baklanova, Nils Njorksten, Jill Cetina, Michelle Farrell, Greg Feldberg, Mark Flood, Rebecca McCaughrin, Stathis Tompaidis, and Julie Vorman.

1. Introduction

In this paper, we present a map of collateral flows in the financial system. The map is descriptive and is intended to provide a schematic for more detailed modeling of the collateral network. It also maintains a direct relationship with the funding network we mapped in a companion paper (Aguar et al., 2014).

Economic systems are built on interdependencies in which funding flows, and related credit and counterparty relationships that are largely supported by collateral flows, occur in a complex network of many diverse financial system participants. Stresses to one part of the system can spread to others. In an extreme case, stresses can threaten financial stability, thus spurring the need for a fundamental understanding of the structure and dynamics of funding and related collateral flows.

Recently, the topic of collateral in the financial system has been a focal point in three strands of theoretical literature. One is the literature on collateral and default that has primarily focused on the role of margin and haircuts (Geanakoplos, 2003; Brunnermeier and Pedersen, 2009; Gorton and Metrick, 2009; Krishnamurthy, Nagel, Orlov, 2010; Shleifer and Vishny, 2011). A second strand of research has focused on the concept of collateral rehypothecation, or reuse, and clarified that collateral has a velocity. Analytical work here includes Adrian and Shin (2010), and Singh (2010), who examined the extent of rehypothecation using market data from hedge funds and prime brokers. The third and newest strand of research focuses on liquidity mismatches and the role of collateral in intermediation chains. Brunnermeier, Gorton, and Krishnamurthy (2011) introduced a liquidity mismatch index, where weights can be assigned to capture the lengths of intermediation chains, thus focusing on the velocity of collateral.

Just as our funding map showed the path of funding from key sources, we have developed a collateral map to show the path of collateral to its end points, differentiating among the paths for bilateral repos, triparty repos, and cleared transactions through central counterparties (CCPs). For the flow of funding and collateral, the key intermediaries are large, bank-affiliated broker-dealers, which we call “Bank/Dealers” in this paper.²

Each path facilitates different transformations of collateral. These transformations include credit transformations, where less-creditworthy market participants such as hedge funds access funding sources through intermediaries with a higher credit standing; and liquidity transformations, where less-liquid assets such as mortgages are structured into debt instruments with liquid tranches. Funding flows also include risk transformations, where the return distribution of assets is changed, for example, by using derivatives. The nature of these transformations and the form in which collateral is held ultimately have implications for the routes of vulnerability during a financial crisis.

Collateral fuels secured funding, just as secured funding fuels the ability of market-makers to buy and sell assets. Buying and selling assets, in turn, creates market risk that may be hedged by derivative transactions. Derivatives positions once again bring collateral into play — collateral exchanges provide

² Our paper focuses on bank-affiliated broker-dealers because they are believed to account for a bigger share of the secured funding and derivatives market than non-affiliated ones. They also may be affected by regulations imposed on large bank holding companies.

a level of security to parties in derivative transactions, reduce exposures, alleviate counterparty credit concerns, and protect clearing members from counterparty defaults.

Understanding the linkages between the collateral, derivatives, and funding components of the financial network is critical for analyzing the financial system as a dynamic process rather than as a snapshot. To understand the financial network, we first must map the interactions and transformations across the agents. Our collateral map shows the complex movements and transformation of collateral that a large bank may not fully understand as its various business units conduct daily transactions that move collateral in and out of the bank. The financial industry typically focuses on cash and balance-sheet items that do not capture the movement of collateral. Although some regulatory financial disclosure requirements cover collateral movements, they do not disaggregate the activity into business drivers or counterparties. Enhanced transparency can help regulators understand and examine the types of collateral flows across market participants.

2. Overview of Collateral

2.1. Collateral Quality

Collateral quality is an important consideration. Collateral is intended to limit a lender's exposure to a borrower's credit risk. The amount of collateral received by the lender includes a margin or haircut based on the quality of the collateral to protect the lender if the borrower defaults. This means the market value of the collateral will exceed the amount of the loan. The haircut represents the potential loss in value of the collateral. As the quality of collateral declines, the haircut increases.

If there is market or product-specific stress, secured lenders may believe the collateral they hold is insufficient to make them whole because of rapidly deteriorating prices of the collateral. This may trigger lenders to request a higher haircut, or cause them to halt lending altogether. Margins can also vary depending on the borrower's creditworthiness, which makes it more likely for a lender to focus on the collateral securing the loan.

Credit and liquidity stress events usually lead to a flight to quality, as investors seek to hold high quality collateral. Investors who have extended debt against lower quality collateral or collateral that has recently deteriorated in value may no longer desire to lend against this type of asset.

2.2. How Market Participants Use Collateral

Collateral changes hands for different purposes, including reasons listed below. Ultimately, market participants with these motivations pair up and enter into transactions moving collateral from one party to the other.

Secured funding. A market participant seeks funding by pledging its inventory of securities to a secured funding investor, borrowing cash or highly liquid securities in return. The borrower pays an interest rate based on the quality of the collateral and tenor of the transaction. The borrower must also provide collateral as margin in excess of borrowing — otherwise referred to as a haircut — to protect the investor from collateral price fluctuations should the borrower default.³ If the borrower defaults, the investor can liquidate the collateral in the market. For example, a hedge fund may pledge \$110 worth of securities to a Bank/Dealer in exchange for \$100 in cash, which implies a 10 percent margin or haircut.⁴ Secured funding can be executed via repo or securities lending transactions, depending on the preference of the secured funding investor. Generally, Bank/Dealers will both provide financing to clients (e.g., Bank/Dealer provides cash and client provides collateral) and seek financing from investors (e.g., Bank/Dealer provides collateral and investor provides cash).

Investment. A market participant enters into a secured funding transaction as an investor because it wants to earn a yield for investing its cash or for providing high-quality securities in exchange for less liquid securities. In this case, the investor earns an interest rate and receives securities as collateral, including margin (haircut) from the borrower. Bank/Dealers will play the role of investor and borrower to different counterparties.

Short selling. A market participant borrows specific securities to establish a short position in the market. The borrower typically uses cash or highly-liquid collateral and pays a fee to the lender. In this instance, the borrower pays a margin (haircut) to the lender of securities. For example, a borrower receives \$100 worth of securities in exchange for \$105 in cash paid to the lender, implying a 5 percent margin. Typically, broker-dealers facilitate short selling for hedge fund clients by sourcing and providing securities. As market-makers, Bank/Dealers may also do their own short selling.

Lending by securities owners. A portfolio manager lends its portfolio of securities to earn incremental revenue or meet funding needs. Securities lenders invest in securities themselves, or manage a portfolio of securities for other beneficial owners. Securities owners can lend directly to borrowers or through an agent. The principal owner of the securities lends its securities against cash or noncash collateral, earning a fee or rebate and receiving margin from the borrower. Most equities are loaned under securities lending agreements. Fixed income products may be loaned in such

³ Ideally, collateral should be free of credit and liquidity risks. The market value of such collateral would be certain and it would be easy to sell in the event of a default. The type of asset that comes closest to this paradigm, and is, in fact, the most commonly-used type of collateral in the repo market, is a bond issued by a creditworthy government. Assets that pose material credit and/or liquidity risks can be used as collateral, but not for their full market value. Instead, a risk-adjusted value is calculated, which is less than the market value, by deducting a haircut from the market value of collateral or by multiplying the purchase price by an initial margin. The haircut represents the potential loss of value due to: (1) price volatility between regular margining dates (in case there is a default between the calculation of a margin call and the payment or transfer of margin in response to that margin call); and (2) the probable cost of liquidating collateral following an event of default. There are three broad issues: time delays, price volatility, and the potential price impact of a default by the issuer of the collateral asset. Time delays include: how long it takes to respond to a margin call (operational risk); the likelihood of a delay in liquidation due to a legal challenge to the non-defaulting party's title to the collateral asset or his right to net (legal risk); and how quickly the entire holding of a collateral asset could be liquidated without a significant market impact or how far might the price fall or be forced down by faster selling (liquidity risk). Many parties factor in the credit risk of their repo and derivative counterparties, taking into account of any significant correlation between the credit risks of the counterparty and the issuer of the collateral (so-called 'wrong-way risk').

⁴ For a detailed discussion of the definitions of these terms, see Adam Copeland, Antoine Martin, and Michael Walker, "Repo Runs: Evidence from the Tri-Party Repo Market," Federal Reserve Bank of New York Staff Report no. 506, July 2011, available at www.newyorkfed.org/research/staff_reports/sr506.pdf.

agreements or through repo agreements. Bank/Dealers often borrow securities from agent lenders, who represent beneficial securities owners, to cover short positions.

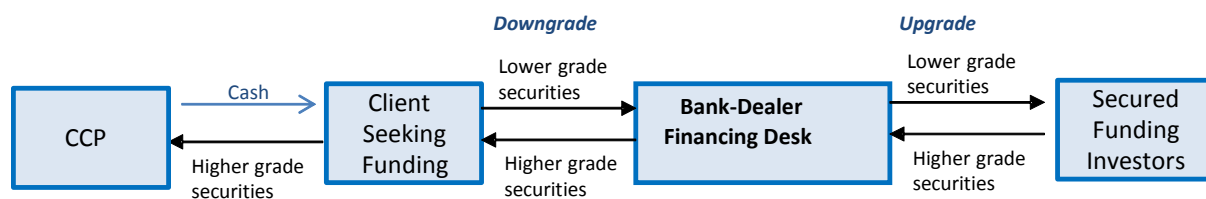
Sourcing securities for collateral or margin requirements. A market participant needs to source collateral for various reasons. For instance, a securities lender may prefer to receive highly liquid sovereign bonds instead of cash collateral. This would be an example of liquidity transformation. The securities borrower must first convert its own cash into sovereign bonds through a reverse repo transaction. Only then can it enter into the securities borrowing transaction and collateralize the borrowing with sovereign bonds. Another example is a market entity that clears its products, whether securities financing transactions or derivatives, which will need to source eligible collateral to post to the central counterparty (CCP) to fulfill variation margin, initial margin and guarantee fund requirements. Generally, eligible collateral at CCPs consists of cash or highly liquid securities.

Securities-for-securities transactions. Collateral can also be exchanged in two directions in a securities-for-securities financing transaction. Securities-for-securities transactions arise from different but paired incentives to lend or borrow securities. For instance, two parties agree to exchange different sets of equities through a securities lending transaction to facilitate each other’s short selling.

Another example of a collateral exchange could be the need for a party to source liquid securities, coupled with a simultaneous need to fund its lower-quality securities. For instance, a Bank/Dealer may need to source U.S. Treasuries to fulfill its margin obligations to a CCP, and it may also need to finance its corporate debt long inventory. By entering into a securities-for-securities funding transaction — known as an upgrade transaction — a Bank/Dealer can agree to deliver its corporate bonds to an investor in exchange for U.S. Treasuries, instead of entering into a cash repo transaction to fund the corporate bonds and a separate cash reverse repo to source U.S. Treasuries.

Figure 1 shows how a Bank/Dealer’s client can upgrade its lower-grade securities for higher-grade securities. The Bank/Dealer facilitates this by entering into a downgrade transaction with the client. The Bank/Dealer has an option to finance the lower grade securities received from the client through a cash-secured funding transaction, or by entering into an upgrade transaction of its own with secured funding investors. In the end, the client has achieved its goal, which in this example was to upgrade its securities to raise cash with high quality liquid assets.

Figure 1. Collateral Upgrades and Downgrades



Source: Authors

Collateral rehypothecation. Often a Bank/Dealer can reuse the collateral it receives in securities

financing transactions such as repo, securities lending, and margin loans. A Bank/Dealer may repledge the collateral in transactions with other counterparties to raise secured financing that in turn supports the financing provided to clients. In the derivatives market, rehypothecation is a method of repledging or reusing client assets that were posted as collateral by clients. Clients who allow rehypothecation of their collateral may be compensated through a rebate on fees or lower cost of borrowing. Rehypothecation is sometimes called “reuse,” which refers to any use of securities delivered in one transaction to collateralize another transaction.⁵

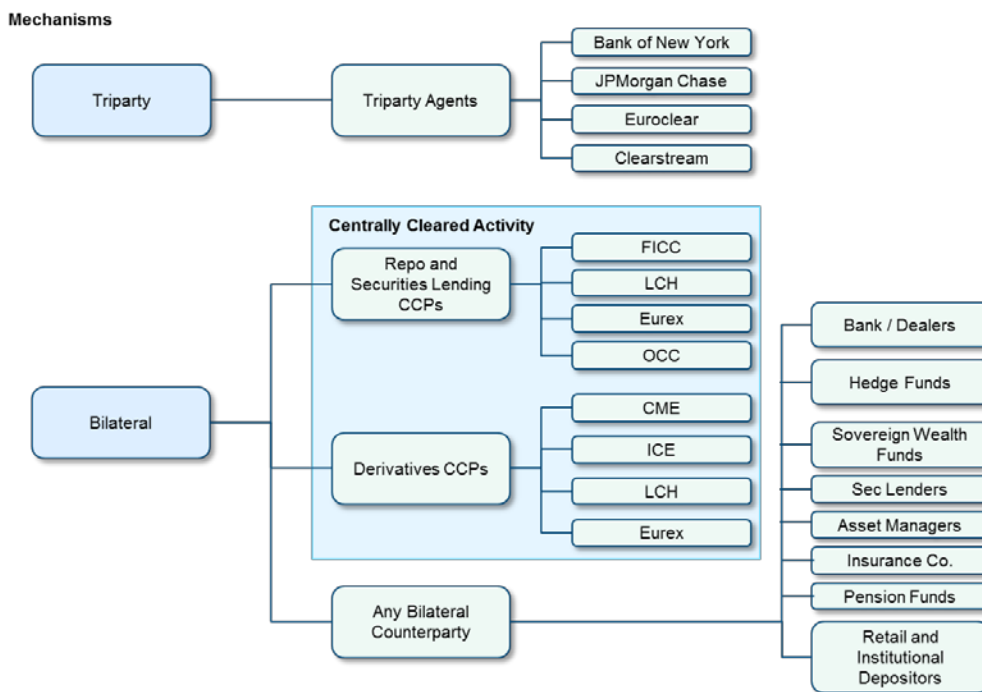
2.3. Collateral Channels – Bilateral, Triparty, and Central Clearing

The main channels of collateral flows are bilateral, triparty, and central clearing via central clearinghouses (CCPs). **Figure 2** lists the primary attributes of each channel for securities movements, and then shows the types of channels and the main actors involved in each (for an extended discussion of these, see Baklanova et al., 2015).

Figure 2. Collateral Channels and Mechanisms

Channels	Transactions	Advantages	Primary Examples
Triparty	Securities financing	Payment and settlement, collateral custody and collateral management services provided by triparty agent.	Bank of New York Mellon Euroclear JPMorgan Chase Clearstream
Bilateral	Securities financing Derivatives	Control over collateral. Ability to reuse collateral within limitations imposed by collateral provider.	Any counterparty
Central Clearing via CCPs	Securities financing Derivatives	Reduced counterparty credit exposure. Increased opportunity to compress or net transactions (relief for balance sheet and capital). Reduced risk of fire sales.	Depository Trust & Clearing Corporation (DTCC) / Fixed Income Clearing Corporation (FICC) Options Clearing Corporation (OCC) London Clearing House (LCH) Eurex Intercontinental Exchange (ICE) Chicago Mercantile Exchange (CME)

⁵ The Financial Stability Board (FSB) has been examining collateral re-use practices and their potential impact on financial stability. The FSB asked its Data Experts Group to develop recommendations on potential measures of collateral velocity and data elements by the end of 2016. See “Transforming Shadow Banking into Resilient Market-based Finance – Possible Measures of Non-Cash Collateral Re-Use,” Feb. 23, 2016, available at www.fsb.org/wp-content/uploads/Report-on-possible-measures-of-non-cash-collateral-reuse.pdf.



Source: Authors

Bilateral collateral. Bilateral collateral flows move collateral directly from one party’s custodial securities account to the counterparty’s custodial securities account. Bilateral activity does not rely on a third-party clearing and settlement platform. There are many motivations for entering into a bilateral transaction, rather than a triparty or centrally cleared transaction. A counterparty may not be in a position to settle trades on a triparty platform, given the costs or infrastructure required. Or, a counterparty may want to reuse the securities, which is restricted to certain types of participants in a triparty transaction. Another reason may be that the product is not supported in the region by a triparty agent or a CCP. Similarly, derivatives transactions may be bilateral because the product is not supported by a CCP, the client is not required to clear through a CCP, or the haircut, initial margin, and guarantee fund requirements make clearing unattractive for certain counterparties.

Triparty collateral services. Triparty activity introduces a third party to the transaction. A triparty agent facilitates collateral custody, selection, payment, and settlements throughout the life of the trade. The triparty agent does not become a principal to the transaction and merely provides collateral services.⁶ However, the triparty agent benefits the two parties in a trade by actively managing and monitoring all collateral margin requirements.

Central clearing. Although mechanically the movement of collateral between a market participant and the CCP is bilateral, the flow is differentiated in this paper from a simple bilateral flow, given the change in the principal to the transaction. Instead of two market participants directly facing each other, they now both face a CCP.

⁶ See Viktoria Baklanova, Adam Copeland, and Rebecca McCaughrin, “Reference Guide to U.S. Repo and Securities Lending Markets,” OFR Working Paper no. 15-17, 2015.

CCPs, also known as central clearinghouses, perform several functions. After a trade is agreed upon by two parties and registered with a CCP, the CCP inserts itself into the transaction and becomes the credit counterparty. Unlike in a triparty transaction, the CCP does not become a principal to the transaction. What was one contract becomes two as the CCP becomes the buyer to the seller and the seller to the buyer. CCPs are generally considered high quality counterparties because they strictly collateralize their exposures and are usually backed by reserves, a default fund, and other safeguards. CCPs, therefore, can provide an attractive low-risk counterparty model.

Another function performed by a CCP is to net transactions between members on a multilateral basis. This means delivery of a security due from parties A and B is netted off against deliveries of the same security due on the same day to parties C and D. Netting of transactions is allowed within a single counterparty relationship, not across counterparties. A financial market participant that clears more of its transactions with a CCP, rather than transacting bilaterally with multiple counterparties, has a greater opportunity to reduce its net balance sheet consumption. CCPs may also provide regulatory benefits for large banks subject to capital standards. A Bank/Dealer can improve its balance sheet by using a CCP for netting of securities financing transactions and compression of capital-intensive derivatives transactions. Compression reduces notional values by collapsing offsetting transactions into a smaller number of trades, without changing trade economics. Another CCP benefit for a Bank/Dealer is reducing its risk-weighted assets, specifically credit risk, because bank regulators assign qualified CCPs a lower credit risk weighting compared to other types of counterparties. Additionally, qualified CCPs are currently excluded from exposure limits, resulting in more capacity to trade.

As CCPs assume the credit risk between two counterparties to a cleared transaction, a CCP minimizes its own credit risk by collecting initial margin and guarantee funds from each member. Each CCP has its own method for calculating both components. Initial margin is meant to be the first line of defense to cover losses from a member's default. Typically, after the initial margin is depleted, a CCP may use the failed member's default or guarantee fund contribution. Following that, the CCP may resort to its own equity to absorb losses or turn to the default funds of non-defaulting clearing members. CCPs require that members satisfy their initial margin and guarantee fund requirements with either cash or highly liquid sovereign bonds. Thus, a global move to central clearing has increased market demand for highly liquid collateral.

CCPs serve another function by enhancing market liquidity through convening buyers and sellers in one place. More liquidity increases efficiency in market trading, which, coupled with lower counterparty credit concerns, can lead to more market activity.

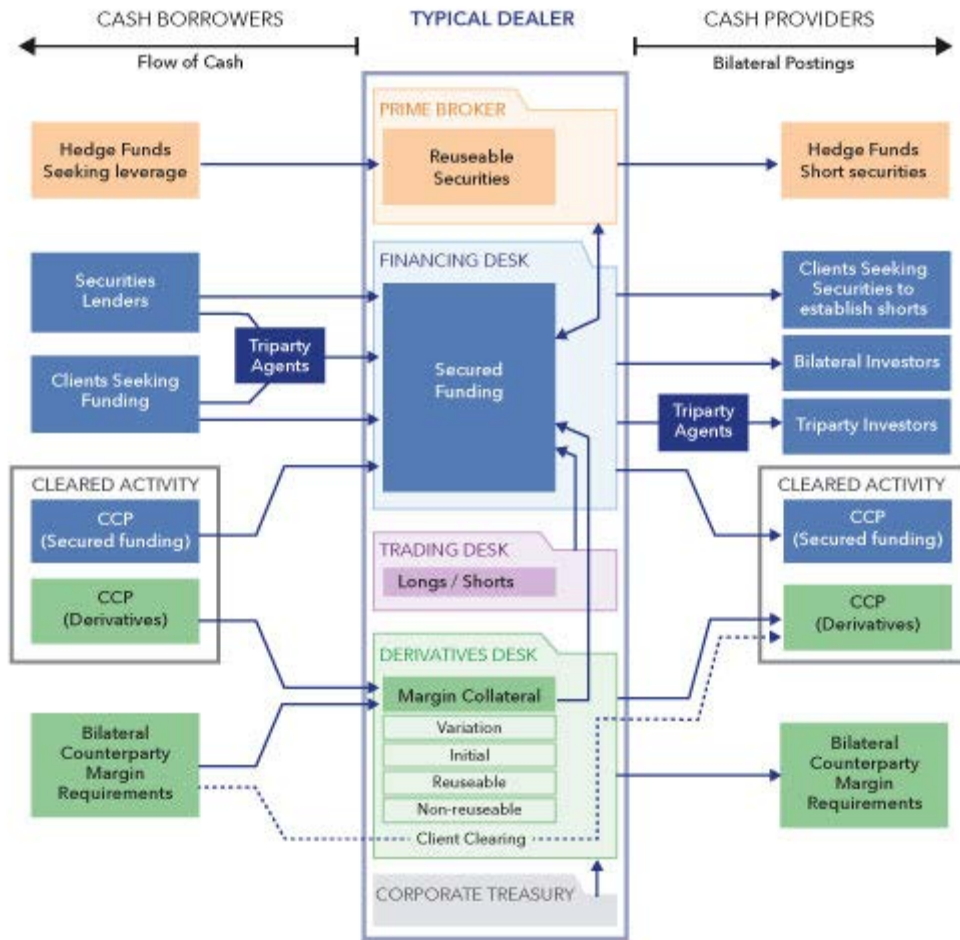
3. The Collateral Map

3.1. Collateral Map Introduction

The dynamics and vulnerabilities of the financial system rest on the flow of funding on the one hand, and the flow of securities on the other. These flows are typically represented as a network with

financial entities such as Bank /Dealers as the nodes, and funding linkages as the edges. Our collateral map in **Figure 3** depicts the pathway of collateral across various agents.

Figure 3. The Collateral Map: Critical Agents and Flows



Source: Authors

The collateral map shows how collateral flows of different types, quality, and durability run through the pipes of the financial system. The map contains more detail than other network analyses in at least two respects.

First, the map details the internal workings of a Bank/Dealer and its central role in intermediating the flow of collateral. It shows how collateral comes into the Bank/Dealer through a number of channels, and is dispatched through the bilateral or triparty mechanisms, or through a CCP. The Bank/Dealer’s Prime Broker (orange) is the conduit of collateral from the hedge funds. The Financing Desk (blue) is the conduit for securities lending and repo. The Derivatives Desk (green) handles futures, forwards,

swaps, options, and related activities. The Bank/Dealer's Financing Desk is the engine for key collateral transformations. It is here that collateral is reused and collateral upgrades are managed. Underpinning this activity is the Bank/Dealer's collateral management function that dictates the level and quality of collateral that can be used for securities financing transactions and derivatives obligations.

Second, a key aspect of the collateral map is that it represents the pipelines for collateral flows. Collateral can be passed directly to the funding agent as a bilateral flow, can be held by a triparty agent, where all counterparties have their collateral pooled but where that pooling remains distinct for each borrower; or can be passed to a CCP, where the collateral could pass through to other CCP members. In the case of secured funding, the pathways that collateral takes are two-way streets: when there is funding in one direction, there is a flow of collateral in the other direction. For any secured funding flow, there is collateral moving in the opposite direction. As secured funding moves from cash providers to end users through the Bank/Dealer, the collateral map shows collateral moving from end users back to cash providers.

Unlike secured funding transactions, collateral movements related to derivative transactions are one-way flows governed by the derivative agreement between two parties. In the case of cleared derivatives transactions, collateral is also governed by any CCP margin requirements. The collateral for derivatives transactions can be in the form of variation margin, initial margin, or guarantee fund. Variation margin collateral offsets the mark-to-market exposure between two parties that would otherwise be uncollateralized and lead to credit risk for one of the parties. Initial margin is additional collateral beyond the exposure amount, which accounts for the credit risk associated with one of the parties, and is usually collateral provided by the lower-rated party to the other.⁷ Guarantee fund collateral is only associated with cleared transactions in which a CCP demands that all members provide contributions to a guarantee or default fund, a pool of liquidity that can be used to absorb losses after a defaulting member's initial margin is depleted.

3.2. Comparison to the Funding Map

The flow of collateral is distinguished from the flow of funding by its types, uses, and points of termination. Funding, on the other hand, is largely standardized and fungible. As noted in Aguiar et al. (2014), the defining characteristic of funding is its term or durability. By contrast, the defining characteristic of collateral is its quality, which can vary widely. And while the path of funding moves from a starting point to an end point, collateral often is pooled outside the funding path, either with a triparty agent or a CCP.

As in the case of the funding map, the collateral map identifies collateral sources, potential stress points, and risk amplifiers within the system, through the Bank/Dealer and the CCP, and through their interactions with funding sources and customers. In general, any negative change in a borrower's credit standing or decline in its credit rating brings into question the borrower's ability to repay debt. This change primarily affects the borrower's ability to access unsecured funding markets. However, changes in a borrower's creditworthiness may also affect its ability to raise *secured* funding. Changes in

⁷ New regulations for uncleared derivatives beginning in September 2016 will mandate that both parties to an uncleared transaction, rather than only one, exchange initial margin.

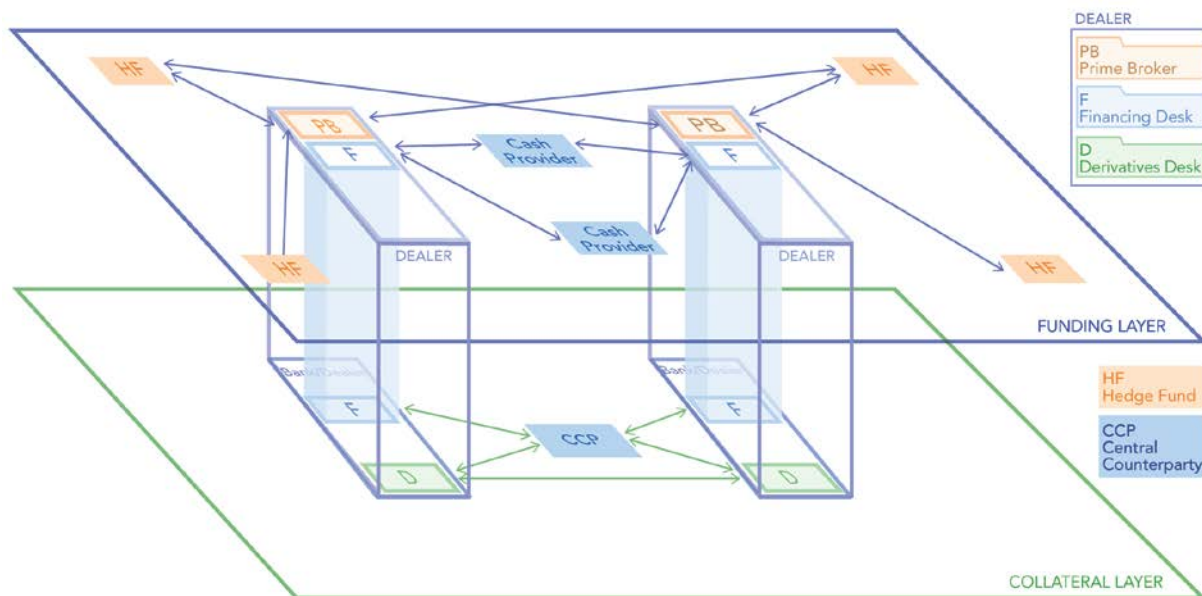
a firm's credit rating may also trigger an obligation to post additional collateral to derivative counterparties or allow these counterparties to terminate their trades.

3.3. Combining the Collateral and Funding Maps: A Two-layer Network

We gain insights by laying the collateral map on top of the funding map, much like acetone leaves in an anatomy book show connections and relationships. The maps represent two layers of a multilayer financial network. When combined with an asset map, the three layers show the complex interactions, flows, and transmissions across the markets. **Figure 4** is a schematic overlay of the collateral and funding maps, with an emphasis on the Bank/Dealer acting as a bridge between the two.

Recent research in network science has moved from a single network to a multilayer network, or network of networks (Boccalatti et al., 2014; Kenett et al., 2014). However, there are few applications of these frameworks in economics or finance. Multilayer networks incorporate multiple channels of connectivity and are a natural environment to describe systems linked through different categories of connections. Each channel is represented by a layer and the same node or entity may have different kinds of interactions. In this context, the collateral and funding maps are first expanded to a network consisting of several entities such as a Bank/Dealer, hedge fund, or CCP making the jump from a collateral/funding map to a collateral/funding network. Some financial products – such as derivatives – play a role mostly in the collateral network. Also, some entities, notably the Prime Broker and the Derivatives Desk, are active in both funding and collateral networks, consequently acting as links or bridges between the networks.

Figure 4. The Collateral Map and Funding Map Form a Multilayer Financial Network



Source: Authors

Figure 4 shows a funding layer and collateral layer, each a network with core nodes and periphery nodes. The periphery nodes tie into the core nodes, but do not tie into other periphery nodes. The

nodes of each layer act as suppliers, users, or intermediaries. For example, in the funding layer, hedge funds are periphery users of funding, cash providers are periphery suppliers of funding, and Bank/Dealers are core nodes that act as intermediaries.

For the collateral layer in this example, the core is made up of CCPs. There can be flows in two directions on different levels. Or, one node might supply to one node and use from another. For funding, the supplier is the cash provider, while the user is the hedge fund. For collateral, the supplier is the one getting funding, and the user is the one who gets the collateral to secure its funding. These can be hard to differentiate, but the distinction is important during periods of crisis. The connections between the different agents can also span across the layers. The most notable is a Bank/Dealer, which acts as a core intermediary and spans both layers to play a critical role in the functioning of the financial system.

By viewing the funding and collateral maps as two layers in the financial multilayer system, we can uncover hidden vulnerabilities that result from interconnections and interdependence between the two. Furthermore, we can better understand how shocks are transmitted and amplified between the two layers. Thus, combining the uncovered topology of the collateral map with that of the funding map, helps pave the way to a new framework describing the structure of the financial system. This shows that while there is an overlap with the two layers, differences do exist. Further work, beyond the scope of this paper, is needed to investigate the dependencies between these two central activities in the financial system, and how they lead to new forms of risks and vulnerabilities.

4. A New Era of Collateral: Changes in Demand and Capacity Constraints

Significant changes have been made in U.S. banking regulations to help prevent future crises. The regulatory changes are affecting the structure of the financial system, and in particular, the structure of the collateral network and its flows.

The main bank regulatory changes affecting collateral markets are:

Liquidity Coverage Ratio (LCR). The liquidity coverage ratio (LCR) refers to the percentage of high quality liquid assets (HQLA) such as cash or Treasury bonds that must be held by large banks to meet short-term obligations in the event of a liquidity disruption. Banks are required to hold an amount of HQLA equal to or greater than their net cash outflows over a 30-day period (having at least 100 percent coverage). The LCR discourages banks from issuing short-term debt because they must hold a durable level of cash and highly-liquid assets against short-term obligations (i.e., funding should last for longer than 30 days).

Mandatory clearing. Mandatory clearing through CCPs is required by the Dodd-Frank Wall Street Reform and Consumer Protection Act to standardize certain swaps and promote price transparency. It also allows market participants to mitigate their counterparty credit risk to dealers through netting, although the netting available through CCPs may have the undesirable effect of reducing counterparty transparency. Before the law was passed, most swaps were traded on a bilateral basis. Under the new

mandatory clearing regime, the ultimate counterparty in cleared swaps is a CCP, not the entity with whom the participant traded.

OTC uncleared margin requirements. The Basel Committee on Banking Supervision and the International Organization of Securities Commissions have developed new global standards for margin requirements on uncleared derivatives, beginning September 1, 2016.⁸ The new requirements are intended to reduce contagion and spillover effects by ensuring collateral is available to offset losses from default of a counterparty. Margin requirements on uncleared derivatives, which generally have higher risks, will promote central clearing for clearing-eligible products.

Enhanced Supplementary Leverage Ratio (eSLR). The Basel III capital framework introduced a minimum 3 percent Tier 1 supplementary leverage ratio for the biggest banks, that takes into account both on-balance sheet assets and off-balance sheet exposures. U.S. regulators implemented an enhanced standard for large internationally active bank holding companies and their affiliated depository charters. The framework requires a 5 percent minimum leverage ratio for bank holding companies with assets greater than \$250 billion or international exposures in excess of \$10 billion. The standard also imposes a 6 percent minimum leverage ratio for insured depository institutions.

4.1. Effects of New Regulations

These new regulations affecting collateral use in the financial system are illustrated in **Figure 5**. One major effect of these regulations is an increase in demand for HQLA, and further decline in demand for illiquid collateral. CCPs demand either cash or highly liquid sovereign bonds as collateral to fulfill margin requirements, which has introduced additional demand for liquid collateral in the financial system. This additional demand directly affects Bank/Dealers and their leverage ratio capacity constraint. Bank/Dealers have to source liquid collateral to satisfy their own collateral requirements, but they are also market-makers in these asset classes and would likely be one of the primary sources of liquid collateral for clients.

Regulatory changes have discouraged a Bank/Dealer to finance assets for its clients and to act as an intermediary in collateral markets. In addition, the regulatory regime has reduced the size of the Bank/Dealers' balance sheets and their appetite to increase balance sheets in the future. Reduced Bank/Dealer balance sheets translate into reduced intermediary capacity, potentially attracting other, less-regulated market participants.

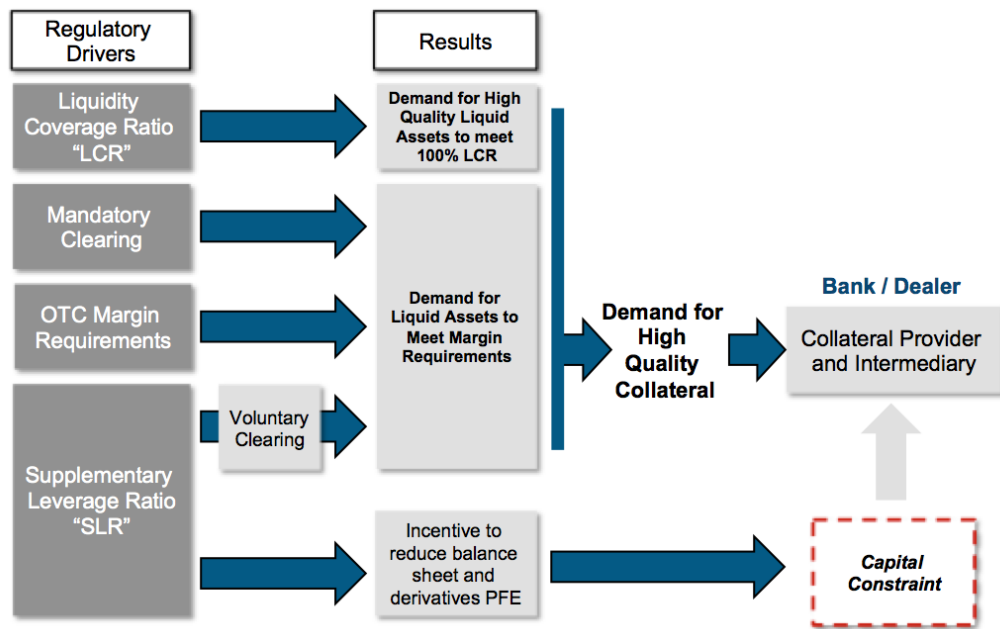
The leverage ratio regulations increased banks' incentive to "backload" derivatives, or migrate bilateral derivative transactions to central clearing. The regulations also encouraged banks to use derivatives compression, or netting of offsetting derivatives trades with a CCP or with a bilateral counterparty. Compression results in a lower notional value of derivatives, which in turn reduces the potential future exposure (derived from the notional) that forms part of the leverage ratio denominator.

The supplementary leverage ratio rule constrains the size of a Bank/Dealer's intermediary function.

⁸ See Basel Committee on Banking Supervision and International Organization of Securities Commissions report, "Margin Requirements for Non-Centrally Cleared Derivatives," March 18, 2015.

This affects not only the Bank/Dealer and its clients, but also overall market liquidity in certain products, particularly low-returning assets such as sovereign debt. The leverage ratio requirement makes it difficult to justify using the bank's balance sheet for low-margin activity, such as client financing of U.S. Treasury instruments, which yield small returns on equity. As a result, some banks have downsized their fixed income trading activity. Reduction in repo volumes could lead to a lower level of liquidity for the highest quality assets. Moreover, the reduction in Bank/Dealers' ability to support this financing activity may lead to a shift in market activity toward nonbank broker-dealers, and consequently away from bank regulation. Declining activity by certain market participants — coupled with pressure to meet external leverage ratio and internal return on equity targets — could lead to significant widening in the bid/offer spreads for liquid assets, if these costs were passed on to clients, with an estimated seven-fold increase in the bid/offer spread for U.S. Treasuries, if the business were measured on a stand-alone basis.⁹

Figure 5. New Bank Regulations are Increasing Demand for High Quality Collateral



PFE = potential future exposure

Source: Authors

The new regulatory requirements have resulted in a more important role for CCPs. The credit risk reduction and the netting benefits that CCPs are able to offer lead to significant potential for increased capacity and market liquidity. This benefit, coupled with mandatory clearing, has given CCPs a more important role in the collateral map, since they have become the center point for collateral flows that were previously bilateral or non-existent (i.e., uncollateralized).

⁹ According to internal Morgan Stanley estimates assuming a 5 percent return on equity requirement and 2.5x netting.

Although initial margin, haircuts, and default fund contributions may superficially make CCPs look unattractive, the ability to face one creditworthy counterparty rather than multiple market participants provides members with several options for trading efficiency. Furthermore, in the derivative space, there are new margin rules that will apply to uncleared derivative transactions,¹⁰ requiring bilateral exchange of initial margin and variation margin. These uncleared margin requirements are expected to be more punitive than CCP requirements. The incentive to use central clearing is likely to increase over time for clearing-eligible products as the new uncleared margin rules come into play.

However, there are also some potential drawbacks to the use of CCPs. As a higher proportion of trading is cleared through CCPs, more credit, liquidity, and operational risk will be concentrated in CCPs and they could become potential sources of systemic risk to the financial system. The concentration of risk within the CCPs has historically led to a collective reliance on a limited range of risk management methodologies, which may synchronize reactions to negative market news (e.g., concerns lead CCP's to increase haircuts or restrict collateral eligibility) and generate pro-cyclical shocks to the financial system. Aggressive haircutting by CCPs arguably had this effect on Greece, Ireland, Italy, Portugal, and Spain in 2011.¹¹

Credit rating agencies and regulators have acknowledged many of the concerns associated with the growth in cleared activity and are finding ways to address them. Bank/Dealers may also have to apply stricter internal assessments. These may include increased stress testing, lower credit limits to a CCP, or contingent funding to support a CCP if a default by one or more members exhausts its margin and default funds. On the other hand, CCPs may soon be encouraged to have “skin in the game” or equity of their own to absorb defaulting members’ losses without affecting other clearing members.

5. Crisis Examples in the Context of the Collateral Map

It is difficult to anticipate the shocks to the financial system that may trigger funding runs and asset fire sales,¹² but we can assess points of vulnerability to possible shocks. These include sizable durability mismatches; a constriction in funding flows that will have large downstream effects for those who depend on that funding for securities operations and portfolio holdings; collateral and credit sensitivity that may fuel contagion; and structural vulnerabilities such as capacity limitations.

The collateral landscape has changed markedly since the 2007-09 crisis. Repo markets and related collateral have diminished, while CCPs and their high-quality collateral standards have moved front and center. Because of these changes, the historical vulnerabilities of collateral do not track those that have emerged since the crisis.

¹⁰ See BCBS-IOSCO report, 2015.

¹¹ See Charles Boissel, Francois Derrien, Evren Ors, and David Thesmar, 2014, “Systemic Risk in Clearing Houses: Evidence from the European Repo Market,” HEC Paris, working paper.

¹² See Brian Begalle, Antoine Martin, James McAndrews, and Susan McLaughlin, “The Risk of Fire Sales in the Tri-Party Repo Market,” Federal Reserve Bank of New York Staff Report no. 616, 2013.

We use a collateral map to examine three examples of vulnerabilities — two from the recent past and one scenario now unfolding. Our examples do not encompass the full extent of the propagation of shocks through the financial system because we have not expanded the collateral map to a broader network of multiple Bank/Dealers and other entities such as insurance companies. However, even this limited schematic shows how collateral can carry the effects of the initial shock beyond its point of origin.

Example: European Debt Crisis Raises Margin Required for Spanish and Italian Debt

The European debt crisis escalated during the second half of 2011, putting pressure on European sovereign debt that was used to collateralize securities financing transactions. LCH.Clearnet, a CCP, responded to the increased stress and credit deterioration of peripheral countries by raising margin requirements for debt issued by Spanish and Italian governments that previously was considered liquid and creditworthy.

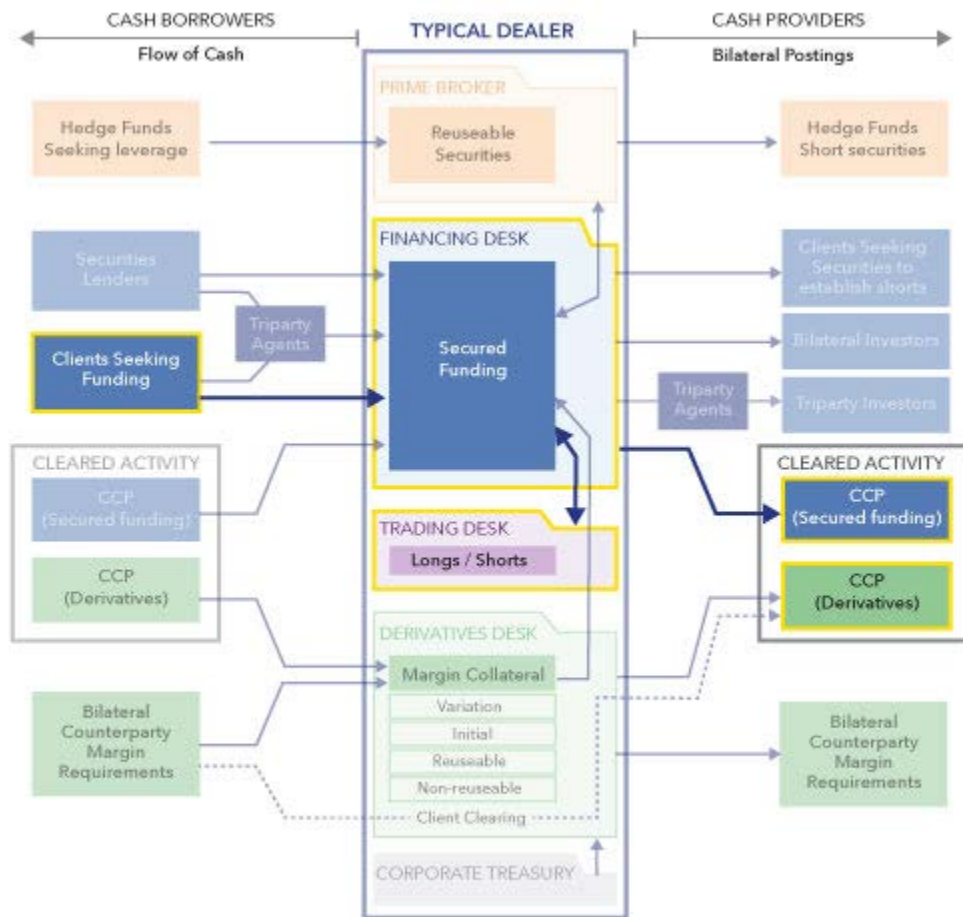
Haircuts for Spanish and Italian debt maturing in seven-to-ten years were increased by more than 100 basis points during the final quarter of 2011. This action sent a strong and public signal to the markets, which in turn drove secured funding investors to reconsider their own margin requirements. The stress continued to worsen during the first quarter of 2012, when LCH again raised its margin requirements on Spanish and Italian sovereign debt. During late 2011 to early 2012, the margin requirement on Italian debt nearly doubled.

This example highlights how a stress event affecting a collateral asset class can quickly escalate as a CCP requires increased margins and secured funding investors take similar actions (see **Figure 6**). The key difference is that CCPs have a unilateral right to increase collateral margin requirements at any point during the life of a trade.

Figure 6. Evolution of a Collateral Stress Event Exacerbated by Rising CCP Margin Requirements

This map shows the relationships that can contribute to a collateral stress event.

First, a CCP increases margin requirements on collateral. Next, other secured funding investors increase their haircut requirements or roll off the funding provided against this asset. The Bank/Dealer responds to growing pressure by turning to unsecured sources of funding to fund the additional haircut. Depending on the size of the haircut increase and the severity of secured funding roll offs, the Bank/Dealer may reduce client financing and sell assets. Finally, the deterioration of an asset’s collateral value increases the risk of fire sales for that asset class.



Source: Authors

Example: Capacity Constraints on a Bank/Dealer’s Ability to Provide Client Clearing

Certain Bank/Dealers with CCP membership can qualify as clearing brokers so they can clear OTC and futures products on behalf of clients who don’t have direct access to the CCP. The intermediary service provided by clearing brokers allows clients to comply with mandatory clearing rules and/or voluntarily clear eligible products.

This clearing service is generally a stand-alone business with low returns, given the capital-intensive cost to the clearing broker. The notional amount of derivatives cleared on behalf of a client are included in the clearing broker's calculation of off-balance sheet leverage assets, which have a 5-6 percent regulatory capital requirement under the supplementary leverage ratio for U.S. clearing brokers affiliated with a bank. The notional amount can be mitigated if clients compress their portfolios. However, some clients lack the infrastructure or capacity to compress bilateral trades. In response to these limitations, clearing houses and vendors are expanding their compression and coupon-blending¹³ function to nondealers.

Recent U.S. banking regulations increased the capital burden further by including in the clearing broker's leverage assets the initial cash margin posted at the CCP on behalf of the client – despite the clearing broker not guaranteeing this cash back to the client. These capital costs make this business increasingly unattractive, unless the client contributes to the clearing broker's revenues in other areas.

Clearing brokers could offset higher capital costs by increasing prices charged to clients. This would likely slow clients' voluntary clearing activity.

The capital treatment of cash margin has led to a few clearing brokers exiting the business. Some of the remaining clearing brokers are requesting noncash collateral from clients because only cash margin is included in the leverage assets calculation. The noncash collateral is limited mostly to highly liquid sovereign bonds to meet the CCP's collateral eligibility for initial margin.

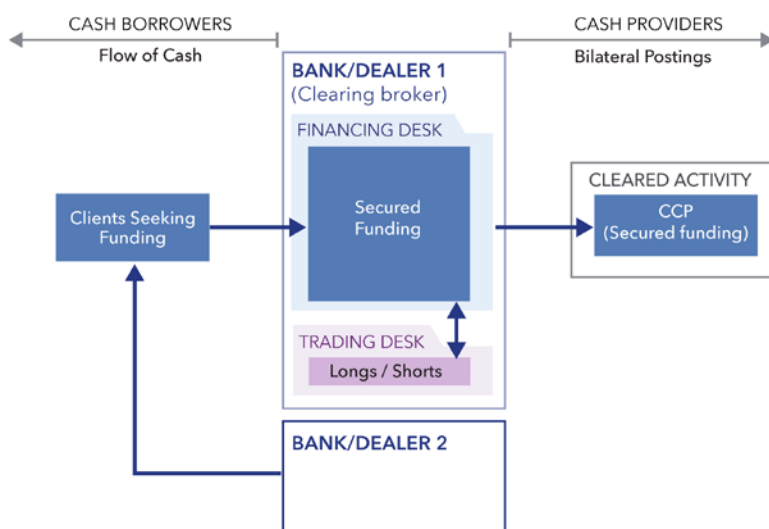
In **Figure 7**, we show how Bank/Dealer 1 could reduce its capital requirements by asking for noncash collateral. However, the capacity constraint problem simply shifts to Bank/Dealer 2 as this activity increases their balance sheet usage, and therefore their leverage capital requirements.

¹³ See Securities and Exchange Commission, "Notice of Filing and Immediate Effectiveness of Proposed Rule Change Relating to IRS Coupon Blending," May 29, 2014, available at www.sec.gov/rules/sro/cme/2014/34-72272.pdf

Figure 7. The Effect of Capital Requirements on Bank/Dealers' Leverage

This portion of the collateral map shows how more than one Bank/Dealer can be affected by an increase in collateral requirements.

First, Bank/Dealer 1 requests noncash collateral from a client for initial margin required at a CCP. This helps Bank/Dealer 1, given it will not need to report this on its balance sheet. Next, the client obtains collateral from Bank/Dealer 2 in a securities financing transaction. This transaction will likely increase the balance sheet of Bank/Dealer 2.



Source: Authors

This scenario is still unfolding and needs close monitoring. Some 72 clearing brokers, also known as futures commission merchants in CFTC regulations, existed in November 2015, down from 95 clearing brokers two years earlier.¹⁴ If the rate of consolidation continues among clearing brokers due to reduced profitability and economies of scale, new issues could emerge. In addition to higher fees for clearing services, consolidation may reduce the overall clearing capacity. When two clearing brokers combine operations, it is unclear if the new entity will provide the same clearing capacity.

The reduced capacity and increased costs will directly impact insurance companies and others unable to directly access CCPs.

¹⁴ See CFTC, “Selected FCM Data as of November 30, 2015,” and CFTC, “Selected FCM Data as of November 30, 2013,” www.cftc.gov/idc/groups/public/@financialdataforfcms/documents/file/fcmdata1113.pdf

Example: AIG's Cash Collateral Management in Securities Lending¹⁵

In the years leading up to the financial crisis, American International Group, Inc. (AIG), with its strong credit rating and \$160 billion portfolio of high-quality securities to lend, was an attractive counterparty. Its insurance companies' assets were available to make securities borrowers whole in the event that AIG could not return securities borrowers' cash collateral. AIG's domestic life-insurance and retirement-services unit accounted for nearly 80 percent of AIG's securities lending activities in 2007.

AIG lent securities to generate cash for reinvestment, as shown in **Figure 8** and so most of AIG's secured trades were term loans. Indeed, at the end of 2007, less than 15 percent of the securities loans were one-day tenor. The longer terms gave AIG some measure of security, but a maturity mismatch still existed and left AIG exposed to liquidity risk. Before the crisis, AIG's securities lending transactions, consistent with the market standard, were over-collateralized and their value marked to market daily with periodic collateral adjustments. That changed as the financial crisis swept over AIG and the rest of the marketplace. AIG's insurance companies held residential mortgage-backed securities (RMBS) and other asset-backed securities in their investment portfolios including reinvested collateral from securities lending transactions. AIG increased the size of its securities lending program by lending more securities to generate cash, which it then invested heavily in RMBS. The concentration of securities lending collateral in RMBS was risky and created a maturity mismatch — the term of the RMBS was longer than that of the securities loans that generated the cash.

AIG had a relatively small cash cushion to meet redemptions from counterparties that wanted their cash back. The ability of AIG's securities lending program to hold long-term RMBS depended on the willingness of securities borrowers to keep rolling over their loans and keep posting cash collateral without altering the loans' terms. Borrowers that routinely rolled over loans changed their behavior during the crisis.

In August 2007, AIG's securities lending program began to experience problems. The company responded by lending additional securities to generate cash. AIG also stopped reinvesting cash collateral it received in anything other than cash equivalents, and sold securities from its collateral investment pool that it could sell at no loss or a small loss. The additional lending increased the size of the securities lending program from \$70 billion in August 2007 to an all-time high of \$94 billion in October 2007.

AIG's attempts to mitigate liquidity issues came at a cost. AIG wanted to hold on to its cash and did not want to sell the securities in its reinvestment pool. It needed to keep lending securities, even at the higher rates its counterparties were demanding. The balance shifted more and more in favor of borrowers as the financial crisis deepened and firms tried to build up their own liquidity. AIG eventually was paying securities borrowers more for the cash collateral than it received on its investment of that cash.

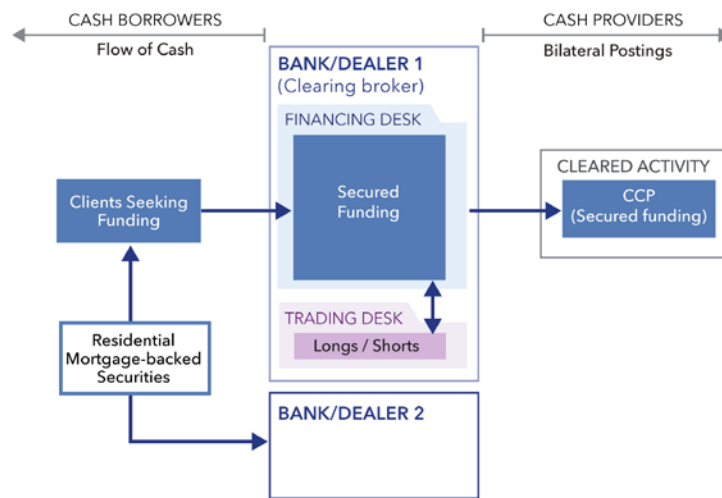
A run started in earnest during September 2008. Borrowers asked AIG for \$24 billion of their cash

¹⁵ This section borrows heavily from the Financial Crisis Inquiry Report (2011), Fleming and Sarkar (2014), and Aguiar et al. (2014).

collateral from September 12 through 30, 2008. In November, AIG announced a loss of \$24.47 billion for the third quarter of 2008, half from securities lending. AIG used money received from Maiden Lane II, one of the new entities created as part of a federal bailout and restructuring, to repay \$19.9 billion in outstanding obligations to securities lending counterparties, including the Federal Reserve Bank of New York.

Figure 8. Maturity Mismatch in Securities Lending, RMBS Investments

The client seeking funding in this example is AIG. AIG lent long term and short term securities to the Bank/Dealer 1, in exchange for cash collateral. AIG re-invested the cash collateral in residential mortgage backed securities (RMBS). This resulted in maturity mismatches in its securities lending business.



Source: Authors

6. Data Gaps

The accounting of pledged collateral suggests that many banks are funded through collateral. Pledged collateral is listed in the off-balance-sheet footnotes (see Singh, 2014). This can lead to a gap between the off-balance-sheet pledged collateral (via repo, securities lending, OTC derivatives in the money and prime broker loans), and on-balance-sheet entries that may pick up only some of the off-balance-sheet funding. A better mechanism is required to account for the pledged collateral.

Our collateral map suggests that the data required to evaluate the three examples presented in Section 5 needs to be granular, complete, and broken out by functional areas. For example, Bank/Dealers could provide the amount of derivatives collateral pledged to CCPs in each operating region, while securities lenders could provide the volume of cash and noncash collateral received from top borrowers.

Existing regulatory and public data do not meet this need. For example:

- The Federal Reserve’s quarterly Financial Accounts of the United States aggregates data at a high level with a macroeconomic focus, and excludes derivatives transactions.
- Another Federal Reserve dataset, the Government Securities Dealers Reports, collects daily and weekly data only from primary dealers and aggregates the data.
- Bank-specific financial data in 10-Q reports filed with the Securities and Exchange Commission, Focus reports filed with the Financial Industry Regulatory Authority, and FR Y-9C reports filed with the Federal Reserve give an incomplete picture due to netting, lack of detail, and off-balance-sheet issues.

Data are incomplete because Bank/Dealers report secured funding for cash transactions on their balance sheet and only after allowable netting. Noncash transactions, such as when a Bank/Dealer lends equities and receives U.S. Treasuries, and netted cash transactions are not reported on the balance sheet. Customer receivables also do not show the full amount of Prime Broker margin loans or cash collateral posted to derivative payables, because of allowable collateral and counterparty netting.

Currently, data on repo activity is collected using two different approaches. The first collects aggregated repo data from a set of market participants, such as Bank/Dealers. Mutual funds and insurance companies report their financing activities, including those in the repo market, as part of their regulatory filings. Regulators that aggregate the data get insights into financing activities of some market participants, although the data do not cover the entire market. The data are highly aggregated, and lack information on rates, haircuts, or counterparty exposures (see Baklanova et al., 2015). Another major shortcoming is the lack of a centralized data repository. Reports are collected by various regulatory agencies at the federal or state levels, depending on the type of entity (Baklanova, 2015). Some reported data, especially those filed by registered investment companies and publicly-traded companies are available through the SEC’s EDGAR database. However, data submitted by hedge funds on the SEC’s Form PF are not publicly available, and bank-related data are available to the public in an aggregated form.

The second approach collects data on specific segments of securities financing activities, such as the recent granular dataset about the triparty repo market and General Collateral Financing repo transactions. This data collection approach omits a substantial part of the repo market that is settled outside the triparty repo platform.¹⁶ However, the Federal Reserve and the Office of Financial Research have been discussing a possible formal collection of bilateral repo data. CCPs can also facilitate market transparency by collecting transaction-level data and publishing aggregated price and volume data.

Conclusion

¹⁶ The Federal Reserve Bank of New York publishes monthly aggregated repo market data on its website at www.newyorkfed.org/banking/tpr_infr_reform_data.html.

The 2007-09 crisis highlighted how little was known about the underlying structure and plumbing of the financial system. While research has since been devoted to understanding funding flows in the financial system (Aguilar et al., 2014), less attention has been paid to the accompanying flows of collateral. Furthermore, when tackling the issue of collateral flows, it becomes apparent that collateral is not simply the opposite of funding. The flow of collateral has its own special characteristics.

Significant regulatory changes have been made to prevent future crises. These changes affect the structure and plumbing of the financial system, especially the flow of collateral and intermediaries in the collateral process. One key aspect of the evolution in the financial system structure is the increasing importance and role of CCPs. New tools and policies for monitoring systemic risk must give more attention to CCP functions and activities.

The collateral map allows us to understand the sources of collateral and how collateral moves through the financial system. To assess systemic risk from potential failures within the collateral network, data are needed to track collateral flows through different market participants linked to a Bank/Dealer. Once populated with the needed data, the collateral map can show collateral-related vulnerabilities, possible paths of contagion, and alternative paths for critical collateral flows if one path becomes congested. The map can also be used to detect areas of increased volume and speed of flows, showing where capacity constraints are becoming problematic.

Finally, in this paper we have recast the roles of collateral and funding. Instead of simply looking at collateral flows as moving in the opposite direction of secured funding, we show how collateral and funding are two different layers in a multilayer map or network. The role of the Bank/Dealer bridges both layers, thus explaining one aspect of the Bank/Dealer's systemic importance.

References

- Aguiar, A., R. Bookstaber, and T. Wipf. "A Map of Funding Durability and Risk." Office of Financial Research Working Paper no. 14-03, 2014.
- Adrian, T. and H. S. Shin. "Liquidity and Leverage," *Journal of Financial Intermediation*, Vol. 19, July 2010.
- Baklanova, V., "Repo and Securities Lending: Improving Transparency with Better Data." Office of Financial Research Brief no. 15-03, 2015.
- Baklanova, V., A. Copeland, and R. McCaughrin. "Reference Guide to U.S. Repo and Securities Lending Markets." Office of Financial Research Working Paper no. 15-17, 2015.
- Bank for International Settlements, "Capital Requirements for Bank Exposures to Central Counterparties," April 2014.
- Bank for International Settlements, "Public Quantitative Disclosure Standards for Central Counterparties," February 2015.
- Bank for International Settlements, "Statistics on Payment, Clearing, and Settlement Systems in the CPMI Countries - Figures for 2014," 521-33, December 2015.
- Boccaletti, S., G. Bianconi, R. Criado, C. Del Genio, J. Gomez-Gardenes, M. Romance, I. Sendina-Nadal, Z. Wang, and M. Zanin. "The Structure and Dynamics of Multilayer Networks." *Physics Reports*, 544(1):1–122, 2014.
- Brunnermeier, M. and L. Pedersen. "Market Liquidity and Funding Liquidity," *Review of Financial Studies*, Vol. 22, 2201–38, 2009.
- Brunnermeier, M., G. Gorton, and A. Krishnamurthy. "Risk Topography," NBER Macroeconomics Annual 2011, Vol. 26, 2011.
- Capponi, A., W. Allen Cheng, and S. Rajan. "Systemic Risk: The Dynamics Under Central Clearing." Office of Financial Research Working Paper no. 15-08, 2015.
- Comotto, R. "Haircuts and Initial Margins in the Repo Market," International Capital Market Association-European Repo Council, 2012.
- Duffie, D. and H. Zhu. "Does a Central Clearing Counterparty Reduce Counterparty Risk?" *Review of Asset Pricing Studies* 1.1, 74-95, 2011.
- Duffie, D., M. Scheicher, and G. Vuillemeij. "Central clearing and Collateral Demand." *Journal of Financial Economics*, 2015.
- Financial Crisis Inquiry Commission (2011). *The Financial Crisis Inquiry Report*, Washington, D.C.
- Financial Research Advisory Committee of the Office of Financial Research. "Securities Lending

Collateral Flow Map” and “Cleared Swaps Customer Collateral Map” discussion documents at FRAC meeting on February 4, 2014.

Financial Stability Board, “Progress Report on the CCP Workplan,” September 22, 2015.

Financial Stability Board, “Transforming Shadow Banking into Resilient Market-based Finance – Possible Measures of Non-Cash Collateral Re-Use,” September 23, 2016.

Fleming, M. and A. Sarkar. “The Failure Resolution of Lehman Brothers,” *Economic Policy Review*, 20:2, 1-54, 2014.

Garratt, R. and P. Zimmerman. “Does Central Clearing Reduce Counterparty Risk in Realistic Financial Networks?” Federal Reserve Bank of New York Staff Report no. 717, March 2015.

Geanakoplos, J. “Liquidity, Default and Crashes,” Cowles Foundation Paper no. 1074, 2003.

Glasserman, P., C. Moallemi, and K. Yuan. “Hidden Illiquidity with Multiple Counterparties.” Office of Financial Research Working Paper no. 15-07, 2015.

Kenett, D.Y., J. Gao, X. Huang, S. Shao, I. Vodenska, S. V. Buldyrev, G. Paul, H. E. Stanley, and S. Havlin. “Network of Interdependent Networks: Overview of Theory and Applications” in *Networks of Networks: The Last Frontier of Complexity*, 3–36. Springer, 2014.

Krishnamurthy, A., S. Nagel, and D. Orlov. “Sizing up Repo,” *Journal of Finance*, 69(6): 2381-2417, 2014.

Peirce, H. “Securities Lending and the Untold Story in the Collapse of AIG.” Mercatus Center Working Paper no. 14-12, George Mason University, 2014.

Shliefer, A. and R. Vishny. “Fire Sales in Finance and Macroeconomics,” *Journal of Economic Perspectives*, 25(1): 29-48, 2011.

Singh, M. “Collateral, Netting and Systemic Risk in OTC Derivatives Market,” IMF Working Paper no. 10/99, 2010.

Singh, M. and J. Aitken. “The Sizable Role of Rehypothecation in the Shadow Banking System,” IMF Working Paper no. 10/172, 2010.

Singh, M. “Collateral and Monetary Policy,” IMF Working Paper no. 13/186, 2013.

Singh, M. “Collateral and Financial Plumbing,” Risk Books, 2014.