International Shock Transmission: Does Bank Organizational Structure Matter?*

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Abstract

The organization structure of global banks affects how they respond to liquidity shocks and matters for international shock transmission. Liquidity shocks to global banks induces a fire sales of securities by their international branches that rely on parent banks for funding, but not by their international subsidiaries that are independently capitalized and domestically funded. Domestic banks allocate funds to purchase securities sold in such fire sales, but in turn reduce credit supply, causing liquidity shocks to spill-over. Our study contributes to the debate regarding optimal regulation of global banks and externalities arising from securities trading by such banks.

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1 Introduction

Among the many factors alleged to have contributed to the global propagation of the financial crisis of 2007–2008, increased cross-border connections among global banks – defined as banks with a physical network of branches in many countries – is perhaps the most debated. Such connections can improve risk sharing if they allow global banks to easily reallocate capital via cross-border, internal capital markets on the basis of relative needs (Karolyi, Sedunov, and Taboada (2018)). Alternatively, cross-border connections among global banks can be harmful if they allow liquidity shocks to easily propagate across countries (Cetorelli and Goldberg (2012)). In this paper, we examine if the organization structure of global banks affects how they respond to liquidity shocks and whether it plays a role in transmission of such shocks across countries. The answer to these questions has important implications for future regulation of global banks.

To provide compelling evidence on whether the organization structure of global banks matters for international transmission of liquidity shocks, however, one needs to overcome two key challenges. First, liquidity shocks to global banks are typically systemic in nature, and affect many banks and many financial markets in several countries simultaneously. This makes it difficult to distinguish between direct shocks and those transmitted via a network of global banks. Ideally, one needs a setting in which liquidity shocks to global banks are uncorrelated with the financial markets being analyzed, and in which similar banks differ in their exposure to liquidity shocks. Second, to examine how global banks respond to liquidity shocks one needs detailed data, at a reasonably high frequency, on bank portfolio holdings and transactions, ideally at the individual bank-level. However, such data is typically not available to researchers.

In this paper, we address these challenges by examining how liquidity shocks in global money markets during the recent global financial crisis, which we interpret as liquidity shocks to global banks, impact the daily holdings of securities by their international branches in Australia.[1] We focus on securities holding because Kashyap and Stein (2000) show that securities held by banks is a key measure of their liquidity, and that liquidity shocks to banks first and foremost affect their securities holdings. That is, banks responds to liquidity shocks by first drawing down on their buffer of liquid securities, and only then by curtailing credit.[2]

Our setting is ideal because Australian financial markets were not directly exposed to U.S. sub-prime

[1] By global money markets we refer to the short-term borrowing and lending markets between banks and bank-like institutions. Throughout this paper we use the term money markets and interbank markets interchangeably.

[2] Later, we also examine how liquidity shocks affect credit provided by banks.

securities, and global money markets, which many U.S. and European banks relied on prior to the crisis, were not a significant source of funds for many Australian banks (Deans and Stewart (2012) and Debelle (2012)). In addition, as we explain below, bank organization structure in Australia results in a variation in exposure to global money markets across similar banks. Finally, the largest depository service in Australia granted us access to a proprietary data-set that covers nearly all fixed income market transactions in Australia, and allows us to directly observe daily fixed income market transactions and holdings for almost all financial and nonfinancial firms in Australia.

Our empirical strategy relies on the fact that Australian banks can be divided into three distinct categories – *domestic Australian*, *global subsidiary*, and *global branch* banks – that differ in their exposure to global money markets. Domestic Australian banks are primarily funded by domestic deposits and money markets. Global subsidiary banks are part of global non-Australian banks that are capitalized independently from their parent banks and are also funded by domestic deposits and money markets. Global branch banks are also part of global non-Australian banks, but are dependent on their parent banks for funding. We contend that global branch banks are more exposed to global money markets than either domestic Australian or global subsidiary banks.

The following example illustrates our intuition. Suppose Westpac Bank (WEST), Citibank–Australia (CITI-A), and Bank of America–Australia (BOA-A) are three banks in Australia. WEST is a domestic Australian bank, while CITI-A and BOA-A are global subsidiary and branch banks, respectively. BOA-A is more exposed to global money markets than WEST AND CITI-A because it relies on its parent bank (BOA-US) for funding, which in turn relies on global money markets (at least during our sample period). Thus, shocks to global money markets that adversely impact BOA-US may either cause BOA-A to receive a lower than expected quantity of funding from its parent bank, or the transfer price of such funding may unexpectedly increase.[3] After a liquidity shock to global money markets, BOA-US, can also require BOA-A to sell liquid assets in a fire sale in a global scramble for liquidity.[4] Global money market shocks are less critical for both WEST and CITI-A as they are primarily funded via domestic deposits and money markets. In addition, subsidiaries usually operate independently from parent banks, and CITI-A is unlikely to be required to sell securities even if CITI-US engages in a global scramble for liquidity in

[3]Transfer pricing refers to the price at which funds are exchanged among separate divisions of the same firm. Hirshleifer (1956) and Grubert and Mutti (1991), review the literature on transfer pricing, and conclude that firms typically use market-based prices to determine the cost at which to transfer funds among divisions.

[4]Acharya, Afonso, and Kovner (2016) document how global banks scramble for liquidity in the aftermath of a global money market shock.

the aftermath of a liquidity shock.[5]

In the above example, WEST and CITI-A *are still* exposed to shocks to domestic money markets. An unexpected increase in domestic deposit or money market rates can adversely impact both WEST and CITI-A, but may not affect BOA-A. Thus, as long as the correlation between global and domestic money market shocks is low, a fact that we verify below, our setting is ideal for analyzing how global banks respond to liquidity shocks, and whether they transmit such shocks across countries.

Given this setting, our empirical analysis proceeds in four steps. First, we provide convincing evidence for our empirical strategy by analyzing the financial performance of domestic Australian, global subsidiary, and global branch banks during the financial crisis of 2007–2008. Both domestic Australian and global subsidiary banks were relatively unaffected by the global financial crisis. Measures of profitability and liquidity such as net income to total assets, interest expense to total assets, liquid securities to total assets, and operating cost to income remained relatively stable throughout this period for both these categories of banks. Conversely, all measures of profitability and liquidity were adversely impacted, especially after Lehman Brothers filed for bankruptcy in September 2008, for global branch banks. In fact, global branch banks are the only category of banks in Australia to experience losses during the financial crisis.

Second, we examine how shocks to global money markets affect holdings of liquid fixed income securities (i.e., bond holdings) of domestic Australian, global subsidiary, and global branch banks.[6] Following Acharya and Skeie (2011) and Gorton and Metrick (2012), we interpret an unexpected increase in the three-month Libor-OIS spread as an indicator of global money market stress or a global liquidity shock. Using a panel regression framework, we regress change in bond holdings at the individual bank-level on unexpected changes in the three-month Libor-OIS spread. We find that global liquidity shocks induce global branch banks to substantially reduce their bond holdings, but has relatively little impact on the bond holdings of both domestic Australian or global subsidiary banks. The results are economically and statistically significant. On average, a one-standard deviation unexpected increase in the Libor-OIS spread is associated with an approximately 9-19% reduction in the bond holdings of global branch banks.

The evidence for global liquidity shock induced fire sales of bonds by global branch banks is stronger

[5] Goldberg and Saunders (1981), Ball and Tschoegl (1982), Cerutti, Dell'Ariccia, and Martínez Pería (2005), and more recently Dell'Ariccia and Marquez (2010) study the organizational differences between bank subsidiaries and branches. While branches are legally a part of the parent bank and parent banks are responsible for the liabilities of their branches, subsidiaries are organized as separate legal entities and operate independently from parent banks. For a bank branch, capital resides with and is managed by the parent bank.

[6] Fixed income securities comprise the majority of liquid securities held by Australian banks. See monthly banking statistics provided by Australian Prudential Regulatory Authority, available at ttps://www.apra.gov.au/publications/monthly-banking-statistics.

during the financial crisis, and for those global branch banks that are already financially constrained. We control for a variety of bank-level and security-level characteristics and find that bond sales by global branch banks in response to global liquidity shocks do not represent a flight to quality as global branch banks divest bond holdings across all categories of bonds. Global branch banks are also not merely selling riskier bonds to replace them with more liquid, safer bonds. These sales do not reflect 'information-based' trades, as global branch banks sell bonds regardless of their maturity, yield, and issuer. A falsification test confirms that global branch banks do not adjust their bond holdings in response to stresses in domestic money markets (i.e., domestic liquidity shocks), but that both domestic Australian and global subsidiary banks do so.

Third, we document that the fire sale of bonds by global branch causes the market prices of bonds sold in such sales to fall below their fundamental values. We follow an approach similar to Feldhütter (2012) and compare the average price of all bonds sold by global branch banks to the average price of similar bonds sold by other market participants on days with global liquidity shocks. We find that on such days average prices of bonds sold by global branch banks are \$0.19 - \$2.08 lower than prices of similar bonds sold by other market participants, indicating that simultaneous selling pressure causes bond prices to temporarily decrease below their fundamental value. Such deviations between market and fundamental prices, however, do not persist. The quick price reversal for bonds sold in fire sales by global branch is primarily on account of domestic banks, nonfinancial firms, and the central bank of Australia (the Reserve Bank of Australia or the RBA) stepping-in to purchase bonds sold in fire sales. Following a global liquidity shock, domestic banks and nonfinancial firms allocate funds to profit from trading opportunities, purchasing 70-80% of bonds sold by global branch banks in response to liquidity shocks.

Finally, we show that domestic banks' purchase of securities sold in fire sales spills over and affects the supply of credit to the real economy. We analyze the ratio of total loans to total asset and find that in each month in which global branch banks engage in a fire sale, this ratio is 1-9% lower for domestic banks that purchase securities sold in fire sales as compared to banks that do not participate in fire sales. Thus, fire sales of bonds by global branch banks, and the subsequent purchase of these bonds by domestic entities in response to a liquidity shock, reduces credit supply, and may cause global liquidity shocks to spill-over.

Our key contribution is that we provide compelling evidence on the channel through which global banks transmit liquidity shocks across countries and quantify the magnitude of the effects. We establish that one of the transmission mechanisms is via fire sales of liquid securities by international branches of global banks that are dependent on parent banks for funding. These 'forced' trades by international branches of banks affected by global liquidity shocks induce further changes in portfolios of domestic banks and the regulator, even though the latter entities are not directly exposed to events that caused the original global liquidity shock.

Our paper is related to a large literature on the effects of liquidity shocks to banks. A comprehensive review of this literature is beyond the scope of this paper. Most of this literature, however, focuses on the question of how bank liquidity shocks affect credit supply and real economic activity. For instance, recently Campello (2002) and Chava and Purnanandam (2011) use cross-bank variation in exposure to liquidity shocks to study how such shocks impact bank credit supply. Our paper instead analyzes how bank liquidity shocks can affect financial markets using banks' actual transactions and holdings.

A recent, growing literature examines the effects of bank organizational structure on bank risk taking, monetary policy, and international shock transmission. Cetorelli and Goldberg (2012) show that global banks based in developed markets transmit liquidity shocks by reducing their credit supply in emerging markets. Similarly, Cetorelli and Goldberg (2016) provide evidence that the organizational complexity of a bank is a fundamental driver of the business model of the bank and how such a bank manages its balance sheet. Dell'Ariccia and Marquez (2010) show that country risk is an important determinant of bank corporate structure when expanding to new markets. When economic risk is high, banks chose to establish subsidiaries, when entering new markets. Conversely, when expropriation risk is high, banks chose to establish branches, when entering new markets.

We also contribute to studies on international financial contagion. This literature suggests that one possible mechanism by which shocks in one market may spill over into other markets is via financial linkages among investors in different markets. Financial linkages can cause contagion if investors who have suffered losses in one market, find their ability to obtain funding impaired, potentially divest their holdings in a fire sales, leading to a downward spiral in liquidity in other markets. Important contributions on this topic include Eichengreen, Rose, and Wyplosz (1996), Glick and Rose (1999), Allen and Gale (2000), Kyle and Xiong (2001), Forbes and Rigobon (2002), Goldberg (2009), Kiyotaki and Moore (2002), Kodres and Pritsker (2002), Kaminsky, Reinhart, and Vegh (2003), Allen and Gale (2004), Forbes (2004), Brunnermeier and Pedersen (2005), Brunnermeier and Pedersen (2009), Cetorelli and Goldberg (2011), Cetorelli and Goldberg (2012), Jotikasthira, Lundblad, and Ramadorai (2012a), among others

Shleifer and Vishny (2010), Diamond and Rajan (2011), and Stein (2013) study the implications of securities trading by banks, and argue that during a crisis banks that trade securities may allocate funds to purchase securities sold in fire sales to profit from trading opportunities, in-turn reducing credit supply. Our proprietary dataset with security-level holdings for all banks in Australia at the daily frequency allows us to examine the timing of trading and confirms this behavior on the part of banks during a crisis.

Finally, this paper also relates to studies on the differences between foreign- and domestically-owned banks. Empirical work in this area includes Peek and Rosengren (2000), Berger, Klapper, and Udell (1999), Diamond and Rajan (2001), Detragiache and Gupta (2006), Mian (2006), Arena, Reinhart, and Vazquez (2007), Detragiache, Tressel, and Gupta (2008), Gormley (2010), among others.

The rest of the paper is organized as follows: Section 2 discusses the background and our identification strategy in more detail. Section 3 describes the data and presents summary statistics. Sections 4 present the empirical results. Section 5 concludes.

2 Background

The collapse of the U.S. sub-prime market triggered the global financial crisis of 2007–2008 and lead to significant losses and capital impairment for many global banks. Such large losses and capital impairment directly compromised the liquidity of global banks and in turn lead to an increase in the price of liquidity in global money and interbank markets. Participants in these markets were either unwilling to provide funding to global banks or did so only at substantially higher rates (Acharya and Merrouche (2012) and Ashcraft, McAndrews, and Skeie (2011)). Thus, the global financial crisis provides an ideal laboratory for studying if global banks transmit liquidity shocks in global money markets across countries.[7]

Our identification strategy relies on the fact that global branch banks depend on global money markets for funding, while this is not the case for domestic Australian and global subsidiary banks.[8] Global subsidiary and branch banks also exist in many other countries including the U.S., Canada, U.K., European Union, and Japan. Thus, while we use data exclusively for Australia, our results are more generally

[7]For a full description of the causes and consequences of the global financial crisis see Gorton and Metrick (2012), Mishkin (2011), Brunnermeier (2009), Lastra and Wood (2010), and Lane (2012), among others. Fahlenbrach, Prilmeier, and Stulz (2012), Demirguc-Kunt, Detragiache, and Merrouche (2013), and Beltratti and Stulz (2012) document how the performance for global banks deteriorated during this period.

[8]While some large domestic Australian banks do borrow in global money markets, it is not a major source of funding for these banks (Henry et al. (2011)). The Reserve Bank of Australia provides a detailed description for the three categories of banks and their primary funding sources (http://www.rba.gov.au/publications/fsr/2006/mar/pdf/0306.pdf).

applicable.[9] We focus on Australia as Australian financial markets were not directly exposed to the U.S. sub-prime crisis and Australia did not suffer a banking crisis, allowing us to empirically distinguish between direct shocks to Australian financial markets and those transmitted via a network of global banks.

To provide convincing evidence of our identification strategy, Figure 1 plots the profitability and liquidity measures for all categories of banks. In each month, we first aggregate balance sheet and income statement data for all banks belonging to a particular category. Using this monthly, aggregated data, we compute and plot the following ratios: interest expense to total assets, profit before tax to total assets, net income to total assets, cost to income ratio, liquid assets to total assets, short-term borrowing to total assets, long-term borrowing to total assets, and the year-on-year growth rate of loan commitments, separately for domestic Australian, global subsidiary, and global branch banks. In Figure 1, each panel plots the data for a separate ratio. In each panel, the black solid line, the blue dashed line, and the red dotted line plot the data for domestic Australian, global subsidiary, and global branch banks, respectively.

All measures of profitability and liquidity for global branch banks were adversely impacted during the global financial crisis, especially after Lehman Brothers' filed for bankruptcy in September 2008. For example, during 2007–2009, interest expense to total assets (top-left panel) for global branch banks spikes as compared to that for domestic Australian and global subsidiary banks. Similarly, profitability, either measured by profit before tax to total assets or net income to total assets, is lower for global branch banks than for the other two categories of banks. Global branch banks also experience a higher cost to income ratio (ratio of operating expense to operating income), a key measure of operating efficiency for banks. During this period global branch banks are increasingly funded with short-term liabilities. Further, the ratio of liquid assets to total assets is lower for global branch banks, perhaps because these banks are selling securities in a scramble for liquidity during this turbulent period. Finally, note that all measures of profitability and liquidity for global branch banks are more volatile than those for domestic Australian and global subsidiary banks.

Table 1 presents the summary statistics for the liquidity and performance measures. Panel A presents the summary statistics for the full sample, while Panel B presents the summary statistics for the financial

[9] When expanding operations to a new country, global banks can choose from among a variety of organizational forms, such as, subsidiaries, branches, representative offices, and investment companies. Subsidiaries and branches are the most popular organizational forms. The exact organizational form selected by a global bank will vary depending on many factors including, banking regulations, tax laws, management and shareholder preferences, transaction costs, and the anticipated size and profits from the new operations. See Goldberg and Saunders (1981), Ball and Tschoegl (1982), Cerutti, Dell'Ariccia, and Martínez Pería (2005), and more recently Dell'Ariccia and Marquez (2010) for a discussion of global banks' choice regarding organizational form.

crisis. During the financial crisis, the average interest expense (INTEXP) of global branch banks was 73% higher as compared to the average over the full sample. Average interest expense is also higher for domestic Australian and global subsidiary banks, but only by 25% and 17%, respectively. Thus, global branch banks experience a significant increase in their funding costs during the financial crisis. The higher funding costs for global branch banks during the crisis may reflect their parent banks' inability to provide funding or to provide such funding only at a higher cost.

During the financial crisis average profitability (PROFIT) is nearly -100% lower for global branch banks, but only -6% and -27% lower for domestic Australian and global subsidiary banks, respectively. In fact, global branch banks are the only category of banks in Australia for whom the average ratio of net income to total assets (NETINC) is negative during the crisis. The lower profitability of global branch banks during the crisis can in-part be traced to an increase in their operating expenses (CSTINC), which jumps by nearly 15% during the financial crisis. Conversely, operating expenses for both domestic Australian and global subsidiary banks remains relatively stable. Finally, during the financial crisis, global branch banks reliance on short-term funding increases which either because market participants were unwilling to provide long-term funding to these banks or willing to do so at substantially higher cost (Acharya and Merrouche (2012) and Ashcraft, McAndrews, and Skeie (2011)).

Table 1 also reports the summary statistics for the year-on-year growth rate of loan commitments, a key measure of liquidity provided by a bank to its customers.[10] The average growth rate of loan commitments of global branch banks drops from 8.71% over the full sample to -2.45% during the financial crisis, a drop of nearly 125%. Thus, global branch banks cut back significantly on loan commitments and are either unable or unwilling to provide liquidity to their customers during the crisis. While the average growth rate of loan commitments also declines for global subsidiary banks, it does not turn negative. Conversely, average growth rate of loan commitments is always negative for domestic Australian banks, but actually increases (i.e., becomes less negative) during the financial crisis. The large drop in loan commitment growth rates for global branch banks during the financial crisis can again be a symptom of distress due to reliance on parent banks for funding.

The relative poor performance of global branch banks as compared to domestic Australian and global subsidiary banks is not due to any systematic differences in their investment strategies. Table A1 in

[10] A loan commitments allows the borrower to take the loan down on demand over a specified period of time. For this reason, Kashyap, Rajan, and Stein (2002) argue that loan commitments are an important indicator measure of how much liquidity banks provide to their customers.

Appendix A reports additional summary statistics for all three categories of banks. In particular, we report summary statistics for size (total book value of assets in Australian dollars or AUD), total loans, commercial and industrial loans, fixed assets, deposits, and securities for the cross-section of banks by type. In all cases, except for size, variables are normalized by total book value of assets.

Global subsidiary and branch banks are smaller than domestic Australian banks. The average book value of assets for a domestic Australian banks is AUD 34 billion, while it is AUD 13 and AUD 9 billion for global subsidiary and branch banks, respectively. The smaller size for global subsidiary and branch banks is expected given that they report data for assets and liabilities only pertaining to Australia. Note also that while they are smaller than domestic Australian banks, global subsidiary and branch banks are of similar size as compared to each other.

Regardless of size, all three categories of banks follow similar investment strategies. On average, traditional loans represent 60-70% of total assets, and commercial and industrial loans represent 15-18% of total assets for all three categories of banks. In addition, all banks hold 15-19% of total assets as liquid securities. Provisions for non-performing loans (normalized by total loans) is small and comparable across all three categories of banks. This ratio equals 0.66% for domestic Australian banks, and 0.71% and 0.07% for global subsidiary and branch banks, respectively. The lower provisions ratio for global branch banks during the financial crisis suggests that their relative poor performance cannot be on account of poor quality or riskier loans.

Independent studies by Australian regulators (Deans and Stewart (2012) and Debelle (2012)) confirm that domestic Australian and global subsidiary banks were not, but global branch banks are affected by liquidity shocks to global money markets, especially during the financial crisis. Overall, then our setting provides a quasi natural experiment, where the exposure to liquidity shocks in global money markets varies across Australian banks. We exploit this feature of the data to investigate how global banks transmit liquidity shocks across countries.

3 Data and summary statistics

In this section, we present details regarding our data sources. We also present summary statistics for transaction and holdings data for fixed income securities and describe how we measure liquidity shocks to global banks.

3.1 Bond market transaction and holdings

For our study, we require detailed data regarding bank fixed income holdings and transactions at the individual bank level. However, in Australia, as in most countries, fixed income securities trade primarily in over-the-counter markets. For example, sovereign debt, corporate bonds, and mortgage-backed securities all trade in over-the-counter markets. Because of the inherent decentralized nature of these markets, transactions and holdings data of market participants in these markets are difficult to observe. This is why empirical research on how financial institutions adjust their liquid securities portfolios (which mostly consists of fixed income securities) in response to liquidity shocks is limited.[11]

We were fortunate to be given access to an extensive proprietary dataset with fixed income securities transaction and holdings data for Australia by Austraclear, (henceforth ASX). ASX is the largest settlement and depository firm in Australia and is the primary custodian for all Australian dollar denominated debt issued in Australia. Data in ASX accounts for more than 95% of all fixed income transactions in Australia. More than 800 unique financial and nonfinancial firms, including banks, credit unions, mutual funds, government entities, insurance firms, and non-financial corporations, use the ASX system.[12]

Every day, for each transaction, ASX provides us with the trade date, the transaction price, the international securities identification number (ISIN code), and a numerical code for the buyer and seller. The ISIN code uniquely identifies the asset class, issuer, maturity date, issue date, face value, coupon rate, and coupon payment frequency for each security. Every quarter, ASX also provides us with a table that lists the numerical codes and the names for all registered ASX participants. These lists are easily cross-referenced with daily ASX data to identify the buyer and seller for each transaction.

We limit our analysis to only three categories of securities: bonds issued by the federal government of Australia (henceforth federal bonds), bonds issued by the state governments of Australia (henceforth municipal bonds), and short-term bonds issued by large financial and nonfinancial firms (henceforth money market bonds). On average, these three categories of securities account for more than 65% of transactions in ASX on any given day. The remaining transactions, pertaining to corporate bonds, foreign exchange instruments, and interest rate derivatives, do not exceed more than 35% of transactions.[13]

[11] A notable exception is Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018), who study capital commitment of dealers and liquidity in corporate bond markets in the U.S. using an enhanced database of corporate bond transactions.

[12] Further details regarding data and services provided by ASX is available at http://www.asx.com.au.

[13] The market for corporate bonds, foreign exchange instruments, and interest rate derivatives is small and illiquid with little trading activity. For example, in 2016, the total face value of all corporate bonds outstanding in Australia was USD $50 billion. As a benchmark, the total face value of all corporate bonds outstanding in the same year in the U.S. was USD 8 trillion.

We construct separate time series for the amount of federal, municipal, and money market bonds held by participants in ASX. *Holdings* equals the total face value of bonds of a particular category held by a participant at the end of each day. We do not measure holdings in terms of market price of bonds as such a measure is likely to be endogenous and can bias our estimates, especially if liquidity shocks induce fire sales of bonds, and such fire sales subsequently impact market prices.[14]

Table 2 presents the summary statistics for holdings. For each category of bonds, we normalize holdings by the total face value of all bonds of that category held by all participants in ASX. Further, we sort all participants in ASX into two groups and report summary statistics for holdings for the cross-section of banks (panel A) and nonfinancial firms (panel B). Table 2 presents summary statistics for the full sample as well as for the crisis years. In each panel, each row reports the summary statistics for a separate category of bonds.

Over the full sample, the average bank holds 0.43%, 1.85%, and 1.19% and the average nonfinancial firm holds 0.50%, 0.47%, and 0.14% of federal, municipal, and money market bonds. Thus, an average bank holds nearly 4 times as many municipal bonds and nearly nine times as many money market bonds than an average nonfinancial firm. However, an average nonfinancial firm's holding of federal bonds exceeds that of an average bank's by 16%. Collectively, all banks together hold between 35%-55% and all nonfinancial firms hold 45%-65% of all federal, municipal, and money market bonds on any given day. Thus, banks play a central role in bond markets in Australia.

Table 2 also reports the standard deviation, minimum, 25^{th}-percentile, median, 75^{th}-percentile, and maximum values of holdings. The dispersion of holdings across banks is large, with a standard deviation of nearly 0.59-2.31% across all categories of bonds. A bank at the 25^{th}-percentile level holds only 0.01%, 0.05%, and 0.02%, whereas a bank at the 75^{th}-percentile level holds nearly 0.47%, 3.85%, and 1.31% of federal, municipal, and money market bonds, respectively. The maximum value of federal, municipal, and money market bonds held by a bank is 2.25%, 7.73%, and 6.73%, respectively. The average first-order autocorrelations exceeds 0.60 in all cases indicating that holdings are somewhat persistent.[15]

The last nine columns of Table 2 reports summary statistics for the crisis years. During the crisis, an average bank holds 0.37%, 0.83%, and 1.27% and an average nonfinancial firm holds 0.65%, 0.80%,

[14]In Section 4 below we confirm that our results are robust to alternate measures of holding, including those computed using market price of bonds.

[15]The high first-order correlation does not imply inactive markets with little trading. Since, holdings are based on face value of bonds their values can be persistent even with banks actively trading bonds, if such trading leaves the total face value of bonds held of a particular category unchanged. Figures 2 and 3 below present summary statistics for trading activity in these markets.

and 0.17% of all federal, municipal, and money market bonds. That is, during the crisis an average nonfinancial firm's holdings of federal bonds exceeds that of an average bank's by nearly 76%, while an average bank's holding of municipal bonds exceeds that of an average nonfinancial firm's by 4%. During the crisis, an average bank hold nearly 6 times as many money market bonds than an average nonfinancial firm. Comparison to averages over the full sample indicates that an average bank's holdings of federal and municipal bonds declines by 14% and 123%, but that of money market bonds increases marginally by 6.72%. For an average nonfinancial firm, holdings of federal, municipal, and money market bonds increases by 30% and 70%, and 21%, respectively during the crisis period as compared to over the full sample. Thus, even the simple summary statistics presented in Table 2 indicate that the financial crisis adversely impacts banks' holdings of liquid fixed income securities.

Table 3 reports summary statistics for the cross-section of domestic Australian, global subsidiary, and global branch banks. An average domestic Australian banks hold 0.64%, 2.06%, and 1.89% of federal, municipal, and money market bonds, respectively. The corresponding holdings for an average global subsidiary banks are 0.63%, 0.97%, 1.36% and for global branch banks are 0.22%, 0.37%, and 0.52%. Thus, average bond holdings are of similar order of magnitudes for an average domestic Australian and global subsidiary bank, but somewhat smaller for an average global branch bank. However, the holdings of an average global branch bank are comparable or larger than that of an average nonfinancial firm. For instance, the average global branch bank holds nearly 0.37% and 0.52% of all municipal and money market bonds, respectively. This is comparable or larger than the 0.47% and 0.14% of all municipal and money market bonds held by an average nonfinancial firm. Thus, despite their smaller size of their holdings, fire sales by global banks can significantly impact market prices and can have spill-over effects on other market participants.

During the crisis an average domestic Australian banks holdings for federal and municipal bonds declines by 27% and 36%, respectively, but that for money market bonds increases marginally by 3%. Bond holdings of federal and municipal bonds also somewhat decline but those of money market bonds are relatively stable for an average global subsidiary bank. Conversely, bond holdings for an average global branch bank slightly increase across all categories of bonds. This, however, does not imply that global branch banks' holdings for liquid securities were unaffected by the financial crisis. Note that holdings across all categories of bonds for global branch banks are substantially more volatile during the crisis than over the full sample. In contrast, volatility of holdings either decreases or increases only marginally for both domestic Australian and global subsidiary banks.[16]

In Tables 2 and 3, the number of banks and nonfinancial firms is smaller during the financial crisis than over the full sample. This is because to be included in our sample a bank or a nonfinancial firm had to trade at least on 50% of the days during the sample period. The reduced number of banks and nonfinancial firms during the crisis years simply reflects the fact that some banks and nonfinancial firms that did not actively trade during this period and were excluded from our sample. The reduced number of banks and nonfinancial firms does not necessarily indicate that these entities exited our dataset due to financial distress or bankruptcy.

Figures 2 and 3 indicate the extent to which domestic Australian, global subsidiary, and global branch banks actively trade federal, municipal, and money market bonds. Figure 2 plots the histogram for the number of bond market transactions by bond and bank type. The first column plots data for federal bonds, and the remaining two columns plot data for municipal and money market bonds, respectively. Similarly, the first row plots data for domestic Australian banks, and the remaining two rows plot data for global subsidiary and branch banks, respectively. We sort the total number of days in our sample (1830) into 8 bins based on the number of transactions: days with less than 10, between 10–25, between 26–50, between 51–75, between 76–100, between 101–150, between 151–200, and more than 200 transactions. In each plot, bin values are indicated on the X-axis, and the bar height corresponds to the percentage of total days with a corresponding number of transactions. Thus, the top-left panel indicates that on 550 days (30% of our sample), domestic Australian banks traded federal bonds between 150–200 times. Similarly, the middle panel shows that on 428 days (25% of our sample), global subsidiary banks traded municipal bonds between 26–50 times.

The transaction volume (based on the face values of the traded bonds) in Australian bond markets is plotted in Figure 2. Here, we sort the total number of days in our sample into 8 bins by transaction volume: days with less than \$0.10 billion, between \$0.10–\$0.25 billion, between \$0.26–\$0.50 billion, between \$0.51–\$1.00 billion, between \$1.00–\$2.00, between \$2.00–\$5.00, between \$5.00–\$10.00, and more than \$10 billion in face value traded. Bar heights corresponds to the percentage of total days in our sample with a corresponding transaction volume. Thus, the top-left panel indicates that on 1,032 days (56% of our sample), total face value of federal bonds traded by domestic Australian banks was between \$5–\$10 billion. Similarly, the bottom-left panel shows that on 652 days (36% of our sample), total face value of

[16] The averages reported in Table 3 also do not differentiate between days when domestic Australian, global subsidiary, and global branch banks may or may not have experienced liquidity shocks, an analysis we turn to in the next Section.

money market bonds traded by global branch banks was between \$5–\$10 billion. Overall, these figures indicate that all categories of bonds are actively traded by all types of banks.

3.2 Data on liquidity shocks

We use two separate proxies to measure liquidity shocks to banks in Australia. Our first measure is the unexpected increase in the spread between the 3-month London interbank offer rate (Libor) and the 3-month overnight index swap (OIS) rate, which we label the Libor-OIS spread. The 3-month Libor is the average interest rate on an unsecured interbank loan for a period of three months. Although, Libor is computed for ten different currencies and fifteen maturities, we focus on the widely used 3-month Libor for loans denominated in U.S. Dollars.[17]

From the 3-month Libor, we subtract the 3-month OIS rate, which equals the rate on a fixed-for-floating interest rate swap where the floating payment is the effective (average) federal funds rate, compounded daily, for a period of 3-months. For example, if the 3-month OIS rate is 2 percent and the geometric average of the annualized effective federal funds rate for a 3-month period is 1.91 percent, the net cash inflow on an 3-month OIS with a national amount of \$10 million equals \$2,250 ($(0.0200 - 0.0191) \times 3/12 \times \$10 million$). As with all swaps, there is no exchange of notional values and only the net amount is paid at the maturity of the swap. Thus, OIS contracts have little to no credit risk exposure.

Our second measure of liquidity shocks to banks in Australia is the unexpected increase in the spread between the 3-month Australian Bank Bill Rate (BAB) and the 3-month OIS rate, which we label the BAB-OIS spread. The BAB rate is the mid-rate on short-term debt securities such as, negotiable certificates of deposits, bank accepted bills, with outstanding maturities of one to six months issued by Australian banks. It is considered to be the wholesale interbank rate for Australia and reflects the quantity and price of liquidity in Australian money markets. The BAB rate is computed daily by the Australian Financial Markets Association. One critical difference between Libor and BAB is that, unlike Libor, BAB does not

[17] Till 2014, Libor was computed daily by the British Bankers' Association (BBA) in London. Following allegations of Libor manipulation, the Intercontinental Exchange (ICE) took over the administration of Libor in February 2014, and the computation methodology for Libor was also modified. This change in administrator and computation methodology does not affect our results as it does not occur till after the end of our sample period (January 2014). However, during our sample, Libor manipulation can bias our estimate for the effect of liquidity shocks on banks downward. To see this, consider the fact that one way in which banks manipulated Libor was by reporting lower than actual interbank borrowing rates. If Libor, which is the average of these reported interbank borrowing rates, underestimates the true cost of liquidity in interbank markets, it can bias our measure of a liquidity shock to banks downward. See Gandhi, Golez, Jackwerth, and Plazzi (2019) for detailed discussion regarding the motivation for Libor manipulation and the resulting changes in Libor administration and computation.

rely on survey data but is based on prices for actual transactions.[18]

Data for Libor-OIS and BAB-OIS spread are collected daily over our entire sample from September 2006 to January 2014. Table 4 reports the summary statistics (in basis points) for the Libor-OIS and BAB-OIS spreads over the whole sample as well as over the crisis years. Over the full sample, the mean and standard deviation of the Libor-OIS spread is 37.43 and 45.07 basis points, respectively. During the financial crisis, the average Libor-OIS spread is significantly higher (68.29 basis points) and it is also more volatile (64.16 basis points). In contrast, the full sample mean and standard deviation of the BAB-OIS spread is just 14.96 and 11.98 basis points, respectively. While the mean for the BAB-OIS spread also increases and it too becomes more volatile during the financial crisis, the magnitude of the increase are smaller in comparison to that of the Libor-OIS spread. For example, during the financial crisis, the mean BAB-OIS spread increases by just 30%, from 14.96 to 20.20 basis points, while the mean Libor-OIS spread nearly doubles from 37.43 to 64.16 basis points. Similarly, the BAB-OIS spread reaches a maximum of 65.50 basis points, while the Libor-OIS spread peaks at nearly 365 basis points during the financial crisis. Thus, while the financial crisis impacts liquidity in both global and Australian money markets, the magnitude of its affect is muted for Australian money markets.

We interpret an unexpected increase in the Libor-OIS spread as a shock to the price and quantity of liquidity available to global branch banks and an unexpected increase in the BAB-OIS spread as a shock to the price and quantity of liquidity available to domestic Australian and global subsidiary banks. The unexpected change in either spread equals the daily value of the spread less its moving average computed over a period of one month. Since both daily Libor-OIS and BAB-OIS are persistent (with a first-order autocorrelation of 0.99), the spreads less their respective 1-month moving averages provides a good approximation for the changes in the spreads that are not anticipated by banks.

Our intuition for liquidity shocks is as follows: The global money or interbank market, whose state the Libor-OIS spread references, serves as the private lender-of-last-resort for short-term liquidity needs for many global banks.[19] Conventional wisdom suggests that an unexpected liquidity shock in this market can impair the liquidity of global banks, and in turn their international branches in Australia that depend on the parent global banks for funding. An unexpected increase in the Libor-OIS spread does not affect

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[18]Since February 2014, Libor is based in-part on prices for actual transactions in the interbank market in London. See Duffie and Stein (2015) for further details regarding changes in Libor administration and computation.

[19]Gorton and Metrick (2012) find that a high Libor-OIS spread serves as a liquidity shock to global U.S. banks. Similarly, Acharya and Merrouche (2012) show that an increase in the Libor-OIS spread adverse affects liquidity available to global U.K. banks. Further, Acharya and Skeie (2011) argue that an increase in the Libor-OIS spread indicates heightened solvency and liquidity risk for global banks.

domestic Australian or global subsidiary banks because these banks are primarily funded from domestic sources.[20] Conversely, global branch banks are impervious to an unexpected increase in the BAB-OIS spread, which adversely affects liquidity of only domestic Australian and global subsidiary banks.

In other words, an unexpected increase in the Libor-OIS spread helps us identify liquidity shocks to global branch banks, and an unexpected increase in the BAB-OIS spread helps us identify liquidity shocks to domestic Australian and global subsidiary banks. Throughout the rest of the paper, we refer to an unexpected increase in the Libor-OIS spread as 'global liquidity shock' and an unexpected increase in the BAB-OIS rate as a 'domestic liquidity shock'.

Our identification strategy works best when global and domestic liquidity shocks are imperfectly correlated. Figure 4 plots the Libor-OIS and BAB-OIS spreads. The two spread react differently to the financial crisis. For example, while the Libor-OIS spread increases sharply in September 2008, in the aftermath of the Lehman bankruptcy, the BAB-OIS spread remains remarkably lower and increases only marginally. The full sample correlation between unexpected changes in the Libor-OIS and BBA-OIS spread is just 25%. During the crisis the correlation between these spreads is just 21%.

Having described our data sources and presented summary statistics, we now turn to the main analysis in this paper and examine the relation between global liquidity shocks, domestic liquidity shocks, and bond holdings of banks in Australia.

4 Results

In this section, we first examine how global and domestic liquidity shocks affect bond holdings of domestic Australian, global subsidiary, and global branch banks. We then extend our analysis along several dimensions, discuss potential alternative channels, and present results for further robustness tests.

[20] Henry et al. (2011) show that prior to and during the financial crisis, large Australian banks relied on global money markets for at most 5% of their total funding. Small Australian banks' reliance on global money markets is almost negligible. Domestic deposits and money markets account for nearly 60% of funding for domestic Australian and global subsidiary banks.

4.1 Do global liquidity shocks induce fire sales by global banks in Australia?

To estimate how liquidity shocks affect bond holdings of global banks in Australia, we estimate a panel regression of the following form:

$$\begin{aligned} \log(H_{i,j,t}) - \log(\mu[H_{i,j,t} \mid \Omega_t]) &= \alpha + \beta_L(Libor - OIS)_t + \beta_S GS \times (Libor - OIS)_t \\ &+ \beta_B GB \times (Libor - OIS)_t + Controls + BFE + TFE + \epsilon_{i,j,t} \end{aligned} \quad (1)$$

Here, $H_{i,j,t}$ is the actual face value and $\mu[H_{i,j,t} \mid \Omega_t]$ is the expected face value of bonds of category j held by bank i on day t. The expected face value of bonds held is conditional on the information set Ω_t, and is estimated using a 1-month lagged moving average. That is:

$$\mu[H_{i,j,t} \mid \Omega_t] = \frac{1}{30} \sum_{k=t-31}^{k=t-1} H_{i,j,k} \quad (2)$$

To estimate how global and domestic liquidity shocks differentially affect bond holdings of domestic Australian, global subsidiary, and global branch banks, we use two dummy variables, GS and GB, that take the value 1 if bank i is a global subsidiary or global branch bank, respectively and are zero otherwise. Thus, equation (1) measures the change in holdings of global subsidiary and branch banks, relative to change in holdings of domestic Australian banks in response to global and domestic liquidity shocks. The coefficients of primary interest are β_S and β_B. If global branch banks divest their holdings of liquidity securities in response to a global liquidity shock, we expect the coefficient β_B to be negative and statistically significant.

We estimate equation (1) separately for each category of bond, i.e., federal, municipal, and money market bonds. In all cases we control for total issuance ($Issuance$) and total holdings of nonfinancial firms ($Nonfin$). $Issuance$ is the total face value of bonds outstanding on any given day and proxies for the total supply of bonds of a particular category. $Nonfin$ is the total face value of bonds held by all nonfinancial firms and proxies for the total demand for the bonds of a particular category. We also control for $Maturity$ which is the total face value of bonds across all categories held by bank i maturing on day t. This variable proxies for the total 'natural' demand of securities by bank i on day t arising from a roll-over in its securities holdings. Since global liquidity shocks can coincide with domestic liquidity shocks, each regression also includes the unexpected change in the BAB-OIS spread as a control variable. Finally, all regressions include bank and time fixed effects, and report t-statistics based on standard errors clustered at the bank level.

Table 5 presents the estimates for the panel regression in equation (1). Each column presents the results for a separate category of bonds. Columns (1)–(3) present results for the full sample, while columns (4)–(6) and (7)–(9) present results for the crisis and post-crisis period, respectively. Over the full sample, the coefficient for global branch banks ($GB \times (Libor - OIS)$) is always negative and statistically significant at the 1% level for all category of bonds, indicating that an unexpected increase in the Libor-OIS spread, i.e., a shock to global money and interbank market, induces global branch banks to divest their bond holdings.

The coefficient for global subsidiary banks ($GS \times (Libor - OIS)$) while also negative is almost never statistically significant. In addition, the magnitude of the coefficients for global branch banks is significantly smaller than the corresponding coefficients for global branch banks. For example, in column (1), which presents the results for federal bonds, the coefficient for global subsidiary banks (-0.13) is less than half the coefficient for global branch banks (-0.30). Similarly, in column (3), which presents the estimates for municipal bonds, the coefficient for global branch banks (-0.11) is nearly three times larger than the one for global subsidiary banks (-0.03). Thus, global liquidity shocks have a considerably larger impact on bond holdings of global branch banks than on holdings of global subsidiary banks, and the results for the latter are not statistically significant.

In table 5, the coefficient on Libor-OIS itself measures the response of domestic Australian banks to global liquidity shocks. For federal and municipal bonds, the coefficient is positive although (not statistically significant). The positive coefficient suggests that domestic Australian banks do not liquidate and in fact increase their holdings of federal and municipal bonds in response to global liquidity shocks. The coefficient on Libor-OIS is negative and statistically significant only for money market bonds (-0.05 in Column (3), t statistic of -3.69) indicating that domestic Australian banks reduce holdings of money market bonds in response to global liquidity shocks. Such divestment of money market bonds by domestic Australian banks may not be a scramble for liquidity but may represent a flight to quality. Money market bonds include short-term bonds issued by some global banks in Australia and it is entirely rational for domestic Australian banks to sell money market bonds and replace them with higher quality federal and municipal bonds issues by sovereign entities in Australia following global liquidity shocks. Since ASX provides us with issuer, buyer, and seller identities, we can confirm that sales of money market bonds by domestic Australian banks on days when Libor-OIS spread unexpectedly increases relate to money market bonds issued by global banks. [21]

It is important to provide some sense of the economic significance of the coefficients in table 5. For federal bonds, the marginal effect of the coefficient on $GB \times (Libor - OIS)$ is -0.30, while the standard deviation of the Libor-OIS spread is 0.45. Thus, a one standard deviation increase in the Libor-OIS spread is associated with a 7.72% (-0.30 $\times$ 0.45 divide by the mean of the log holdings) reduction in the face value of federal bonds held by global branch banks. Similarly, a one standard deviation increase in the Libor-OIS spread is associated with a 18.81% reduction in face of municipal bonds and a 6.76% reduction in face value of money market bonds by global branch banks.

We can also assess the significance of the fire sale by comparing the volume of bonds sold by a global branch bank following a global liquidity shocks to the typical daily turnover in its bond portfolios. Over our entire sample, the average daily turnover (i.e., the face value of bonds bought or sold normalized by the face value of bond held by a bank) for an average global branch bank is 0.50%, 0.13% and 1.54% for federal, municipal, and money market bonds, respectively. That is, on a typical day, an average global branch bank trades just 0.50%, 0.13%, and 1.54% of face value of federal, municipal, and money market bonds held by it. Following a global liquidity shock, the face value of federal bonds sold by a typical global branch banks is 11 times higher than its average daily turnover. For municipal bonds the face value of bonds sold is 21 times higher than its average daily turnover. The higher sale volume of relatively safe and liquid federal and municipal bonds is consistent with global branch banks scrambling for liquidity by selling high quality liquid securities following a global liquidity shock. The volume of money market bonds sold by an average global branch bank is just 25% higher on days with a global liquidity shock as compared to its average daily turnover. However, this is not surprising as money market bonds are mostly issued by private entities, and are likely to suffer a larger price drop in the event of a fire sale due to information asymmetry. Hence, they are likely to be sold by liquidity constrained investors in a fire sale, only as a last resort, and only if such investors are close to financial distress.

To gain further insight into the transmission of global liquidity shocks by global banks, we re-estimate the baseline regression in equation (1) using data for just the credit crisis of 2006–2009. Columns (4)–(6)

[21] Another reason why domestic Australian banks may want to sell money market bonds is to generate funds that they can subsequently allocate to buy federal and municipal bonds sold in fire sales by global branch banks in response to global liquidity shocks. Shleifer and Vishny (2010), Diamond and Rajan (2011), and Stein (2013) discuss how banks may direct capital to profit from trading opportunities generated by fire sales in times of financial distress.

of table 5 present the estimates for the panel regression in equation (1) for the crisis period, and columns (7)–(9), present the results for the post-crisis period. The dates for the start and end of the global financial crisis are September 2006 and June 2009, respectively. These dates align with accounts of the global financial crisis in other academic studies, such as Stulz (2010), Fahlenbrach and Stulz (2011), and Duchin, Ozbas, and Sensoy (2010).[22]

While the coefficient on $GB \times (Libor - OIS)$ is negative both during the crisis and the post-crisis periods, it is statistically significant at conventional levels only during the crisis years. In columns (4)–(6), the magnitude of the coefficient on $GB \times (Libor - OIS)$ for all category of bonds nearly equals that over the full sample. In terms of economic significance, a one standard deviation increase in the Libor-OIS spread is associated with a 7.46%, 11.58%, and 6.76% reduction in the holdings of federal, municipal, and money market bonds of global branch banks, respectively. These results suggest that bond holdings of global branch banks are most sensitive to global liquidity shocks during known periods of distress for their parent banks, and when their parent banks are likely to be liquidity constrained. Acharya, Afonso, and Kovner (2016) show that during the crisis, market participants fearing that values of asset-backed securities held by global banks were far less than anticipated, either became reluctant to lend money to global banks or agreed to lend to these banks at only exceptionally high rates. This lack of funding put a severe stress on global banks, and our evidence shows that these stresses were transmitted to branches of global banks dependent on their parents for funding.

Note that in columns (4)–(6), the coefficient for global subsidiary banks (i.e., $GS \times (Libor - OIS)$ is not statistically significant for the crisis years, indicating that shocks to global money and interbank markets did not have a significant impact on bond holdings of independently capitalized subsidiaries of global banks even during times of severe financial distress for global banks. Further, as is the case for the full-sample, the coefficient on Libor-OIS is not statistically significant in most cases, indicating global liquidity shocks do not affect domestic Australian banks. Finally, as is the case for the full sample, the only control variable that enters with a statistically significant coefficient is $Maturity$.

[22] Unfortunately, data limitations prevent us from analyzing the pre-crisis period. The data provided by ASX begins only in September 2006. By this time events leading up the global financial crisis had already begun to take shape. In May 2006, American Insurance Group (AIG) had already stopped selling credit protection against asset-backed collateralized debt obligations and by June of that year, Ameriquest, the largest sub-prime mortgage lender in the U.S. had closed most if its operations and laid-off nearly all its employees.

4.2 Do the results vary with bank or bond characteristics?

The impact of global liquidity shocks should be arguably stronger on global branch banks that are already financially constrained. To check if the coefficient on $GB \times (Libor - OIS)$ in equation (1) varies systematically with bank characteristics, we interact this variable with a dummy that captures the size and liquidity of global branch banks. We expect that larger branches with more liquid balance sheets to be less responsive to shocks to global money markets. Panel A of Table 6 presents the results.

We measure size by the total book value of assets and liquidity by the ratio of total liquid assets (including cash) to total book value of assets. Data for total book value of assets and total liquid assets is available from Australian Prudential Regulatory Authority (APRA) at a monthly frequency. In each month, we double-sort global branch banks by size and liquidity. In any month, a global branch bank is said to be big if its total book value of assets ranks in the top 5 of all branch banks in that month. Similarly, a global branch bank is defined to have high liquidity if the ratio of its liquid assets to total book value of assets ranks in the top 5 of all branch banks in that month. Based on these rankings, we define four dummy variables: Dummy variables $D_{B,H}$ and $D_{B,L}$ take the values 1 if a global branch bank is big and has high and low liquidity at time t, respectively. Similarly, dummy variable $D_{S,H}$ and $D_{S,L}$ take the values 1 if a global branch bank is small and has high and low liquidity at time t, respectively.

Panel A of table 6 shows that the adverse impact of global liquidity shocks is more significant for global branch banks that are either small or are already liquidity constrained. An unexpected increase in the Libor-OIS spread causes small global branch banks to reduce their bond holdings, regardless of their balance sheet liquidity. Over the full sample, the coefficients for small global branch banks with high liquidity are -0.28, -0.22, and -0.14 for federal, municipal, and money market bonds implying that a one standard deviation increase in the Libor-OIS spread causes these banks to reduce their holdings of federal, municipal, and money market bonds by 7.21%, 15.92%, and 8.61% percent, respectively. All of the coefficients are statistically significant at the 1% level. The coefficients for small global branch banks with low liquidity are also always negative (-0.44%, -0.03%, and -0.03%) implying these global branch banks reduce their holdings of federal, municipal, and money market bonds by 11.32%, 2.17%, and an 1.84%, respectively. Surprisingly, none of the coefficients for small global branch banks with low liquidity are statistically significant. This may be due to the fact that by definition these banks lack sufficient balance sheet liquidity and may not have a stockpile of liquid securities that they can sell in response to global liquidity shocks.

An unexpected increase in the Libor-OIS spread also forces big global branch banks with low liquidity to reduce their holdings for all categories of bonds. For these banks the coefficients are -0.60, -1.28, -0.10, implying that a one standard deviation increase in the Libor-OIS spread forces these banks to reduce their holdings of federal, municipal, and money market bonds by 15.44%, 92.60%, and 6.15%, respectively. Conversely, the coefficient on $GB \times (Libor - OIS)$ is positive and marginally statistically significant for big, high liquidity global branch banks, suggesting that these banks, along with other entities may be stepping-in to profit from a trading opportunities, and purchasing bonds sold in a fire sale. Finally, as in Table 5, columns (4)–(9) indicate that the effects are entirely driven by the crisis period. In all specifications, the magnitude of the estimates computed over the crisis period are comparable to those computed over the full sample, and the coefficients are also statistically significant at the 10% level or better. The results for the post-crisis period (Columns (7)–(9)) are for the most part not statistically significant.

A natural question that arises is if the geographical location of the parent bank matters for our results. Several studies (Guidara, Soumaré, Tchana et al. (2013), Beltratti and Stulz (2012), and Erkens, Hung, and Matos (2012)) suggest that the global financial crisis that engulfed banking systems in the U.S. and Europe did not have a significant impact on banks in Canada and Asia. For example, Bordo et al. (2015) argue that the financial crisis that caused bank failures, government bank bailouts, and the worst recession in the U.S. and Europe since the 1930s largely bypassed Canada. Canada did not suffer major bank failures or large scale government bailouts of banks during the period identified as the Great Recession. Although, on account of its close proximity and dependence on the US economy, Canada did suffer a recession during this period, the severity of this recession was far less than the contemporaneous recession in the U.S. or the Canadian recession of the 1980s and the 1990s.

In panel B of Table 6 we interact $GB \times (Libor - OIS)$ with a dummy variable that depends on the geographical location of the parent bank of the global branch bank. The dummy variable D_{US} takes the value 1 if the parent bank's headquarters is located in the U.S. and is zero otherwise. Similarly, the dummy variables, D_{EU}, D_{CA}, and D_{AS} take the values 1 if the parent banks' headquarters are located in the European Union, Canada, or Asia, respectively, and are zero otherwise. The impact of a global liquidity shock is more severe for global branch banks with headquarters in U.S. or Europe. For global branch banks with headquarters in Canada or Asia, the effect is hardly detectable and is at best marginally significant. The coefficients for global branch banks with headquarters in Europe (-0.53, -0.24, and -0.10) imply that a one standard deviation increase in the Libor-OIS spread leads to a 13.64%, 17.36%, and 6.15% reduction in holdings of federal, municipal, and money market bonds, respectively. Such shocks also causes global branch banks with headquarters in the U.S. to reduce their municipal and money market bonds by 10.85% and 9.22%, respectively. However, global liquidity shocks do not affect holdings of federal bonds by branches of U.S. global banks. The coefficient on $GB \times (Libor - OIS) \times D_{US}$ (column (4)) is positive and not statistically significant.

Finally, we note that in all cases the coefficients for banks with headquarters in Canada or Asia are mostly small and statistically insignificant. For global branch banks headquartered in Canada, none of the coefficient are statistically significant. Similarly, global liquidity shocks cause global branch banks headquartered in Asia to reduce holdings of federal and municipal bonds but not of money market bonds. For Asian banks, the coefficient for federal and municipal bonds is -0.30 and -0.14 with t-statistics of -2.71 and -1.76, respectively. Columns (4)–(9) again confirm that as in all other specifications these results are again largely driven by data for the crisis period.

The stronger results for global branch banks with headquarters in Europe in Table 6 are consistent with evidence in He, Khang, and Krishnamurthy (2008), Ashcraft, Bech, and Frame (2010), and Cetorelli and Goldberg (2012). These papers document that during the credit crisis, global banks headquartered in the U.S. facing liquidity shocks were able to tap into alternative funding sources such as the deposit market, through time deposits and in the form of advances from Federal Home Loan Banks (FHLBs). Conversely, foreign global banks, especially those in Europe, scrambled for liquidity, had limited access to deposit and government funding sources, and instead relied mainly on the relatively more fragile money and interbank markets for funding. Thus, facing a liquidity shock, global banks headquartered in Europe were more likely to activate internal capital markets, shuffling funds in and out of global locations based on relative needs.

Finally, Table 7 investigates if the sales by `Global Branch` banks in response to global liquidity shocks was restricted to particular kinds of bonds. On each day, we separately sort all bonds of a particular category into three bins by time and yield to maturity. Bonds in the top 30% measured by time-to-maturity are classified as long-term bonds, and those in the bottom 30% are classified as short-term bonds. Similarly, bonds in the top 30% by yield-to-maturity are classified as high yield bonds, and those in the bottom 30% are classified as low yield bonds. Dummy variable D_{Long} equals 1 for bonds with long terms-to-maturity and dummy variable D_{High} equals 1 for bonds with high yields-to-maturity. In addition, we define a dummy variable, D_{AAA} that equals 1 for bonds with a AAA credit rating and is zero otherwise. Since federal and municipal bonds are both issued by sovereign entities, the credit rating dummy is applicable only for money market bonds issued by private entities.

The estimates in Table 7 indicate that during the global financial crisis, an unexpected increase in the Libor-OIS spread caused global branch banks to sell bonds regardless of their time-to-maturity, yield-to-maturity, or credit rating. In panel A, the coefficient on $GB \times (Libor - OIS)$ is negative for both long- and short-term bonds and most of the coefficients are statistically significant at the 10% level or better. In panel B, the coefficient on $GB \times (Libor - OIS)$ is negative for bonds with both high and low yields-to-maturity, even though the results are not always statistically significant. However, during the crisis period (columns (4)–(6)), the coefficient on $GB \times (Libor - OIS) \times D_{Low}$ is negative and statistically significant, indicating that in times of financial distress global branch banks sell high value bonds (i.e., those with low yields to maturity). Finally, panel C of this Table indicates that global branch banks do not take a bond's credit rating into account when choosing which bonds to sell during the crisis period. Such indiscriminate selling is exactly what one would expect if the bond sales was a scramble for liquidity. These results also suggest that holdings divestment by global branch banks in response to global liquidity shocks is indeed a flight for liquidity and does not reflect proprietary trading based on information.

Table A2 in appendix B shows that holdings divesture global branch banks in response to global liquidity shocks also does not represent a flight to quality. In this table, the dependent variable is the ratio of holdings of federal and money market bonds of a particular bank i at time t. If global branch banks respond to global liquidity shocks by re-balancing their portfolio towards less risky, sovereign securities, we should observe that the ratio of federal to money market bonds held by these banks should increase. That is, a flight to quality implies that the coefficient on $GB \times (Libor - OIS)$ should be positive and statistically significant in table A2. However, the results indicate that during the crisis, the coefficient on $GB \times (Libor - OIS)$ is negative and not statistically significant, suggesting bond divestments by global branch banks represents a true scramble for liquidity and not merely a flight to quality. The estimates in column (2) indicate that during the post-crisis period there is some evidence for global branch banks responding to global liquidity shocks by re-balancing their portfolios towards safer, less riskier bonds. In the post-crisis period, the coefficient on $GB \times (Libor - OIS)$ is positive and statistically significant at the 5% level. Overall, the results so far indicate that global liquidity shocks do not affect holdings of liquid securities for domestic Australian or global subsidiary banks, but do so for global branch banks.

4.3 Do global banks respond to domestic liquidity shocks?

To eliminate the concern that our results are spurious we conduct a placebo test in which we replace unexpected changes in the Libor-OIS spread by unexpected changes in the BAB-OIS spread. That is, we check if domestic liquidity shocks affect bond holdings of global branch banks (which do not depend on domestic money markets for funding) and domestic Australian banks and global subsidiary banks (which do depend on domestic money markets for funding). If we observe that global branch banks react to domestic liquidity shocks then this may suggest that alternative or competing economic channels (such as informed trading, a flight to quality, search for yield, etc.) rather than a scramble for liquidity explains our results documented in the previous sections.[23]

Table 8 reports the results for the placebo test. - To estimate how domestic liquidity shocks differentially affect bond holdings of domestic Australian, global subsidiary, and global branch banks, we now interact the two dummy variables, GS and GB, with the unexpected changes in the BAB-OIS spread. If global branch banks are not affected by domestic liquidity shocks the coefficient on $GB \times (BAB - OIS)$ should be statistically insignificant. Conversely, we expect the coefficients on BAB-OIS and $GS \times (BAB - OIS)$ to be negative and statistically significant, indicating that domestic Australian banks and global subsidiary banks respond to domestic liquidity shocks.

The results in Table 8 provide compelling support for our story. Over the entire sample, the coefficients for global branch banks ($GB \times (BAB - OIS)$) is never statistically significant. At times the coefficient is even positive, suggesting that global branch banks increase their bond holdings in response to domestic liquidity shocks. The coefficient for global subsidiary banks ($GS \times (BAB - OIS)$) is always negative, suggesting these banks reduce their bond holdings in response to domestic liquidity shocks. In terms of economic significance, a one standard deviation increase in the BAB-OIS spread is associated with an 4.18%, 1.16%, and 3.44% reduction in holdings of federal, municipal, and money market bonds by global subsidiary banks. Note that while the coefficient is always negative it is only statistically significant for money market bonds (t-statistic of -2.67 over the full sample). Surprisingly, the coefficient for domestic

[23]See Balduzzi, Elton, and Green (2001), Beber, Brandt, and Kavajecz (2008), Becker and Ivashina (2015), among others for an explanation of these competing, alternative economic channels. Balduzzi, Elton, and Green (2001) study informed trading in bond markets in response to economic news and announcements. Beber, Brandt, and Kavajecz (2008) investigates how bond investors rebalance their portfolios towards less risky, more liquid securities (i.e., a flight to quality) in times of economic distress. Finally, Becker and Ivashina (2015) document how portfolio decisions of large institutional investors may be driven by a 'search for yield' which they define as a propensity to invest in riskier bonds to generate higher returns.

Australian banks is not statistically significant for any specification and is at times is even positive. This suggests that even domestic Australian banks collectively increase bond holdings in response to liquidity shocks to domestic money markets. However, this is consistent with studies conducted by the reserve bank of Australia that show that domestic Australian banks rely on deposits and long-term loans for a majority of their funding, and rarely tap the wholesale, short-term, interbank market for liquidity.[24]

4.4 Who purchases bonds sold in fire sales?

The fire sale of liquid securities by global branch banks in response to global liquidity shocks naturally creates a unique trading opportunity for well-capitalized buyers not subject to these shocks. Typical studies on asset fire sales and purchases (See, for example Coval and Stafford (2007), Ellul, Jotikasthira, and Lundblad (2011), and Jotikasthira, Lundblad, and Ramadorai (2012b)), find it difficult to identify who exactly buys securities sold in a fire sales. However, our unique data set, which identifies buyers and sellers by name, allows us to shed light on this question.

Table 9 provide information on exactly who buys securities sold in a fire sale by global branch banks. To construct this table, we first identify days when global money and interbank markets experience a liquidity shock. In panel A, these are defined as days when the Libor-OIS spread is above the 99^{th}-percentile, computed over a 1-month rolling window. In panel B, these are defined as days when the Libor-OIS spread is above its 95^{th}–percentile (again, computed over a 1-month rolling window). As a benchmark, panel C reports data for days when the Libor-OIS spread approximately equals (i.e., is within $+/-10\%$ from) its median value.

Next, on each day identified above we determine the counterparty (i.e., the buyer) for each transaction where the seller is a global branch bank. We classify the counterparties into five categories: domestic Australian banks, global subsidiary bank, global branch banks other than the seller, the Reserve bank of Australia (i.e., the central bank of Australia), or a nonfinancial firms. We then count the number of transactions and the total face value of bonds bought by all counterparties of a particular category from a global branch bank. We normalize these by the total number of sales transactions and total face value of bonds sold by all global branch banks branches on that day, respectively. That is, we compute the percentage of transactions and percentage face value of bonds bought by domestic Australian banks,

[24]See for example the analysis of bank funding sources conducted by the Reserve Bank of Australia in 2012, and available at `https://www.rba.gov.au/speeches/2012/sp-ag-220312.html`. The report states that deposits and long-term loans account for more than 70% for an average domestic bank in Australia, prior to and during the financial crisis.

global subsidiary banks, global branch banks other than the seller, the central bank, and nonfinancial firms from global branch banks on each day with a global liquidity shock. We repeat this process for all identified days and report the mean proportion of transactions and the verage value of bonds bought by all counterparties of a particular category. Each row in each panel reports data for a separate category of bonds.

Panel A indicates that when the Libor-OIS spread is above its 99^{th}-percentile domestic banks or nonfinancial firms in Australia are most likely to buy bonds sold by a global branch bank. For federal bonds (first row, panel A) domestic Australian banks and nonfinancial firms are buyers in approximately 84% of the sales transactions by global branch banks. In the remaining 16% of cases, the buyer is either a global subsidiary banks, another global branch bank, or the central bank of Australia. Collectively, domestic Australian banks and nonfinancial firms purchase 77% of face value of federal bonds sold by global branch banks on days when the Libor-OIS spread is above its 99^{th}-percentile. The second and third rows of panel A shows that these conclusions also hold for municipal and money market bonds. Domestic Australian banks and nonfinancial firms act as buyers in 78% of transactions, purchasing 68% of face value of municipal bonds sold by global branch banks. These entities also act as buyers in 84% of transactions purchasing 82% of money market bonds sold by global branch banks. Using data for days when the Libor-OIS spread exceeds the 95^{th}-percentile hardly impacts these conclusions. In panel B, across all three categories of bonds, domestic Australian and nonfinancial firms collectively are buyers in 80-84% of the transactions, purchasing 73-81% of the face value of bonds sold by branches.

As a benchmark, panel C reports counterparty activity on days when the Libor-OIS spread trades at close to its median value (i.e., a typical trading day). Here, again domestic Australian banks and nonfinancial firms are the primary buyers in a majority of cases (i.e., 77-84% of all sales transactions by global branch banks). These banks purchase 71-82% of the face value of bonds sold by branches.

At first sight, these results may suggest that trading activity on days with or without liquidity shock days is similar. That is, no matter what the level of the Libor-OIS spread, domestic banks and non banks act as buyers in 80% of the cases and purchase 70-80% of the face value of bonds sold by branches. However, recall that global branch banks are selling a substantially higher number of bonds on days when the Libor-OIS spread is high. Table 5 documents that a one-standard deviation increase in the Libor-OIS spread increases the sales volume for global branch banks by 11-21 times. Thus, if domestic banks and nonfinancial firms purchase the same percentage of bonds sold by global branch banks, the purchase volume is 11-21 times higher on days with a global liquidity shock.

More importantly, Table 9 also sheds light on the actions the central bank of Australia (the RBA) takes to support bond markets on days with global liquidity shocks. When the Libor-OIS spread trades at close to its median value (panel C), the RBA acts as a counterparty in only 1-3% of transactions, purchasing only 2-7% of the face value of bonds sold by global branch banks on these days. Conversely, on days when the Libor-OIS spread is above the 99^{th}-percentile (panel A), the RBA acts as a counterparty in nearly double the number of transactions, purchasing nearly 2-10% of the face value of bonds sold. Thus, the central banks steps-in to purchase bonds sold by global branch banks to perhaps mitigate the price impact of fire sales.

The results in Table 9 are consistent with the empirical analysis in Abbassi, Iyer, Peydró, and Tous (2016), and the theoretical models in Diamond and Rajan (2011) and Stein (2013). These papers suggest that during a crisis, healthy banks (such as, domestic Australian banks) may allocate funds to buy securities sold in fire sales by weak banks (such as, global branch banks) to profit from trading opportunities. Allocating capital to securities trading, can create spill over effects and negative externalities, for example, by lowering the amount of capital available for making loans, and reducing credit supply. This is a question we turn to next.

4.5 Do fire sales affect credit supply?

To examine the lending behavior of banks, we exploit the monthly balance sheet and income statement data at the bank level released by the Australian Prudential Regulatory Authority (APRA). Specifically, we estimate a panel regression of the following form:

$$Credit_{i,t}/Assets_{i,t} = \alpha + \beta_D(D^{Buyer})_{i,t} + Controls + BFE + TFE + \epsilon_{i,j,t} \tag{3}$$

Here, $Credit_t/Assets_t$ is the ratio of book value of loans to book value of assets held by bank i in month t. $D_{i,t}$ is a dummy variable that equals 1 if bank i purchases bonds sold in fire sales by global branch banks in month t and is zero otherwise. Controls include the ratio of book value of liquid assets to book value of total assets and the ratio of book value of deposits to book value of total assets. If banks' purchase of securities sold in fire sales by global branch banks reduces their credit supply, we expect the coefficient on D^{Buyer} to be negative. Table 10 reports the estimates for the panel regression in Equation 3.

An important identification concern is that the demand for bank credit and borrower risk profile may vary over time and affect the left hand side in Equation (3). Ideally, one would like to control for borrower characteristics and include proxies for time-varying credit demand. Unfortunately, loan level information with borrower identities and characteristics are not available to us. Therefore, for identification, we rely on the assumption that demand for credit is not perfectly correlated across different categories of customers. That is, we analyze the credit supplied by banks that do or do not participate in fire sales for all customers including households (Panel A), nonfinancial corporate borrowers (Panel B), and financial firms (Panel C).

In Table 10, the coefficient on D^{Buyer} is negative and statistically significant in all specifications and for all categories of loans. The fact that the credit to asset ratio falls for all categories of loans (i.e., households, nonfinancial corporations, and financial firms) is consistent with the drop in credit being driven by variation in credit supply. To interpret the magnitude of the coefficient, the credit to assets ratio is 2-5% lower for total loans, and 1-5% lower for loans to nonfinancial and financial firms, in months in which they participate and purchase bonds sold in fire sales by global branch banks, as compared to months in which the same banks do not participate in fire sales.

All in all, the results in Table 10 suggest that fire sale of securities due to global liquidity shocks has important spill over and macro effects for the domestic economy. These results are most consistent with domestic banks increasing their investments in securities during fire sales to profit from trading opportunities, leading out to a crowding out of credit supply by 1-5% points. Note also that while these results suggest spillover effects for credit markets, it also highlights an important role that domestic banks and nonfinancial firms play in providing liquidity to the stressed market for domestic securities.

4.6 Do fire sales affect market prices and liquidity?

We next investigate if fire sales by global branch banks in response to global liquidity shocks impacts liquidity and prices in bond markets in Australia. We begin by examining the affect of fire sales on bond market execution costs. For this, we analyze data only for the subset of transactions among dealers and non-dealers. That is, we filter out all transactions among dealers (inter-dealer) and non-dealers (inter-non-dealer). Such filtering allows us to naturally identify the trade initiator, which is assumed to be the non-dealer (i.e., the client of the dealer bank) in all cases.[25]

We then estimate the following panel regression on the subset of transactions among dealers and non-dealers:

$$EC_{k,t} \quad = \quad \alpha + \beta_L (LIBOR - OIS)_{i,t} + Controls + SFE + \epsilon_{i,j,t} \tag{4}$$

Here, $EC_{k,t}$ is the average execution cost for security k on day t. For each security, for each date, execution cost equals the difference between its traded cash price and its benchmark daily cash price (both computed per \$100 face value). We multiply the execution cost by a dummy variable, $I_{k,t}$, which takes the value of 1 (-1) for buyer-initiated (seller-initiated) trades. Benchmark cash prices are computed by using the benchmark rates (i.e., yields-to-maturity or yields) provided by the RBA. When necessary, these benchmark rates are interpolated to compute the benchmark cash price of the security being analyzed. We use the benchmark rates for government bonds to compute cash prices of federal and municipal, and the benchmark rates for the bank bills to compute cash prices of money market bonds. In the panel regression (4), the independent variables include measures of global and domestic liquidity shocks, all control variables previously defined, as well as the Macauley Duration of security k on day t, the logarithm of the total number of trades in security k on day t, and security fixed effects (SFE). The latter account for the differential average execution (i.e., liquidity) costs across securities.

Table 11 reports the estimates for the regression in equation (4) and indicates that the coefficient on $Libor - OIS$ is positive and significant at 1% level for all categories of bonds during the crisis period. Thus, execution costs (or liquidity spreads) paid by clients, i.e., non-dealer banks, increases on days with global liquidity shocks or when global branch banks engage in fire sales. In terms of magnitude, a one standard deviation increase in the Libor-OIS spread is associated with a 0.1371 and 0.0106 standard deviation increase in the execution costs for federal and money market bonds respectively. This effect is primarily driven by the crisis period, as during the post-crisis period, the coefficient on Libor-OIS is not statistically significant at conventional levels. Thus, fire sales by global branch banks do not affect market execution costs during normal times, presumably either because the market is more resilient or because

[25] To identify dealers and non-dealers, we follow Issa and Jarnecic (2019) and classify dealers as those market participants that serve as active market makers. All other participants are assumed to be non-dealers. The list of active market makers is available from the Australian Office of Financial Management at `https://www.aofm.gov.au/securities/treasury-bonds.`.

the magnitude of fire sales by global branch banks in response to liquidity shocks in normal times more limited in scope.

These results in Table 11 are consistent with the literature that investigates the execution quality in corporate bond markets and has found a dispersion in execution quality when the same security is traded among different customer groups.[26]. These studies have found that smaller and less active traders receive significantly worse execution paying more or receive less for buying and selling bonds than larger or more active investors. Similarly, on days with global liquidity shocks, when global branch banks are selling a substantially higher number of bonds, non-dealers (i.e., less active, smaller traders) in Australian bond markets face worse execution costs.

In our final test, we investigate if fire sale by global branch banks in response to global liquidity shocks affects price in bond markets in Australia. That is, we check if bond prices temporarily decrease below their fundamental value when almost all global branch banks seek to sell bonds at the same time. To identify the effect of selling pressure on bond prices, we follow an approach similar to Feldhütter (2012). On each day, for each category of bonds, we begin by sorting all transactions into two mutually exclusive bins – transactions where the seller is a global branch bank and transactions where the seller is either a domestic Australian bank or a global subsidiary bank (i.e., a non-global branch bank). Next, we compute an index of average prices using data for all transactions in a particular bin. At the end of this exercise, we have two daily price indices (for each bond category) one of which refers to average prices when a global branch bank is the seller, and the other refers to average prices when a non-global branch bank is the seller. We then estimate a panel regression of the following form:

$$Price_{GBB,t} - Price_{OTH,t} = \alpha + \beta_L (LIBOR - OIS)_{i,t} + Controls + SFE + \epsilon_{i,j,t} \quad (5)$$

The dependent variable ($Price_{GBB,j,t} - Price_{OTH,j,t}$) is the difference in average price of bonds of category j, sold by global branch banks on day t ($Price_{GBB,t}$) and the average price of bonds of category j, sold by other entities on the same day ($Price_{OTH,j,t}$). We regress the difference in price indices on our proxies of global and domestic liquidity shocks and control variables. The control variables are as defined

[26]See for example Schultz (2001), Edwards, Harris, and Piwowar (2004), Bessembinder, Maxwell, and Venkataraman (2006), Green, Hollifield, and Schürhoff (2006), Harris and Piwowar (2006), Green, Hollifield, and Schürhoff (2007), Goldstein and Hotchkiss (2007), Feldhütter (2012), and Hendershott and Madhavan (2015).

above. If sales by global branch banks on days with a global liquidity shock is motivated by a fire sale and a scramble for liquidity, we should observe a drop in the average price of bonds sold by global branch banks as compared to the average price of similar bonds sold by others entities. That is the coefficient on (Libor-OIS) in equation (5) should be negative and statistically significant.

Results for the panel regression in equation (5) are in Table 12 and show that this is indeed the case. When the (Libor-OIS) spread increases (i.e., global money markets experiences a liquidity shocks) prices of bonds sold by global branch banks are lower than prices of similar bonds sold by other banks. A one standard deviation increase in the global shock variable is associated with a decline in the price of similar bonds sold by global branch banks (relative to non-branches) of \$0.1955 and \$0.2933 for federal and municipal bonds, respectively. Note also that during the crisis period, the coefficient on the proxy for global liquidity shock is positive, although not statistically significant. This is consistent with the results in Table 5 which shows that while the face value of federal and municipal bonds sold by a typical global branch banks is 11 and 21 times higher than its average daily turnover, the volume of money market bonds sold by an average global branch bank is just 25% higher on days with a global liquidity shock as compared to its average daily turnover. Thus there being no price impact for money market bonds is not surprising.

Table 12 also shows that the affect is present during both the crisis and post-crisis periods. However, the magnitude of the effect is considerably larger during the post-crisis period when a one standard deviation increase in the global shock variable is associated with a decline in the price of similar bonds sold by global branch banks (relative to non-branches) of \$2.08, \$1.26, and \$0.02 for federal, municipal, and money market bonds, respectively.

5 Conclusion

In recent decades, global have expanded internationally by establishing foreign subsidiaries and branches in many countries. Our paper shows that such increased cross-border linkages among global banks provides a channel for transmission of liquidity shocks across countries. In particular, liquidity shocks induce fire sales of liquid securities by international branches of global banks that are dependent on their parent banks for capital and funding. Thus, response of global banks to liquidity shocks can result in an increased correlation between the performance of financial markets in times of financial distress. While we use data exclusively from Australia, our results are more general, as existence of global branches or subsidiaries is not unique to Australia.

Our paper contributes to the current debate regarding optimal regulation of global banks in the aftermath of the global financial crisis. Regulators, concerned that global banks can transmit shocks across countries, have proposed a slew of new regulations that require global banks to establish independently capitalized subsidiaries (from their parent banks). For example, the Dodd-Frank Act 'Intermediate Holding Company' rule in the U.S. requires all global banks in the U.S. to be organized as independently capitalized subsidiaries. Similarly, the European 'Capital Requirements Directive and Capital Requirements Regulation' requires all non-EU banks to be independently capitalized from their parent bank. Global banks resist such regulations arguing that holding multiple, fragmented pools of capital around the world, is inefficient as compared to operating a centrally managed capital pot, and that it increases the cost of bank credit. By documenting that independently capitalized subsidiaries of global banks are less prone to transmit shocks across borders, and by quantifying the magnitude of the effect, our study helps regulators and bankers to better understand the costs and benefits of new capital regulations imposed on global banks.

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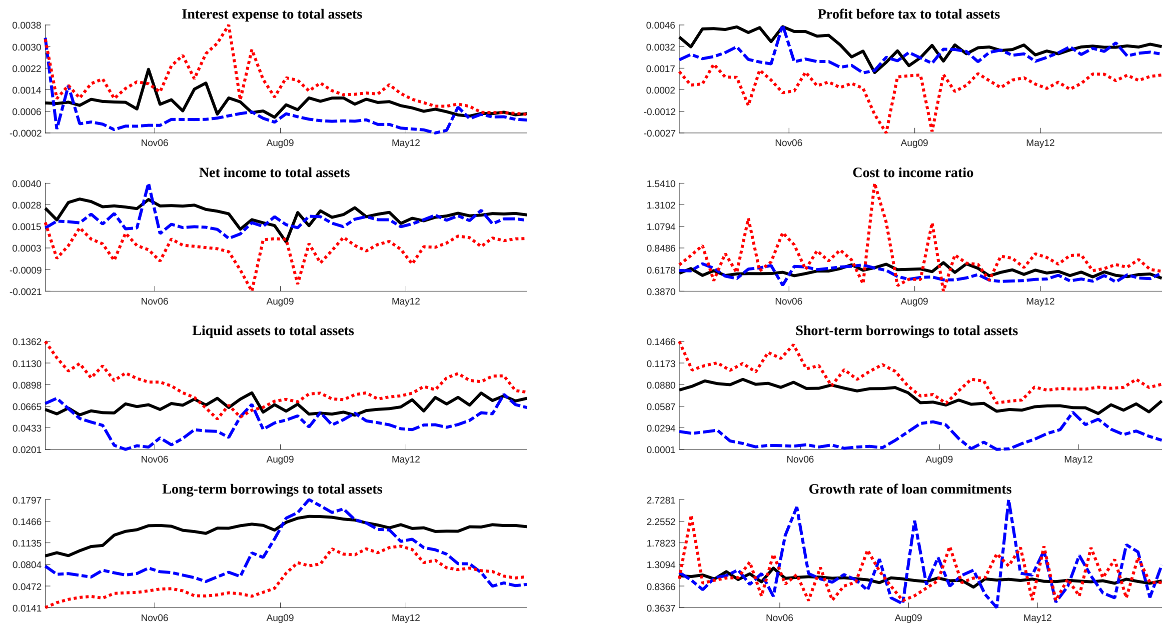

Figure 1. Time-series plots for profitability and liquidity measures for banks in Australia.

This figure plots the time-series of liquidity and profitability measures for domestic Australian, global subsidiary, and global branch banks. In each month, we aggregate data for all banks belonging to a particular category. Using monthly aggregated categorical data we compute: interest expense to total assets, profit before tax to total assets, net income to total assets, cost to income ratio, liquid assets to total assets, short-term borrowing to total assets, long-term borrowing to total assets, and the year-on-year growth rate of loan commitments, separately for domestic Australian banks, global subsidiary banks, and global branch banks. Each panel plots the time-series for a distinct liquidity or profitability measure. In each panel, the black solid line, the blue dashed line, and the red dotted line plot the data for domestic Australian, global subsidiary, and global branch banks, respectively. Monthly data, 2006–2014.

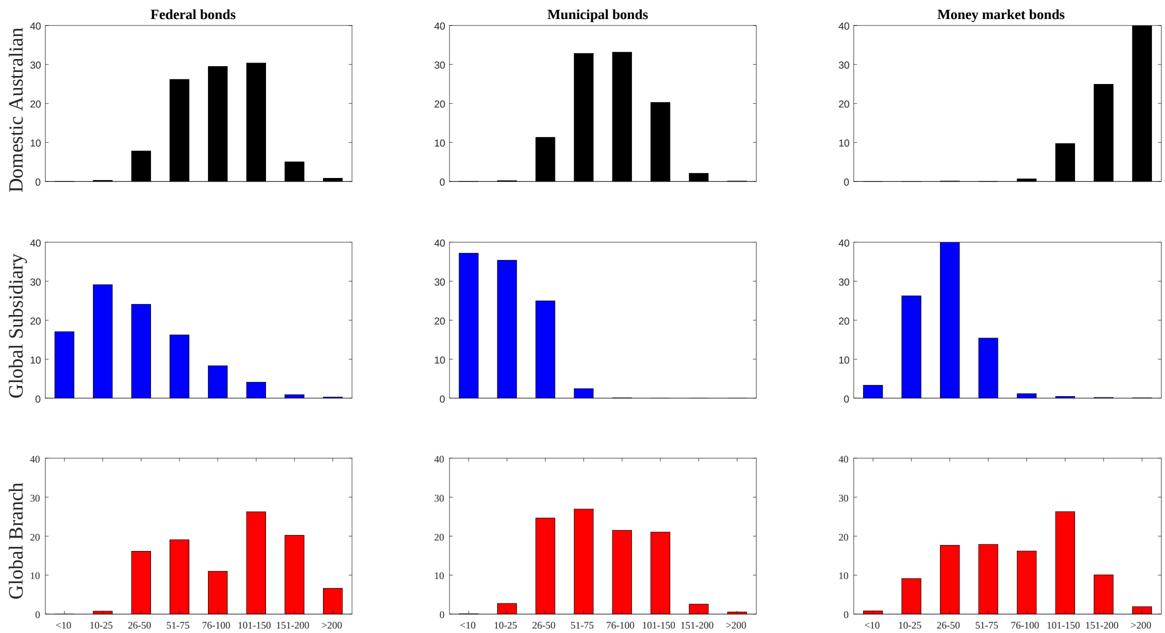

Figure 2. Histogram for the number of daily bond market transactions in Australian bond markets.

This figure plots the histogram for the number of bond market transactions by bond and bank type. The first column plots data for federal bonds, and the remaining two columns plot data for municipal and money market bonds, respectively. The first row plots data for domestic Australian banks, and the remaining two rows plot data for global subsidiary and branch banks, respectively. We sort the total number of days in our sample (1830) into 8 bins based on the number of transactions: days with less than 10, between 10–25, between 26–50, between 51–75, between 76–100, between 101–150, between 151–200, and more than 200 transactions. In each plot, bin values are indicated on the X-axis, and the bar height corresponds to the percentage of total days with a corresponding number of transactions. Daily data, 2006–2014.

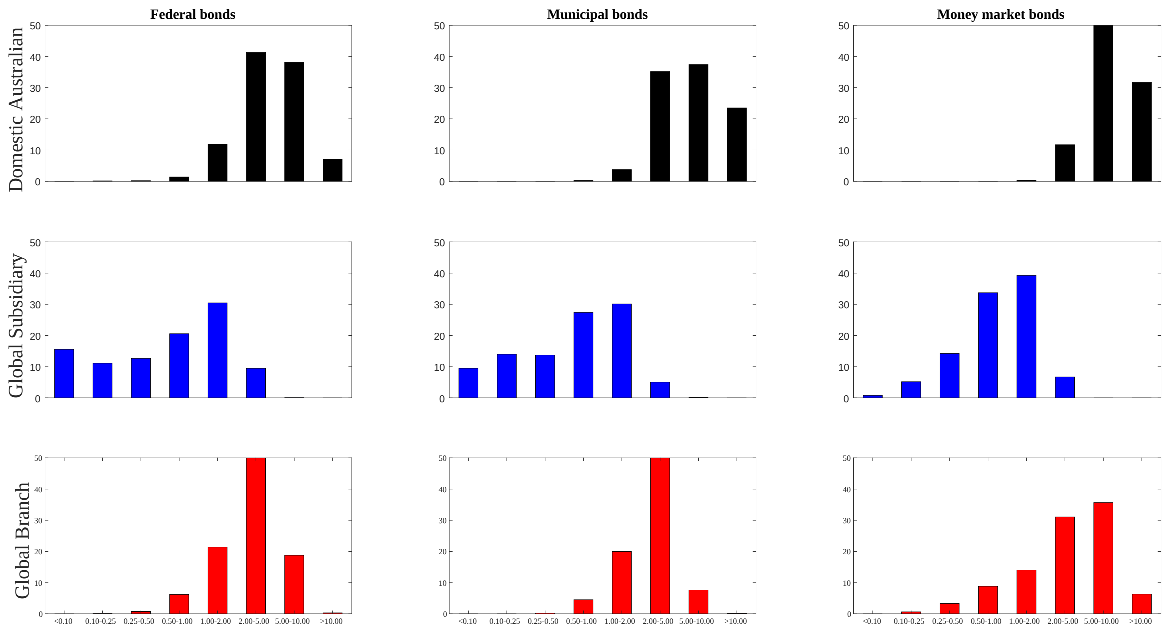

Figure 3. Histogram for the daily transaction volume in Australian bond markets.

This figure plots the histogram for the transaction volume based on the face value of traded bonds by bond and bank type. The first column plots data for federal bonds, and the remaining two columns plot data for municipal and money market bonds, respectively. The first row plots data for domestic Australian banks, and the remaining two rows plot data for global subsidiary and branch banks, respectively. We sort the total number of days in our sample (1830) into 8 bins based transaction volume: days with less than \$0.10 billion, between \$0.10–\$0.25 billion, between \$0.26–\$0.50 billion, between \$0.51–\$1.00 billion, between \$1.00–\$2.00, between \$2.00–\$5.00, between \$5.00–\$10.00, and more than \$10 billion in face value traded. In each plot, bin values are indicated on the X-axis, and the bar height corresponds to the percentage of total days with a corresponding transaction volume. Daily data, 2006–2014.

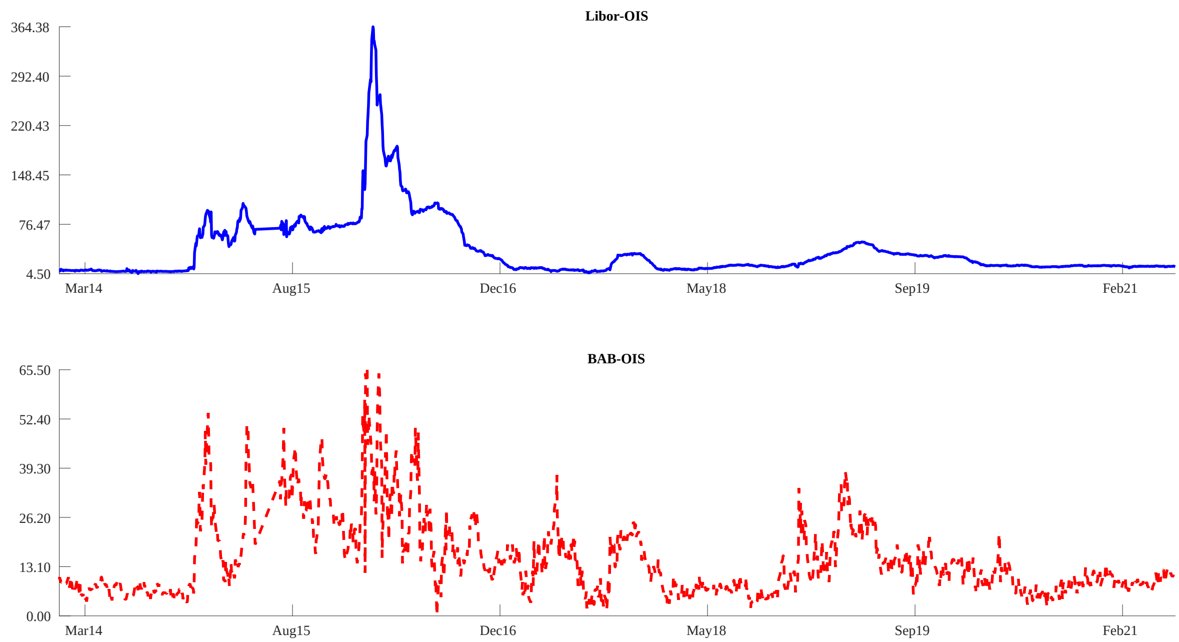

Figure 4. Time-series plots for Libor-OIS and BAB-OIS spreads.

This figure plots the time-series for the Libor-OIS and the BAB-OIS spread. Libor is the average interest rate on an unsecured interbank 3-month loan denominated in U.S. Dollars. The BAB rate is the mid-rate on short-term debt securities such as, negotiable certificates of deposits, bank accepted bills, with outstanding maturities of one to six months issued by Australian banks. OIS rate, which equals the rate on a fixed-for-floating interest rate swap where the floating payment is the effective (average) federal funds rate, compounded daily, for a period of 3-months. All spreads are in basis points. Daily data, 2006–2014.

Table 1. Summary statistics for domestic Australian, global subsidiary, and global branch banks.

Notes: This table reports summary statistics for profitability and liquidity measures for domestic Australian, global subsidiary, and global branch banks. In each month, we aggregate data for all banks belonging to a particular category. Using monthly aggregated categorical data, we compute: interest expense to total assets (INTEXP), profit before tax to total assets (PROFIT), net income to total assets (NETINC), cost to income ratio (CSTINC), liquid assets to total assets (LIQUID), short-term borrowing to total assets (SBORROW), long-term borrowing to total assets (LBORROW), and the year-on-year growth rate of loan commitments (COMMIT). We report the mean and standard deviation of the liquidity and performance measures separately for domestic Australian banks, global subsidiary banks, and global branch banks. Panel A presents the summary statistics for these variables for the full sample, and Panel B presents the summary statistics for these variables over the financial crisis. Monthly data, 2006–2014.

Category		INTEXP	PROFIT	NETINC	CSTINC	LIQUID	SBORROW	LBORROW	COMMIT
Panel A: Full Sample, 2004–2014									
Domestic	mean	0.0832	0.3261	0.2262	0.5943	0.0669	0.0717	0.1380	-0.0379
	σ	0.0003	0.0007	0.0005	0.0388	0.0067	1.4601	0.0151	0.0767
Global subsidiary	mean	0.0309	0.2541	0.1800	0.5646	0.0485	0.0161	0.0803	0.1303
	σ	0.0006	0.0005	0.0005	0.0624	0.0142	1.3049	0.0397	0.5471
Global branch	mean	0.1497	0.0629	0.0369	0.7295	0.0816	0.0882	0.0593	0.0871
	σ	0.0008	0.0009	0.0007	0.2133	0.0165	2.0577	0.0240	0.4067
Panel B: Financial crisis, 2007–2008									
Domestic	mean	0.0965	0.3022	0.2321	0.6249	0.0718	0.0824	0.1355	-0.0039
	σ	0.0004	0.0010	0.0005	0.0346	0.0052	0.3071	0.0048	0.0440
Global subsidiary	mean	0.0362	0.1966	0.1407	0.6378	0.0418	0.007090	0.0669	0.0358
	σ	0.0001	0.0004	0.0003	0.0188	0.0139	0.7577	0.0133	0.2096
Global branch	mean	0.2557	0.0008	-0.0064	0.8534	0.0684	0.1021	0.0356	-0.02451
	σ	0.0009	0.0014	0.0010	0.3361	0.0125	1.1517	0.0042	0.3998

Table 2. Summary statistics for holdings by banks and nonfinancial firms.

Notes: This table shows the summary statistics for holdings for the cross-section of banks (Panel A) and nonfinancial firms 9panel B). Column 1 indicates the category of bonds. Columns 2–9 report the summary statistics for the full sample and columns 11–17 report the summary statistics for the crisis years. We report the mean, the standard deviation, the minimum, the 25^{th}-percentile, the median, the 75^{th}-percentile, the maximum values, and the auto-correlation of daily holdings. Daily data, 2006–2014.

	Mean	σ	Min	25^{th}	50^{th}	75^{th}	Max	ρ	N	Mean	σ	Min	25^{th}	50^{th}	75^{th}	Max	ρ	N
	Full sample									Crisis years								
							Panel A: Banks											
Federal	0.43	0.59	0.01	0.07	0.16	0.47	2.25	0.76	30	0.37	0.56	0.00	0.00	0.15	0.51	2.66	0.62	22
Municipal	1.85	2.31	0.05	0.30	0.80	3.85	7.73	0.87	34	0.83	1.29	0.00	0.07	0.19	0.81	4.84	0.73	28
Money market	1.19	1.60	0.02	0.24	0.57	1.31	6.73	0.95	37	1.27	1.64	0.03	0.28	0.55	1.48	6.80	0.93	37
							Panel B: Nonfinancial firms											
Federal	0.50	1.39	0.00	0.01	0.03	0.20	7.48	0.64	65	0.65	1.92	0.00	0.01	0.05	0.28	11.86	0.79	46
Municipal	0.47	1.24	0.00	0.01	0.04	0.25	6.38	0.81	78	0.80	1.98	0.00	0.02	0.15	0.51	11.69	0.87	58
Money market	0.14	0.80	0.00	0.00	0.01	0.03	9.58	0.81	323	0.17	0.73	0.00	0.00	0.01	0.03	6.26	0.77	230

Table 3. Summary statistics for holdings for domestic Australian, global subsidiary, and global branch banks.

Notes: This table shows the summary statistics for holdings of domestic Australian (panel A), global subsidiary (panel B), and global branch banks (panel C). Column 1 indicates the category of bonds. Columns 2–10 report the summary statistics for the full sample and columns 11–18 report the summary statistics for the crisis years. We report the mean, the standard deviation, the minimum, the 25^{th}-percentile, the median, the 75^{th}-percentile, the maximum values, and the auto-correlation of daily holdings. Daily data, 2006–2014.

	Mean	σ	Min	25^{th}	50^{th}	75^{th}	Max	ρ	N	Mean	σ	Min	25^{th}	50^{th}	75^{th}	Max	ρ	N
	Full sample									Crisis years								
							Panel A: Domestic Australian Banks											
Federal	0.64	0.72	0.02	0.07	0.34	1.47	1.83	0.74	10	0.47	0.44	0.00	0.24	0.39	0.53	1.51	0.54	9
Municipal	2.06	2.73	0.05	0.19	0.45	4.20	7.73	0.98	12	1.32	1.50	0.04	0.13	0.42	2.75	3.92	0.84	12
Money market	1.89	1.84	0.16	0.50	1.43	2.97	6.73	0.98	14	1.95	2.04	0.10	0.37	1.35	2.98	6.80	0.96	14
							Panel B: Global Subsidiary Banks											
Federal	0.63	0.94	0.04	0.06	0.15	0.63	2.25	0.94	5	0.62	1.16	0.00	0.00	0.00	0.42	2.66	0.92	3
Municipal	0.97	1.47	0.00	0.09	0.45	0.98	3.85	0.79	7	0.96	1.92	0.00	0.00	1.21	0.48	4.84	0.71	4
Money market	1.36	2.39	0.02	0.10	0.37	1.13	6.17	0.97	7	1.38	2.15	0.03	0.10	0.57	1.38	5.64	0.96	7
							Panel C: Global Branch Banks											
Federal	0.22	0.22	0.01	0.08	0.13	0.24	0.86	0.72	15	0.22	0.29	0.00	0.00	0.11	0.51	0.95	0.62	11
Municipal	0.37	0.37	0.03	0.11	0.20	0.52	1.37	0.82	15	0.38	0.53	0.00	0.10	0.16	0.51	1.60	0.63	12
Money market	0.52	0.39	0.04	0.29	0.45	0.68	1.48	0.91	16	0.63	0.52	0.04	0.34	0.49	0.71	1.95	0.88	16

Table 4. Summary statistics for the Libor-OIS and BAB-OIS spread.

Notes: This table shows the summary statistics for the Libor-OIS and BAB-OIS spreads. Panel A shows the summary statistics for the full sample, while panel B reports summary statistics for the crisis years. Column 1 indicates the rate for which summary statistics are computed. Columns 2–10 report the mean, the standard deviation, the minimum, the 25^{th}-percentile, the median, the 75^{th}-percentile, the maximum of daily holdings for each category of bonds, the auto-correlation of daily holdings, and the number of observations. Daily data, 2006–2014.

	Mean	σ	Min	25^{th}	50^{th}	75^{th}	Max	ρ	N
Panel A: Full sample									
Libor-OIS	37.43	45.07	4.50	12.89	16.85	44.11	364.38	0.99	1810
BAB-OIS	14.96	11.98	0.00	7.70	12.00	20.00	65.50	0.72	1854
Panel B: Crisis-years									
Libor-OIS	68.29	64.16	4.50	9.06	68.25	91.25	364.38	0.99	637
BAB-OIS	20.20	13.39	0.00	8.00	17.38	28.64	65.50	0.94	680

Table 5. Effect of liquidity shocks on bank holdings.

Notes: This table shows the estimated coefficients for the panel regression:

$$\begin{aligned}\log(H_{i,j,t}) - \log(\mu[H_{i,j,t} \mid \Omega_t]) &= \alpha + \beta_L(Libor - OIS)_t + \beta_S GS \times (Libor - OIS)_t \\ &+ \beta_B GB \times (Libor - OIS)_t + Controls + BFE + TFE + \epsilon_{i,j,t}\end{aligned}$$

Here, $H_{i,j,t}$ is the actual face value and $\mu[H_{i,j,t} \mid \Omega_t]$ is the expected face value of bonds of category j held by bank i on day t. $(Libor - OIS)_t$ is the unexpected change in the Libor-OIS spread measured at time t. GS and GB are dummy variables that take the value 1 if bank i is a global subsidiary or global branch bank, respectively and are zero otherwise. We control for total issuance of bonds of category j ($Issuance$), total holdings of bonds of category j by nonfinancial firms ($Nonfin$), the total face value of bonds across all categories held by bank i maturing on day t ($Maturity$), and the unexpected change in the $(BAB - OIS)$ spread. The numbers in parenthesis are t-values. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. Daily data, 2006–2014.

$i =$	Federal	Municipal	Money market	Federal	Municipal	Money market	Federal	Municipal	Money market
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Full Sample			Crisis period			Post-crisis period		
$Libor - OIS$	0.06	0.10	-0.05***	0.03	0.08	-0.04***	1.75*	-0.08	-0.09
	(0.58)	(1.58)	(-3.69)	(0.28)	(1.50)	(-4.54)	(1.77)	(-0.14)	(-0.25)
$GB \times (Libor - OIS)$	-0.30***	-0.17***	-0.11***	-0.29***	-0.16***	-0.11***	-0.72	-0.49	-0.11
	(-3.24)	(-3.04)	(-5.66)	(-3.43)	(-2.71)	(-5.97)	(-0.63)	(-1.13)	(-0.35)
$GS \times (Libor - OIS)$	-0.13	-0.12*	-0.03	-0.13	-0.12*	-0.02	0.10	0.15	-0.43
	(-0.89)	(-1.89)	(-1.42)	(-0.89)	(-1.72)	(-1.29)	(0.13)	(0.37)	(-1.26)
$BAB - OIS$	0.22	-0.04	-0.06	0.23	0.13	0.04	0.02	-0.46	-0.23
	(0.66)	(-0.23)	(-0.49)	(0.49)	(0.67)	(0.88)	(0.05)	(-1.52)	(-0.69)
$Issuance$	-0.44	0.01	0.23	-1.38	-0.78*	0.42**	0.19	0.18	0.06
	(-0.71)	(0.08)	(1.13)	(-0.75)	(-1.72)	(2.25)	(0.45)	(1.59)	(0.16)
$Nonbank$	0.27	0.12	0.17	0.53***	0.31	-0.08	0.07	0.06	0.20*
	(1.44)	(0.82)	(1.51)	(2.67)	(0.91)	(-0.78)	(0.29)	(0.38)	(1.80)
$Maturity$	0.04*	0.02***	0.02***	0.09***	0.06***	0.01***	0.01	0.01*	0.02***
	(1.73)	(2.89)	(7.97)	(4.10)	(5.21)	(8.20)	(0.45)	(1.94)	(9.97)
BFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-value	7.92***	5.27***	19.33***	9.22***	3.75***	21.44***	2.66***	6.46***	16.23***
N	22,488	20,614	43,102	7,920	7,260	15,180	14,568	13,354	27,922

Table 6. Results by bank characteristics.

Notes: This table shows the estimated coefficients for the panel regression:

$$\begin{aligned}\log(H_{i,j,t}) - \log(\mu[H_{i,j,t} \mid \Omega_t]) &= \alpha + \beta_L(Libor - OIS)_t + \beta_S GS \times (Libor - OIS)_t \\ &+ \beta_B GB \times (Libor - OIS)_t + Controls + BFE + TFE + \epsilon_{i,j,t}\end{aligned}$$

Here, $H_{i,j,t}$ is the actual face value and $\mu[H_{i,j,t} \mid \Omega_t]$ is the expected face value of bonds of category j held by bank i on day t. $(Libor - OIS)_t$ is the unexpected change in the Libor-OIS spread measured at time t. GS and GB are dummy variables that take the value 1 if bank i is a global subsidiary or global branch bank, respectively and are zero otherwise. We control for total issuance of bonds of category j ($Issuance$), total holdings of bonds of category j by nonfinancial firms ($Nonfin$), the total face value of bonds across all categories held by bank i maturing on day t ($Maturity$), and the unexpected change in the $(BAB - OIS)$ spread. Dummy variables $D_{B,H}$ and $D_{B,L}$ equal 1 if a global branch bank is big and has high and low liquidity at time t, respectively. Similarly, dummy variables $D_{S,H}$ and $D_{S,H}$ equal 1 if a global branch is small and has high and low liquidity at time t, respectively. Dummy variables D_{EU}, D_{EU}, D_{CA}, and D_{AS} take the value 1 if the parent bank is located in the U.S., European Union, Canada, or Asia, respectively, and is zero otherwise. The numbers in parenthesis are t-values. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. Daily data, 2006–2014.

$i =$	Federal (1)	Municipal (2)	Money market (3)	Federal (4)	Municipal (5)	Money market (6)	Federal (7)	Municipal (8)	Money market (9)
	Full Sample			Crisis period			Post-crisis period		
Panel A: By bank characteristics									
$GB \times (Libor - OIS) \times D_{B,H}$	0.65	0.83	0.05	0.22	1.39*	0.07*	0.96	-0.39	-0.27
	(0.95)	(1.35)	(1.23)	(0.26)	(1.81)	(1.68)	(1.60)	(-0.55)	(-1.09)
$GB \times (Libor - OIS) \times D_{B,L}$	-0.60*	-1.28	-0.10**	-0.53	-9.32***	-0.10**	-2.51	-1.06	-0.06
	(-1.87)	(-0.78)	(-2.20)	(-1.41)	(-10.31)	(-2.30)	(-1.12)	(-0.56)	(-0.07)
$GB \times (Libor - OIS) \times D_{S,H}$	-0.28***	-0.22***	-0.14***	-0.26***	-0.21***	-0.15***	-0.94*	-0.70	0.39
	(-3.05)	(-4.54)	(-3.19)	(-3.15)	(-4.51)	(-3.41)	(-1.63)	(-1.19)	(0.28)
$GB \times (Libor - OIS) \times D_{S,L}$	-0.44	-0.03	-0.03	-0.46*	-0.02	-0.02**	-0.28	0.24	-0.12
	(-1.09)	(-0.73)	(-0.16)	(-1.67)	(-0.11)	(-1.99)	(-0.22)	(0.16)	(-0.19)
Controls, BFE, TFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: By parent's geographic location									
$GB \times (Libor - OIS) \times D_{US}$	0.05	-0.15	-0.15***	0.16	-0.17*	-0.15***	1.37*	-0.48	-0.84
	(0.30)	(-1.39)	(-7.13)	(0.27)	(-1.73)	(-5.21)	(1.91)	(-1.04)	(-0.96)
$GB \times (Libor - OIS) \times D_{EU}$	-0.53***	-0.24*	-0.10***	-0.42***	-0.26***	-0.11***	1.17*	0.13	-0.30
	(-4.27)	(-1.83)	(-3.32)	(-2.36)	(-2.91)	(-3.81)	(1.73)	(0.11)	(-0.47)
$GB \times (Libor - OIS) \times D_{CA}$	-0.14	-0.15	-0.03	0.11	-0.12	-0.04*	-0.51	-0.58	1.49***
	(-1.35)	(-1.54)	(-0.88)	(0.87)	(-0.96)	(-1.76)	(-0.61)	(-0.69)	(-3.47)
$GB \times (Libor - OIS) \times D_{AS}$	-0.30**	-0.14*	-0.02	-0.24*	-0.07	-0.03	0.46	0.46	-0.03
	(-2.71)	(-1.76)	(-0.81)	(-1.84)	(-0.85)	(-1.02)	(0.74)	(1.61)	(-0.16)
Controls, BFE, TFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 7. Results by bond characteristics.

Notes: This table shows the estimated coefficients for the panel regression:

$$\begin{aligned}\log(H_{i,j,t}) - \log(\mu[H_{i,j,t} \mid \Omega_t]) &= \alpha + \beta_L(Libor - OIS)_t + \beta_S GS \times (Libor - OIS)_t \\ &+ \beta_B GB \times (Libor - OIS)_t + Controls + BFE + TFE + \epsilon_{i,j,t}\end{aligned}$$

Here, $H_{i,j,t}$ is the actual face value and $\mu[H_{i,j,t} \mid \Omega_t]$ is the expected face value of bonds of category j held by bank i on day t. $(Libor - OIS)_t$ is the unexpected change in the Libor-OIS spread measured at time t. GS and GB are dummy variables that take the value 1 if bank i is a global subsidiary or global branch bank, respectively and are zero otherwise. We control for total issuance of bonds of category j ($Issuance$), total holdings of bonds of category j by nonfinancial firms ($Nonfin$), the total face value of bonds across all categories held by bank i maturing on day t ($Maturity$), and the unexpected change in the $(BAB - OIS)$ spread. Dummy variable D_{Long} equals 1 for bonds with long maturity. Dummy variable D_{High} equals 1 for bonds with high yields to maturity. On each day, bonds are sorted into terciles based on maturity and yields. The top 30% of bonds by maturity are defined as long-term bonds. Similarly, the top 30% of bonds by yields are defined as high yield bonds. The numbers in parenthesis are the t-values. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. Daily data, 2006–2014.

$i =$	Federal	Municipal	Money market	Federal	Municipal	Money market	Federal	Municipal	Money market
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Full Sample			Crisis period			Post-crisis period		
Panel A: By time to maturity									
$GB \times (Libor - OIS)$	-0.29***	-0.13	0.05	-0.10	-0.03	0.02	-0.99	-0.85	1.61
	(-2.45)	(-1.60)	(0.56)	(-0.90)	(-0.35)	(0.26)	(-1.28)	(-1.08)	(1.37)
$GB \times (Libor - OIS) \times D_{Long}$	-0.19***	-0.26**	-0.12	-0.32*	-0.11**	-0.25***	0.02	-0.67	0.26
	(-2.38)	(-2.19)	(-1.08)	(-1.91)	(-2.00)	(-6.71)	(0.02)	(-0.83)	(0.40)
$GB \times (Libor - OIS) \times D_{Short}$	-0.08	-0.34***	-0.05	-0.40***	-0.35***	-0.08*	0.70	-1.73***	0.31
	(-0.68)	(-4.13)	(-0.73)	(-2.94)	(-6.43)	(-1.66)	(0.59)	(-2.69)	(0.45)
Controls, BFE, TFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: By yield									
$GB \times (Libor - OIS)$	-0.30**	-0.23**	0.06	-0.28**	-0.20*	0.06	-1.05*	-1.17	0.28
	(-2.32)	(-2.12)	(0.38)	(-2.24)	(-1.71)	(0.35)	(-1.84)	(-1.24)	(0.42)
$GB \times (Libor - OIS) \times D_{High}$	-0.14	0.06	-0.38***	-0.01	0.05	-0.05	0.20	-0.75	-0.31
	(-1.05)	(0.35)	(-2.55)	(-0.05)	(0.42)	(-1.21)	(0.19)	(-0.93)	(-0.56)
$GB \times (Libor - OIS) \times D_{Low}$	0.29**	0.26	-0.12	-0.48***	-0.15*	-0.32***	1.25	-0.91	0.16
	(2.14)	(1.23)	(-0.69)	(-2.99)	(-1.94)	(-4.67)	(1.05)	(-1.59)	(0.27)
Controls, BFE, TFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel C: By credit risk									
$GB \times (Libor - OIS)$			-0.13***			-0.10***			0.01
			(-7.47)			(-11.87)			(0.02)
$GB \times (Libor - OIS) \times D_{AAA}$			-0.27***			-0.14***			-0.30
			(-6.56)			(-3.73)			(-0.60)
Controls, BFE, TFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 8. Falsification test.

Notes: This table shows the estimated coefficients for the panel regression:

$$\begin{aligned}\log(H_{i,j,t}) - \log(\mu[H_{i,j,t} \mid \Omega_t]) &= \alpha + \beta_L(BAB - OIS)_t + \beta_S GS \times (BAB - OIS)_t \\ &+ \beta_B GB \times (BAB - OIS)_t + Controls + BFE + TFE + \epsilon_{i,j,t}\end{aligned}$$

Here, $H_{i,j,t}$ is the actual face value and $\mu[H_{i,j,t} \mid \Omega_t]$ is the expected face value of bonds of category j held by bank i on day t. $(BAB - OIS)_t$ is the unexpected change in the BAB-OIS spread measured at time t. GS and GB are dummy variables that take the value 1 if bank i is a global subsidiary or global branch bank, respectively and are zero otherwise. We control for total issuance of bonds of category j ($Issuance$), total holdings of bonds of category j by nonfinancial firms ($Nonfin$), the total face value of bonds across all categories held by bank i maturing on day t ($Maturity$), and the unexpected change in the ($Libor - OIS$) spread. The numbers in parenthesis are t-values. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. Daily data, 2006–2014.

$i =$	Federal (1)	Municipal (2)	Money market (3)	Federal (4)	Municipal (5)	Money market (6)	Federal (7)	Municipal (8)	Money market (9)
	Full Sample			Crisis period			Post-crisis period		
$BAB - OIS$	0.52	-0.04	-0.06	0.67	0.09	0.05	0.05	-0.40*	-0.25
	(1.11)	(-0.31)	(-0.69)	(0.97)	(0.59)	(1.21)	(0.09)	(-1.83)	(-1.05)
$GB \times (BAB - OIS)$	-0.48	0.02	0.05	-0.73	0.15	0.02	-0.03	-0.21	0.13
	(-1.19)	(0.06)	(0.54)	(-1.34)	(0.32)	(0.25)	(-0.07)	(-0.35)	(0.56)
$GS \times (BAB - OIS)$	-0.61	-0.06***	-0.21	-0.90	-0.16	-0.10***	-0.11	0.16	-0.43***
	(-1.10)	(-0.42)	(-2.67)	(-1.14)	(-1.02)	(-2.68)	(-0.17)	(0.87)	(-2.36)
$Libor - OIS$	-0.10	0.02	-0.09***	-0.13**	0.01	-0.09***	1.39*	-0.26	-0.17
	(-1.63)	(0.42)	(-7.22)	(-2.26)	(0.18)	(-6.41)	(1.92)	(-0.44)	(-0.44)
$Issuance$	-0.44	0.01	0.23	-1.38	-0.78*	0.42**	0.19	0.18	0.06
	(-0.71)	(0.07)	(1.13)	(-0.75)	(-1.72)	(2.25)	(0.46)	(1.59)	(0.16)
$Nonbank$	0.27	0.12	0.17	0.53***	0.31	-0.08	0.07	0.06	0.20*
	(1.44)	(0.82)	(1.51)	(2.67)	(0.91)	(-0.78)	(0.29)	(0.38)	(1.80)
$Maturity$	0.04*	0.02***	0.02***	0.09***	0.06***	0.01***	0.01	0.01*	0.02***
	(1.72)	(3.00)	(7.95)	(4.07)	(8.96)	(8.17)	(0.44)	(2.03)	(9.95)
BFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-value	7.66***	4.77***	19.06***	9.04***	3.27***	18.95***	2.57***	6.37***	16.32***
N	22,488	20,614	43,102	7,920	7,260	15,180	14,568	13,354	27,922

Table 9. Counterparty to fire sales.

Notes: This table reports the mean number of transactions and the mean transaction volume by type of counterparty on days when global money and interbank markets experience a liquidity shock. In panel A, these are defined as days when the Libor-OIS spread is above the 99^{th}-percentile, computed over a 1-month rolling window. In panel B, these are defined as days when the Libor-OIS spread is above its 95^{th}-percentile (again, computed over a 1-month rolling window). As a benchmark, panel C looks at days when the Libor-OIS spread (approximately) equals its median value. In all cases, the seller is a global branch bank located in Australia. We classify the counterparties into five categories: a domestic Australian bank, a global subsidiary bank, a global branch bank other than the seller, the Reserve bank of Australia (i.e., the central bank), or a nonfinancial firm. We count the number of transactions and the total face value of bonds bought by all counterparties of a particular category, normalize these by the total number of sales transactions and total face value of bonds sold by global branch banks branches on that day, respectively. We repeat this process for all days and report the mean proportion of transactions and the mean proportion of face value of bonds bought by all counterparties of a particular category. Each row in each panel reports data for a separate category of bonds. Daily data, 2006–2014.

	Domst	Subsd	Brnch	RBA	Nonfin	Domst	Subsd	Brnch	RBA	Nonfin
	Number of transaction					Volume				
Panel A: Libor-OIS spread above 99^{th} percentile										
Federal bonds	25.10	6.61	8.30	1.49	58.50	29.54	6.88	13.86	2.14	47.59
Municipal bonds	12.59	9.23	8.26	4.61	65.32	24.27	10.57	11.23	10.12	43.81
Money market bonds	18.40	5.60	7.22	3.06	65.72	28.75	3.58	7.20	6.83	53.64
Panel A: Libor-OIS spread above 95^{th} percentile										
Federal bonds	25.68	6.66	7.86	1.40	58.40	29.65	7.24	11.45	2.77	48.89
Municipal bonds	16.82	8.60	7.96	3.79	62.83	29.72	8.59	10.07	8.47	43.15
Money market bonds	18.22	6.47	6.35	4.21	64.76	29.90	5.53	6.06	7.77	50.75
Panel C: Libor-OIS spread at 50^{th} percentile										
Federal bonds	26.06	6.53	8.69	1.06	57.67	30.94	6.90	11.85	2.09	48.23
Municipal bonds	17.67	8.07	8.79	3.21	62.27	30.92	9.43	11.79	7.42	40.44
Money market bonds	20.63	7.16	8.14	2.75	61.32	30.95	4.64	9.31	5.62	49.49

Table 10. Counterparty to fire sales.

Notes: This table reports the estimated coefficients for the panel regression:

$$Credit_{i,t}/Assets_{i,t} \quad = \quad \alpha + \beta_D (D_{Buyer})_{i,t} + Controls + BFE + TFE + \epsilon_{i,j,t}$$

Here, $Credit_t/Assets_t$ is the ratio of book value of loans to book value of assets held by bank i in month t. $D_{i,t}$ is a dummy variable that equals 1 if bank i purchases bonds sold in fire sales by global branch banks in month t and is zero otherwise. Controls include the ratio of book value of liquid assets to book value of total assets and the ratio of book value of deposits to book value of total assets. The numbers in parenthesis are t-values. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. Monthly data, 2006–2014.

	(1)	(2)	(3)	(4)
		Panel A: All loans		
D_{Buyer}	-0.05***	-0.02***	-0.05***	-0.02***
	(-3.70)	(-7.19)	(-6.44)	(-7.19)
Liquid		-0.68***		-0.66***
		(-6.79)		(-5.15)
Deposit			0.22***	0.10***
			(9.27)	(5.34)
BFE	Yes	Yes	Yes	Yes
TFE	Yes	Yes	Yes	Yes
N	41,254	41,254	41,254	41,254
		Panel B: Loans to nonfinancial firms		
D_{Buyer}	-0.02***	-0.05*	-0.02***	-0.01***
	(-5.68)	(-1.85)	(-7.68)	(-2.79)
Liquid		-0.43***		-0.42***
		(-7.19)		(-5.80)
Deposit			0.15***	0.07***
			(10.28)	(5.01)
BFE	Yes	Yes	Yes	Yes
TFE	Yes	Yes	Yes	Yes
N	41,254	41,254	41,254	41,254
		Panel C: Loans to financial firms		
D^{Buyer}	-0.01***	-0.02**	-0.09***	-0.03***
	(-5.41)	(-2.08)	(-6.31)	(-2.81)
Liquid		-0.15***		-0.14***
		(-2.74)		(-2.55)
Deposit			0.07***	0.04***
			(6.33)	(4.85)
BFE	Yes	Yes	Yes	Yes
TFE	Yes	Yes	Yes	Yes
N	41,254	41,254	41,254	41,254

Table 11. Effect of liquidity shock on execution costs.

Notes: This table shows the estimated coefficients for the panel regression:

$$EC_{k,t} = \alpha + \beta_L(LIBOR - OIS)_{i,t} + Controls + SFE + \epsilon_{i,j,t}$$

Here, $EC_{k,t}$ is the average execution cost for security k on day t. For each trade, execution cost equals the difference between the traded cash price and a benchmark daily cash price for the security (both computed per \$100 face value) multiplied by an indicator trade-initiation variable $I_{k,t}$. The indicator variable $I_{k,t}$ takes the value of 1 if the trade is buyer-initiated or -1 if seller-initiated. On each day, for each security, benchmark cash prices are computed by using benchmark term-structure of yields-to-maturity (yields) provided by the RBA. $(Libor - OIS)_t$ is the unexpected change in the Libor-OIS spread measured at time t. $(BAB - OIS)_t$ is the unexpected change in the BAB-OIS spread measured at time t. We control for total issuance of bonds of category j ($Issuance$), total holdings of bonds of category j by nonfinancial firms ($Nonfin$), the total face value of bonds across all categories held by bank i maturing on day t ($Maturity$), the Macauley Duration of security k on day t ($Duration_{k,t}$), and the logarithm of the total number of trades in security k on day t ($Activity_{k,t}$), The numbers in parenthesis are t-values. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. Daily data, 2006–2014.

$i =$	Federal (1)	Municipal (2)	Money market (3)	Federal (4)	Municipal (5)	Money market (6)	Federal (7)	Municipal (8)	Money market (9)
	Full Sample			Crisis period			Post-crisis period		
$Libor - OIS$	0.03	0.03	0.01***	0.09***	0.01	0.01***	0.06	0.03	0.01
	(1.31)	(1.43)	(3.17)	(2.78)	(3.13)	(0.53)	(0.50)	(0.25)	(0.73)
$BAB - OIS$	0.05	-0.19*	-0.01	0.02	-0.23**	-0.01	0.10	-0.09*	0.01
	(0.46)	(-1.89)	(-0.36)	(0.16)	(-2.04)	(-0.73)	(0.51)	(-0.48)	(1.04)
Duration	-0.01	0.02***	-1.02***	0.07**	0.02	-1.01***	-0.01	-0.01	-1.02***
	(-0.68)	(2.91)	(-3.02)	(2.25)	(0.69)	(-10.97)	(-0.79)	(-0.17)	(-22.34)
Activity	-0.06	-0.25	-0.32***	1.29*	0.01	-0.85***	-0.69	-0.23	-0.16
	-0.18	-0.77	-3.23	(1.79)	(0.02)	(-3.93)	(-1.50)	(-0.59)	(-1.62)
SFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	23,949	42,428	7,318	6,195	11,152	2,639	17,754	31,276	4,679

Table 12. Effect of liquidity shock on bond prices.

Notes: This table shows the estimated coefficients for the panel regression:

$$Price_{GBB,j,t} - Price_{OTH,j,t} \quad = \quad \alpha + \beta_L(LIBOR - OIS)_{i,t} + Controls + SFE + \epsilon_{i,j,t}$$

Here, $Price_{GBB,t}$ is the average of bonds of category j sold by global branch banks on day t and $Price_{OTH,j,t}$ is the average price of bonds of category j sold by other entities on day t. $(Libor - OIS)_t$ is the unexpected change in the Libor-OIS spread measured at time t. $(BAB - OIS)_t$ is the unexpected change in the BAB-OIS spread measured at time t. Other control variables are as defined in previous tables. The numbers in parenthesis are t-values. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. Daily data, 2006–2014.

$i =$	Federal (1)	Municipal (2)	Money market (3)	Federal (4)	Municipal (5)	Money market (6)	Federal (7)	Municipal (8)	Money market (9)
	Full Sample			Crisis period			Post-crisis period		
$Libor - OIS$	-0.23**	-0.31***	0.00	-0.20**	-0.29***	0.00	-2.08***	-1.26*	-0.02
	(-2.39)	(-2.78)	(0.20)	(-2.17)	(-2.82)	(0.25)	(-3.64)	(-1.79)	(-0.34)
$BAB - OIS$	-0.28	-0.34	0.07***	-0.18	0.24	0.05	-0.28	-1.02**	0.11***
	(-1.16)	(-1.13)	(2.50)	(-0.62)	(0.65)	(1.08)	(-0.75)	(-2.14)	(2.48)
N	18,366	10,997	6,854	4,018	2,638	2,505	14,348	8,359	4,349

How do Global Banks Transmit Liquidity Shocks Across Countries: Evidence from Down Under

A Additional summary statistics

Summary statistics for the characteristics: Table A1presents the summary statistics for the characteristics of domestic Australian banks (DAB), global subsidiary banks (GSB), and global branch banks (GBB).

B Additional results

Table A2 checks if global branch banks re-balance their holdings towards less risky bonds in response to global liquidity shocks. Here, $Federal_{i,j,t}$ and $MoneyMarket_{i,t}$ are the face values of all federal and money market bonds held by bank i at time t. $\overline{Federal_t}$ and $\overline{MoneyMarket_t}$ is the expected value of federal and money market bonds held by bank i on date t and equals the 1-month lagged moving average of the face value of these bonds, respectively. $(Libor - OIS)_t$ is the unexpected change in the Libor-OIS spread measured at time t. GB and GS are dummy variables that equal 1 if bank i is a global branch or global subsidiary bank, respectively. We control for total issuance of bonds of category j ($Issuance$), total holdings of bonds of category j by nonfinancial firms ($Nonfin$), total face value of bonds across all categories that are held by bank i and are maturing on day t ($Maturity$), and unexpected change in the domestic money market spread ($BAB - OIS$). The numbers in parenthesis are the t-values. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively.

$$\begin{aligned}\log(H_{i,j,t}) - \log(\mu[H_{i,j,t} \mid \Omega_t]) &= \alpha + \beta_L(Libor - OIS)_t + \beta_S GS \times (Libor - OIS)_t \\ &+ \beta_B GB \times (Libor - OIS)_t + Controls + BFE + TFE + \epsilon_{i,j,t}\end{aligned}$$

Table A1. Summary statistics for characteristics of domestic Australian, global subsidiary, and global branch banks.

Notes: This table reports summary statistics for the characteristics for the three categories of banks in Australia. In each month, we aggregate data for all banks belonging to a particular category. Using monthly aggregated categorical data, we compute: total assets (TOTASSTS) measured in Australian dollar billions, total loans to total assets (TOTLOANS), real estate loans to total assets (RELOANS), commercial loans to total assets (CILOANS), fixed assets to total assets (FIXASSTS), securities to total assets (SECURITY), deposits to total assets (DEPOSITS), and the ratio of loan losses to total loans (BADLOANS). Panels A, B, and C report the mean, standard deviation, minimum, 25^{th} percentile, median, 75^{th} percentile, and maximum values for these variables for domestic Australian banks (DAB), global subsidiary banks (GSB), and global branch banks (GBB), respectively. Value for TOTASSTS is in Australian Dollar billions. Monthly data, 2006–2014.

Category	TOTASSTS	TOTLOANS	CILOANS	FIXASSTS	SECURITY	DEPOSITS	BADLOANS
Panel A: Domestic Australian banks (excluding 4 mega banks)							
Mean	34.2186	0.5942	0.1753	0.0035	0.1723	0.5197	0.0066
σ	11.6986	0.0502	0.0190	0.0022	0.0341	0.0572	0.0025
Min	20.3315	0.5120	0.1392	0.0011	0.1131	0.4202	0.0026
25^{th}	22.6918	0.5469	0.1600	0.0020	0.1401	0.4817	0.0040
Median	30.0819	0.6009	0.1804	0.0025	0.1780	0.5231	0.0073
75^{th}	47.3337	0.6343	0.1914	0.0052	0.1970	0.5756	0.0086
Max	52.3294	0.6722	0.2077	0.0096	0.2246	0.5981	0.0109
Panel B: Global subsidiary banks							
Mean	12.6509	0.7761	0.1472	0.0015	0.1482	0.7371	0.0071
σ	1.8751	0.0220	0.0534	0.0004	0.0135	0.0418	0.0023
Min	9.4937	0.7111	0.0788	0.0009	0.1237	0.6576	0.0037
25^{th}	11.4882	0.7687	0.0936	0.0012	0.1377	0.7067	0.0055
Median	12.3986	0.7811	0.1264	0.0015	0.1470	0.7383	0.0072
75^{th}	14.0937	0.7898	0.1985	0.0016	0.1574	0.7638	0.0085
Max	16.4456	0.8026	0.2287	0.0024	0.1735	0.8168	0.0145
Panel C: Global branch banks							
Mean	8.5988	0.7276	0.1510	0.0007	0.1859	0.3583	0.0007
σ	1.7923	0.0430	0.0092	0.0002	0.0354	0.0319	0.0002
Min	5.3655	0.6410	0.1315	0.0004	0.1387	0.3127	0.0000
25^{th}	7.5679	0.6935	0.1449	0.0005	0.1535	0.3329	0.0000
Median	8.5987	0.7366	0.1504	0.0005	0.1750	0.3509	0.0008
75^{th}	9.3145	0.7627	0.1565	0.0009	0.2118	0.3765	0.0009
Max	12.3354	0.7957	0.1679	0.0010	0.2602	0.4282	0.0009

Table A2. Flight to quality.

Notes: This table shows the estimated coefficients for the forecasting regression:

$$\log(\frac{Federal_{i,t}}{MoneyMarket_{i,t}}) - \log(\mu[\frac{Federal_{i,t}}{MoneyMarket_{i,t}} \mid \Omega_t]) = \alpha + \beta_L (Libor - OIS)_t + \beta_B GS \times (Libor - OIS)_t + \beta_B GB \times (Libor - OIS)_t + Controls + TFE + BFE + \epsilon_{i,j,t}$$

Here, $Federal_{i,j,t}$ and $MoneyMarket_{i,t}$ is the face value of all federal and money market bonds held by bank i at time t. $(Libor - OIS)_t$ is the unexpected change in the Libor-OIS spread measured at time t. GS and GB are dummy variables that take the value 1 if bank i is a global subsidiary or global branch bank, respectively. We control for total issuance of bonds of category j ($Issuance$), total holdings of bonds of category j by nonfinancial firms ($Nonfin$), the total face value of bonds across all categories that are held by bank i and are maturing on day t ($Maturity$), and unexpected change in the domestic money market spread ($BAB - OIS$). The numbers in parenthesis are the t-values. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. Daily data, 2006–2014.

$i =$	Crisis period (1)	Post-crisis period (2)
$(Libor - OIS)$	0.01	-0.14
	(0.40)	(-0.25)
$GB \times (Libor - OIS)$	-0.01	1.41**
	(-0.05)	(2.23)
$GS \times (Libor - OIS)$	-0.03	-0.04
	(-0.44)	(-0.04)
$BAB - OIS$	0.10*	-0.17
	(1.82)	(-0.74)
$Issuance$	7.97***	4.36
	(3.60)	(1.55)
$Nonbank$	-0.90**	0.99
	(-2.02)	(0.54)
$Maturity$	0.01	0.02
	(0.23)	(0.15)
BFE	Yes	Yes
TFE	Yes	Yes
F-value	7.57***	17.23***
N	6,759	9,196