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by Iñaki Aldasoro, Torsten Ehlers and Egemen Eren

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Business Models and Dollar Funding of Global Banks☆

Iñaki Aldasoro, Torsten Ehlers, Egemen Eren[1]

Abstract

Since the eurozone crisis, there has been a stark divergence between European banks and Japanese banks in their dollar uses and sources. We show that these shifts have implications for the price of dollar funding. We document a "Japan Repo Premium." Japanese banks pay a premium for repos with US money market funds (MMFs), despite identical contract and risk characteristics. Using the US MMF reform as a natural experiment, we establish that Japanese banks' long maturity dollar assets generate a relatively inelastic demand for long maturity dollar borrowing. Differences in the demand for dollar funding combined with market and supply side frictions can explain these pricing differences. MMFs mainly provide short term repos and favor longer term clients for long maturity repos. Japanese banks concentrate their repo borrowing, reducing their bargaining power in order to extend their funding maturity. Our results have implications for the formation of global dollar funding networks. We provide evidence for European banks intermediating repos to Japanese banks, with economically significant estimated spreads from maturity transformation.

Keywords: Global banks, dollar funding, money market funds, relationship frictions, US Money Market Fund reform
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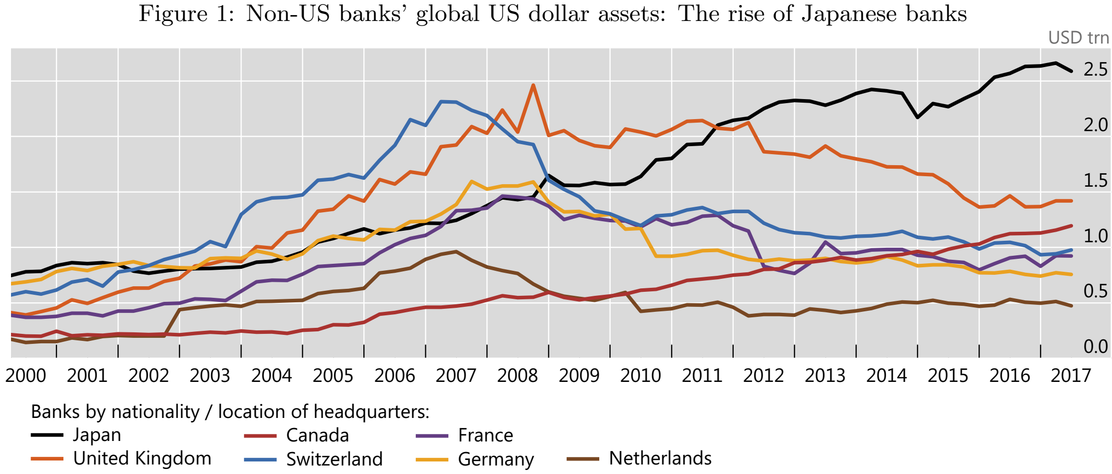
[1]Bank for International Settlements, Centralbahnplatz 2, 4051 Basel, Switzerland. ✉: Inaki.Aldasoro@bis.org, Torsten.Ehlers@bis.org, Egemen.Eren@bis.org (Corresponding author).

"I need a dollar dollar, a dollar is what I need. And if I share with you my story would you share your dollar with me." Aloe Blacc

1. Introduction

Non-US global banks collectively hold $12.6 trillion of dollar denominated assets - rivaling those of US banks (Shin (2012), Ivashina, Scharfstein and Stein (2015)). Since the Great Financial Crisis (GFC) and the eurozone crisis, however, there has been a stark divergence between European and Japanese banks. Between 2007 and 2017, global dollar assets of Japanese banks have increased by 88%, while those of European banks have shrunk by 42% (Figure 1).

Figure 1: Non-US banks' global US dollar assets: The rise of Japanese banks



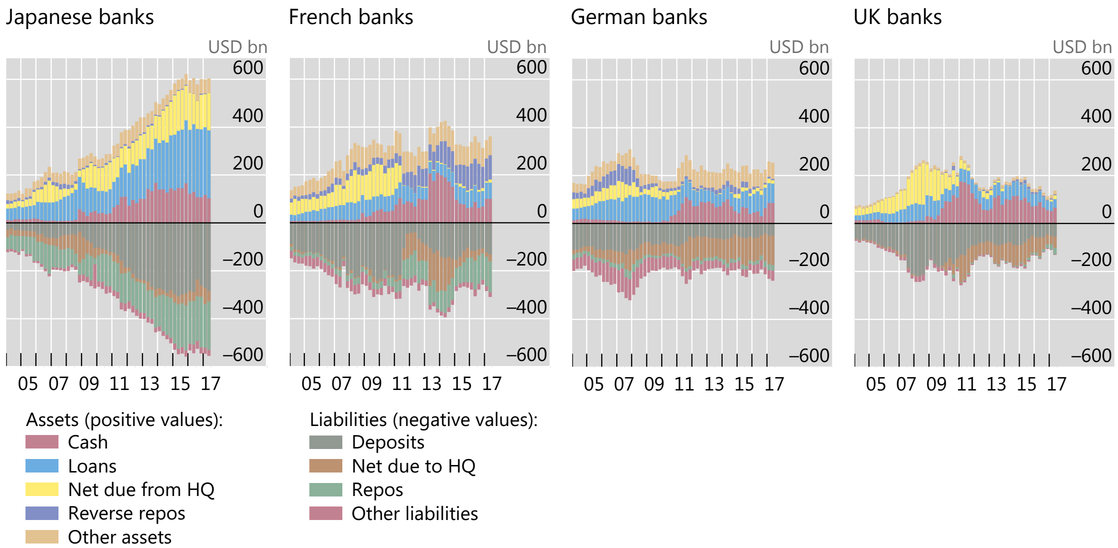
Note: Excludes interoffice positions.

Source: BIS locational banking statistics; BIS consolidated banking statistics.

There has also been a drastic change in the sources and uses of dollars for European and Japanese banks, as is clearly reflected in the balance sheets of the branches and agencies in the United States in Figure 2. Prior to 2008, the composition of balance sheets of European and Japanese US bank branches were indistinguishable. Since then, however, there have been dramatic changes in both the assets and liabilities for European banks, while Japanese banks' US branches have grown mostly through traditional banking activities and longer maturity assets. Since the eurozone crisis, investments of European banks in interest earning excess reserves and repo intermediation have replaced loans to a large extent. Moreover, European banks' US branches have become net borrowers of dollars from their headquarters.

In this paper, we focus on the implications of the stark divergence of global banks' business models for dollar funding markets. With limited access to customer dollar deposits, global banks fund increasingly different assets by competing in the same, mostly short-term, wholesale dollar funding markets. Does the heterogeneity in business models lead to heterogeneity in the demand for dollar funding? What does it imply for

Figure 2: Balance Sheets of US Branches and Agencies of Foreign Banks



Source: FFIEC 002

the competition for dollar funding? What are the pricing implications? How do the pricing implications affect the composition of dollar funding by global banks?

We focus on the markets for repurchase agreements (repos), commercial paper (CP), certificates of deposits (CD) and asset-backed commercial paper (ABCP) between global banks and US money market funds (MMFs). US MMFs are a significant source of dollar funding for foreign banks and their regulatory filings allow us to use granular data for a detailed analysis of the dollar funding profiles of global banks.

We document a "Japan Repo Premium." Japanese banks pay a higher interest rate than other global banks on repos with US MMFs controlling for various measures of risk, such as the underlying collateral, the 5-year CDS spread of the issuing bank and other contract characteristics. It is present even for overnight repos backed by US Treasuries, the safest possible repo contract. The Japan Repo Premium, which is around 3 basis points, cannot be explained by any unobserved measure of counterparty risk, since there is no Japan premium for riskier and typically longer maturity instruments, such as CP, CD and ABCPs. In fact, we find that Japanese banks can obtain funding through those instruments at a discount compared to other global banks.

The fact that these pricing differences persist points to the existence of frictions in these markets. Therefore, understanding the nature of these frictions is a crucial auxiliary step to address the questions we set out to answer. These markets are in effect over-the-counter (OTC) markets, therefore we expect that the relative bargaining power of banks and MMFs should matter for pricing (Duffie, Garleanu and Pedersen (2005)). Indeed, we show that measures of bargaining power in part explain the Japan Repo Premium. Japanese banks rely only on a limited set of counterparties to provide repo funding, while their borrowing in CP, CD and ABCPs is much more diversified.

Furthermore, once bargaining power is accounted for, the Japan Repo Premium exists only for longer maturity repos.

Do Japanese banks have a relatively more inelastic demand for longer-maturity dollar funding due to the longer maturity of their dollar assets? Our sample period provides us with a natural experiment to answer this question. The US MMF reform, implemented in October 2016, introduced floating net asset values (NAV) and redemption gates and fees for institutional prime funds, in effect making them less attractive to MMF investors. In response to the reform, many fund families converted their prime funds into government funds. Prime funds are the only ones that are allowed to invest in CP, CD and ABCP issued by banks and these instruments are the main source of longer maturity funding.

We argue that this was an exogenous negative supply shock to long maturity funding for banks. In the face of such a negative supply shock, all else constant, banks with relatively inelastic demand for long maturity funding should see prices increase more. We test this in a differences-in-differences setup and find that the post-reform price that Japanese banks pay for CP, CD and ABCPs is higher.

Our results have implications for the formation of dollar funding networks. Why do Japanese banks not diversify their repo borrowing as they do with their non-repo borrowing? The liquidity rules for MMFs constrain their capacity to provide longer term repos. Faced with this constraint, MMFs favor longer term clients when it comes to providing longer maturity repos. We indeed find that this is true across different specifications, even when we follow the relationship of the same counterparties across time. The same bank is able to get longer maturity repos from the same counterparty as the length of their relationship increases. Moreover, in line with our previous results, this is most pronounced for Japanese banks. The bottom line is: Japanese banks concentrate their repo borrowing. This reduces their bargaining power, while it extends their funding maturity.

A related fact we document is that MMFs account for a relatively small share of the total repos of Japanese banks in the US, whereas for other banks this share is substantially larger. In line with our results, we show that there is room for other banks to intermediate repos through maturity transformation to Japanese banks. We estimate that a non-Japanese bank (with similar characteristics to Japanese banks) can earn a spread of 16 basis points by borrowing overnight from MMFs and lending to a Japanese bank at 30 days, charging the price that MMFs charge, against the same collateral. This is an economically significant spread compared to the interest on excess reserves (IOER) arbitrage that European banks engage in, which earns around 8 basis points. Furthermore, for some European banks this intermediation can be done free of any capital charges between quarter-ends due to the way Basel III rules are implemented in their home countries.

Even though there are no data on bilateral exposures, we show indirect evidence for this intermediation. We use the fact that European, and especially French, banks retreat from repo markets at quarter ends. This is a decision taken at the headquarter level, based on their leverage ratio calculations at the end of the quarter and is arguably exogenous to Japanese banks. We show that the larger the retreat of French banks in terms of volumes, the wider the 1-week JPY/USD basis, consistent with the hypothesis that Japanese banks use the more expensive FX swap market to weather through the quarter end effects until European banks return to repo markets.

This paper fits into the growing literature on global banking (see Cetorelli and Goldberg (2012), Acharya and Schnabl (2010), Shin (2012), Bruno and Shin (2015), Bräuning and Ivashina (2017)). Our paper relates most closely to Ivashina et al. (2015). They take the presence of global banks in dollar markets as given and focus on the consequences for cyclical variation in credit supply across countries. We complement this perspective by documenting changes in the *composition* of global dollar markets to: first, derive stylized facts about the business models of global banks in relation to their dollar uses and sources, and second, to analyze the dollar pricing implications of this.

The focus on business models of global banks also links our paper to Correa, Sapriza and Zlate (2016), McGuire and von Peter (2012) and Pozsar and Smith (2016) among others. While the focus of Correa et al. (2016) is on the real effects of dollar funding squeezes for global banks, we zoom in instead on the implications of divergent business models, particularly in terms of pricing. A global perspective on dollar funding of non-US banks is taken by McGuire and von Peter (2012), who propose a measure of the dollar funding gap to study the dollar shortage during the GFC. The dollar funding gap, which measures the mismatch between on-balance sheet dollar assets and liabilities, can be considered as a rough approximation to the (inelastic) demand for dollar funding we focus on in this paper. Pozsar and Smith (2016) use the FFIEC 002 filings of US branches and agencies of foreign banks, which we also use to derive our stylized facts, to describe the business models of global banks in relation to the constraints imposed by Basel III regulations. The focus on pricing of dollar funding, in particular regarding pricing heterogeneity in the cross-section of banks, links our paper to the recent contribution by Abassi and Bräuning (2018). They find large cross-sectional variation in the cost of dollar hedging for virtually identical contracts, and provide evidence that this can be accounted for by banks' dollar funding gaps, dollar funding composition, access to internal capital markets and bank capital.

Our paper also contributes to the new and rapidly growing literature on relationships in OTC money markets. Chernenko and Sunderam (2014) show that during the eurozone crisis, MMFs with low exposure to eurozone banks provided financing to issuers with pre-existing relationships. Han and Nikolaou (2016) find that relationships between MMFs and banks affect the likelihood and terms of trade and help buffer demand and supply shocks. Hu, Pan and Wang (2015) document heterogeneity in pricing across fund families. However, their main focus is haircuts for equity and corporate bond collateral. Li (2017) finds evidence of reciprocal lending relationships, whereby MMFs and banks use a "bundling" strategy across short term and longer term markets. This paper relates to ours as it centers around a similar trade-off: banks want to lengthen maturities while MMFs want to keep them very short.[2] We contribute to

[2]Our paper is also related to the literature on the functioning and characteristics of money market funds. For related papers, see Christoffersen and Musto (2002), Kacperczyk and Schnabl (2013), Mc-

this literature by highlighting that bargaining power and relationships can be important determinants of pricing, and by emphasizing that this effect plays out particularly at the level of fund families.

Our results also inform the literature on the significant and persistent covered interest parity (CIP) deviations since the GFC.[3] Finally, our paper is related to others that study the impact of the US MMF reform on US dollar funding markets. Aldasoro, Ehlers, Eren and McCauley (2017b) and Pozsar (2017) show the changes in the balance sheet composition of non-US banks following the US MMF reform. Cipriani, La Spada and Mulder (2017) document the reaction of money market fund investors and portfolio managers to the reform.

2. Business Models of Global Banks: Stylized Facts

Dollar banking activities of non-US banks have become increasingly heterogeneous. Since the GFC, and even more so after the eurozone crisis, Japanese banks have become the most significant player in dollar banking in terms of size. European banks have retreated from their dollar loan business and have instead concentrated on short term profit opportunities. Japanese banks, however, have continued to expand their long term dollar loans to become the largest holders of dollar assets among non-US global banks.

We argue and show that these diverging patterns of dollar businesses of global banks affect the demand and the pricing of wholesale dollar funding and lead to the formation of dollar funding networks.

We first establish four key stylized facts about global banks' US dollar asset exposures and funding patterns to form the basis of our analysis:

Fact 1: *Dollar assets and loan exposures of Japanese banks are large and growing compared to other foreign banks. European banks have increased investments in excess reserves and repo intermediation, replacing loans.*

Japanese banks run an increasingly distinctive dollar business model compared to other foreign banks. As we show in Figure 1, they hold approximately $2.5 trillion of US dollar claims on the non-bank sector, 1.7 times as much as UK banks, and more than twice as much as German or French banks, which traditionally have run large dollar books. As European banks deleveraged in response to the GFC and the eurozone crisis, they reduced their dollar loans. Japanese banks, on the contrary, continued to expand their dollar loan book. Japanese banks' dollar exposures have not only become the

Cabe (2010), Strahan and Tanyeri (2015), Krishnamurthy, Nagel and Orlov (2014), Parlatore (2016), Baba, McCauley and Ramaswamy (2009), Schmidt, Timmermann and Wermers (2016), DiMaggio and Kacperczyk (2017), La Spada (2017).

[3]For papers studying post-crisis CIP deviations, see Du, Tepper and Verdelhan (2017), Sushko, Borio, McCauley and McGuire (2016), Rime, Schrimpf and Syrstad (2017), Avdjiev, Du, Koch and Shin (2016).

largest in size, but are also longer term and harder to scale back. In Figure 2 we show that Japanese banks collectively form the largest branches and agencies in the United States, with a large loan book on the asset side that by its nature is longer term. This comes with the need to have larger amounts of longer term dollar funding on the liability side - assuming that banks or supervisors manage risks prudently. Figure 2 indicates that European banks, on the other hand, have even shifted towards short term activities.

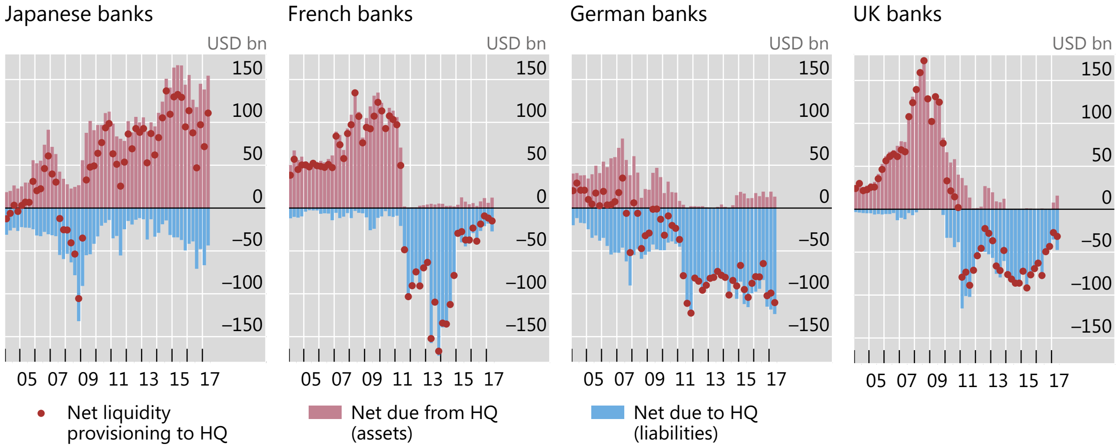
Fact 2: *The headquarters of Japanese banks use their US branches and agencies as a conduit for dollar funding, whereas the US branches of European banks receive net dollar transfers from their headquarters, investing them mostly in their reserve accounts at the Federal Reserve.*

The operations of global banks in the United States play a key role in funding and conducting their dollar operations, due to their easier access to wholesale dollar funding markets. The headquarters of Japanese banks have consistently used their branches and agencies in the United States as a conduit for dollar funding. European banks, on the other hand, have fundamentally changed their operations in the United States since 2011. This change can be attributed to two main factors: the intensification of the euro area sovereign debt crisis and the implementation of new FDIC measures.[4] European banks have continuously reduced their long term loan exposures to reduce risks following the eurozone crisis (Figure 2). Further, their US branches and agencies abruptly became net receivers of dollars from their head offices, as opposed to being a conduit for supplying dollar liquidity.[5] Together with the funding obtained from US MMFs, these dollars were, to a large extent, invested in reserves in the so-called interest on excess reserves (IOER) arbitrage (Banegas and Tase (2016)). Shrinking of loan books and the use of dollar liquidity for arbitrage have made the dollar operations of European banks more short term and easily scalable.

[4] See Kreicher, McCauley and McGuire (2013) for details. In essence, new FDIC measures required US banks to pay deposit insurance fees based on total assets, instead of deposit liabilities. This rendered non-US banks in an advantaged position to borrow in wholesale funding markets and invest in reserves.

[5] See also Correa, Sapriza and Zlate (2016)

Figure 3: Interoffice positions of US Branches and Agencies of Foreign Banks



Source: US FFIEC002 Call Reports; authors' calculations.

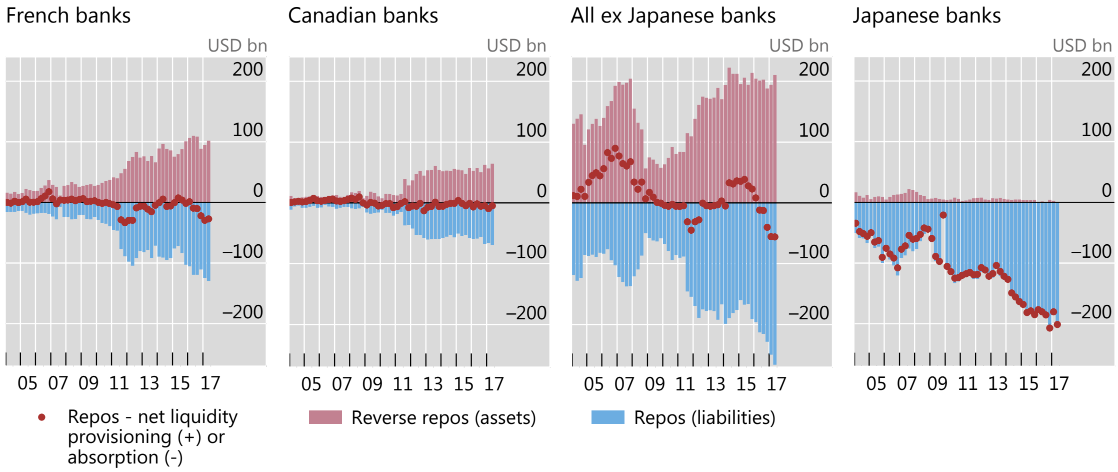
<u>Fact 3:</u> *Global banks are, to a large extent, matched-book repo intermediaries, except for Japanese banks, which are large net borrowers in repo markets. Yet, repos of Japanese banks with US MMFs are significantly smaller.*

Branches and agencies of Japanese banks in the United States mainly borrow through the repo market, with increasing amounts (Figure 4). Figure B.7 shows that in fact this is not a feature unique to the branches and agencies operating in the United States, but of the consolidated operations of Japanese banks globally. In contrast, other banks, especially French and Canadian, act as matched repo book intermediaries. Despite the reliance of Japanese banks on funding through repo markets, a relatively small fraction of their US repos is with MMFs, whereas for other global banks this fraction is substantially larger. As of end-September 2016, this ratio stands between 1.6% and 11.7% for Japanese banks (Norinchukin Bank and Mizuho, respectively), 45% and 52.1% for French banks (Societe Generale and Credit Agricole), and 48% and 62.8% for Canadian banks (Bank of Montreal and Bank of Nova Scotia)[6].

This raises the question whether other non-US banks intermediate repos to Japanese banks, by obtaining dollar funding through repos with US MMFs and providing dollar liquidity to Japanese banks via reverse repos. We discuss this in more detail and provide further evidence in Section 5.1.

[6]Due to data availability and quality issues, we were able to establish these ratios only for a reduced number of banks. We report the ratios before the effects of the MMF reform started to kick in.

Figure 4: Repo books by country



Source: US FFIEC002 Call Reports; authors' calculations.

Fact 4: *Japanese banks rely on MMFs more for non-repo funding than for repos. For others, the mix is more balanced. Within the funding provided by MMFs, non-repos have substantially longer maturities than repos.*

Table 1: Summary statistics of dollar funding through different instruments

	Agg outstanding volume in USD bn			Avg value-weighted maturity in days		
Instruments	Repos	Non-repos	All	Repos	Non-repos	All
Japanese banks	29.4	110.1	139.5	6.2	49.3	40.3
Others	449.3	458.3	907.7	6.5	47.6	27.2

Notes: Agg outstanding volume is the average month-end position aggregated acrosss all banks of the given nationalities.

Consistent with the fact that Japanese banks have large longer term exposures on the asset side, the maturity of their overall liabilities with MMFs is also longer (around 40 days versus 27 days for non-Japanese banks). Longer maturity is easier to obtain through non-repo instruments (CPs, CDs and ABCPs), which on average is around 38 days compared to 6.5 days for repos. Japanese banks have received about 3.7 times more funding from US MMFs through non-repo instruments than through repos.

Overall, the unique business model of Japanese banks suggests they have a relatively inelastic demand for long term dollar funding raised in the United States compared to other global banks. Non-Japanese banks are active in the repo market, but do not rely on the market for funding but rather seem to intermediate repos to exploit profit opportunities. In what follows, we study the implications of diverging business models for the price of dollar funding.

3. The Price of Dollar Funding

In this section, we show that the price of dollar funding differs for global banks in a way that cannot be explained by contract or risk characteristics. Moreover, pricing patterns in the repo and non-repo markets are not identical and pricing at quarter-ends is different from non quarter-ends. We identify and measure relevant frictions due to the OTC structure of this market to explain the puzzling pricing patterns.

We base our analysis on the holdings of US MMFs at month-ends as reported in their regulatory filings to the Securities and Exchange Commission, obtained from Crane data.[7] Throughout the paper, we restrict our analysis to the instruments through which MMF and global banks interact, namely repos, CP, CD and ABCPs.[8] Furthermore, we focus on Global Systemically Important Banks (GSIBs) and non-GSIB banks that are large and active in transacting with MMFs.

We observe information at the contract level c between bank i and fund j, reported as of end of month t. Contracts can be of two broad types: $repo$ and $non-repo$. Any given contract will have a number of characteristics associated to it. The interest rate paid by banks ($Rate_{ijct}$) is our left-hand side variable in most of the regressions. Other variables are the reported remaining maturity of the contract ($Rem.\, maturity_{ijct}$), and the dollar amount of the contract, which we use in logarithm ($Log(value_{ijct})$). Furthermore, contracts will have other key characteristics, which we will capture mostly with fixed-effects. Regardless of the broad contract type, some key characteristics are: the fund type of fund j, which can be either Government, Prime or Treasury ($Fund\, Type_j$); the fund family to which fund j belongs ($Fund\, Family_j$); if the contract is a repo, the broad collateral category used, which can be either Agency collateral ($Agency\, coll._c$), Treasury collateral ($Treasury\, coll._c$) or Other collateral ($Other\, coll._c$); if the contract is "non-repo", the type of instrument considered, which as discussed earlier can be either CP (CP_c), CD (CD_c) or ABCP ($ABCP_c$). Our main dummy variable of interest, namely that which captures whether a bank is headquartered in Japan, is denoted by JP_i. In most regressions we also control for the 5-year CDS spread of bank i as a proxy for counterparty risk ($5y\, CDS_{it}$).

Our sample period runs from February 2011 to December 2017. Our final repo sample consists of a total of 205,165 contracts between 39 banks from 9 countries with 329 funds belonging to 70 fund families. The final non-repo sample (CP, CD and ABCP) consists of 538,848 observations linking 49 banks from 14 countries with 175 funds belonging to 66 fund families.

[7] Details on the data and the cleaning procedure we perform are provided in Appendix A. In the same appendix we also discuss the other datasets used to complement our analysis.

[8] Throughout the paper we group CP, CD and ABCP together and refer to the group as "non-repo".

3.1. The Japan Repo Premium

In what follows, we document the existence of a "Japan Repo Premium." We refer to the Japan Repo Premium as what Japanese banks pay for repos with MMFs *in excess of* the risk premium reflecting bank and contract characteristics. That is, it is the coefficient of the dummy variable that indicates whether a bank is headquartered in Japan after controlling for various measures of bank and contract risk. In a perfectly competitive market, repos with the same risk characteristics should be priced the same, hence our coefficient of interest should be zero. The fact that the headquarter country of the borrower matters in repo pricing over and above the relevant risks points to the existence of frictions in repo pricing.

With the notation above in mind, in Table 2 we estimate the following equation, in steps, for the repo market:

$$\begin{aligned} Rate_{ijct} = {} & \gamma_1 Log(value_{ijct}) + \gamma_2 Rem.\, maturity_{ijct} + \gamma_3 5y\, CDS_{it} \\ & + \gamma_4 Agency\, coll._c + \gamma_5 Other\, coll._c + \gamma_6 JP_i + Fixed\, Effects + \epsilon_{ijct} \end{aligned} \tag{1}$$

We control for theoretically relevant contract and bank characteristics, to evaluate if Japanese banks are paying a higher rate for repos simply because they offer riskier contracts. In particular, we control for the collateral pledged, counterparty risk (5-year CDS spreads), maturity (whereby original maturity is proxied by remaining maturity), size of repos, $date * fund\, type$ fixed effects and $collateral * date$ interaction fixed effects. Finally, we run the regression only on the sample of overnight repos with US Treasury collateral. In all specifications, the Japan Repo Premium persists. The country where a bank is headquartered matters for repo pricing over and above the riskiness of the bank and the contract.

In columns (1)-(4) of Table 2, we progressively add control variables to show the response of our dummy variable of interest (JP_i, i.e. whether a bank is headquartered in Japan). The regressions in columns (4) and (5) make the strongest case. In column (4), we control for $collateral * date$ fixed effects. That is, allowing for the possibility of time-varying riskiness of the underlying collateral and controlling for other risk factors, a bank pays a higher repo rate if it is headquartered in Japan. The market for overnight repos backed by Treasury collateral is the safest and most homogeneous funding market. We show in column (5) that the Japan Repo Premium exists even in this segment.

The Japan Repo Premium is not an artifact of the comparison being made between Japanese banks versus an average of all other banks. There is also a statistically significant Japan repo premium with respect to banks from *each individual* country in almost all specifications.[9]

[9] In the Online Appendix we report the regressions with a dummy for each individual country using the same controls as in Table 2. Hence, the coefficients can be interpreted as how much banks from different countries pay on average for repos relative to Japanese banks, conditional on the control variables. In Appendix D, we report several other robustness checks.

In addition to showing that where a bank is headquartered matters for repo pricing, Table 2 also shows how risks are priced in repos. There are three main takeaways related to the pricing of risk in repos: First, once collateral is taken into account, counterparty risk (measured by CDS spreads) does little to explain pricing as the R^2 hardly improves from column (2) to column (3). Second, there is a stark difference in pricing for different types of collateral. While repo rates are only around 1-2 basis points larger for Agency collateral compared to US Treasury collateral, the repo rates for other collateral are around 26 basis points higher. Third, all else constant, a 3 day increase in maturity increases the repo rates by 1 basis point on average.

Table 2: The Japan repo premium

	(1)	(2)	(3)	(4)	(5)
Sample:	Repo	Repo	Repo	Repo	Repo (O/N UST coll.)†
	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$
$Log(value_{ijct})$	-0.173	0.148	0.0473	-0.00513	0.168*
	(0.220)	(0.172)	(0.137)	(0.145)	(0.0883)
$Rem.\,maturity_{ijct}$	0.462***	0.353***	0.359***	0.359***	
	(0.0424)	(0.0348)	(0.0341)	(0.0343)	
$Agency\,coll._c$		1.383***	1.362***		
		(0.467)	(0.436)		
$Other\,coll._c$		25.58***	26.21***		
		(1.987)	(2.038)		
$5y\,CDS_{it}$			0.0256***	0.0245***	0.00320
			(0.00597)	(0.00629)	(0.00225)
JP_i	4.462***	3.261***	3.023***	2.811**	1.258***
	(0.948)	(1.110)	(1.122)	(1.171)	(0.414)
Observations	193,689	193,689	181,425	181,425	26,113
R-squared	0.814	0.865	0.868	0.872	0.946
Date*Fund Type FE	✓	✓	✓	✓	✓
Date*Collateral FE				✓	

Notes: Regressions at the contract level, the dependent variable is the interest rate (in basis points) paid by a bank when borrowing from a fund. $Log(value_{ijct})$ refers to the logarithm of the value of the contract and $5y\,CDS_{it}$ denotes the 5 year CDS spread of the borrowing bank. JP_i is a dummy which takes the value 1 if the headquarters of the bank are in Japan. The coefficients on $Agency\,coll._c$ and $Other\,coll._c$ capture the pricing difference compared to *Treasury coll.* (where the coefficient on *Treasury coll.* is zero.). †: specification (5) represents a regression only for overnight repos with US Treasury collateral. Standard errors clustered at the fund family level are in parentheses. ***, **, * denote significance at the 1, 5 and 10% level respectively.

3.2. Risk and portfolio cross-subsidization do not explain the Japan Repo Premium

Can the Japan repo premium be explained by some other measure of counterparty risk that is not adequately captured by CDS spreads? If so, we should expect Japanese banks to pay a larger premium for riskier instruments. However, as we show in Table 3, there is a "Japan discount" for riskier and typically longer maturity instruments, such as CP, CD and ABCPs. Furthermore, controlling for time-varying fund level factors, the same funds that provide funding through these instruments to Japanese banks, do so at a premium for repos, but at a discount for CP, CD and ABCPs. Therefore, counterparty risks cannot explain the Japan Repo Premium.[10] In particular, denoting by γ_c^{repo} a dummy variable which captures whether the contract is a repo, we estimate the following equation:

$$\begin{aligned} Rate_{ijct} &= \beta_1 Log(value_{ijct}) + \beta_2 Rem.\,maturity_{ijct} + \beta_3 5y\,CDS_{it} \\ &+ \beta_4 JP_i + \beta_5 JP_i * \gamma_c^{repo} + Fixed\,Effects + \epsilon_{ijct} \end{aligned} \tag{2}$$

Table 3: The Japan discount in CP, CD and ABCP markets

	(1)	(2)	(3)	(4)
Sample:	Non-repo	Non-repo	Full	Repo (Non-prime funds)†
	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$
$Log(value_{ijct})$	-0.119	-0.157	-0.498	0.143
	(0.233)	(0.244)	(0.300)	(0.110)
$Rem.\,maturity_{ijct}$	0.0628***	0.0658***	0.0920***	0.0895***
	(0.00678)	(0.00651)	(0.0116)	(0.0115)
$5y\,CDS_{it}$		0.0370***	0.0267***	0.00247
		(0.00492)	(0.00234)	(0.00244)
JP_i	-4.437***	-4.212***	-4.072***	2.380***
	(0.710)	(0.695)	(0.620)	(0.509)
$JP_i * \gamma_c^{repo}$			5.680***	
			(1.443)	
Observations	295,842	268,966	450,109	91,922
R-squared	0.876	0.881	0.905	0.969
Date*Instrument FE	✓	✓	✓	✓
Date*Fund FE			✓	✓

Notes: Regressions at the contract level, the dependent variable is the interest (in basis points) paid by a bank when borrowing from a fund. Funds are restricted to prime funds, unless otherwise noted. $Log(value_{ijct})$ refers to the logarithm of the value of the contract, while $5y\,CDS_{it}$ denotes the 5 year CDS spread of the borrowing bank. JP_i is a dummy which takes the value 1 if the headquarters of the bank are in Japan. Columns (1)-(2) restrict the instrument to CP, CD and ABCP (i.e. non-repos). Column (3) considers the entire market (i.e. repos and non-repos) and interacts the JP_i dummy with a dummy for repo contracts; Date*Instrument fixed effects in this table control separately for time-varying characteristics of ABCP, CP, CD, and the three different types of collateral within repo contracts (Treasury, Government Agency and Other), wherever applicable. †: Column (4) considers only Non-Prime funds (i.e. government or Treasury funds that can only do repos with banks). Standard errors clustered at the fund family level are in parentheses. ***, **, * denote significance at the 1, 5 and 10% level respectively.

[10] One potential driver of the Japan Repo Premium could be that the sample of banks are different between the repo and non-repo markets. The results go through when we restrict the sample for the non-repo market to the banks that appear in the repo market (see Appendix D).

The first two columns of Table 3, which focus on the non-repo market, show that there is in fact a "Japan discount" on non-repos, which is robust across different specifications. Similar to the repo regressions in Table 2, CDS spreads have a positive and significant effect on pricing, but they do very little to improve the R^2 of the regression. In column (3), we run a regression for the full market, but include an interaction between the dummy capturing whether a bank is headquartered in Japan and a dummy for the contract is a repo contract ($JP * \gamma_c^{repo}$, highlighted in red in Equation 2). In addition to controlling for maturity and $fund * date$ fixed effects, we also include instrument fixed effects, which refer to the three types of non-repo instruments (CP, CD and ABCP), as well as the three types of collateral within repo contracts in column (3) (Government Agency, Treasury and Other collateral). In this way, we test whether the *same* fund at the *same* date for similar maturity, charges a Japanese bank higher prices in repo contracts than CP, CD and ABCP contracts. We find that this is indeed the case.

The results in columns (1)-(3) in Table 3 point to the existence of a discount for Japanese banks in non-repo markets. This raises the question whether the Japan Repo Premium can be explained by cross-subsidization on the part of funds, so that on average they pay the same price as others. In that case, funds would perform portfolio cross-subsidization by charging specific banks a premium in one market, compensated by a discount in the other market. If this were the case, we would expect the Japan Repo Premium to be absent for non-prime funds (i.e. funds that only invest in repos and for which the cross-subsidization argument is therefore irrelevant). In column (4), we test this by restricting the sample to non-prime funds, while still controlling for maturity, $instrument * date$ (i.e. type of collateral) and $fund * date$ fixed effects. Indeed, we find that non-prime funds do charge a premium to Japanese banks, of a magnitude similar to that shown in Table 2. Therefore, cross-subsidization cannot explain the Japan Repo Premium.

3.3. Quarter-end Window Dressing: Implications for the Japan Repo Premium

The implementation of Basel III regulations varies across jurisdictions. For European banks, the leverage ratio, for example, is implemented at quarter-ends, whereas it is implemented averaging daily balance sheet snapshots for other countries. This leads to a more pronounced quarter-end window dressing for European banks. Some European banks expand their balance sheets within quarters, particularly through repos, and substantially unwind this expansion on quarter-end (Munyan (2015), CGFS (2017)). We observe in our dataset such regulatory arbitrage (see Figure 6 in Section 5.2 for further details). As banks shrink their repo positions at quarter-ends, MMFs place their reverse repos with the overnight reverse repurchase program of the Federal Reserve (Aldasoro, Ehlers and Eren (2017a)).

Banks and MMFs do not interact in a centralized platform, but in a market that is essentially an OTC search market. In such markets, the relative bargaining power of parties matters for pricing.

In this subsection, we conjecture that quarter-ends are periods where MMFs have lower bargaining power with banks and test whether this has implications for the Japan

Repo Premium. In particular, Japanese banks should be in a better bargaining position at quarter ends. We therefore expect the Japan Repo Premium to be smaller at quarter ends. An exception to such dynamic would be, however, expected: for overnight Treasury repos there is a relatively attractive alternative option for MMFs to park their funds, namely the overnight reverse repo facility offered by the Federal Reserve. Therefore, we expect the quarter-end effect on the Japan Repo Premium to be smaller or non-existent for overnight Treasury repos. Hypotheses 1a and 1b summarize this conjecture.

Hypothesis 1a *The Japan Repo Premium is lower at quarter ends.*

Hypothesis 1b *Due to the existence of the overnight reverse repo facility of the Federal Reserve, the reduction of the Japan Repo Premium at quarter ends is muted for overnight repos backed by US Treasury collateral.*

Table 4: The Japan repo premium at quarter ends

	(1)	(2)	(3)	(4)	(5)
Sample:	Repo	Repo	Repo	Repo	Repo (O/N UST coll.)†
	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$
$Log(value_{ijct})$	-0.172	0.149	0.0481	-0.00451	0.167*
	(0.220)	(0.172)	(0.137)	(0.145)	(0.0883)
$Rem.\,maturity_{ijct}$	0.462***	0.353***	0.359***	0.359***	
	(0.0424)	(0.0348)	(0.0341)	(0.0343)	
$5y\,CDS_{it}$			0.0256***	0.0245***	0.00320
			(0.00597)	(0.00630)	(0.00224)
JP_i	4.985***	3.639***	3.418***	3.137***	1.026***
	(0.894)	(1.047)	(1.063)	(1.106)	(0.351)
$JP_i * QE_t$	-1.631**	-1.178**	-1.231**	-1.015*	2.224
	(0.716)	(0.583)	(0.588)	(0.540)	(2.210)
Observations	193,689	193,689	181,425	181,425	26,113
R-squared	0.814	0.865	0.868	0.872	0.946
Date*Fund Type FE	✓	✓	✓	✓	✓
Collateral FE		✓	✓		
Date*Collateral FE				✓	

Notes: Regressions at the contract level, the dependent variable is the interest rate (in basis points) paid by a bank when borrowing from a fund. Controls include $Log(value_{ijct})$, $5y\,CDS_{it}$ and $Rem.\,maturity_{ijct}$ where applicable. $Log(value_{ijct})$ refers to the logarithm of the value of the contract and $5y\,CDS_{it}$ denotes the 5 year CDS spread of the borrowing bank. JP_i is a dummy which takes the value 1 if the headquarters of the bank are in Japan. QE_t is 1 if the observation is at a quarter-end. †: specification (5) represents a regression only for overnight repos with US Treasury collateral. Standard errors clustered at the fund family level are in parentheses. ***, **, * denote significance at the 1, 5 and 10% level respectively. The coefficient on QE_t is absorbed by fixed effects.

Table 4 replicates the structure of our baseline regressions in Equation 1, but focuses on quarter end effects by adding an interaction between the JP_i dummy and a dummy which equals one if the date of the contract is a quarter end (QE_t). In line with our hypothesis, we find that the premium paid by Japanese banks is reduced at quarter ends by about 1.2-1.6 basis points. Furthermore, for overnight repos with Treasury collateral we observe that not only the coefficient is not statistically significant, but also the sign reverses. The fact that MMFs have a safe and reliable alternative to park their funds overnight reduces the bargaining power that Japanese banks may have at quarter ends for this specific type of contract.

3.4. Relationship frictions and demand for long maturity

Our results so far show that the Japan Repo Premium is not due to any observed or unobserved measure of counterparty risk and it is lower at quarter ends, in line with the hypothesis that relative bargaining power plays a role in pricing. In this subsection, we construct measures of bargaining power and show that these frictions and demand for longer maturity funding can jointly account for the Japan Repo Premium.

In OTC markets, bilateral relationships are endogenously formed and consolidate through repeated interaction. Such lender-borrower relationship building in money markets has been shown to matter for trading *volumes* (Chernenko and Sunderam (2014), Han and Nikolaou (2016)). We focus on the implications for *pricing*, as also done partly by Han and Nikolaou (2016).

We test whether variables that measure relationship strength or relative bargaining power affect pricing in these markets. If a bank relies heavily on a given lender, then the latter can be expected to have higher "bargaining power". Similarly, if a borrower bank is important within the portfolio of a given lender, then more bargaining power should lie with the bank. This is formalized in our second hypothesis, which posits that relationships matter in the pricing of repos between MMFs and banks.

Ex-ante, it is not clear whether there are pricing complementarities between funds that belong to the same fund family. Therefore, it is possible that a fund's bargaining power does not depend on its own share, but on the share of the fund family it belongs to. We are initially agnostic and express the hypothesis as two sub-hypotheses, for funds (2a) and fund families (2b) respectively.

Hypothesis 2a *Relationships of banks with* funds *matter in the pricing of repos: the more "important" a* fund *(bank) is for a bank (*fund*), the higher (lower) is the price.*

Hypothesis 2b *Relationships of banks with* fund families *matter in the pricing of repos: the more "important" a* fund family *(bank) is for a bank (*fund family*), the higher (lower) is the price.*

In order to test these hypotheses, as well as others that follow, we build measures of relationships in the spirit of Ashcraft and Duffie (2007), Chernenko and Sunderam (2014), and Han and Nikolaou (2016). In particular, for a given market m ($m \in \{repo, non-repo\}$) and date t, we compute how important is a fund j for a bank i as follows:

$$BV_{ijt}^{m} = \frac{\sum_{i,j} Value_{ijt}^{m}}{\sum_{j=1}^{F_i} Value_{ijt}^{m}} \tag{3}$$

where $\sum_{i,j} Value^m_{ijt}$ is the total dollar amount of outstanding contracts between a bank i and a fund j in market m at time t and $\sum_{j=1}^{F_i} Value^m_{ijt}$ is the total dollar amount for bank i on market m and time t, where F_i is the total number of funds the bank interacts with. For fund families instead of funds, the indicator $BV^m_{ij^{ff}t}$ is built in the same manner, but replacing fund j with fund family j^{ff} where appropriate.

Higher readings of this indicator reflect larger fund (fund family) bargaining power, and could therefore be a potential driver of higher prices.

The alternative perspective, namely how important is a bank i for a fund j in market m at time t, is in turn given by:

$$FV^m_{ijt} = \frac{\sum_{j,i} Value^m_{ijt}}{\sum_{i=1}^{B_j} Value^m_{ijt}} \tag{4}$$

where $\sum_{j,i} Value^m_{ijt}$ represents the total dollar amount of outstanding contracts between fund j and bank i in market m at time t, and $\sum_{i=1}^{B_j} Value^m_{ijt}$ is the total dollar amount transacted by fund j in the same market and date, with B_j representing the number of banks fund j interacts with. The indicator for fund families, $FV^m_{ij^{ff}t}$, is constructed analogously. A large score in this indicator points to increased bargaining power on the side of the bank, and we therefore expect the price to be lower under such circumstances.

Japanese banks' repo borrowing is more concentrated than that of other global banks, particularly so at the level of fund families. Summary statistics by country and instrument for these measures are presented in Table 5 and Table 6. In the non-repo market, Japanese banks exhibit a slightly smaller concentration at the fund level. Funds and fund families' repo portfolios, in turn, are relatively less reliant on Japanese banks compared to other banks, whereas for non-repos the picture is reversed. These summary statistics point to Japanese banks relying heavily on a limited set of fund families when it comes to repo contracts, and fund families in turn being more dependent on non-Japanese banks in their overall repo portfolio. In theory, this would reduce the bargaining power of Japanese banks vis-à-vis the fund families that they do repos with.

Table 5: Average shares of funds ($\bar{BV}^m_{ijt}$) and families ($\bar{BV}^m_{ij^{ff}t}$) for banks , by instrument and country

	$\bar{BV}^m_{ij^{ff}t}$		$\bar{BV}^m_{ijt}$	
	Repo	Non-repo	Repos	Non-repo
Japan	38.7	11.0	7.6	3.0
Rest	14.4	10.8	2.9	3.6

Table 6: Average shares of banks for funds ($\bar{FV}^m_{ijt}$) and fund families ($\bar{FV}^m_{ijfft}$), by instrument and country

	$\bar{FV}^m_{ijfft}$		$\bar{FV}^m_{ijt}$	
	Repo	Non-repo	Repos	Non-repo
Japan	5.8	7.1	12.1	7.4
Rest	10.8	5.7	14.5	6.1

We use the relationship variables to test Hypothesis 2a by estimating the following equation:

$$\begin{aligned} Rate_{ijct} = {} & \mu_1^a Log(value_{ijct}) + \mu_2^a Rem.\,maturity_{ijct} + \mu_3^a 5y\,CDS_{it} \\ & + \mu_4^a JP_i + \mu_5^a BV^{repo}_{ijt} + \mu_6^a FV^{repo}_{ijt} + Fixed\,Effects + \epsilon_{ijct} \end{aligned} \tag{5}$$

We estimate the following equation to test Hypothesis 2b:

$$\begin{aligned} Rate_{ijct} = {} & \mu_1^b Log(value_{ijct}) + \mu_2^b Rem.\,maturity_{ijct} + \mu_3^b 5y\,CDS_{it} \\ & + \mu_4^b JP_i + \mu_5^b BV^{repo}_{ijfft} + \mu_6^b FV^{repo}_{ijfft} + Fixed\,Effects + \epsilon_{ijct} \end{aligned} \tag{6}$$

Columns (1) and (2) of Table 7 present the results for Hypotheses 2a and 2b. Under Hypothesis 2, we expect the measure of the importance of a fund (fund family) to a bank to have a positive sign (ie, the larger the fund bargaining power, the higher the price). For the measure of the importance of a bank to a fund, we expect the opposite. In all columns, we control for remaining maturity, size of the contract (in logarithm) and the 5 year CDS of the banks, as well as $date * fund\ type$ fixed effects (where fund type is either Prime, Government or Treasury) and $date * collateral$ fixed effects (where the collateral used for the repo is Treasury, Government Agency, or Other collateral).

Column (1) tests Hypothesis 2a and confirms the expected sign, though statistical significance is lacking. Relationships at the fund level do not seem to be able to significantly affect prices. In column (2) we test Hypothesis 2b. Both signs are as expected and the coefficients are statistically significant. Moreover, the premium paid by Japanese banks in repo contracts becomes smaller and loses its statistical significance. Relationships at the fund family level are therefore more relevant in explaining repo pricing, and render the premium paid by Japanese banks insignificant, though it is still positive.

Our descriptive analysis of business models suggests that Japanese banks have a relatively inelastic demand for longer maturity funding due to their longer maturity assets compared to others. If this is the case, then it should have implications also for the pricing of repos and should be relevant for explaining the Japan Repo Premium:

Hypothesis 3 *The Japan Repo Premium is larger for longer maturity repos.*

We estimate the following equation:

$$
\begin{aligned}
Rate_{ijct} = {} & \phi_1 Log(value_{ijct}) + \phi_2 Rem.\,maturity_{ijct} + \phi_3 5y\,CDS_{it} + \phi_4 BV^{repo}_{ijfft} + \phi_5 FV^{repo}_{ijfft} \\
& + \phi_6 JP_i + \phi_7 JP_i * Rem.\,maturity_{ijct} + Fixed\,Effects + \epsilon_{ijct}
\end{aligned} \tag{7}
$$

Column (3) of Table 7 shows evidence for this hypothesis, which we test by including an interaction between the dummy variable JP_i and the remaining maturity of the contract. Longer maturity repos naturally demand a premium, which is around 0.35 basis points per day in our sample using our standard controls. Japanese banks, however, are willing to pay an extra 0.15 basis points per day on top of that. The additional maturity premium can explain a significant part of the Japan Repo Premium, as the coefficient estimate on the Japan dummy drops from around 3 basis points to a negative and statistically insignificant number. In effect, both dimensions - longer maturity repos and the lack of bargaining power of Japanese banks for repos - are jointly responsible for the repo premium that Japanese banks pay.

Table 7: The Japan Repo Premium: Relationships and maturity

Sample:	(1) Repo $Rate_{ijct}$	(2) Repo $Rate_{ijct}$	(3) Repo $Rate_{ijct}$
JP_i	2.545*	1.244	-0.303
	(1.371)	(1.772)	(2.342)
$Rem.\,maturity_{ijct}$	0.358***	0.355***	0.344***
	(0.0347)	(0.0335)	(0.0343)
$JP_i * Rem.\,maturity_{ijct}$			0.146*
			(0.0846)
BV^{repo}_{ijt-1}	0.0415		
	(0.0304)		
FV^{repo}_{ijt-1}	-0.00827		
	(0.0227)		
$BV^{repo}_{ij^{ff}t-1}$		0.0590**	0.0593**
		(0.0229)	(0.0250)
$FV^{repo}_{ij^{ff}t-1}$		-0.0425***	-0.0411***
		(0.0152)	(0.0152)
Observations	164,634	176,573	176,573
R-squared	0.872	0.873	0.873
Controls	✓	✓	✓
Date*Fund Type FE	✓	✓	✓
Date*Collateral FE	✓	✓	✓

Notes: Regressions at the contract level, the dependent variable is the interest rate (in basis points) paid by a bank when borrowing from a fund.BV^{repo}_{ijt-1} (j^{ff}) refers to the lagged share of a fund (fund family) for a bank in the repo market at a given date. FV^{repo}_{ijt-1} (j^{ff}) refers to the lagged share of a bank for a fund (fund family) in the repo market at a given date. Controls include $Log(value_{ijct})$ *and* $5y\,CDS_{it}$. JP_i is a dummy which takes the value 1 if the headquarters of the bank are in Japan. Standard errors clustered at the fund family level are in parentheses. ***, **, * denote significance at the 1, 5 and 10% level respectively.

4. The Demand for (Long Maturity) Dollar Funding

The results presented so far leave open some questions. Why do Japanese banks not diversify their repo borrowing as they diversify their non-repo borrowing and improve the price they pay for repos? Why do Japanese banks rely on other markets for most of their repos (as we discussed in section 2), even though MMFs arguably provide the best terms for standardized short term repos (as their outside option is the ON RRP rate, a lower bound on interest rates)?

In order to answer these questions, we first use the US MMF reform as a natural experiment to show that Japanese banks indeed have a more inelastic demand for dollar funding, especially at longer maturities. Next, using a rich set of controls and fixed effects, we show that for repos and non-repos alike, relationship frictions affect pricing only for Japanese banks. Others are shielded from the price effects of these frictions, potentially due to the short term and scalable nature of their activities.

4.1. A Natural Experiment: The US MMF reform as a Negative Supply Shock to Longer-Maturity Funding

Our results so far suggest that Japanese banks have a steeper demand function for dollar funding, especially for longer maturities. Clearly identifying the demand effect, however, is not a straightforward task. Nevertheless, we argue that the US MMF reform presents an ideal natural experiment to test this claim.

The US MMF reform took effect in October 2016. It required institutional prime funds and municipal funds to switch to a floating NAV calculation and introduced redemption gates and fees at the discretion of the fund. Government and treasury funds on the other hand were allowed to operate with stable NAVs and without any redemption gates or fees. In effect, the reform made prime funds an unattractive option for many money market investors. In response to the reform, fund families converted many of their prime funds to government and treasury funds, which can only do repos with banks. As a result, the non-repo funding that prime funds provide fell substantially, from around \$536 billion on average in the year prior to the reform to \$239 billion in the year after the reform.

We argue that the US MMF reform was a negative supply shock to dollar funding since it led to the conversion of prime funds into government and treasury funds. We also argue that it was a shock to long maturity dollar funding since the average remaining maturity for non-repo instruments (48.2 days, weighted by volume) is significantly longer than that in the repo market (6.6 days).

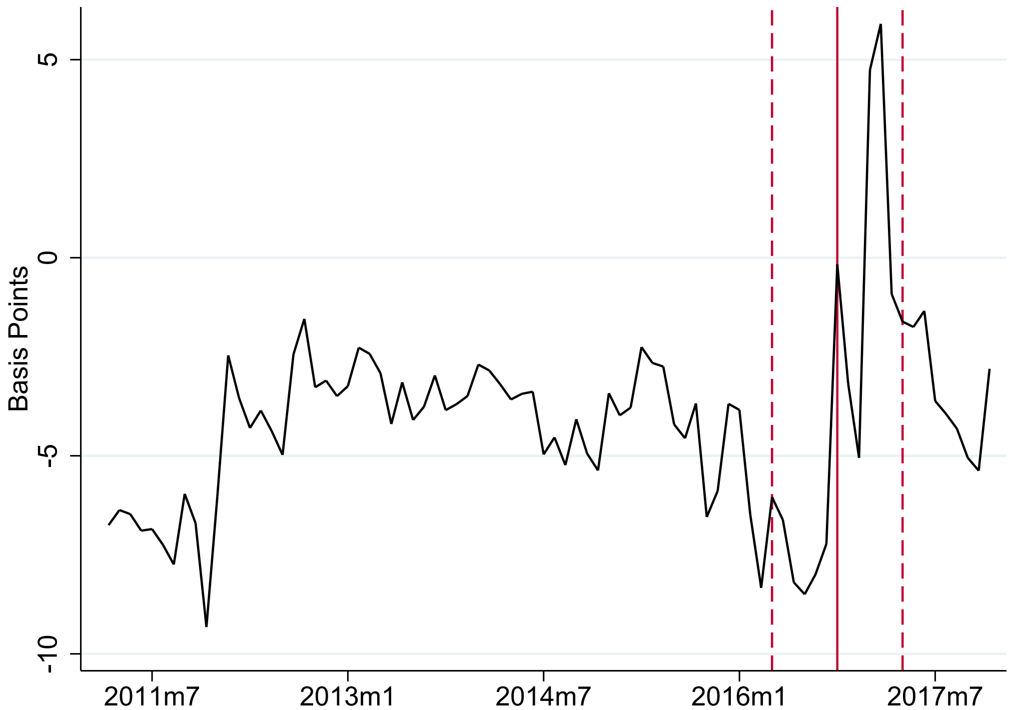
In the face of a negative supply shock, all else constant, banks with relatively inelastic demand for longer maturity funding should see prices increase more. Hence, if Japanese banks have a relatively inelastic demand for long maturity dollar funding, we should see a higher price for these banks in the non-repo market after the reform. We test the following hypothesis:

Hypothesis 4 *The prices Japanese banks pay in the non-repo market rose more than those for other banks in response to the US MMF reform, which was a negative supply shock to the longer term dollar funding that prime funds provide.*

Figure 5 shows clearly that the price that Japanese banks pay for non-repos has increased substantially around the implementation of the reform (marked with a vertical solid red line). We test this more formally in a differences-in-differences setup using the reform as a natural experiment. We focus in the six-month period before and after the implementation in order to identify the impact of the reform more clearly since banks have found ways to substitute the loss of funding by prime funds (marked with vertical dashed red lines).[11] We test Hypothesis 4 by estimating an equation similar

[11] Aldasoro et al. (2017b) show that foreign banks have attracted dollar deposits from non-banks after the reform. We accordingly expect the impact of the treatment to decrease with time and therefore

Figure 5: The Time Series of the Japan Non-Repo Discount



Note: The time series is obtained by running the following regression for the non-repo market: $Rate_{ijct} = \beta_1 Log(value_{ijct}) + \beta_2 Rem.\, maturity_{ijct} + \beta_3 5y\, CDS_{it} + \beta_4 JP_i + \beta_6 \gamma_t + \beta_7 JP_i * \gamma_t + Fixed\, Effects + \epsilon_{ijct}$, where γ_t is a time dummy, and $Fixed\, Effects$ are non-repo instrument dummies. We retrieve the coefficient of interaction between the JP_i dummy and the date dummy γ_t (β_7). We present a less restrictive specification in this figure for illustrative purposes. Relevant fixed effects to control for bank and fund (family) specific factors as well as bank-fund (family) interaction fixed effects are included in Table 8.

to Equation 1 but for the non-repo market, adding an interaction term between the dummy JP_i and a dummy which equals 1 after the MMF reform came into effect ($Post\, Reform_t$), controlling for a large set of fixed effects.

Indeed, we find strong evidence for Hypothesis 4. We show in Table 8 that the post-reform non-repo rates for Japanese banks are significantly higher than others, in the order of 3-5 basis points. To account for any potential effects that would otherwise blur the identification, we include both bank fixed effects as well as $date * fund$ (fund

restrict the end date. As for the beginning date, one might argue that the effect started earlier as fund families started converting prime funds into government funds a few months prior to the deadline of the reform. As the picture shows, moving around our experiment date to an earlier date would not affect our results.

family) fixed effects and $bank * fund$ (fund family) fixed effects to control for possible different price effects for a given bank or a given fund (fund family), such as a greater reliance on borrowing in a given market across banks or a greater reduction in lending at any given point in time across funds (fund families).

Table 8: CP, CD and ABCP prices increase more for Japanese banks post-reform

	(1)	(2)	(3)	(4)
Sample:	Non-Repo	Non-Repo	Non-Repo	Non-Repo
	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$
$JP_i * Post\,Reform_t$	4.929***	4.569***	4.153***	3.214**
	(1.669)	(1.658)	(1.297)	(1.423)
Observations	28,255	28,237	28,191	27,923
R-squared	0.750	0.763	0.804	0.824
Controls	✓	✓	✓	✓
Date*Instrument FE	✓	✓	✓	✓
Bank FE	✓	✓		
Date*FundFamily FE	✓		✓	
Date*Fund FE		✓		✓
Bank*Fund FE				✓
Bank*FundFamily FE			✓	

Notes: Regressions at the contract level, the dependent variable is the interest (in basis points) paid by a bank when borrowing from a fund. All regressions refer to non-repo (CP, CD, ABCP) contracts. The sample contains six months before and six months after the implementation of the US MMF reform on October 14, 2016, hence includes observations between end-April 2016 and end-March 2017. Controls include $Log(value_{ijct})$, $5y\,CDS_{it}$, $Rem.\,maturity_{ijct}$. JP_i is a dummy which takes the value 1 if the headquarters of the bank are in Japan. Standard errors clustered at the fund family level in parentheses. ***, **, * denote significance at the 1, 5 and 10% level respectively. JP_i and $Post\,Reform_t$ are absorbed in fixed effects.

4.2. Relationship frictions matter for Japanese banks, not for others

Another way in which different demand profiles could be identified is through the differential effect of relationship frictions on prices. We claim that relationship frictions affect pricing to the extent that banks are reliant on this funding. As non-Japanese banks have more short term activities that can easily be scaled back if funding becomes expensive, we expect relationship frictions to impact Japanese banks to a higher degree. We test the following hypothesis:

Hypothesis 5 *Relationship frictions matter for pricing more for Japanese banks, as their demand is more inelastic than that of other banks.*

We use the same relationship strength/bargaining power variables as before. We use the rich variation in our data to identify as tightly as possible the effect of the importance of banks and fund families for each other our proxies for relative bargaining power. We use the fact that we observe the *same* bank and the *same* fund family at the *same* date, transacting in both the repo and non-repo market. We also include a battery of other fixed effects to control for differences across time, fund types, instruments and other contract characteristics. We estimate an equation similar to Equation 7, but we do it now for the full market, and add interaction terms between the relationship variables and the JP_i dummy, in order to disentangle whether relationship frictions matter more for Japanese banks. Table 9 presents the results.

Table 9: Relationship frictions matter for pricing for Japanese banks

	(1)	(2)	(3)	(4)
Sample:	Full	Full	Full	Full
	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$	$Rate_{ijct}$
$BV^m_{ij^{ff}t-1}$	0.0258	-0.0171	0.0224	-0.0599
	(0.0230)	(0.0193)	(0.0331)	(0.0454)
$FV^m_{ij^{ff}t-1}$	0.0199	0.0480*	0.0274	0.0837*
	(0.0243)	(0.0260)	(0.0492)	(0.0442)
$JP_i * BV^m_{ij^{ff}t-1}$		0.159***		0.225***
		(0.0388)		(0.0662)
$JP_i * FV^m_{ij^{ff}t-1}$		-0.198*		-0.420
		(0.113)		(0.328)
Observations	467,579	467,579	453,194	453,194
R-squared	0.909	0.909	0.928	0.928
Controls	✓	✓	✓	✓
Date*Fund Type FE	✓	✓	✓	✓
Date*Instrument FE	✓	✓	✓	✓
Date*FundFamily FE	✓	✓		
Date*Bank FE	✓	✓		
Bank*FF FE	✓	✓		
Bank*FF*Date FE			✓	✓

Notes: Regressions at the contract level, the dependent variable is the interest rate (in basis points) paid by a bank when borrowing from a fund.BV^m_{ijt-1} (j^{ff}) refers to the lagged share of a fund (fund family) for a bank in a given market (repo or non-repo at a given date). FV^m_{ijt-1} (j^{ff}) refers to the lagged share of a bank for a fund (fund family) in a given market (repo or non-repo at a given date). Controls include $Log(value_{ijct})$, $5y\,CDS_{it}$, $Rem.\,maturity_{ijct}$. JP_i is a dummy which takes the value 1 if the headquarters of the bank are in Japan. Date*Instrument FE capture the type of non-repo contract (ABCP, CP, CD) or collateral for repos at a given date. Standard errors clustered at the fund family level are in parentheses. ***, **, * denote significance at the 1, 5 and 10% level respectively.

In columns (1) and (3), we present the results for the entire market without differentiating between Japanese banks and others. The coefficients on both $BV^m_{ij^{ff}t-1}$ and $FV^m_{ij^{ff}t-1}$ are insignificant, suggesting that the effect of relationships is nil in the entire market. In column (2), we include the interaction of these variables with the dummy variable that is one if the bank is headquartered in Japan, but instead of the more restrictive $bank * fund\,family * date$ triple interaction fixed effect, we use $bank * date$, $fund\,family * date$ and $bank * fund\,family$ fixed effects. The results are striking. The relationship frictions only matter for Japanese banks; they have the expected sign and they are statistically and economically significant. $BV^m_{ijff\,t-1}$ and $FV^m_{ijff\,t-1}$ have the opposite sign than expected, but have much smaller magnitudes. When we replace the fixed effects with the triple interaction of $bank * fundfamily * date$ fixed effects, the point estimates for Japan get even stronger, though $JP_i * FV^m_{ijff\,t-1}$ becomes insignificant.

Overall, the results of this section suggest that fund families exercise pricing power over Japanese banks when they can, but other banks have more of the pricing power against the fund families of MMFs. Japanese banks and others use this funding for different purposes. The inelastic demand for long-maturity funding of Japanese banks makes them have less bargaining power, while the short term arbitrage activities of other banks largely shield them from the effects that fund family bargaining power can have on pricing.

4.3. Relationship Formation with US MMFs

If diversifying relationships and reducing the relative bargaining power of funds means better pricing, why do Japanese banks not diversify their repo counterparties? In this section we answer this question by combining the demand for long maturity dollar funding of Japanese banks with regulatory constraints on MMFs.

Rule 2a-7 governing US MMFs, in effect, constrains them from providing longer maturity repos. The rule specifies minimum liquidity levels that MMFs are required to hold. As a result, MMFs use repos as an effective liquidity management instrument. As credit risks are very low in the case of repos, any spare cash or required liquidity can be used for repo lending by MMFs, provided that the maturity of the repo satisfies the regulatory liquidity requirements. MMFs generally must hold at least 10% of their assets in investments that can be converted into cash within one day and at least 30% of assets convertible into cash within five business days (Rule 2a-7). Accordingly, more than 76% of repos (by volume) in our sample fall within a remaining maturity of 5 days or less.

Hypothesis 6 *Fund families favor longer term clients as counterparties for their longer maturity repos, due to regulatory constraints that limit the provision of long maturity repos by MMFs.*

We claim that a potential reason why Japanese banks do not improve their bargaining power by diversifying relationships is because MMFs prefer to provide their limited longer maturity repos to longer-term clients. Switching to new fund families would improve the bargaining power of Japanese banks, but may also require them to accept shorter maturity funding for a potentially extended period of time. Therefore building relationships helps Japanese banks obtain longer maturity funding.

To test our hypothesis, we therefore need to show whether fund families indeed offer longer maturities to Japanese banks as relationships build. At any point in time t, we define relationship length ($Rel.\,length^m_{ijff\,t}$) as the number of months for which we have observed a given bank-fund family transaction pair in a given market m (repo or non-repo). Focusing on the repo market, we regress remaining maturity (as a proxy for maturity) on relationship length of a bank and a fund family, as in the following equation:

$$\begin{aligned} Rem.\,maturity_{ijct} &= \omega_1 Log(value_{ijct}) + \omega_2 5y\,CDS_{it} \\ &+ \omega_3 JP_i + \omega_4 Rel.\,length^{repo}_{ijfft} + \omega_5 JP_i * Rel.\,length^{repo}_{ijfft} \\ &+ Fixed\,Effects + \epsilon_{ijct} \end{aligned} \tag{8}$$

The results are presented in Table 10. In all specifications, we control for $bank * fund\,family$ fixed effects which in effect allows us to follow the relationship of a bank and fund family over time. In specification (2), in addition to $bank * fund\,family$ fixed effects and other controls, we control for time varying differences for fund families, by adding $date * fund\,family$ fixed effects. In specification (3), we add a control for time varying differences for banks, by adding $date * bank$ fixed effects.

Table 10: Relationship length and maturity

	(1)	(2)	(3)
Sample:	Repo	Repo	Repo
	$Rem.\,maturity_{ijct}$	$Rem.\,maturity_{ijct}$	$Rem.\,maturity_{ijct}$
$Rel.\,length^{repo}_{ijfft}$	0.00730	0.151**	0.0438
	(0.118)	(0.0733)	(0.0919)
$JP_i * Rel.\,length^{repo}_{ijfft}$	0.174***	0.138***	0.222
	(0.0480)	(0.0362)	(0.261)
Observations	124,477	124,325	133,135
R-squared	0.321	0.343	0.372
Controls	✓	✓	✓
Date*Fund Type FE	✓	✓	✓
Date*Collateral FE	✓	✓	✓
Date*FundFamily FE		✓	✓
Date*Bank FE			✓
Bank*FundFamily FE	✓	✓	✓

Notes: Regressions at the contract level, the dependent variable is the remaining maturity of the contract (proxying for maturity at origination).$Rel.\,length^{repo}_{ijfft}$ refers to the length of the relationship between a bank and a fund family in the repo market measured in months at a given date. JP_i is a dummy which takes the value 1 if the headquarters of the bank are in Japan. Controls include $Log(value_{ijct})$, $5y\,CDS_{it}$. We restrict the sample to repos between January 2012 and October 2016 (due to the US MMF reform potentially causing a structural change in the market). Standard errors clustered at the fund family level in parentheses. ***, **, * denote significance at the 1, 5 and 10% level respectively. The coefficient on $JP_i$is absorbed in the fixed effects.

Overall, we find that relationship length has a larger effect on maturities for Japanese banks. This effect is statistically significant in columns (1) and (2). However, when we also add $bank * date$ fixed effects, while the point estimate becomes stronger, the result becomes statistically insignificant. We suspect, however, that we do not have enough power in column (3) as the number of fixed effects to be estimated increases by 1500 from (2) to (3) and is around 4000.

Our results here shed light on why Japanese banks fail to diversify their repo counterparties. A relationship length of around 5 months is needed on average to increase repo maturities by one day. Combined with the results from the previous section on the demand for longer maturities by Japanese banks, it seems to be optimal for Japanese banks to trade-off a higher price against the ability to obtain longer maturity repo funding.

5. Dollar Funding Networks

Armed with a better understanding of the demand profiles of the banks in this market, as well as the impact of market frictions on pricing, we now turn to the impact on dollar funding networks. Through this analysis, we are able to also provide an explanation for why Japanese banks do not shift more of their repo book towards trades with MMFs.

As shown in **Fact 3**, a striking feature of the operations of branches and agencies of foreign banks in the United States is the existence of matched repo books for essentially all but Japanese banks. Furthermore, the size of the Japanese banks' repo book is large, but MMFs account for a relatively small share of it. In this section, we explore why this is the case. We argue that given the constraints on repo maturities that MMFs provide and the demand to extend repo maturities, there might be room for intermediation. In particular, we ask whether non-Japanese banks intermediate repos between MMFs and Japanese banks by engaging in maturity transformation.

5.1. Implied Spreads from Repo Maturity Transformation

Since we do not have bilateral data, it is not possible for us to prove the existence of profits from such intermediation. However, we estimate implied profits from intermediation through maturity transformation and show that they are economically significant and higher than other potential arbitrage opportunities for non-US global banks, such as the IOER arbitrage. Table 11 presents the results of estimating the following equation for the repo market:

$$\begin{aligned} Rate_{ijct} = {} & \delta_1 Log(value_{ijct}) + \delta_2 5y\,CDS_{it} \\ & + \delta_3 JP_i + \delta_4 Rem.\,maturity_{ijct} + \delta_5 JP_i * Rem.\,maturity_{ijct} + Fixed\,Effects + \epsilon_{ijct} \end{aligned} \tag{9}$$

We show that maturity transformation, whereby other banks borrow overnight and lend at 30 days to Japanese banks (charging the MMF price), all else constant, earns *16 basis points*. We calculate this by adding up the coefficients of JP_i, $30 * Rem.\,maturity_{ijct}$ and the interaction term $30 * (JP_i * Rem.\,maturity_{ijct})$, that is

$\delta_3 + 30 * \delta_4 + 30 * \delta_5$. These spreads are both statistically and economically significant.[12]

Table 11: Repo intermediation spreads

Sample:	(1) Repo $Rate_{ijct}$
JP_i	1.319
	(1.774)
$Rem.\, maturity_{ijct}$	0.348***
	(0.0358)
$JP_i * Rem.\, maturity_{ijct}$	0.141*
	(0.0848)
30-day intermediation spread	16.0 bps***
	(1.1089)
Observations	181,425
R-squared	0.872
Controls	✓
Date*Fund Type FE	✓
Date*Collateral FE	✓

Notes: Regressions at the contract level, the dependent variable is the interest rate (in basis points) paid by a bank when borrowing from a fund in repo contracts. Controls include $Log(value_{ijct})$ and $5y\, CDS_{it}$. JP_i is a dummy which takes the value 1 if the bank is headquartered in Japan. 30-day intermediation spread is calculated by $JP_i + 30 * Rem.\, maturity_{ijct} + 30 * (Rem.\, maturity_{ijct} * JP_i)$, in order to estimate how much a non-Japanese bank would earn as a spread if it borrows overnight and lends to a Japanese bank at 30-days, charging the MMF price. Standard errors clustered at the fund family level in parentheses. ***, **, * denote significance at the 1, 5 and 10% level respectively.

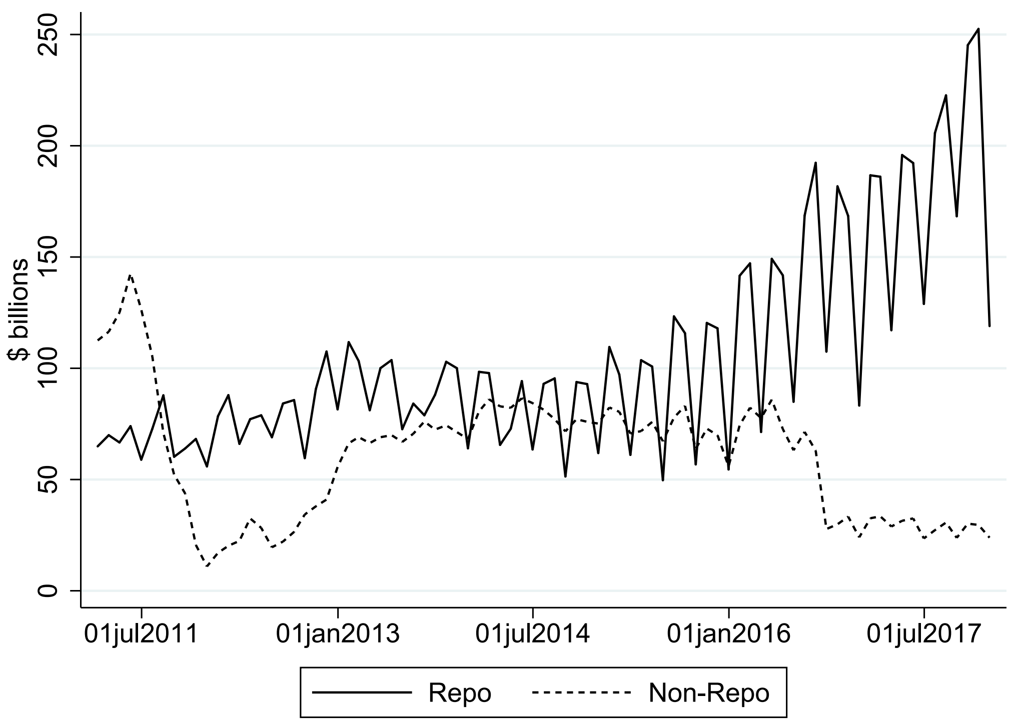
5.2. Quarter-end Window Dressing: Implications for the JPY/USD basis

At every quarter-end, French banks exhibit very large contractions of repo positions with US MMFs, as shown in Figure 6. While quarter-end effects can also be observed for other banks that have large repo positions against US MMFs, we focus on French banks since they exhibit the largest quarter-end reduction in repo positions in our sample and also have a large matched-repo book (Figure 4). If Japanese banks rely on repo intermediation by other banks to obtain dollar funding through repos, the quarter-end retreat of other banks reduces the supply of overall available dollar funding to Japanese banks (or their counterparties if they further intermediate these dollars). Moreover, since European banks reduce their repos at quarter ends as a result of leverage

[12] Another possible form of intermediation that we do not get into detail is through collateral transformation. There are many reasons why banks would like to use other types of collateral in repos compared to Treasury. We estimate that, all else constant, if a non-Japanese bank pledges US Treasuries to MMFs and receives “Other collateral” from Japanese banks, charging the MMF price, the spread would be 32 basis points. We report the results in Table B.14.

ratio considerations at the consolidated level, we can arguably treat this shock as an exogenous negative supply shock for Japanese banks.

Figure 6: French banks' repo and non-repo borrowing from US MMFs



Global dollar markets are interconnected and layered. It is therefore to be expected that disruptions in a given layer will spill over to other markets higher up in the funding hierarchy, such as the FX swap market.[13] Hypothesis 7 formalizes this conjecture:

Hypothesis 7 *Quarter end withdrawal of French banks from repo markets is negatively related to the JPY/USD cross-currency basis at shorter tenors.*

We test this hypothesis by estimating the following equation

$$\Delta JPY/USD_{QE,t} = \alpha_1 + \alpha_2 \Delta FR\,repo_{QE,t} + \epsilon_t \tag{10}$$

where $\Delta JPY/USD_{QE,t}$ denotes the change on the Japanese yen / US dollar basis between quarter ends and the month before quarter ends, and $\Delta FR\,repo_{QE,t}$ denotes

[13]We do find that Japanese banks in fact slightly increase their repo volumes with MMFs at quarter ends. This increase is, however, orders of magnitude smaller than the contraction in available dollar funding due to the window dressing activity of other global banks.

Table 12: The quarter-end effect: JPY basis versus repos with MMF by French banks

	1W	1M	3M	1Y	3Y	5Y
Δ FR repo	-1.36**	0.43**	-0.00	0.04	0.01	0.03
	(0.53)	(0.20)	(0.10)	(0.05)	(0.04)	(0.06)
Observations	24	24	24	24	24	24
R-squared	0.45	0.20	0.00	0.03	0.00	0.01

Notes: Robust standard errors in parentheses. ***, **, * denote significance at the 10, 5 and 1% level respectively. Changes are computed as $month_{quarter-end} - month_{quarter-end-1}$ (the absolute value is taken for changes in French banks' repos with MMFs (in \$billions)). The sample runs from October 2011 (Q4 2011) to September 2017 (Q3 2017). 1W, 1M, 3M, 1Y, 3Y, 5Y refer to the contemporaneous changes in the 1-week, 1-month, 3-month, 1-year, 3-year and 5-year basis, respectively.

the change in repos French banks conduct with MMFs, between quarter ends and the month before quarter ends (say, the total amount of repos reported at end March minus the equivalent number at end February, June versus May, and so on).

Table 12 presents a statistically and economically significant negative relationship between the changes in repo activities of French banks between a month before quarter-ends to the end of a quarter, and the contemporaneous JPY/USD basis. Overall, the retreat of French banks from repo markets at quarter ends explains more than 45% of the contemporaneous variation in the JPY/USD basis. An additional \$10 billion reduction of repos by French banks widens the cross-currency basis by between 1 and 2 basis points.[14]

6. Conclusion

Business models of global banks pertaining to dollar activities have diverged dramatically since the GFC and the eurozone crisis. Japanese banks have become the largest in size, mostly through traditional banking activities. European banks have shrunk in size and shifted their business models towards short term activities, such as IOER arbitrage and matched-book repo intermediation.

Motivated by the shift in global banks' business models, we set out to answer four main questions: Does the heterogeneity in business models lead to heterogeneity in the demand for dollar funding? What does it imply for the competition for dollar funding? What are the pricing implications? How do the pricing implications affect the

[14]We perform a robustness check using the EUR/USD basis instead. The coefficient for the 1W EUR/USD basis is less than half the size of the coefficient reported here, its statistical significance is weaker, and the fit of the regression is considerably smaller. This suggests that the result reported in Table 12 is not due to an omitted quarter end effect but French repos and JPY/USD are indeed related. We exclude the last quarter of 2017 as the last days of December saw big changes in different cross-currency bases that seemed out of the ordinary and left many market participants perplexed.

composition of dollar funding by global banks?

We focused on the interactions between global banks and US MMFs for three reasons. First, US MMFs are significant suppliers of dollar funding to foreign global banks. Second, their regulatory filing allows us to make use of granular data with rich variation. Third, the US MMF reform lies within our sample period, which enables us to use it as a natural experiment.

Our contributions can be summarized as follows: Different dollar business models of global banks imply different demand schedules for dollar funding. Given market and supply side frictions in US money markets, this results in differential pricing for dollar funding across global banks, which cannot be explained by risk characteristics. The Japan repo premium we document is a reflection of this. Japanese banks have a relatively inelastic demand for long term dollar funding, given their large dollar loan books. At the same time, they concentrate repo borrowing among few fund families. While that lowers their bargaining power and increases the price of repo dollar funding they pay, it gives them preferential treatment in obtaining longer maturity repos and other funding.

A direct implication of our analysis is the emergence of a repo dollar funding network among global banks. Since longer maturity repos offered by US MMFs are in short supply, there is room for intermediation whereby other banks provide longer term repos to Japanese banks. European banks have relatively more price elastic dollar demand and they can lever up between quarter-ends due to the way Basel III regulations are implemented. They are therefore in a position to take advantage of lucrative arbitrage opportunities.

We also find evidence that the availability of repo dollar funding affects other dollar funding markets, in particular swap markets. When European banks retreat from the repo market at quarter-ends as regulatory constraints become more binding, the shorter-term JPY/USD basis spread widens significantly. This is evidence for Japanese banks having a significant impact on pricing in FX markets when they switch to more expensive forms of dollar funding at quarter-ends.

The pricing anomalies in dollar funding markets we document and the significant role that global banks and their business models play, raises a number of questions. What are the financial stability implications of the resulting dollar funding networks, both between MMFs and banks and among banks? How will the harmonization of the implementation of Basel III regulations affect the business models of global banks, especially European banks? Can the current trend of switching to CCPs resolve some of the frictions in US money markets and mitigate pricing anomalies (Aldasoro et al. (2017a))? Further, our results suggest that different dollar funding markets, such as repos, CPs, CDs, ABCPs, customer deposits and FX swaps, are interconnected. The real economic consequences, as well as the financial stability implications, of frictions in money markets and global dollar funding networks will eventually hinge on the exact mechanisms through which shocks are transmitted between the different markets; and whether the different players in these markets can share risks or amplify them. We believe that these questions are of high relevance to policy makers and could form the basis of a fruitful research agenda.

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Appendix A. Data

The main dataset used throughout the paper is from Crane Data, which includes information on the holdings of US MMFs at month-ends. The dataset is based on the regulatory filings of MMFs to the Securities and Exchange Commission (SEC N-MFP forms). The dataset provides detailed information on the money market funds themselves, as well as their portfolio holdings. It contains information on the instruments they invest in, such as repos, CP, CD, ABCP, Treasury debt or Agency debt, variable rate demand notes and other instruments.[15] For all the instruments, the dataset also provides information on the total amount of the transaction, the remaining maturity and the yield (the interest rate paid by the banks in case a bank is a counterparty), among other contract characteristics. In addition, for repos we observe whether the borrowing is backed by either Treasury, Government Agency or Other collateral. The sample period runs from February 2011 to December 2017. As of end-December 2017, the holdings of MMFs amounted to a total of 2.9 trillion US dollars.[16]

Since our focus is on the interaction between MMFs and banks, we restrict the sample to repos, CP, CD and ABCP.[17] That leaves the sample with prime funds, government funds and Treasury funds. Prime funds are allowed to invest in all four instruments, while government funds can only invest in government securities or repos backed by government securities and Treasury funds can only invest in Treasury securities and repos backed by Treasury collateral.

As in Chernenko and Sunderam (2014), we link the contract-level information to the parent institution of the issuer, and further link this to the country of headquarters. In this way we can look at the activity of a specific parent company across different market segments through their different controlled companies (say, CDs issued by different branches, or repo contracts entered into by a securities arm of the company). After this aggregation, we restrict the sample of counterparties to include only Global Systemically Important Banks (GSIBs) and non-GSIB banks that are large and active in transacting with MMFs, which leaves us with 51 distinct banks.[18] Furthermore, we exclude all observations with a reported interest rate of zero or missing, and we winsorise interest rates for the remaining sample at the 99.9% level in order to minimize the influence of outliers.[19]

The dataset has some limitations which we address as best as we can. The fact that remaining maturity is reported instead of maturity at contract origination is one such limitation. It poses two problems. First, contracts with maturity that is longer than 30 days appear multiple times in the dataset.[20] We identify such contracts and restrict our regressions to observations for which the contract appears for the first time.

[15] According to the SEC Rule 2a-7 that regulates this market, the US MMFs are only allowed to hold US dollar-denominated instruments. Therefore, our dataset includes only US dollar-denominated instruments held by US MMFs.

[16] Crane Data differs slightly from the SEC N-MFP filings for the earlier part of the sample but still covers around 92% of the US MMF universe. As of end-December 2017, the totals reported in the SEC N-MFP (obtained from the OFR Money Market Monitor) and ICI are almost the same as Crane Data. The 8% difference in the earlier sample is due to internal funds that manage cash for their fund families.

[17] Throughout the paper, we lump CP, CD and ABCP together and refer to them as "non-repo."

[18] See Appendix C for the full list of banks. For repo contracts we exclude banks from Spain and Sweden, as they have very few contracts. Our results are robust to their inclusion.

[19] The results presented throughout are robust to using a non-winsorised sample (though the fit of the regressions is lower), as well as winsorizing at different levels.

[20] For example, a contract with 60 days of remaining maturity appears first in one month with 60 days of remaining maturity. The same contract appears with 29, 30, 31 or 32 days of remaining maturity the next month depending on whether there are 28, 29, 30 or 31 days between the two months.

Second, contracts can contain inaccurate yield information that might potentially bias our results. For example, in the extreme case, suppose a 30-day contract matures at the end of the month. The contract would appear as if it is an overnight contract featuring a large price differential compared to actual overnight contracts, simply due to a term premium. Even though we are aware that this is a data limitation that we cannot fully address with publicly available data, we perform many robustness checks that are highly suggestive that this is not driving our results (see Appendix D).

Another possible data issue is due to funds potentially reporting an identical contract multiple times in a given month. The appearance of a duplicate in the dataset might be due to error or the fact that there are two separate contracts. In our baseline results, we treat such observations as separate contracts. However, our results throughout the paper are robust to the exclusion of these potential duplicates.

Our final repo sample consists of a total of 205,165 contracts between 39 banks from 9 countries with 329 funds belonging to 70 fund families. The final non-repo sample (CP, CD and ABCP) consists of 538,848 observations linking 49 banks from 14 countries with 175 funds belonging to 66 fund families.

Table A.13 presents summary statistics by headquarters and markets. With the exception of banks from the US, banks are on average substantially more active in the non-repo than in the repo market. This is particularly the case for the six Japanese banks in the sample: over the sample period their number of transactions is about four times higher in the non-repo than in the repo market. Despite this difference, the number of funds they transact with is similar in each market. This is in stark contrast to other important issuers like Canadian, UK and French banks, which transact with a substantially larger set of counterparties in the repo market. Further, there are important differences in the average maturity of repo versus non-repo contracts. The average maturity of repo contracts is notably shorter than that in the non-repo market.

Table A.13: Summary statistics

Nationality of bank	Nobs	No banks	No funds	No fund families	Avg contract size	Avg maturity	Avg rate
			Repo market				
AU	158	4	17	6	255.3	2	86.3
BE		0	0	0			
CA	28,154	5	248	47	162.0	5	44.0
CH	16,832	2	205	40	156.2	16	38.4
CN		0	0	0			
DE	12,015	2	232	51	213.0	5	25.9
ES		0	0	0			
FI		0	0	0			
FR	32,660	4	234	41	267.9	4	38.0
GB	23,044	5	276	54	232.6	5	31.5
JP	14,693	6	176	32	166.0	6	62.8
NL	10,048	3	126	17	154.4	7	34.8
SE		0	0	0			
US	67,561	8	295	64	175.3	8	36.3
Total	205,165	39	329	70	193.7	6	38.0
			Non-repo market - ABCP, CD, and CP				
AU	59,326	4	164	62	90.4	43	41.8
BE	1,806	1	43	16	76.2	63	55.9
CA	112,330	5	173	65	83.2	44	42.4
CH	19,528	2	138	45	111.4	50	42.1
CN	2,468	4	25	9	83.5	24	58.8
DE	8,959	2	111	39	105.5	52	33.4
ES	1,858	2	45	20	71.5	20	37.7
FI	12,071	1	128	45	90.1	72	36.8
FR	50,904	4	152	55	98.4	38	39.8
GB	43,187	5	153	55	82.2	48	39.7
JP	100,078	6	153	52	91.3	49	38.5
NL	31,239	3	151	57	95.6	57	40.0
SE	29,068	3	144	52	95.1	55	39.0
US	66,026	7	167	62	65.6	54	42.2
Total	538,848	49	175	66	87.6	48	40.5

Notes: Nobs = number of observations. No banks is the number of banks of a given nationality (location of headquarter). No funds and fund families denotes the total number of money market funds / fund families that banks of a given nationality transacted with. Avg contract size is the average transaction amount between a fund and a bank across banks of a given nationality in millions of USD. Avg maturity is the value-weighted average maturity, and avg rate denotes the corresponding interest rate.

We also retrieve the Call Reports of branches and agencies of foreign banks operating in the US from the Federal Reserve Bank of Chicago (FFIEC 002 filings). We collect all relevant balance sheet items for the entire universe of reporting banks, and aggregate them first by bank (putting together different branches and agencies of the same bank) and then link it to the country of headquarters. The sample period runs from 1994Q1 to 2017Q2.

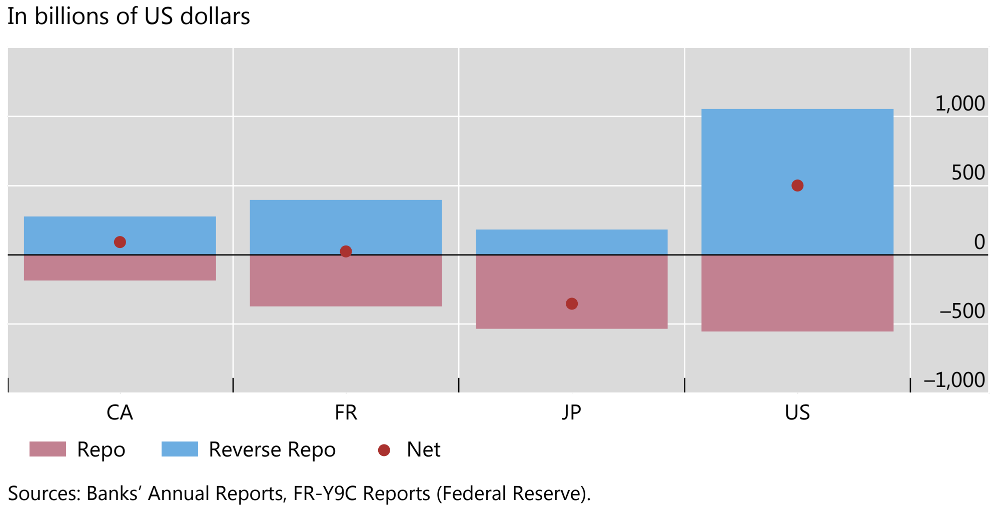
To calculate the global US dollar positions of banks by nationality, we use the quarterly BIS locational and consolidated banking statistics as described in McGuire and von Peter (2012).

We obtain daily CDS data for the banks in our final sample from Markit. We use the 5 year senior tier security mid spread, keep end-of-month observations and merge the data with the main data used for the regressions.

Finally, we retrieve daily currency basis spreads and LIBOR data from Bloomberg. We retrieve the mid-price, keep the end-of-month observations, and merge it with the other datasets.

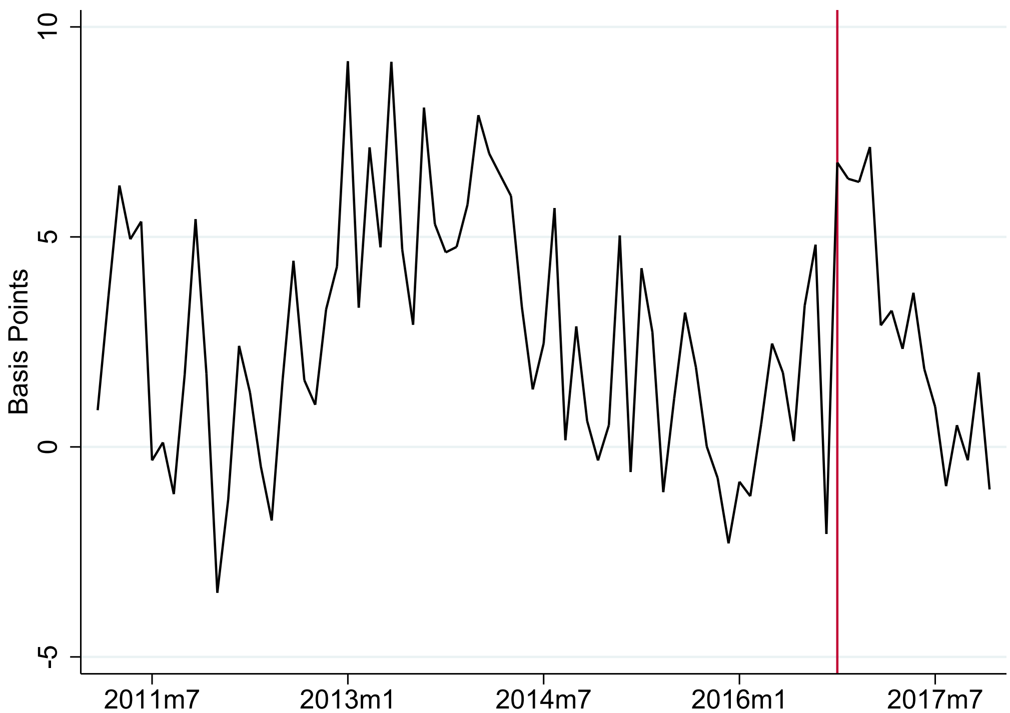
Appendix B. Additional Tables and Figures

Figure B.7: Repo books at the Consolidated Level



Notes: Aggregate by country for all banks active in the MMF data. Data for CA is for end-October 2016, for JP is end-March 2016, and for FR and US is end-December 2016. Includes the aggregate repo book at the consolidated level, encompassing all currencies and geographies.

Figure B.8: The Time Series of the Japan Repo Premium



Note: The time series is obtained by running the following regression for the repo market: $Rate_{ijct} = \beta_1 Log(value_{ijct}) + \beta_2 Rem.\,maturity_{ijct} + \beta_3 5y\,CDS_{it} + \beta_4 JP_i + \beta_5 \gamma_t + \beta_6 JP_i * \gamma_t + Fixed\,Effects + \epsilon_{ijct}$, where γ_t is a time dummy, and $Fixed\,Effects$ includes fund type and collateral fixed effects. We retrieve the coefficient of the interaction between the JP_i dummy and the time dummy γ_t (β_6).

Table B.14: Repo intermediation through collateral transformation: spreads

Sample:	(1) Repo $Rate_{ijct}$
JP_i	2.053***
	(0.467)
$Agency\,coll._c$	1.467***
	(0.434)
$Other\,coll._c$	25.90***
	(2.087)
$JP_i * Agency\,coll._c$	-0.990*
	(0.569)
$JP_i * Other\,coll._c$	3.965
	(3.804)
Collateral transformation spread	31.9 bps***
	(3.4411)
Observations	181,425
R-squared	0.868
Controls	✓
Date*Fund Type FE	✓

Notes: Regressions at the contract level, the dependent variable is the interest rate (in basis points) paid by a bank when borrowing from a fund in repo contracts. Controls include $Log(value_{ijct})$, $Rem.\,maturity_{ijct}$ and $5y\,CDS_{it}$. JP_i is a dummy which takes the value 1 if the bank is headquartered in Japan. The baseline category for repo collateral is Treasury collateral. All coefficients on collateral types are compared to Treasury collateral. Intermediation spread through collateral transformation is calculated by JP+ Other Coll.+ JP*$Other\,coll._c$, in order to estimate how much a non-Japanese bank would earn as a spread if it borrows from the MMF with Treasury collateral and lends to a Japanese bank against Other collateral, charging the MMF price. Standard errors clustered at the fund family level in parentheses. ***, **, * denote significance at the 1, 5 and 10% level respectively.

Appendix C. Banks in the Sample

Table C.15: Banks in the full Crane data sample after applying our cleaning procedure

Country	Bank	# Repo Contracts	# Non-repo contracts
AU	Australia & New Zealand Banking Group Ltd	3	10181
AU	Commonwealth Bank of Australia	13	18038
AU	National Australia Bank Ltd	133	13153
AU	Westpac Banking Co	9	17954
BE	Dexia Group	.	1806
CA	Bank of Montreal	4435	21850
CA	Bank of Nova Scotia	5343	26990
CA	Canadian Imperial Bank of Commerce	305	9877
CA	Royal Bank of Canada	14319	31507
CA	Toronto-Dominion Bank	3752	22106
CH	Credit Suisse	13557	13746
CH	UBS	3275	5782
CN	Agricultural Bank of China Limited	.	415
CN	Bank of China Ltd	.	463
CN	China Construction Bank Co	.	930
CN	Industrial & Commercial Bank of China Ltd	.	660
DE	Commerzbank AG	305	232
DE	Deutsche Bank AG	11710	8727
ES	BBVA	.	118
ES	Banco Santander	.	1740
FI	Nordea	.	12071
FR	BNP Paribas	17323	17139
FR	BPCE	1211	9489
FR	Credit Agricole	5663	12840
FR	Societe Generale	8463	11436
GB	Barclays Bank PLC	11666	14332
GB	HSBC Holdings PLC	7063	13950
GB	Lloyds Banking Group	319	7542
GB	RBS	3960	2293
GB	Standard Chartered Bank	36	5070
JP	Mitsubishi UFJ Financial Group Inc	6218	36983
JP	Mizuho Financial Group	6402	17126
JP	Nomura	651	.
JP	Norinchukin Bank	723	6364
JP	Shizuoka Bank	.	386
JP	Sumitomo Mitsui Financial Group Inc	131	32476
JP	Sumitomo Mitsui Trust Bank	568	6743
NL	ABN Amro Bank	2381	2728
NL	ING Bank	7664	9691
NL	Rabobank	3	18820
SE	Skandinaviska Enskilda Banken AB	.	10210
SE	Svenska Handelsbanken	.	11820
SE	Swedbank AB	.	7038
US	Bank of America	16350	2084
US	Citigroup	10456	19532
US	Goldman Sachs	9841	38
US	JPMC	13388	28537
US	Morgan Stanley	2727	.
US	State Street	440	3981
US	The Bank of New York Mellon	950	367
US	Wells Fargo	13409	11487

Appendix D. Robustness Checks

In this section we address several robustness checks we have performed on the core results presented in the main body of the paper. We present the concerns that give rise to each robustness check performed and discuss the results associated to the checks. For the sake of brevity and space, we leave out tables, which the interested reader can find in an Online Appendix.

The Japan Repo Premium vis-à-vis each country. Is it the case that the Japan Repo Premium only holds on average when all other jurisdictions are combined? In the Online Appendix we replicate the structure of Table 2 but considering Japanese banks vis-à-vis all other banking systems individually and show that indeed the Japan Repo Premium holds vis-à-vis each country. Japanese banks pay a premium in excess of the riskiness of the repo contract and counterparty risk compared to banks from each jurisdiction.

Similarly, the regressions for non-repos also deliver a message consistent with Table 3, with Japanese banks paying less than banks from each jurisdiction, on average, controlling for risk and other relevant characteristics.

Are the results driven by the presence of US banks in the sample? US banks are obviously different from others when it comes to dollar funding, with a much broader access to customer deposits. Is the Japan Repo Premium an artifact of having US banks in the sample? We rerun the regressions for Table 2 and Table 3, excluding US banks from the sample. The results are virtually unchanged.

Is the use of remaining maturity instead of original maturity biasing the results? One major data limitation is that regulatory filings of MMFs through the Form N-MFP, only requires them to report remaining maturity instead of original maturity. This would bias our results towards finding a Japan Repo Premium if Japanese banks have a preference for some reason to engage in repos with MMFs earlier in the month than others. For example, suppose a Japanese banks borrows for 10 days (original maturity) on the 25th of the month at a rate of 50 bps and a non-Japanese bank borrows for 10 days on the 30th and also pays 50 bps. In our data, we would observe the Japanese bank paying 50 bps for 5 days, French paying 50 bps for 10 days. This would create a bias as long as these errors are not random.

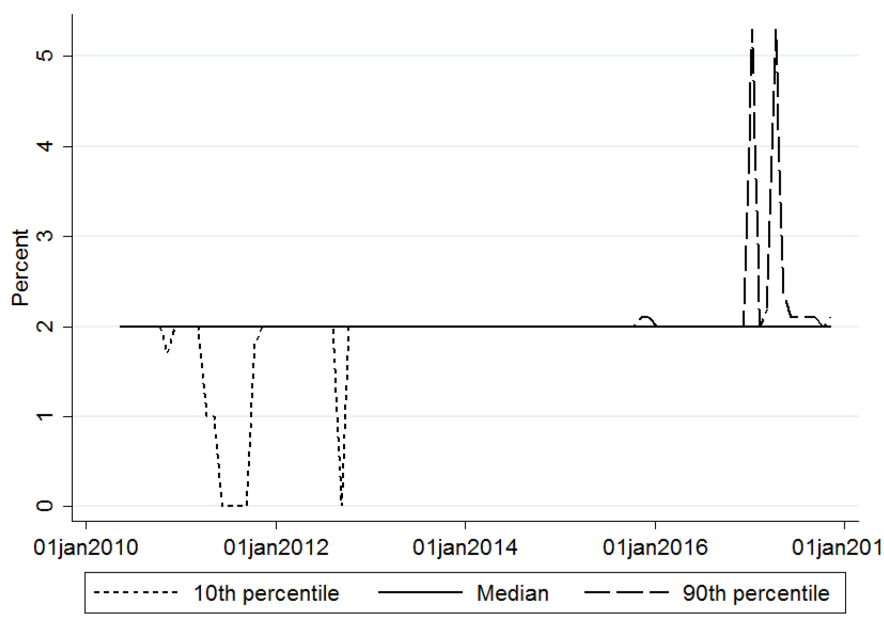
Can it be the case that Japanese banks prefer borrowing through repos earlier in the month? Our dataset contains month-end reporting by the MMFs. Since month-ends are also regulatory reporting dates for banks, such a strategy would mean that Japanese banks would appear to have shorter maturity funding, which does not square well with the revealed preference of Japanese banks for longer maturity funding. Furthermore, if Japanese banks have such a preference, this result would be hard to square with the existence of a discount in the non-repo market.

Moreover, the time series of the Japan Repo Premium and the response at quarter ends would require a complicated explanation if it is only driven by any potential bias created by remaining maturity instead of original maturity. The Japan Repo Premium responds to economically meaningful events such as the Eurozone crisis and the US MMF reform (Figure B.8). Furthermore, at quarter-ends, it reacts in a way consistent with a bargaining power story. In both cases, there is no immediate explanation as to why borrowing time of the month or maturity choice would affect Japanese banks differently.

Finally, in column (5) of Table 2 we also show that the results hold for overnight Treasury repos. Since the volume of actual overnight borrowing is high in this market, any potential bias that is due to this data limitation would be masked relatively more compared to other cuts of the sample.

Are the results driven by a potential haircut-rate trade-off? One other data limitation is the fact that we do not observe haircuts. Since haircuts and rates are two different prices for a single repo contract, it is possible that while there is a Japan Repo Premium in rates, there is a compensating discount in haircuts.[21] Although we cannot fully rule out such a possibility, the fact that the result persists for overnight repos with US Treasury collateral alleviates this concern since there is very little variation in haircuts for US Treasury collateral as shown in Figure D.9. Moreover, the time period where the 10th percentile is lower corresponds to a time when the Japan Repo Premium is lower, further alleviating this concern.

Figure D.9: Haircuts on US Treasury collateral in the tri-party market



Source: Federal Reserve Bank of New York

[21]See, for example, Eren (2014) for a potential rationale due to liquidity management.

Are the results driven by a few time periods? A few banks? Another potential question is whether the Japan Repo Premium is caused by a few time periods or by a few banks. If so, then our results could potentially be interpreted differently. We first show that the Japan Repo Premium is not driven by a few months in the data. It is mostly positive, though it fluctuates and at times becomes negative (see Figure B.8). One such example is the eurozone crisis, during which it turned negative.

Is the Japan Repo Premium driven by a few banks? To answer this, we proceed in the following way. We rank Japanese banks by their size in the repo market with US MMFs.[22] We then exclude the top bank and run the regressions in Table 2. Next, we exclude the top 2 banks, then the top 3 banks and finally the top 4. The results are qualitatively similar in all of these regressions, even though the magnitudes vary with the exclusion of each bank.

Are the results driven by the fact that the banks in the repo and non-repo are different? The fact that there is a Japan Repo Premium, but in the non-repo part of the sample there is on average a discount for Japanese banks makes a convincing case for counterparty risks not playing a role. However, it is a potential concern that this might arise due to these instruments having a different composition of banks underlying the data.

To address this concern, we drop all banks that either appear in the non-repo sample, but not in the repo sample; all banks that appear in the repo sample, but not in the non-repo sample; and all banks that have less than 50 observations in either sample.[23] That leaves us with a balanced sample with 31 distinct banks and nine countries. The estimates are virtually unchanged.

Are the results driven by the choice of clustering? While we believe our benchmark choice of clustering standard errors at the fund family level is the most reasonable, a valid concern can be raised that results are driven by this choice. Clustering at the fund family level gives more conservative standard errors than clustering at the country level (using wild bootstrap to estimate the standard errors) or at the date level. Results are available upon request.

Quarter-end effects in non-repo market? In Table 4 we present evidence that the Japan repo premium is affected by quarter-end effects. For the overall coherence of our story it is important that such quarter end effects are not present in the non-repo market. As we show in the Online Appendix, there is no differential quarter end effect for Japanese banks in the non-repo market.

[22] A Japanese bank in our sample, Norunchukin Bank, is an outlier in many ways. Even though they are subject to Basel III regulations, they have a different regulator than other Japanese banks and face different regulations and investment purposes. Their activities are different from other banks as shown in their annual reports. Their average repo maturity in our data is four times larger than other Japanese banks. They do not pay a premium over and above the riskiness of their contracts. Therefore, including Norinchukin Bank in our benchmark results works against finding a Japan Repo Premium.

[23] Two Japanese banks, Nomura and Shizuoka are dropped from the sample as a result (see Appendix C).

Different samples. When presenting the data in Appendix A we highlighted a couple of shortcomings. First, we observe contracts in consecutive months that look identical, with the exception of having a different interest rate. We treat such observations as separate in our baseline scenario, as ad hoc checks point to such observations as being correct. However, one may suspect that such observations reflect some mis-reporting taking place in the raw data. Second, we observe contracts within the same month that look identical. Checks in the filings to the SEC points to these observations as actually being different. However, as before, a doubt may arise about whether the trades are in fact duplicates. We re-run the baseline repo and non-repo regressions excluding observations associated to the first issue mentioned above, then excluding observations associated to the second issue, and finally excluding observations associated to both issues simultaneously. Results are essentially the same.

Relationship length with fund instead of fund family? Since our previous results favored relationship strength measures at the fund family level insted of fund level, we reported the results in Table 10 using the fund family as the relevant entity. Our results are similar if we use funds instead of fund families.