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Repo market functioning: the role of capital regulation

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Antonis Kotidis[1] and Neeltje van Horen[2]

Abstract

This paper shows that the leverage ratio affects repo intermediation for banks and non-bank financial institutions. We exploit a novel regulatory change in the UK to identify an exogenous intensification of the leverage ratio and combine this with supervisory transaction-level data capturing the near-universe of gilt repo trading. Studying adjustments at the dealer-client level and controlling for demand and confounding factors, we find that dealers subject to a more binding leverage ratio reduced liquidity in the repo market. This affected their small but not their large clients. We further document a reduction in frequency of transactions and a worsening of repo pricing, but no adjustment in haircuts or maturities. Finally, we find evidence of market resilience, based on existing, rather than new repo relationships, with foreign, non-constrained dealers stepping in. Overall, our findings help shed light on the impact of Basel III capital regulation on repo markets.

Key words: Capital regulation, leverage ratio, repo market, non-bank financial institutions.

JEL classification: G10, G21, G23.

(1) University of Bonn. Email: s3ankoti@uni-bonn.de
(2) Bank of England and CEPR. Email: neeltje.vanhoren@bankofengland.co.uk

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Publications and Design Team, Bank of England, Threadneedle Street, London, EC2R 8AH
Telephone +44 (0)20 7601 4030 email publications@bankofengland.co.uk

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"In the context of evaluating the impact of post-crisis regulatory reforms, concerns have been raised that some of the measures introduced have had a negative impact on the functioning of repo markets. Market analysts and industry associations have argued that regulatory reforms have significantly reduced the willingness of banks to provide repo services."

Financial Stability Review, ECB, November 2017

1. Introduction

The market for repurchase agreements (repos) is a critical part of the financial system with around 12 trillion dollar of repo and reverse repo outstanding globally (CGFS, 2017).[1] The market plays a key role in facilitating the flow of cash and securities around the financial system, benefiting both financial and non-financial firms. By supporting liquidity in other markets, it contributes to the efficient allocation of capital to the real economy. And, since the Libor scandal, several central banks have selected benchmark rates based on the repo market.[2] A well-functioning repo market is thus crucial for financial stability and for the efficient transmission of monetary policy.

However, in the wake of the financial crisis, the dynamics in the repo market have changed considerably. Liquidity in core repo markets has dropped, costs faced by some agents have increased and a weakening of repo market functioning has been reported (Bank of England, 2016; Duffie, 2016; CGFS, 2017). It is argued that Basel III regulatory reforms, most notably the leverage ratio, played an important role in this (Duffie, 2016; CGFS, 2017). In the words of Jerome Powell *"many point to post-crisis regulation as a key factor driving any recent decline in liquidity (…) I would agree that it is one factor driving recent changes in market making."*[3] In this paper we show that the leverage ratio indeed affects the repo market, with important heterogeneous effects.

As opposed to the capital ratio, the leverage ratio is a non-risk weighted measure that requires banks to hold capital in proportion to the overall size of their balance sheet. Due to its non-risk weighted nature a binding leverage ratio makes it more costly to engage in low margin

[1] A repo is essentially a secured loan. A dealer sells a debt security, usually a government bond, to another party in exchange for cash and agrees to repurchase it for an equivalent security at a specified date. Reverse repo is the same transaction but seen from the point of view of cash lender.

[2] Recently the Federal Reserve Bank of New York launched as an alternative to the dollar-based Libor a new benchmark rate: the Secured Overnight Financing Rate (SOFR) based on transactions in the Treasury repo market. Switzerland also selected a benchmark rate based on the repo market. The Bank of England and Bank of Japan selected an unsecured rate as the benchmark alternative to sterling- and yen-based Libor.

[3] From his speech on *The Evolving Structure of U.S. Treasury Markets* at the Federal Reserve Bank of New York (October 20, 2015).

activities.[4] This potentially has implications for repo intermediation. The margin on repos is low but they expand a bank's balance sheet and therefore attract a capital charge under the leverage ratio (Figure 1). As a result, the leverage ratio makes engaging in repo activities more costly relative to engaging in activities with higher margins (but equal capital charge). Banks can hence be expected to react to this increase in costs by limiting their repo market activity.

The empirical identification of the impact of the leverage ratio on repo markets is however challenging. First, one needs to find plausibly exogenous variation in the leverage ratio that affects some key participants in the repo market but not all of them. Second, the shock should not coincide with other factors affecting repo markets. Third, one needs to convincingly isolate the adjustment in supply from that driven by demand.

In this paper we address all three empirical challenges by, for the first time, exploiting a policy change that took place in the UK, one of the world's core repo markets. On January 2017, the Bank of England changed the way in which UK regulated banks had to *report* their leverage ratio (Bank of England, 2015a,b). [5] From January 2016 onwards the seven largest (stress-tested) UK regulated banks became formally subject to a 3 percent leverage ratio which they were required to report to the regulator on a quarterly basis.[6] During a transitional period of 12 months, reporting banks could measure their *on*-balance sheet assets on the last day of each month and take the average over the quarter ("monthly averaging"). From January 2017 onwards, the *on*-balance sheet assets had to be measured on each day ("daily averaging"). Both the capital measure as well as the off-balance sheet assets continued to be measured at month-end. This switch from monthly to daily averaging in relation to *on*-balance sheet assets reduced the ability of banks to window-dress their balance sheet at period-ends and effectively made the leverage ratio more binding.[7] [8]

[4] For example, assuming a Tier 1 risk-weighted asset (RWA) capital ratio requirement of 6 percent and a Tier 1 leverage ratio requirement of 3 percent, any asset on the firm's balance sheet that is risk-weighted below 50 percent would attract higher capital requirements under the leverage ratio than under the Tier 1 RWA capital requirements.

[5] The leverage ratio is defined as a bank's Tier 1 capital divided by its total exposure measure which consists of the bank's total on-balance sheet assets and certain off-balance sheet exposures.

[6] These are Barclays, HSBC, Nationwide, Lloyds, RBS, Santander and Standard Chartered.

[7] Recently repo markets have been characterized by volatilities in prices and volumes over period ends (quarter-ends and year-ends) as banks are reducing the size or improving the composition of their balance sheets at these times. Regulatory constraints, such as the leverage ratio, have been identified as one of the drivers behind window-dressing behavior of European dealers (Anbil and Senyuz, 2018). Munyan (2015) shows that unlike non-US dealers, US dealers had no incentive to engage in window-dressing as they report capital ratios based on daily averaging.

[8] See also ICMA European repo and collateral council report (February 2017) which argues that daily averaging reduces overall balance sheet capacity throughout the year. In other words, the shock we exploit is expected to work through the leverage ratio constraint.

The change in reporting requirement of the leverage ratio affected four dealers in the gilt repo market, but not the remaining 12 dealers, providing us with a natural treatment and control group.[9] Furthermore, the change did not coincide with any other regulatory change or adjustment in (unconventional) monetary policy in the UK potentially affecting repo markets. In addition, even though the change in reporting was already announced in November 2015, affected banks had no incentive to adjust their behaviour prior to the actual change in January 2017. Finally, all UK dealers had an incentive to adjust their repo activity even when not close to the regulatory constraint in order to avoid the market reacting to a change in their leverage ratio.

These features make it an ideal quasi-natural experiment to study if and how capital regulation affects repo market functioning. And, as is apparent from the top panel of Figure 2, the four dealers affected by the regulatory change indeed reacted strongly. The graph depicts the evolution of the (standardized) total repo volume intermediated by these dealers over the period October 2016 to February 2017. During the period of "monthly averaging" they reduced repo volumes at each month-end, in line with window-dressing behaviour. After the move to "daily averaging" we do not observe such behaviour anymore, indicating that the leverage ratio effectively became more binding. As expected, the non-affected dealers did not change their behaviour (Figure 2, bottom panel)

Exploiting this intensification of the leverage ratio, we assess how dealers adjusted their repo intermediation in the bilateral dealer-client repo market. We focus on this segment of the market for a number of reasons. First, it allows us to study how the leverage ratio affects the ability of end-users such as banks, insurers, pension funds, hedge funds and asset managers, to invest their cash low risk and to have access to government securities. Due to lack of detailed data, this part of the repo market has hitherto received very little attention. However it is a critical part of the market capturing almost 70 percent of total transaction volume in the UK and about 50 percent in the US.[10] As such, understanding the precise impact of capital regulation on this segment of the market is essential and complements the literature studying its impact on the US tri-party repo market (e.g. Munyan, 2015; Allahrakha, Cettina and Munyan, 2016; Anbil and Senyuz, 2018). Second, it

[9] The affected dealers are Barclays, HSBC, Lloyds and Santander. The unaffected dealers are Bank of America-Merrill Lynch, BNP Paribas, Citigroup, Deutsche Bank, Goldman Sachs, JP Morgan, Morgan Stanley, Nomura, RBC, Scotiabank, TD Bank and UBS.

[10] To the best of our knowledge, the UK is the only core repo market which has data available capturing the universe of bilateral repo transactions. In 2014, the Office of Financial Research and the Federal Reserve System launched a voluntary pilot data collection focused on the US bilateral repo market, but comprehensive data is still lacking (Baklanova, Caglio, Cipriani and Copeland, 2016).

provides us with the unique opportunity to examine how the leverage ratio affects a diverse set of repo market end-users depending on their size, relationship with the dealer and sector. Third, the impact of the leverage ratio is expected to be more pronounced in this segment as these trades are not cleared via a Central Clearing Party (CCP) which reduces the ability of banks to net out a repo with a reverse repo transaction and as such avoid a capital charge.[11] Not surprisingly, there are ample signs of a reduced willingness of banks to use their balance sheet for repo especially affecting end-users in the market (CGFS, 2017).

We employ a new database, the Sterling Money Market Database (SMMD), which contains supervisory transaction-level data covering the near-universe of gilt repo transactions and it has two unique advantages. First, besides detailed information on the volume, pricing and collateral used in each transaction, the database importantly includes both the reporting dealer (the cash borrower) and the counterparty (the cash lender). This enables us to compare adjustments in repo intermediation at the *dealer-client* level allowing for a much tighter identification. Furthermore, as we know each counterparty, we are able to study whether the leverage ratio affects different clients differently. Second, the database clearly identifies each gilt repo transaction. As such, we do not have to rely on a matching algorithm along the lines of Furfine (1999) in order to isolate gilt repo transactions from other transactions and to identify both sides of the transaction.[12] To the best of our knowledge, this is the first paper studying the heterogeneous effects of capital regulation on repo markets.

In a standard difference-in-differences setting, we compare repo intermediation within dealer-client pairs before and after the policy shock differentiating between affected dealers (treatment group) and non-affected dealers (control group). For identification purposes, we focus on clients with at least two dealers and control for observed and unobserved heterogeneity in repo demand and credit risk by employing client fixed effects (Kwaja and Mian, 2008). In other words,

[11] A bank can net out its repo with a reverse repo transaction when it involves transactions to the same counterparty, with the same maturity date and conducted in the same settlement system. This repo transaction then does not count towards the balance sheet anymore and therefore lowers the bank's leverage ratio. Transactions via the CCP are considered transactions to the same counterparty and therefore much more likely to be eligible for netting. In the UK the vast majority of interdealer trades are cleared by a CCP.

[12] When using datasets such as Target2 and Fedwire, the use of algorithms is necessary so the output includes transactions that do not represent transactions that are of interest to the researcher or may discard transactions that should be included and these types of errors can be large (Armantier and Copeland, 2012).

for the *same* client, we compare the differential adjustment in repo volumes by affected and non-affected dealers.

Our main results are as follows. First, we find that dealers affected by the leverage ratio on average reduced repo volume (i.e. accepted less cash) from their clients relative to non-affected dealers. Critically, this result holds when controlling for changes in demand and credit risk at the client level. The economic magnitude of this change is substantial. On average, affected dealers accept 66 percentage points less repo volumes compared to non-affected dealers from the same client in the period after the policy change compared to the period before. [13]

This effect, however, hides some important heterogeneous effects. Motivated by the CGFS (2017) report on repo market functioning, we first differentiate between small and large clients (as measured by their total repo activity in the period prior to the regulatory change) and find that dealer banks subject to the regulatory change reduced repo volume more to their smaller clients compared to their larger clients, relative to non-affected dealers. These results hold when controlling for demand and concurrent factors potentially affecting individual dealers. We also find that dealers tend to move away from clients with whom they have a weaker relationship; however the impact of size dominates. We do not find a differential effect for clients with more long-term repos, that tend to be cash borrowers or that are foreign.

Economic effects are large with affected dealers intermediating on average 133 percentage points lower repo volumes from their small relative to their large clients compared to non-affected dealers.[14] We show that this differential behavior is persistent, consistent with the manifestation of a permanent change in repo market intermediation. Furthermore, affected dealers were not behaving differently prior to the regulatory change reducing concerns that our results are driven by different pre-event trends between the two types of dealers.

When examining the impact on the extensive margin and other loan terms, we document a (persistent) reduction in the frequency of transactions and a reduction in repo rates that affected dealers are willing to offer to their (small) clients. We do not find an adjustment in haircuts or maturities. These findings are as expected as the intensification of the leverage ratio should only affect volumes and prices. Bigger haircuts reflect a worsening of the quality of the underlying

[13] This magnitude reflects the combined effect of affected dealers reducing repo volume they accept from their clients and the non-affected dealers increasing it.

[14] This magnitude again reflects the combined effect of affected dealers reducing the repo volume they accept from their small clients relative to their large clients, while non-affected dealers are increasing theirs.

collateral and maturities mainly relate to a client's business model, so both should not be affected by the intensification of the leverage ratio.[15]

The heterogeneous effects we document are in line with evidence gathered from market participants (CGFS, 2017) and puts rigor to the causal interpretation of our findings. As interactions with large clients are much more frequent, profit margins and franchise value tend to be higher. In addition, larger clients more likely provide ancillary business which justifies use of balance sheet and have more negotiating power over the contract terms. Finally, with larger clients it is more likely that a dealer can net out a repo with a reverse repo transaction which implies that the transaction does not count towards the balance sheet. As such, dealer banks are expected to adjust their repo intermediation to small relative to large clients, in line with our findings.

In the final section of the paper we investigate the aggregate effect and repo substitution. A conservative back of the envelope calculation suggests that, keeping all else equal and not allowing for the possibility of substitution, the withdrawal of affected dealers resulted in small clients being able to place 32 percent, equaling 2.9 billion pounds, less cash in the gilt repo market. However, we find evidence that this is partially offset by non-affected dealers increasing their repo activity to these clients. This was primarily done through an intensification of pre-existing relationships, rather than through the establishment of new ones. In line with this, non-affected dealers increased their market share to small clients from 39 to 49 percent after the regulatory change. These results indicate that competing, non-constrained, foreign dealers took the opportunity to capture market share when affected, UK dealers withdrew from the small end-user segment of the dealer-client market. The market therefore seems to have been resilient and adjusted quickly.

The remainder of the paper is structured as follows. The next section provides a review of the literature. In Section 3 we describe in more detail the gilt repo market and how the leverage ratio affects repo market intermediation. Section 4 outlines our empirical methodology and describes the SMM database that we exploit. Section 5 presents and discusses our empirical findings and Section 6 analyses the aggregate effect and market adjustment. Section 7 concludes and discusses the policy implications of our findings.

[15] Our non-result is in line with the notion that collateral and maturity are substitute mechanisms in mitigating agency problems (e.g. Ortiz-Molina and Penas, 2008).

2. Related literature

Our paper contributes to and combines two main strands of the literature. First, it contributes to the literature that studies the repo market. Most recent studies have focused on the functioning of the US repo market around the global financial crisis (Gorton and Metrick, 2012; Krishnamurthy, Nagel, and Orlov, 2014 ; Copeland, Martin, and Walker, 2014) or the European repo market around the sovereign debt crisis (Mancini, Ranaldo and Wrampelmeyer, 2016; Boissel, Derrien, Ors and Thesmar, 2017), broadly concluding that both markets resisted the stress fairly well with no significant decline in volumes but with some increases in haircuts.

A more nascent part of this literature focuses explicitly on how regulation affects repo markets. Studying the US tri-party repo market Munyan (2015) and Anbil and Senyuz (2018) provide evidence that indicates that non-US banks reduce their repo activity around financial reporting dates to appear better capitalized.[16] Allahrakha, Cettina and Munyan (2016) document a number of changes in the US tri-party repo market after the announcement of the leverage ratio in the US, such as a reduction in borrowing, an increase in use of more volatile collateral and a shift towards non-bank dealers. Using a sample of European banks, Baldo, Bucalossi and Scalia (2018) show that repo activity outside the leverage ratio reporting dates has not decreased. Focusing primarily on the interdealer segment of the gilt repo market, Bicu, Chen and Elliott (2017) find no statistically significant evidence of a reduction in repo liquidity after the announcement of the leverage ratio in the UK.

Our work extends this literature in several ways. First, we explicitly focus on the dealer-client segment of the repo market, which hitherto received very little attention due to unavailability of data. As this is a major segment of the repo market (more than 70 percent in the UK), understanding its functioning is essential. Second, in contrast to the above literature, the quasi-natural experiment that we exploit in combination with detailed transaction level data allows us to address the empirical challenges that one faces when isolating the impact of the leverage ratio from other confounding factors and to isolate demand from supply. This enables us to make a clean assessment of the causal impact of the leverage ratio on repo market functioning. Third, the data

[16] A related literature studies window-dressing behavior in other markets. Du, Tepper and Verdelhan (2018) document covered interest rate parity violations at quarter-ends indicating that post-crisis regulation drives a wedge between supply and demand due to costly financial intermediation. Abbassi, Iyer, Peydro and Soto (2017) find that after the ECB's announcement of its asset quality review, reviewed banks decreased their share of riskier securities and loans and the level of overall securities and credit supply.

allow us to examine how capital regulation affects different clients and therefore to uncover heterogeneous effects.

Second, our paper contributes to the literature that studies the consequences of capital regulation. Not surprisingly, given its early introduction, most of this literature has focused on the impact of changes in the capital ratio, showing that an increase in capital requirements (or cost) leads banks to contract lending (see among others, Berger and Udell, 1994; Aiyar, Calomiris, Hooley, Korniyenko and Wieladek, 2014; Jimenez, Ongena, Peydro and Saurina, 2017) with important negative real effects on firms (Gropp, Mosk, Ongena and Wix, 2018) and that it induces credit re-allocation towards non-bank financial intermediation (Irani, Iyer, Meisenzahl and Peydro, 2018).

While the leverage ratio has received a lot of press coverage and is discussed extensively in policy debates, the academic literature on its impact is still relatively scarce. However it is growing rapidly. Adrian, Boyarchenko and Shachar (2017) find evidence that indicates that leverage regulation leads to a reduction in bond liquidity. Acosta Smith, Grill and Lang (2017) and Choi, Holcomb and Morgan (2018) show that the leverage ratio incentivizes banks to shift their portfolio to riskier assets but does not increase overall bank risk. Furthermore, recent research shows that the leverage ratio discourages dealers to engage in FX trading activity (Cendese, Della Corte and Wang, 2018) reduces their willingness to clear derivatives on behalf of clients (Acosta Smith, Ferrara and Rodriguez-Tous, 2018) and to participate in spread-narrowing trades (Boyarchenko, Eisenback, Gupta, Shachar and Van Tassel, 2018). We add to this literature by showing that the leverage ratio affects repo market functioning with dealers moving away from smaller end-users when the leverage ratio becomes more binding.

3. Leverage ratio and repo market intermediation

This section describes the functioning of the gilt repo market in the UK and then discusses how the leverage ratio in general and the change in the reporting requirement in particular affect the repo market functioning.

3.1 Gilt repo market

Formally, a repo is a "repurchase agreement": an agreement to sell securities (referred to as collateral) at a given price to a counterparty with the commitment to repurchase the same (or

similar) security at a specified future date for a specified price. The difference between the price at which the security is sold and repurchased reflects an annualized interest rate known as the repo rate. From the point of view of the cash borrower the transaction is referred to as repo, while from the point of view of the cash lender it is referred to as reverse repo. A repo transaction is economically equivalent to a secured loan since the securities provide credit protection in the event that the seller (i.e. the cash borrower) is unable to complete the second leg of the transaction. Collateral haircuts and regular margin payments further protect the lender against fluctuations in the value of the collateral. The majority of repo transactions are overnight transactions; however a substantial share consists of maturities ranging from a couple of days to a number of months.

Repo markets play a key role in facilitating the flow of cash and securities around the financial system. They create and support opportunities for the low-risk investment of cash, as well as efficient management of liquidity and collateral by financial and non-financial firms. The repo market supports the smooth functioning of derivatives markets as it provides market participants with means to obtain high-quality collateral that can be used as margin. Movements in short-term repo rates change the market-based financing conditions for banks and hence their conditions for trading with firms and households. This means that repo rates are a prime channel through which changes in the monetary policy stance are transmitted to the broader financial system and the real economy. The repo market is therefore key to the short-term liquidity needs of banks and non-bank financial institutions and a cornerstone of the transmission of monetary policy.

Although the precise structure of the repo market varies across jurisdictions, there are two segments: the dealer-to-dealer (interdealer) and the dealer-to-client segment (dealer-client). In the interdealer market, dealers transact to finance their market-making inventory, source short-term funding or invest their cash and they transact on behalf of their clients. In the dealer-client segment, end-users meet with dealers to provide collateral in return for cash (e.g. asset managers, pension funds, hedge funds and insurance companies) or to invest in cash while receiving collateral (e.g money market funds or corporate treasurers). Banks in addition use reverse repo to borrow gilts for their liquid asset buffers.

Trades can be settled in three ways: bilateral, triparty and via a Central Clearing Party (CCP). The difference between bilateral and triparty repo is that in the latter market a third party called a clearing bank acts as an intermediary and alleviates the administrative burden between two parties engaging in a repo. The clearing bank does not assume the credit risk of the counterparties

in the transaction. When trades are settled through a CCP the CCP acts as the clearing bank but also assumes the credit risk by becoming the buyer to all sellers and the seller to all buyers. Only members of the CCP can trade through the CCP. As CCP membership is expensive it is typically limited to large banks and dealers.

In the UK the vast majority of interdealer transactions are cleared by a CCP and this accounts for close to 30 percent of all repo transaction volume. The dealer-client segment is almost entirely settled bilaterally and captures almost 70 percent of total transaction volume. Only a tiny segment of the UK repo market is settled on tri-party basis (less than 5 percent). In contrast, half of the dealer-client segment of the US repo market segment is settled bilaterally and half is settled tri-party via a clearing bank, such as the Bank of New York Mellon and JP Morgan Chase (Baklanova, Dalton and Tompaidis, 2017).

The vast majority of sterling-denominated repo involves the sale and repurchase of gilts (UK government bonds) issued by the UK Debt Management Office (DMO). Around the policy shock there were 16 dealer banks active in the market. These are Bank of America-Merrill Lynch, Barclays, BNP Paribas, Citigroup, Deutsche Bank, Goldman Sachs, HSBC, JP Morgan, Lloyds, Morgan Stanley, Nomura, RBC, Santander, Scotiabank, TD Bank and UBS.[17] As of mid-2016, there was about 900 billion USD repo and reverse repo collateralized by gilts outstanding, which makes the UK the fourth largest repo market (after the Euro area, US and Japan) (CGFS, 2017).

3.2 Leverage ratio

In the wake of the global financial crisis the Basel Committee of Banking Supervision (BCBS) undertook a significant program of reform to banking regulation known as Basel III. The reform introduced new international regulatory standards for both capitalization and liquidity risk management. One of the key regulatory reforms was the introduction of the leverage ratio. As opposed to the capital ratio, the leverage ratio is a non-risk weighted measure that requires banks to hold capital in proportion to the exposure measure (including both on-balance sheet exposures and some off-balance sheet items). The requirement constrains leverage in the banking sector and thus helps to mitigate the risk of destabilizing deleveraging processes. Furthermore, as it is independent

[17] There are also two non-bank dealers active, but we do not include them in the analysis.

of risk, the leverage ratio provides a safeguard against model risk and measurement error which affects the capital ratio.

However, because of its non-risk weighted nature the leverage ratio effectively makes it more costly for banks to engage in low margin activities. This potentially has implications for repo intermediation as the margin on repos is low but they expand a bank's balance sheet and therefore attract a capital charge under the leverage ratio (Figure 1). As a result, the leverage ratio makes it effectively more costly for banks to assign balance sheet to repos relative to assets with higher margins (but equal capital charge). Banks can hence be expected to react to this increase in cost by limiting their repo activity.

The BCBS first indicated that it planned to introduce a leverage ratio in a consultation document in 2009 and proposed a 3 percent target in 2010 (BCBS, 2009 and 2010). At this time it also proposed a transition path to implementation whereby banks would be required to publicly disclose their leverage ratios starting in January 2015. In 2014, the BCBS finalized the definition of the leverage ratio and reiterated that the leverage ratio would become a Pillar 1 requirement from 2018 onwards (BCBS, 2014).

The way domestic regulators have implemented the leverage ratio varies across jurisdictions. UK authorities have implemented the leverage ratio earlier than the Basel and EU timelines. The seven largest UK banks (those subject to regulatory stress-tests) have been expected to meet a 3 percent leverage ratio since January 2014 (Bank of England, 2013). End 2015 the UK leverage ratio framework was announced, stipulating a 3 percent minimum requirement for the seven banks (Barclays, HSBC, Nationwide, Lloyds, RBS, Santander and Standard Chartered) starting in January 2016 (Bank of England, 2015a,b). Other UK regulated banks (smaller domestic banks and foreign subsidiaries other than Santander) will become subject to a 3 percent minimum requirement under CRD IV to be implemented after 2019. For a detailed timeline of the implementation of the leverage ratio in the UK see Appendix Table 1. [18]

4. Empirical methodology and data

4.1 Quasi-natural experiment: Change in regulatory reporting requirements

[18] For a further description of how UK authorities implemented the leverage ratio see Bicu, Chen and Elliott (2017)

In order to examine how the leverage ratio affects repo intermediation in the bilateral dealer-client market, we exploit a regulatory change in the UK which modified the way banks had to report their leverage ratio. This policy change affected some dealers in the UK sterling money market but left the other dealers unaffected and, thus, provides us with an ideal quasi-natural experiment.

As of January 2016 four dealers in the gilt repo market, Barclays, HSBC, Lloyds and Santander, became formally subject to a 3 percent leverage ratio which has to be reported on a quarterly basis. During a transitional period of 12 months the reporting banks could measure their on-balance sheet assets on the last day of each month and take the average over the quarter ("monthly averaging"). From January 2017 onwards the on-balance sheet assets had to be measured on each day ("daily averaging"). This switch from monthly to daily average reporting reduced the ability of banks to window-dress their balance sheet and effectively made the leverage ratio more binding. The remaining 12 dealers did not have to report their leverage ratio to the Bank of England and as such were not subject to the change in this requirement providing us with a natural treatment and control group.[19]

Figure 2 shows that the change in reporting requirements indeed affected the behavior of the UK regulated dealers. It depicts the evolution of the (standardized) total repo volume intermediated by UK regulated (top panel) and non-UK regulated (bottom panel) dealers over the period October 2016 to February 2017. As the graph shows, prior to the regulatory change the UK regulated dealers substantially reduced their repo volumes around month-ends, while non-UK regulated dealers did not. After the regulatory change the volume reductions were much less pronounced and more in line with the behavior of non-UK regulated dealers. These patterns show that "monthly averaging" incentivized UK regulated dealers to window-dress their balance sheet, which after the regulatory change was not beneficial anymore.

The change in regulatory reporting provides us with plausibly exogenous variation in the intensification of the leverage ratio in order to assess its impact on repo intermediation. Using the change in reporting requirements instead of the introduction of the leverage ratio is useful for

[19] These dealers are headquartered in the EU, US and Canada and therefore (also) subject to regulation in their home markets. The US implementation of the Basel III leverage ratio is the supplementary leverage ratio that requires certain banks to hold tier 1 capital equivalent to 3 percent of total exposures. US banks that are subject to the supplementary leverage ratio began disclosing and reporting their ratios in 2015, and must be in compliance by 2018. In addition, an enhanced supplementary leverage ratio (eSLR) will come into effect in 2018 and requires G-SIBs and insured depository institutions of G-SIBs to meet a 5 percent and 6 percent minimum leverage ratio, respectively. Canadian banks have to maintain a leverage ratio that meets or exceeds 3 percent at all times since January 2015. European banks have to disclose their leverage ratio since 2015 but do not have to meet a 3 percent minimum as part of their Pilar 1 capital requirements.

several reasons. First, the policy shock is much cleaner compared to the introduction of the leverage ratio itself. The UK regulatory authorities announced the implementation of the leverage ratio ahead of time specifically to give banks time to gradually adjust their balance sheet. Therefore it is hard to contribute changes in the repo market to the *introduction* of the leverage ratio. The change in reporting requirement that we exploit was also announced ahead of its actual implementation (at the end of 2015), however dealers did not have an incentive to change their behaviour ahead of the implementation date. The vast majority of repo transactions are very short-term, so dealers do not have to adjust their repo rates or volumes until the daily average requirement comes into effect. This makes it possible to isolate the impact of the leverage ratio on repo intermediation from other confounding factors. Furthermore, all UK dealers had an incentive to adjust their repo activity even without a binding leverage in order to avoid the market reacting to a change in their leverage ratio. Finally, and crucial for our identification, the change in regulation did not coincide with any other regulatory changes or changes in (unconventional) monetary policy in the UK that could affect repo market intermediation. As such, the reporting change provides us with a suitable exogenous policy shock that affects some dealers in the gilt repo market, while leaving others unaffected.

4.2 Identification strategy

We want to assess how the leverage ratio affects the ability of end-users such as banks, insurers, pension funds, hedge funds and asset managers, to invest their cash low risk and to have easy access to government securities. Having identified exogenous variation in the intensification of the leverage ratio allows us to perform a difference-in-differences analysis in which we compare repo intermediation within dealer-client pair before and after the policy shock differentiating between dealers affected and not affected by the shock.

We compare the behaviour of the two types of dealers in the month before and after the regulatory change. To avoid any bias from increased volatility resulting from dealers' practices to window-dress and adjust their balance sheets at year-end, we drop the last two business weeks of December 2016 and the first business days of January 2017 (see Figure 2). [20] We ensure that both

[20] At year end both types of dealers significantly reduce their repo volumes as banks reduce the size or improve the composition of their balance sheets because of regulatory constraints such as the leverage ratio, the G-SIB surcharge and the SRF levy, and because of commercial and taxation consideration (CGFS, 2017).

the pre and post periods have the same number of week days as to assure that results are not driven by different activity on certain days of the week. As such, our *pre* period ranges from November 21 to December 16, 2016 and the *post* period ranges from January 5 to February 1, 2017 (i.e. 4 business weeks each). We use a relatively short period of time for two reasons. One, this market is very different from the corporate loan market: it is very short term, often overnight, and clients tend to use the market repeatedly during a short time window. Second, as the market is affected by unconventional monetary policy and (changes in) other regulatory requirements (CGFS, 2017), the longer the time window around the event the more likely confounding factors will affect the estimates. However, we show that our results remain robust when we consider alternative time windows.

We analyse the same dealer-client pair before and after the policy shock. However, it is crucial to also control for changes in demand and risk at the client level. Therefore we focus on clients that were placing cash in the pre-period with at least 2 different dealers and continue to transact with them in the post period.[21] This allows us to saturate the specification with client fixed effects and to control for both observed and unobserved heterogeneity in client fundamentals (demand, quality and risk). In other words, for the *same* client, we compare the differential adjustment in repo intermediation by affected and non-affected dealers (Khwaja and Mian, 2008).

4.3 Data

We use a new regulatory database called the Sterling Money Market Database (SMMD). The aim of this data collection is to secure and improve information available to the Bank of England on conditions in the sterling money market to help the Bank meet its monetary policy and financial stability objectives. The database contains virtually all transactions, from overnight to one year, conducted in the secured and unsecured sterling money market as reported by the 23 most active participants in the market (this captures about 95 percent of the total market).[22] The transactions include both repos and reverse repos secured against gilts and known as gilt repo. The database includes transactions in both the interdealer and the dealer-client repo market, but we focus

[21] Clients with only one dealer represent <1 percent of total repo volume in our sample.

[22] The data that are available from 1 February 2016 contain a subset of 'early adopters', comprising roughly 80 percent of the full population. The full reporting population is contributing since 1 July 2016. This full population of reporters is chosen to cover 95 percent of the volume of activity in the sterling money market, and may be expected to change over time to remain in line with this aim. For more information on the scope of and process for reporting, see www.bankofengland.co.uk/statistics/Documents/reporters/defs/instructions_smm.pdf.

exclusively on the latter segment of the market. We have access to five months of data: October 2016 – February 2017.

The SMM database has two unique advantages. First, besides detailed information on the volume, pricing and collateral used in each transaction, the database importantly includes both the reporting dealer (the cash borrower) and the counterparty (the cash lender). This allows us to effectively compare adjustments in repo intermediation *within* dealer-client pairs and to examine in detail differential adjustments across client types. Second, as the database clearly identifies gilt repo transactions, we do not have to rely on a matching algorithm along the lines of Furfine (1999) in order to isolate the gilt repo transactions from other transactions and to identify both sides of the transaction, a procedure that is necessary when using transaction level datasets such as Target2 and Fedwire. As such we can say with certainty that all transactions we capture are indeed gilt repo transactions, that we do not wrongly exclude repo transactions from any of the reporting banks and that the party identified as the cash lender is indeed the correct counterparty.

We clean the data in a number of ways. First, while there are 23 reporting entities, only 16 of those are dealers in the repo market. As the dealers are the biggest intermediaries we capture the vast majority of trades (>95% in terms of repo volumes). Second, we are only interested in clients that are banks or non-bank financial institutions, such as pension funds, hedge funds and insurance companies, and therefore we drop all repo transactions involving non-financial corporates. In addition, we drop dealer-client transactions in which the client is another dealer (interdealer transactions), a State, a Central Bank or a trust, because of different business models. Third, for most transactions counterparties are reported using either their unique legal entity identifier (LEI) or their name (for about 70 percent of the transactions the LEI is provided). However, in a few instances (<10 percent of total transactions), due to privacy laws, only the sector of the counterparty is provided. As our identification relies on changes in repo intermediation at the dealer-client level, we cannot include transactions for which the counterparty name is not available, hence we drop these.[23] We further drop transactions with variable rate, pool or multiple collateral and tri-party repo transactions.[24]

As counterparty names are provided at the legal entity level, different funds of the same asset manager are reported as different counterparties. Although a laborious task, we manually

[23] This mainly affects transactions reported from institutions based in France.
[24] Transactions with these characteristics represent less than 5 percent of total transactions.

aggregate these different legal entities into a parent company and use this as the client in our model.[25] We take this approach as credit risk, reputation and size of the parent company will ultimately determine to what extent a dealer will adjust its repo activity. Furthermore, focusing on the parent company avoids classifying the same legal entity as different counterparties because different dealers use different reporting conventions.

In order to control for demand and changes in credit risk we only include clients that were placing cash with at least two different dealers and who continue to transact with these dealers in the post period. Our final sample therefore contains 15 dealers, 38 clients and 126 dealer-client pairs. On average a client interacts with 3 different dealers, but the number of dealers a client interacts with ranges from 2 to 10. Over 80 percent of the dealer-client pairs involve clients that are non-bank financial institutions, with the largest groups being hedge funds and asset managers.

In the period preceding the change in reporting requirements 4,218 repo transactions worth 306 billion pounds took place between our group of dealers and clients. Of those 75 percent were overnight, 13 percent had a maturity of one week and 11 percent of more than one week. On average a dealer-client pair interacted 33 times. The affected dealers accounted for 31 percent of total repo volume accepted.

5. Empirical results

5.1 Baseline effect

In order to examine the impact of the exogenous intensification of the leverage ratio on repo intermediation we estimate the following model:

$$\Delta log(Volume)_{ij} = \beta_1 \times Affected\ Dealer_i + \beta_2 \times Relationship_{ij} + \mu_j + \varepsilon_{ij}, \quad (1)$$

where $\Delta log(Volume)_{ij}$ is the pre-post change in the (log of) the total repo volume accepted by dealer *i* from client *j*, with pre={November 21-December 16} and post={January 05-February 01}. We aggregate the daily transactions between a dealer-client pair before and after the regulatory change because most clients do not trade every day. Also, this way we eliminate concerns of estimation bias due to serial correlation. The variable is winsorized at the 1 and 99th percentile.

[25] A similar consolidation procedure is applied by the Office of Financial Research in the U.S. Money Market Fund Monitor data.

$Affected\ Dealer_i$ is a dummy variable equal to 1 if the dealer was subject to the UK leverage ratio at the time of the policy change, and to 0 otherwise; $Relationship_{ij}$ is defined as the pre-determined ratio of frequency of repo transactions between dealer *i* and client *j* to total number of repo transactions of dealer *i* [26]; μ_j is a vector of client fixed effects; and ε_{ij} is the error term. The model is estimated using OLS and, in addition, we cluster standard errors at the dealer level. We choose this level of clustering because the coefficient of interest varies at the dealer level, as well as to account for the fact that changes in repo volumes are likely correlated within dealer. Appendix Table 2 shows the definition and summary statistics of all variables used throughout the paper.

Our coefficient of interest is β_1. A negative coefficient for β_1 would imply that—all else equal—affected dealers intermediate lower repo volumes after the policy change, compared to non-affected dealers. Put differently, the numerical estimate of β_1 captures the difference in adjustment of repo market intermediation induced by switching from the control group to the treatment group. The cross-section specification in first differences eliminates any time-invariant (un)observed heterogeneity at the dealer, client and dealer-client pair level as well as shocks common to all clients and dealers. The relationship measure controls for the importance of the client in the dealer's portfolio before the regulatory change. In our preferred specification we also include client fixed effects to allow us to control for (un)observed heterogeneity in changes in client demand, quality and risk. As such, we isolate the impact of the change in the reporting requirement of the leverage ratio on repo intermediation by comparing the change in repo volumes accepted by the same client from affected vis-à-vis non-affected dealers.

The result in Table 1, column (1) indicates that dealers affected by the leverage ratio on average reduced the repo volume they were willing to accept from their clients relative to non-affected dealers (significant at the 5 percent level). Without controlling for demand we find that after the regulatory change affected dealers on average reduce repo volume they accept by 27 percent, while non-affected dealers on average increase it by 14 percent. In column (2) we control for the strength of the pre-shock relationship between dealer and client. We find no evidence that the strength of the relationship has an impact on the change in repo volume accepted.

[26] We use the definition of relationship strength put forward by Petersen and Rajan (1994). For robustness, we construct an alternative measure of relationship between dealer-client pair, defined as the pre-determined ratio of volume of repo transactions between dealer-client to total volume of repo transactions of dealer (e.g. Afonso, Kovner and Schoar, 2011). Our conclusions remain unchanged when we employ the alternative measure.

One could be concerned that some of the clients placing cash at affected banks have a lesser need to place cash or experienced and increase in credit risk after the change in reporting requirement, relative to clients from non-affected banks. If this was the case, the reduction in repo volume instead of a supply side reaction by dealers, would be driven by lower demand and/or quality of the client. To address this concern, we first add sector fixed effects to control for changes in demand that are sector driven (column 3). Controlling for demand at the sector level barely affects our coefficient of interest.

As we only study clients that interact with multiple dealers, we next include client fixed effects to control both for heterogeneity in observable and unobservable characteristics at the client level. We find that, for the *same* client, affected dealers reduce repo intermediated compared to non-affected dealers. The coefficient now increases significantly which suggests that sector fixed effects may not be enough to control for demand in this market.

The economic magnitude of the change we document is substantial. The most saturated and therefore preferred model in column (4) shows that affected dealers accept almost 66 percentage points less repo volumes compared to non-affected dealers from the same client in the period after the policy change compared to the period before. As is evident from the results without client fixed effects, the magnitude of this effect reflects the combined effect of affected dealers reducing repo volumes and non-affecting dealers increasing it. In other words, an intensification of the leverage ratio reduces dealers' willingness to engage in repo market activity. This average effect might however hide some important heterogeneous effects. An issue we turn to next.

5.2 Heterogeneous effects: Small versus large clients

Motivated by the CGFS (2017) report on repo market functioning, we start by differentiating between small and large clients. As interactions with large clients are much more frequent, profit margins and franchise value tend to be higher. In addition, larger clients are more likely to provide ancillary business which justifies use of balance sheet and have more negotiating power over the contract terms. Finally, with larger clients it is more likely that a dealer can net out a repo with a reverse repo transaction which implies that the transaction does not count towards the balance sheet. As such, we expect that dealers adjust their repo intermediation to small relative to large clients when faced with a more binding leverage ratio.

To examine this conjecture we expand model (1) and allow the impact of the regulatory change to differ between small and large clients. Our model is as follows:

$$\Delta\log(Volume)_{ij} = \beta_1 \times Affected\ Dealer_i \times Small_j + \beta_2 \times Relationship_{ij} + \mu_j + \varphi_i + \varepsilon_{ij} \quad (2)$$

where $\Delta log(Volume)_{ij}$, $Affected\ Dealer_i$ and $Relationship_{ij}$ are defined as before; $Small_j$ is a dummy variable equal to 1 if the client is small, defined as engaging in below median volume of repo transactions in the pre period, and 0 if large; μ_j is a vector of client fixed effects; φ_i is a vector of dealer fixed effects; and ε_{ij} is the error term. $Affected\ Dealer_i$ and $Small_j$ are only included in the specification on their own in versions of Model (2) which exclude μ_j and φ_i, respectively, because otherwise the effect of the former is subsumed in the dealer fixed effects, and the effect of the latter is subsumed in the client fixed effects. The model is again estimated using OLS and standard errors are clustered at the dealer level.

A negative $\beta_1$would imply that – all else equal – affected dealers reduce the volume of repo they are willing to accept from small clients relative to large clients after the policy change, compared to dealers not affected by the tightening of the leverage ratio. Besides controlling for the pre-shock relationship strength and client fixed effects, this specification also allows us to control for dealer fixed effects. As such, our model effectively controls for concurrent factors that potentially influence affected dealers differently from non-affected dealers, such as a regulatory change or (unconventional) monetary policy shocks in the home country of the non-affected dealer.

In terms of raw statistics we see that small and large clients differ substantially. In the month prior to the regulatory change large clients on average transact 183 times and place on average 14 billion pounds cash, while small clients transact 13 times and place on average 557 million pounds. In this period, the affected dealers accounted for 31 and 61 percent of total repo volume accepted from large and small clients respectively.

As in Table 1 we first show results without any controls (Table 2, column 1). We find that dealers subject to the regulatory change reduced repo volume to their smaller clients while dealers not affected by the change increased it. We do not find a differential effect for large clients. On average, affected dealers reduce repo volume accepted from their smaller clients by 53 percent, while non-affected dealers increase it by 51 percent with the difference being statistically significant. For large clients, affected dealers also reduce repo volume accepted, but by 12 percent,

so the adjustment is much more subdued. On the other hand, non-affected dealers slightly increased it by 2 percent. The difference between the two groups of dealers in this case is however not significant.

Controlling for relationship strength (column 2) and sector fixed effects (column 3) barely affects the coefficients. When we next control for client fixed effects and thus control for demand and changes in quality and credit risk at the client level in column (4) the differential effect becomes even more pronounced. In column (5) we also include dealer fixed effects. This means that we effectively control for concurrent factors that potentially influence the affected dealers differently from the non-affected dealers. Using this very restrictive specification we confirm the previous results. The estimate of the interaction term remains statistically significant at the one percent level and the magnitude remains relatively unchanged compared to the specification with only client fixed effects.

In terms of economic magnitude, we find (using the most saturated specification in column 5) that affected dealers are willing to accept 134 percentage points lower volume from their smaller clients relative to their larger clients compared to non-affected dealers. Again, the magnitude reflects the combined effect of affected dealers reducing repo volume they accept from their small relative to their large clients and the non-affected dealers increasing it. Because we control for client and dealer fixed effects in a first differences model, it is unlikely that our results are driven by observable or unobservable time-invariant or time-varying dealer heterogeneity or by changes in demand or credit-risk at the client level. Summarizing, our results thus indicate that affected dealers reduced their repo market intermediation for their smaller clients as a result of the change in reporting requirements that effectively made the leverage ratio more binding. Larger clients on the other hand were not affected.

5.3 Heterogeneous effects: Other client types

Motivated by the CGFS (2017) report on repo market functioning, we first focused our analysis on small vis-à-vis large clients with respect to the market as a whole. However, it is possible that affected dealers also react differently with respect to other client characteristics. Furthermore, one could be worried that *Small* dummy is a proxy for another client characteristic that might be driving our results. Therefore in this section we examine a number of other client characteristics.

We use the same specification as in Table 2, column 5, meaning that in all regressions we control for changes in demand and credit risk at the client level and concurrent factors at the dealer level.

First, we focus on the strength of the existing repo relationship between dealer and client and examine how this affects the adjustment in repo intermediation. We create a dummy variable *Relationship* which is one if the ratio of the frequency of repo transactions between dealer *i* and client *j* to total number of repo transactions of the dealer in the pre-period is above the median, zero otherwise. Since repo liquidity conditions are determined by the dealer, we want to capture the importance of the client in the dealer's portfolio. For this reason, we define the share within a dealer, rather than client.

The result in Table 3, column 1 shows that a stronger relationship between dealer and client prior to the policy change lowers the effect of the leverage ratio on repo volume and this effect is significant at the 10 percent level. In other words, relationships seem to matter. However, when we do a horserace between the impact of being small and having a strong relationship with the dealer, the impact of small is dominant (column 2).[27] In other words, while being an important client from the point of view of the dealer matters, the average size of the client seems to matter more.

Next, we test whether dealers are more likely to withdraw from clients that tend to want to place cash at longer maturities. With "daily averaging" a repo transaction with a one week maturity would count five days towards the exposure measure, while under "monthly averaging" only one day and only if it is on the dealers' balance sheet at months-end. Furthermore, small clients tend on average to have somewhat longer maturities. We create a dummy variable *Long-Term Repos* which is one if the average maturity of all repo transactions of the client in the pre-period is above the median, zero otherwise. The results in columns 3 and 4 show that the length of a normal repo transaction does not influence an affected dealer's decision to withdraw from a particular client. The interaction with *Small*, however, remains large and statistically significant at the 5 percent level.

Next we examine whether the adjustment is stronger for foreign clients as affected (UK) dealers might be more willing to continue lending to domestic clients. While the parameter estimate on the interaction with *Foreign* is negative, it is statistically insignificant (columns 5 and 6). Finally, we examine whether affected dealers are less likely to adjust to clients that engage more in reverse repo. For these clients it might be easier for the dealer to net out a repo with a

[27] The correlation between the relationship and the small dummy is below 50 percent.

reverse repo transaction and as a result the dealer might be more willing to accept repo from them. To examine this we create a dummy variable, *Reverse Repo*, which is one if the client's sector traditionally transacts more in the reverse repo market (pension funds, insurance companies and asset managers). The results, columns 7 and 8, show that affected dealers do not differentially adjust to these clients. Importantly, in both cases, the interaction between affected dealer and small remains of the same magnitude and statistically significant.

Summarizing, the defining client characteristic which determines whether a dealer faced with an intensification of the leverage ratio adjusts its repo intermediation seems to be the size of the client in the market. This finding is consistent with the conjecture of CGFS (2017) and market intelligence. In the rest of the paper we therefore continue to differentiate between small and large clients.

5.4 Dynamic effects

Up till now we focused exclusively on the period directly surrounding the change in reporting requirements. However, it is insightful to see how the parameter on our main interaction effect (*Affected Dealer * Small*) behaves over time. This allows us to examine how persistent the change in the market is and to make sure that our results are not driven by any pre-event trends. To this end we re-estimate our model (fully saturated with client and dealer fixed effects) but estimate the coefficients with rolling symmetric time-windows that end or start in our original *Pre* period {November 21-December 16}. The blue dots in Figure 3 indicate the estimate of β_1 and the vertical lines indicate the 90 percent confidence intervals. Standard errors are again clustered at the dealer level.

The first point estimate in the graph (labelled as *Pre-1 – Pre*) represents a placebo test and examines whether in the months before the change in regulatory requirements affected and non-affected dealers behave differently. In this regression the pre-period is moved one month back and ranges from October 24 to November 18, 2016. The dependent variable $\Delta log(Volume)_{ij}$ is defined as the log change in repo volume accepted between this period and the original pre-period by dealer *i* from client *j*. The point estimate shows that in the months before the change in

regulatory requirements affected and non-affected dealers do not behave differently, reducing concerns that our results are driven by different pre-event trends between the two types of dealers.[28]

After the change in regulatory reporting requirements, the two groups of dealers start diverging with the parameter labelled as Pre-Post representing the point estimate of Table 2, column 5. Importantly, the results show that this differential effect persists into February (labelled Pre-Post+1). This finding is consistent with the manifestation of a persistent change in repo market intermediation because of the intensification of the leverage ratio, with affected dealers moving away from smaller clients.

5.5 Other margins of adjustment

Up till now we focused our attention on how dealers adjusted repo volumes they accepted from their (smaller) clients. However, our database is rich and allows us to study other margins of adjustment as well. This helps us to put rigor to the causal interpretation of our findings as one would expect dealers to react to an intensification of the leverage ratio by adjusting volume and prices, however it should not affect the margins that capture credit risk or business models as those are not affected by the change in the reporting requirements.

We construct four new dependent variables. First we look at the extensive margin and create the dependent variable $\Delta log(\#Transactions)$ which is the pre-post change in the (log of) the total number of repo transactions accepted by dealer *i* from client *j*. While our previous dependent variable captures the outcome of the negotiation between dealer and client in terms of repo size, this variable captures whether the dealer and client match (i.e. the extensive margin of trading activity). We would expect that affected dealers adjust on this margin.

In line with our expectation, we find that affected dealers after the policy change reduced the number of transactions they engaged in with 39 percentage points compared to non-affected dealers (Table 4, column 1). When we again allow the impact to differ across small and large clients (column 2), we find that dealers subject to the regulatory change significantly reduced the number of transactions they engaged in with smaller clients relative to the number of transactions with large clients compared to dealers not affected by the change. Again, as we saturate the model

[28] To further mitigate such concerns, we run a second placebo experiment comparing the beginning of our data sample period (October 03 to October 21) to our Pre-1 period (October 24 to November 18). The results from this exercise again confirm that there are no pre-event trends between treatment and control group. Results are available upon request.

with client and dealer fixed effects this result is not driven by changes in demand or riskiness as the client level or concurrent factors affecting dealers. In terms of economic magnitude, we find that affected dealers reduce with 83 percentage points the number of transactions with their smaller clients relative to larger clients compared to non-affected dealers.

Second, we study the adjustment in repo rates that affected dealers are willing to offer. If the cost of repo increases because of the intensification of the leverage ratio, dealers can, besides lowering the volume or the number of transactions, also lower the repo rates they are willing to offer to clients that want to place cash. To examine whether dealers also adjust on the price dimension we construct the dependent variable *ΔRate* which equals the pre-post change in the average repo rate offered by dealer *i* to client *j*. The result in column (3) shows that following the change in reporting requirements affected dealers were on average not adjusting repo rates to their clients relative to non-affected dealers. However, when we allow for heterogeneous effects (column 4) we find that affected dealers indeed adjusted repo rates offered to their small clients. In terms of economic magnitude, we find that affected dealers are willing to pay a 9 basis points lower repo rate to their smaller clients relative to their larger clients compared to non-affected dealers.

Third, we examine whether dealers adjust haircuts after the change in reporting requirements. In repo transactions haircuts are used to protect the cash lender from credit and liquidity risk associated with the asset used as collateral. A haircut represents the difference between the market value of the asset used as collateral in the transaction and the purchase price paid at the start of a repo. The haircut is expressed as the percentage deduction from the market value of collateral. As the haircut protects the cash lender against credit and liquidity risk, we should not expect an adjustment in the wake of the intensification of the leverage ratio. Hence, examining the change in haircut at the dealer-client pair level can function as a falsification test. We construct a new dependent variable, *ΔHaircut,* which measures the change in the average haircut before and after the change in reporting requirements. As expected, and in line with our interpretation of a causal impact of the leverage ratio on repo intermediation, we do not find an adjustment on haircuts (columns 5 and 6).

A final margin we look at is the maturity of repo. The majority of repo transactions tend to be overnight (70 percent in our sample), however they can also have longer maturities. The maturity requested by the end-user is often a function of their business model. For example,

insurance companies tend to opt for longer maturities compared to banks. Furthermore, the willingness to extend longer maturity repos is also related to the riskiness of the client. For both these reasons one would not necessarily expect a change in maturity due to the intensification of the leverage ratio. However, on the other hand, dealers might be less willing to engage in longer term repo after the change in regulatory reporting as now the dealer has to include the repo in its exposure measure on each day until maturity, while before it only had to include it if it had not matured at month-end. Our fourth dependent variable *Δlog(Maturity)* is defined as the pre-post change in the (log of) the average maturity (in number of days) of the transactions between dealer *i* from client *j*. In line with the interpretation that repo maturities reflect the business model of the client, we do not find a change in maturities after the change in regulatory reporting. Not in general and not for smaller clients in particular (columns 7 and 8).

Finally, we examine the dynamic adjustment for the two margins (number of transactions and repo rates) that are adjusted by the affected dealers differentiating between small and large clients. As with the adjustment in the repo volume, we find that in the months before the change in regulatory requirements affected and non-affected dealers do not behave differently (Figure 4). The two groups of dealers only start diverging after the shock and this differential effect persists.

5.6 Further robustness

In this section we set out to put further robustness to our results. We first perform an additional falsification test by examining whether affected dealers were also reducing the volume of cash they were willing to lend (reverse repo) after the change in regulatory requirements. Reverse repo does not affect the balance sheet so we do not expect an impact of the intensification of the leverage ratio. Indeed, the results in Table 5 show that affected dealers were not reducing the amount of cash they were lending to their clients relative to non-affected dealers (column 1). We also do not detect any differential effect with respect to their small clients (column 2). These results again indicate that a reduction in repo intermediation by affected dealers can be attributed to the intensification of the leverage ratio. [29]

[29] It would also be insightful to examine whether the reduction in volume is stronger for repos conducted against general compared to repos conducted against special collateral. Special collateral is a repo in which the cash provider requests a specific security (individual ISIN) to be provided by the cash borrower (security-driven repos). General collateral is a repo in which the security lender may choose the security to pledge as collateral with the cash provider (cash-driven repos). When negotiating special repos, a dealer agrees on the collateral first and then the size, price and term of such transactions. As such, the rate of special repos is usually below the rate of general repos, in other words,

Next we examine the sensitivity of our results to our definition of small clients. Up till now we identified a client as small if it engaged in below median volume of repo transactions in the pre period. In Table 6 we first define small as a client with the number of transactions below the median (column 1). In addition, we use three continuous variables: the log volume of the client in the repo market (column 2), the log number of transactions of the client in the repo market (column 3) and the log volume divided by the number of transactions of the client in the repo market (column 4), all three measured before the regulatory change. In all cases the interaction of affected with small is of the right sign and significantly different from zero, indicating that our results are not sensitive to our definition of small clients.

Any choice of sample period is arbitrary as it is not obvious how much time it would take for the adjustment in the market to take place. Focusing on a short time horizon could bias the results against finding anything because especially smaller clients might not be active in both periods. Taking a longer time horizon increases the risk of other factors (both in the UK and abroad) affecting the market convoluting our identification strategy. Furthermore, it is not entirely clear how much time one should account to nullify the impact of the end-of-year volatility. To this end we adjust in Table 7 the time period along several dimensions. In columns 1 and 2 we only exclude the last day of the year. In columns 3 and 4 we drop the days in November as at two points during this month there is a drop in repo volume accepted by the affected dealers. In columns 5 and 6 we expand the pre-period and have it start on October 31, 2016 and in columns 7 and 8 we extend the post-period and have it end on February 22. Regardless of the time period we exploit, our results indicate that dealer banks subject to the regulatory change reduced repo volume to their smaller clients compared to dealer banks not affected by the change.

Finally we test whether our results are robust to different specifications and assumptions regarding the clustering of the error terms and how we deal with outliers. In Table 8, in order to mitigate concerns that differences in maturity drives the impact of repo volumes on dealer balance sheets, we first re-estimate our baseline and heterogeneous models employing Weighted Least Squares (WLS) using as weights the average maturity of transactions of dealer-client pairs before

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the margin on these repos is higher. As such one would expect affected dealers to especially reduce general collateral repo. Unfortunately, our data do not allow us to identify with certainty whether repos are conducted against general or special collateral, because this field is optional to report. In our sample period, approximately 43 percent of transactions provide no such information, 24 percent are special and 33 percent are general repos.

the policy change.[30] Columns 1 and 2 confirm our conclusions, although the estimate of the interaction effect is somewhat smaller. Next, although Bertrand, Duflo and Mullainathan (2004) show that cluster-robust standard errors still perform reasonably well with 15 clusters, we eliminate remaining concerns by employing a wild cluster bootstrap method as recommended by Cameron, Gelbach and Miller (2008) and Cameron and Miller (2015). This procedure allows us to account for the correlation in the error terms of clients placing cash with the same dealer bank with relatively few clusters. In columns 3 and 4, we report wild cluster bootstrap p-values, which confirm our conclusions suggesting that the clustering strategy has little effect on our results.[31] Finally, we employ an alternative winsorising technique at the 5th and 95th level instead of the 1st and 99th and we find again very similar results as in our baseline models.

6. Aggregate effect and market adjustment

Finally, we investigate the aggregate effect of the intensification of the leverage ratio which incentivised affected dealers to move away from small end-users. We can do a conservative back of the envelope calculation and assess to what extent small end-users were affected in aggregate. Using the OLS estimates of Table 2, column 1 we estimate that affected banks on average reduced repo volume to their small clients with 53 percent.[32] As affected dealers were prior to the regulatory change intermediating 61 percent of total repo volume from small end-users, this implies that, keeping all else equal and not allowing for the possibility of substitution, the withdrawal of affected dealers resulted in small end-users being able to place 32 percent, equaling 2.9 billion pounds, less cash in the gilt repo market.

The next question is whether these small end-users were able to switch to other, non-affected dealers and place their cash with them instead. To check whether indeed this was the case, we run a set of client-level regressions with the growth rate of the client's total repo volume as the dependent variable. We are interested to see if small clients that were more exposed to the affected dealers were experiencing lower growth rates compared to small clients less exposed. To this end

[30] We also test whether our results are driven by clients trading in very long maturities. We confirm that our conclusions remain unchanged when we restrict our sample to dealer-client pairs that only engage in repo with a maturity of up to 4 weeks.

[31] We generate these p-values by employing the post-estimation command *boottest* (Roodman, 2015), assuming the null hypothesis and setting replications to 1000.

[32] This is the combined effect of the constant, the affected dummy, the small dummy and the affected*small interaction effect.

we construct a measure of the average exposure to affected dealers for each client before the policy shock. That is, for each client we measure the ratio of each client's repo volumes with affected dealers to the client's total repo volumes before the regulatory change. As we are interested in the growth rate at the client level, we cannot absorb client demand directly with client fixed effects. If the exposure measure is correlated with demand, something we cannot rule out, our OLS estimates would be biased. In order to control for clients' repo demand we follow Abowd, Kramarz and Margolis (1999), Bonaccorsi di Patti and Sette (2016) and Cingano, Manaresi and Sette (2016) and include in our model a vector of client-level estimated dummies $\hat{\mu}_j$ that we extract from model (2) in Section 5.2.[33] The model we estimate is as follows:

$$\Delta\, log(AggrVolume)_j = \beta_1 \times Highly\ Exposed_j + \beta_2 \times Highly\ Exposed_j \times Small_j + \beta_3 \times Small_j + \hat{\mu}_j + \varepsilon_j, \quad (3)$$

where $\Delta log(AggrVolume)_{ij}$ is the pre-post change in the (log of) the total repo volume accepted by *all* (new and existing) dealers from client *j*, winsorized at the 1 and 99 percentiles. $HighlyExposed_j$ is a dummy variable equal to 1 if the client has above median share of its repos intermediated by affected dealers, zero otherwise; $Small_j$ is a dummy variable equal to 1 if the client is small, defined as engaging in below median volume of repo transactions in the pre period, and 0 if large*;* $\hat{\mu}_j$ is a vector of client-level estimated dummies capturing demand; and ε_{ij} is the error term. To account for correlation in the error terms of clients within the same sector, and given that the number of sectors is 7, we employ the wild cluster bootstrap method of Cameron, Gelbach and Miller (2008) and report the respective p-values.[34]

The result in Table 9, column 1 shows that highly exposed clients experience a lower growth in total repo volume (i.e. the amount of cash they are placing with all dealers), but this effect is not significant. When we allow this effect to differ between large and small clients (column 2) we find that it is driven by the small clients, in line with our previous results. The parameters are smaller (less negative) compared to the estimates at the dealer-client level. This

[33] Bonaccorsi di Patti and Sette (2016) and Cingano, Manaresi and Sette (2016) show that this methodology is equivalent to an alternative methodology to control for demand developed by Jimenez, Mian, Peydro and Saurina (2014), where a numerical correction of the difference of the OLS and FE estimate is applied.

[34] Clustering at the sector level would not perform well and would lead to high rejection rates when the number of clusters is approximately 6, as suggested by Bertrand, Duflo and Mullainathan (2004).

suggests that partial substitution was possible, in line with our previous finding that non-affected dealers were on average accepting more repo from their small clients after the policy change.

In the last two columns of Table 10 we examine whether this substitution was primarily done through an intensification of pre-existing relationships or through the establishment of new ones. We construct a new dependent variable, *New Repo Relationship*, which is a dummy variable equal to one if the client started in the month after the regulatory change a relationship with a dealer with whom it had no relationship in the pre-period, zero otherwise. We do not find any indication that more exposed clients are more likely to start a new relationship, which suggests that exposed clients substitute with non-affected dealers with whom they already had a relationship and did not switch to new dealers.

Our finding that the small end-users, particularly the ones less exposed to affected dealers, were able to substitute with non-affected, foreign dealers is confirmed when we look at the change in market share of affected and non-affected dealers after the intensification of the leverage ratio. While the group of affected dealers increased their market share of the large clients from 31 to 34 percent, they reduced it from 61 to 51 percent for the smaller clients.

7. Conclusion and policy implications

This paper investigates the impact of the leverage ratio on dealer-client repo intermediation, focusing on both bank and non-bank end-users. We exploit a new, unique, supervisory transaction-level dataset capturing the near-universe of bilateral gilt repo market trading in combination with a regulatory change in the UK. Studying adjustments within dealer-client pairs, we find that dealers subject to a tightening of the leverage ratio due to a change in its reporting requirements persistently reduced repo volume they accepted from their small clients compared to dealers not affected by the change. Large clients were not affected. We also find that dealers tend to move away from clients with whom they have a weaker relationship; however the impact of size dominates. In addition, we document a (persistent) reduction in the frequency of transactions and in repo rates offered, but no adjustment in haircuts or maturities. Studying the aggregate effect, we find evidence that suggests that competing, non-constrained, foreign dealers took the opportunity to capture market share when affected, UK dealers withdrew from the small end-user segment of the dealer-client market. The market therefore seems to have been resilient and adjusted quickly.

All in all, our results show that dealers react to an intensification of the leverage ratio by stepping away from smaller end-users. This finding has important policy implications as it shows that capital regulation has the potential to undermine the level playing field of small banks and non-bank financial institutions relative to their larger competitors as the increased cost of engaging in repo activity is disproportionately levied onto them. Without other dealers stepping in, this implies that these smaller end-users ultimately have to pass on these costs to their clients. Furthermore, it can incentivize them to invest their cash in more risky ways (e.g. longer maturities or against lower quality or no collateral), it can impair their access to derivatives markets and it can increase the cost they face when hedging interest rate risk. These effects can be mitigated if other dealers step into the void as seems to have happened in the UK. While this can alleviate the short-run impact of a more binding leverage ratio it has the potential to make the market more unstable. A stronger reliance on foreign dealers can potentially imply more instability as during times of stress foreign lenders tend to flight home (Gianetti and Laeven, 2012) and reduce lending especially to marginal borrowers (De Haas and Van Horen, 2013).

A possible way to reduce the impact of the leverage ratio on repo market liquidity for small end-users would be to widen participation in CCPs to end-users of repos. If end-users are members of the same CCP as their intermediating dealer, then the dealer will be able to net the transaction for the purpose of the regulation. In recent years there have been several initiatives, including by the Bank of England, to reduce barriers for smaller firms to joining the CCP. Furthermore, intermediation might be improved through competition effects by disintermediation of banks in return for a larger role for non-bank intermediaries not subject to the leverage ratio. However, a growing role of non-bank dealers in the repo market can also make the market more susceptible to financial instability risks as these dealers are not regulated.

Importantly, our paper does not attempt to quantify the net benefits of the regulatory leverage ratio. The leverage ratio has important benefits for the financial system as a whole. By increasing the capitalization of banks, the leverage ratio mitigates the risk of destabilizing deleveraging processes. Furthermore, as it is independent of risk, it provides a safeguard against model risk and measurement error which affects the capital ratio. In addition, as there are risks associated with excessive liquidity a lower level of liquidity in the repo market might not be sub-optimal. While quantifying the net costs/benefits of the leverage ratio is beyond the scope of this paper, our results indicate that the leverage ratio affects some end-users in the repo market more

than others. As such, policy measures that improve repo market liquidity for these end-users might be useful.

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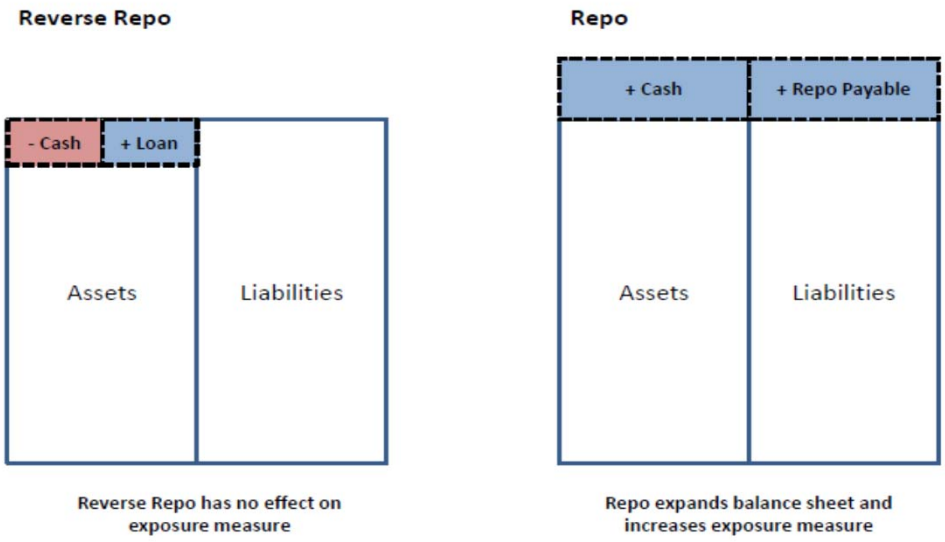
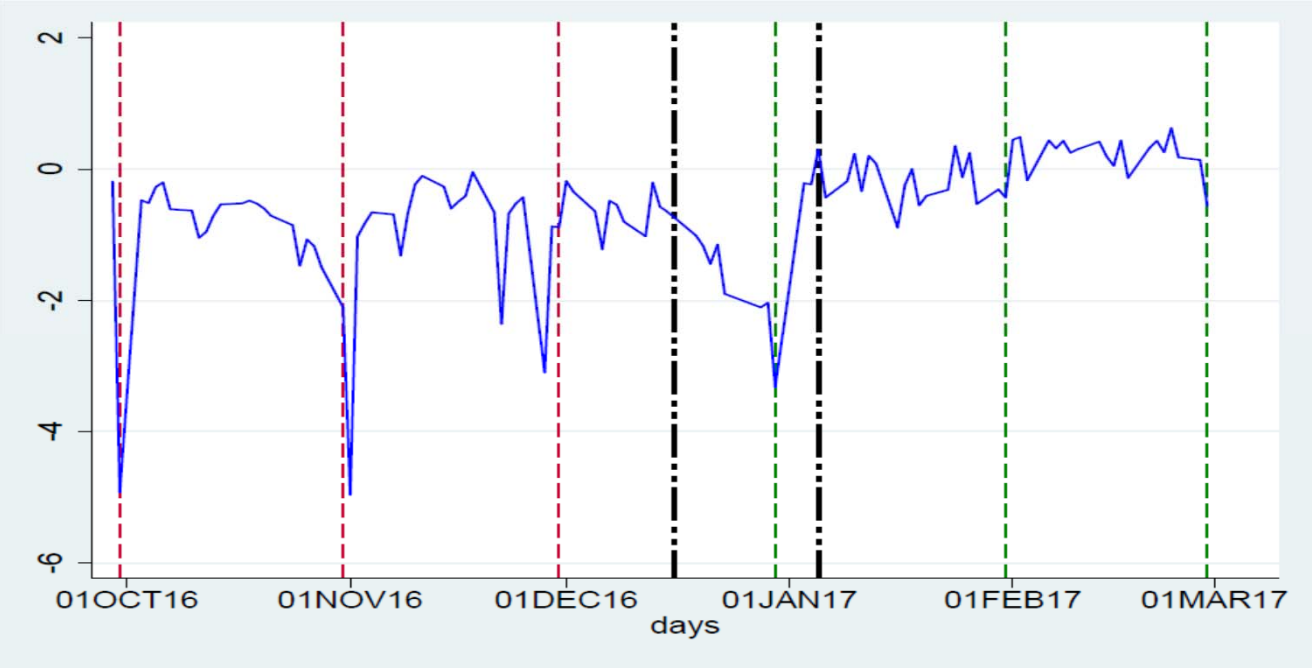
Figure 1: Leverage Ratio and Repo Market



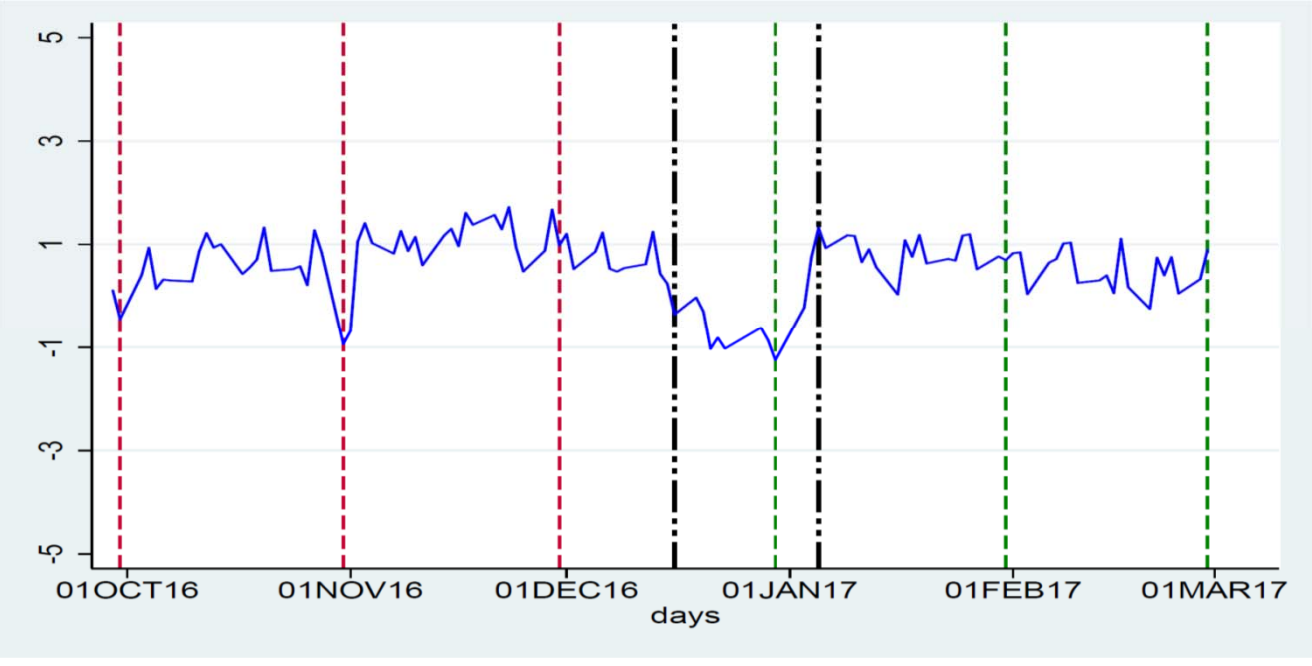
Note: The figure presents the impact of reverse repo and repo on a bank's balance sheet and the exposure measure used to calculate the leverage ratio.

Figure 2a: Daily Repo Volume by Affected Dealers



Note: The figure presents the evolution of (standardized) repo volume intermediated by affected dealers over the period October 2016 - February 2017. The vertical dashed lines correspond to month-ends before (red) and after (green) the regulatory change in the reporting requirement of the leverage ratio. The black vertical dashed lines correspond to the adjustment period before and after year-end, which we exclude from our main analysis.

Figure 2b: Daily Repo Volume by Non-Affected Dealers

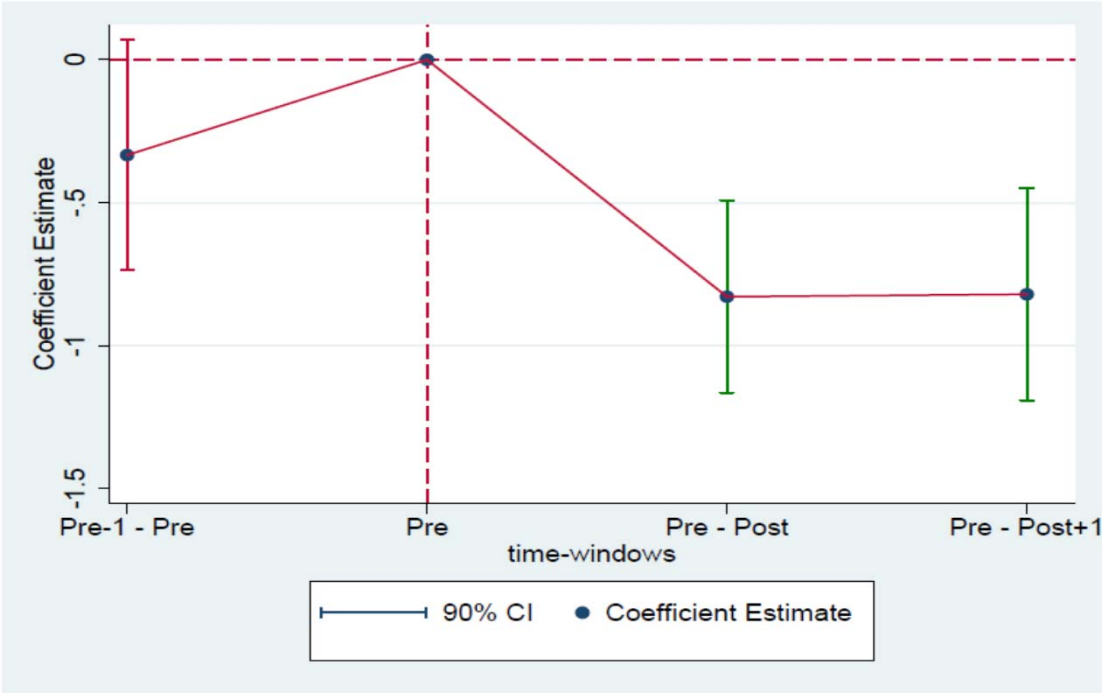


Note: The figure presents the evolution of (standardized) repo volume intermediated by non-affected dealers over the period October 2016 - February 2017. The vertical dashed lines correspond to month-ends before (red) and after (green) the regulatory change in the reporting requirement of the leverage ratio. The black vertical dashed lines correspond to the adjustment period before and after year-end, which we exclude from our main analysis.

Figure 3: Repo Volume Time-Varying DiD Estimates: Small-Large

Note: The figure presents the time-varying DiD estimates of the variable *Affected Dealer* * *Small* using model (2) where the dependent variable is Δ*log(Volume)*. Coefficients are estimated with rolling symmetric time-windows that end or start in period {November 21-December 16}, which is denoted as *Pre*. *Pre-1* corresponds to period {October 24-November 18}, *Post* corresponds to period {January 05-February 01} and *Post+1* corresponds to period {February 02-February 22}. The plot uses 90% confidence intervals, where standard errors allow for correlation at the dealer level.

Figure 4a: Extensive Margin Time-Varying DiD Estimates: Small-Large



Note: The figure presents the time-varying DiD estimates of the variable *Affected Dealer * Small* using model (2) where the dependent variable is Δ*log(#Transactions)* . Coefficients are estimated with rolling time-windows that end or start in period {November 21-December 16}, which is denoted as *Pre. Pre-1* corresponds to period {October 24-November 18}, *Post* corresponds to period {January 05-February 01} and *Post+1* corresponds to period {February 02-February 22}. The plot uses 90% confidence intervals, where standard errors allow for correlation at the dealer level.

Figure 4b: Repo Rate Time-Varying DiD Estimates: Small-Large

Note: The figure presents the time-varying DiD estimates of the variable *Affected Dealer * Small* using model (2) where the dependent variable is Δ*Rate.* Coefficients are estimated with rolling time-windows that end or start in period {November 21-December 16}, which is denoted as *Pre. Pre-1* corresponds to period {October 24-November 18}, *Post* corresponds to period {January 05-February 01} and *Post+1* corresponds to period {February 02-February 22}. The plot uses 90% confidence intervals, where standard errors allow for correlation at the dealer level.

Table 1. Leverage Ratio and Repo

	Δlog(Volume)			
	[1]	[2]	[3]	[4]
Affected Dealer	-0.404**	-0.431**	-0.446*	-0.664*
	0.179	0.174	0.231	0.312
Relationship		-0.767	-1.074	-1.705
		0.993	1.056	1.276
Constant	0.137	0.159		
	0.113	0.108		
Client's Sector FE	no	no	yes	no
Client FE	no	no	no	yes
N	126	126	126	126
R^2	0.027	0.031	0.065	0.333

Significance Levels: .01***; .05**; .1*

Note: The table presents results from OLS regressions. Daily transactions are collapsed before and after the regulatory change using a time window of one month, where Pre={November 21-December 16} and Post={January 05-February 01}. *Δlog(Volume)* is defined as the pre-post change in the (log of) the total repo volume accepted by dealer *i* from client *j* and is winsorized at 1 and 99 percentiles. *Relationship* is a (demeaned) pre-determined continuous variable, defined as the ratio of frequency of repo transactions between dealer- client pair to total number of repo transactions of the dealer. Standard errors allow for correlation at the dealer level.

Table 2. Heterogeneous Effects: Small versus Large

	Δlog(Volume)				
	[1]	[2]	[3]	[4]	[5]
Affected Dealer * Small	-0.900***	-0.880***	-0.829*	-1.415**	-1.345***
	0.228	0.228	0.397	0.514	0.433
Affected Dealer	-0.139	-0.159	-0.196	-0.305	
	0.207	0.2	0.233	0.278	
Small	0.490**	0.446*	0.506**		
	0.19	0.204	0.195		
Relationship		-0.487	-0.575	-1.217	-1.101
		1.071	1.091	1.328	1.547
Constant	0.017	0.042			
	0.138	0.133			
Client's Sector FE	no	no	yes	no	no
Client FE	no	no	no	yes	yes
Dealer FE	no	no	no	no	yes
N	126	126	126	126	126
R^2	0.057	0.058	0.089	0.378	0.463

Significance Levels: .01***; .05**; .1*

Note: The table presents results from OLS regressions. Daily transactions are collapsed before and after the regulatory change using a time window of one month, where Pre={November 21-December 16} and Post={January 05-February 01}. *Δlog(Volume)* is defined as the pre-post change in the (log of) the total repo volume accepted by dealer *i* from client *j* and is winsorized at 1 and 99 percentiles. *Small* is a pre-determined dummy variable, defined as client with log volume of repo transactions below the median client in the market. *Relationship* is a (demeaned) pre-determined continuous variable, defined as the ratio of frequency of repo transactions between dealer - client pair to total number of repo transactions of the dealer. Standard errors allow for correlation at the dealer level.

Table 3. Heterogeneous Effects: Other Client Types

	Δlog(Volume)							
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Affected Dealer * Relationship	1.259*	0.77						
	0.656	0.795						
Affected Dealer * Long-Term Repos			0.408	0.419				
			0.487	0.491				
Affected Dealer * Foreign					-0.483	-0.159		
					0.414	0.41		
Affected Dealer * Reverse Repo							-0.093	-0.300
							0.637	0.616
Affected Dealer * Small		-0.870**		-1.350**		-1.325**		-1.383***
		0.386		0.449		0.45		0.433
Client FE	yes	yes	yes	yes	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes	yes	yes	yes	yes
N	126	126	126	126	126	126	126	126
R^2	0.459	0.469	0.429	0.468	0.427	0.464	0.425	0.465

Significance Levels: .01***; .05**; .1*

Note: The table presents results from OLS regressions. Daily transactions are collapsed before and after the regulatory change using a time window of one month, where Pre={November 21-December 16} and Post={January 05-February 01}. *Δlog(Volume)* is defined as the pre-post change in the (log of) the total repo volume accepted by dealer *i* from client *j* and is winsorized at 1 and 99 percentiles. *Relationship* is a pre-determined dummy variable, defined as the above median ratio of the frequency of repo transactions between dealer i and client j to total number of repo transactions of the dealer. *Long-Term Repos* is a pre-determined dummy variable, defined as client with average repo maturity above the median client in the market. *Foreign* is a dummy variable, defined as client with headquarters outside the UK. *Reverse Repo* is a dummy variable, defined as client's sector traditionally transacting more in the reverse repo market and includes pension funds, insurance companies and asset managers. *Small* is a pre-determined dummy variable, defined as client with log volume of repo transactions below the median client in the market. Models [1]-[2] control for the level effect of *Relationship* (omitted). Models [5]-[8] control for the strength of the pre-determined relationship of dealer - client pair (omitted). Standard errors allow for correlation at the dealer level.

Table 4. Other Margins of Adjustment

	Extensive Margin		*Repo Loan Terms*					
	Δlog(# Transactions)		ΔRate		ΔHaircut		Δlog(Maturity)	
	Baseline	Heterogeneous	Baseline	Heterogeneous	Baseline	Heterogeneous	Baseline	Heterogeneous
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Affected Dealer	-0.388**		-0.006		0.503		0.343	
	0.175		0.026		0.407		0.219	
Affected Dealer * Small		-0.829***		-0.088***		1.168		-0.155
		0.204		0.022		0.86		0.238
Client FE	yes	yes	yes	yes	yes	yes	yes	yes
Dealer FE	no	yes	no	yes	no	yes	no	yes
N	126	126	126	126	126	126	126	126
R^2	0.32	0.475	0.405	0.53	0.409	0.563	0.309	0.452

Significance Levels: .01***; .05**; .1*

Note: The table presents results from OLS regressions. Daily transactions are collapsed before and after the regulatory change using a time window of one month, where Pre={November 21-December 16} and Post={January 05-February 01}. In columns [1]-[2], *Δlog(# Transactions)* is defined as the pre-post change in the (log of) the total number of repo transactions accepted by dealer *i* from client *j* and is winsorized at 1 and 99 percentiles. In columns [3]-[8], *ΔRate, ΔHaircut* and *Δlog(Maturity)* denote the pre-post change in the average repo rate, average collateral haircut and the pre-post growth of average maturity (in days) and are winsorized at 1 and 99 percentiles. *Small* is a pre-determined dummy variable, defined as client with log volume of repo transactions below the median client in the market. All models control for the strength of the pre-determined relationship of dealer- client pair (omitted). Standard errors allow for correlation at the dealer level.

Table 5. Leverage Ratio and Reverse Repos

	Δlog(Volume)	
	Baseline	Heterogeneous
	[1]	[2]
Affected Dealer	-0.283	
	0.197	
Affected Dealer * Small		0.703
		0.682
Client FE	yes	yes
Dealer FE	no	yes
N	133	133
R^2	0.372	0.494

Significance Levels: .01***; .05**; .1*

Note: The table presents results from OLS regressions. Daily transactions are collapsed before and after the regulatory change using a time window of one month, where Pre={November 21-December 16} and Post={January 05-February 01}. *Δlog(Volume)* is defined as the pre-post change in the (log of) the total repo volume accepted by dealer *i* from client *j* and is winsorized at 1 and 99 percentiles. *Small* is a pre-determined dummy variable, defined as client with log volume of reverse repo transactions below the median client in the market. All models control for the strength of the pre-determined relationship of dealer - client pair in the reverse repo market (omitted). Standard errors allow for correlation at the dealer level.

Table 6. Alternative Definitions for Small Client

	Δlog(Volume)			
	Frequency (dummy)	*Volume (continuous)*	*Frequency (continuous)*	*Volume/Trans.*
	[1]	[2]	[3]	[4]
Affected Dealer * Small	-1.345***	0.367**	0.427*	0.516**
	0.433	0.143	0.194	0.212
Client FE	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes
N	126	126	126	126
R^2	0.463	0.468	0.459	0.442

Significance Levels: .01***; .05**; .1*

Note: The table presents results from OLS regressions. Daily transactions are collapsed before and after the regulatory change using a time window of one month, where Pre={November 21-December 16} and Post={January 05-February 01}. *Δlog(Volume)* is defined as the pre-post change in the (log of) the total repo volume accepted by dealer *i* from client *j* and is winsorized at 1 and 99 percentiles. *Frequency (dummy)* is a pre-determined dummy variable, defined as client with log frequency of repo transactions below the median client in the market. *Volume (continuous)* is a pre-determined continuous variable, defined as the log volume of repo transactions of client in the market. *Frequency (continuous)* is a pre-determined continuous variable, defined as the log frequency of repo transactions of client in the market. *Volume/Trans.* is a pre-determined continuous variable, defined as the log volume to frequency of repo transactions of client in the market. All models control for the strength of the pre-determined relationship of dealer- client pair (omitted). Standard errors allow for correlation at the dealer level.

Table 7. Alternative Time-Windows

	Δlog(Volume)							
	Drop Year-End Day Only		*Drop November Adjustment*		*Expand Pre-Period*		*Expand Post-Period*	
	Baseline	Heterogeneous	Baseline	Heterogeneous	Baseline	Heterogeneous	Baseline	Heterogeneous
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Affected Dealer	-0.598*		-0.916**		-0.594*		-0.354	
	0.303		0.331		0.277		0.271	
Affected Dealer * Small		-0.868*		-1.087*		-0.812*		-0.824**
		0.49		0.506		0.422		0.368
Client FE	yes	yes	yes	yes	yes	yes	yes	yes
Dealer FE	no	yes	no	yes	no	yes	no	yes
N	134	134	109	109	139	139	142	142
R^2	0.265	0.397	0.352	0.48	0.466	0.555	0.394	0.455

Significance Levels: .01***; .05**; .1*

Note: The table presents results from OLS regressions. In columns [1]-[2] daily transactions are collapsed before and after the regulatory change dropping the year-end business day only, where Pre={November 21-December 29} and Post={January 02-February 01}. In columns [3]-[4] daily transactions are collapsed before and after the regulatory change dropping November adjustment, where Pre={December 05-December 16} and Post={January 05-February 01}. In columns [5]-[6] daily transactions are collapsed before and after the regulatory change expanding the pre-period, where Pre={October 31-December 16} and Post={January 05-February 01}. In columns [7]-[8] daily transactions are collapsed before and after the regulatory change expanding the post-period, where Pre={November 21-December 16} and Post={January 05-February 22}. *Δlog(Volume)* is defined as the pre-post change in the (log of) the total repo volume accepted by dealer *i* from client *j* and is winsorized at 1 and 99 percentiles. All models control for the strength of the pre-determined relationship of dealer- client pair (omitted). Standard errors allow for correlation at the dealer level.

Table 8. Further Robustness Checks

	Δlog(Volume)					
	WLS		*Wild Cluster Bootstrap*		*Winsorize 5/95*	
	Baseline	Heterogeneous	Baseline	Heterogeneous	Baseline	Heterogeneous
	[1]	[2]	[3]	[4]	[5]	[6]
Affected	-0.653**		-0.664*		-0.436*	
	0.275		[0.056]		0.227	
Affected Dealer * Small		-1.096*		-1.345*		-0.953***
		0.655		[0.054]		0.284
Client FE	yes	yes	yes	yes	yes	yes
Dealer FE	no	yes	no	yes	no	yes
N	126	126	126	126	126	126
R^2	0.342	0.586	-	-	0.362	0.492

Significance Levels: .01***; .05**; .1*

Note: The table presents results from baseline regressions. Daily transactions are collapsed before and after the regulatory change using a time window of one month, where Pre={November 21-December 16} and Post={January 05-February 01}. *Δlog(Volume)* is defined as the pre-post change in the (log of) the total repo volume accepted by dealer *i* from client *j* and is winsorized at 1 and 99 percentiles. In columns [1]-[2] we employ a weighted least squares estimation technique using as weights the average maturity before the policy change. In columns [3]-[4] we correct the inference with the wild cluster bootstrap method. Wild cluster bootstrap p-values are reported in brackets employing the post-estimation command boottest, assuming the null hypothesis and setting replications to 1000. In columns [5]-[6] we employ an alternative winsorizing technique at the 5 and 95 percentiles. *Small* is a pre-determined dummy variable, defined as client with log volume of repo transactions below the median client in the market. All models control for the strength of the pre-determined relationship of dealer- client pair (omitted). Standard errors allow for correlation at the dealer level.

Table 9. Market Adjustment: Substitution and New Repo Relationships

	Δlog(AggrVolume)		New Repo Relationship	
	Baseline	Heterogeneous	Baseline	Heterogeneous
	[1]	[2]	[3]	[4]
Highly Exposed	-0.390	-0.136	-0.007	-0.093
	[0.273]	[0.889]	[0.971]	[0.452]
Highly Exposed * Small		-0.584*		0.165
		[0.088]		[0.3]
Small		-0.084		0.186
		[0.714]		[0.354]
Constant	0.285	0.371**	0.419	0.326
	[0.388]	[0.047]	[0.159]	[0.471]
Client Demand	yes	yes	yes	yes
N	38	38	38	38

Significance Levels: .01***; .05**; .1*

Note: The table presents results from OLS regressions. Daily transactions are collapsed before and after the regulatory change using a time window of one month, where Pre={November 21-December 16} and Post={January 05-February 01}. *Δlog(AggrVolume)* is defined as the pre-post change in the (log of) the total repo volume accepted by all dealers from client j and is winsorized at 1 and 99 percentiles. *New Repo Relationship* is a dummy that is one if the client established a new relationship with a dealer after the regulatory change. *Highly Exposed* is a pre-determined dummy variable, defined as client with above median share of repos intermediated by affected dealers to total repos intermediated by all dealers in the market. *Small* is a pre-determined dummy variable, defined as client with log volume of repo transactions below the median client in the market. Client demand is a vector of client-level dummies estimated in the within-client regression. We employ the wild cluster bootstrap method. Wild cluster bootstrap p-values are reported in brackets, assuming the null hypothesis and setting replications to 1000. Standard errors allow for correlation at the client's sector level.

Appendix Table 1: UK Leverage Ratio Timeline

Dates	Policy Measure
December 2010	Basel announces 3% leverage ratio for disclosure purposes as of 01/01/2015 and with a view to moving to a minimum requirement in 2018
January 2011	Basel deadline for supervisory monitoring period for LR
January 2013	Basel deadline for LR reporting
January 2013	PRA contacts the 7 major UK banks asking them to start disclosing year-end and mid-year leverage ratios based on the Basel definition
June 2013	Publication of EU CRR, announcing a mandatory LR disclosure requirement as of 01/01/2015
December 2013	Major EU banks start voluntarily disclosing LRs
July 2014	FPC consults on a review considering the need for a LR requirement
October 2014	FPC finalises its LR review and recommends HMT give them powers of Direction for a LR
January 2015	Introduction of LR disclosure requirements as per EU law
April 2015	HMT gives FPC powers of Direction over a LR
July 2015	FPC publishes policy statement on the LR and directs PRA to implement a LR
December 2015	PRA finalises LR policy
January 2016	LR requirement comes into force for the 7 major UK banks, which also start reporting exposures based on the average of the last day of every month ("monthly average")
August 2016	FPC and PRA announce the exclusion of central bank reserves from the exposure measure of the UK requirement that applies to the 7 banks
January 2017	7 UK banks start reporting leverage exposures based on average of every day in quarter ("daily average")
June 2017	FPC and PRA consult on a recalibration of the minimum LR requirement that applies to the 7 major UK banks
October 2017	FPC and PRA recalibrate the minimum LR requirement that applies to major UK banks to 3.25%
January 2018	The 7 major UK banks start disclosing daily average exposure measures

Note: The table presents the timeline of the UK leverage ratio requirement.

Appendix Table 2: Summary Statistics

Variables	*Units*	*Definition*	*N*	*mean*	*sd*	*p(10)*	*p(25)*	*p(50)*	*p(75)*	*p(90)*
Δlog(Volume)	%	The log change in repo volume accepted by dealer *i* from client *j* in the month after the regulatory change compared to the month before, winsorized at 1 and 99th percentile	126	-0.02	1.19	-1.26	-0.48	0.05	0.54	1.18
Δlog(# Transactions)	%	The log change in frequency of repo transactions between dealer *i* and client *j* in the month after the regulatory change compared to the month before, winsorized at 1 and 99th percentile	126	-0.04	0.70	-0.92	-0.41	0	0.34	0.69
ΔRate	Δ	The first-difference change in the average repo rate offerred by dealer *i* to client *j* in the month after the regulatory change compared to the month before, winsorized at 1 and 99th percentile	126	0.04	0.1	-0.03	0.00	0.03	0.05	0.11
ΔHaircut	Δ	The first-difference change in the average collateral haircut required by dealer *i* from client *j* in the month after the regulatory change compared to the month before, winsorized at 1 and 99th percentile	126	0.19	1.47	0	0.00	0.00	0.00	0.26
Δlog(Maturity)	%	Log change of average maturity (in days) offerred by dealer *i* to client *j* in the month after the regulatory change compared to the month before, winsorized at 1 and 99th percentile	126	0.01	0.91	-0.92	-0.39	0.00	0.37	1.18
Affected dealer	0/1	Dealer in gilt repo market subject to the regulatory change	126	0.38	0.49	0	0	0	1	1
Small	0/1	Client with repo volume below the median client in month before the regulatory change	126	0.29	0.45	0	0	0	1	1
Small (frequency dummy)	0/1	Client with number of transactions below the median client in month before the regulatory change	126	0.30	0.46	0	0	0	1	1
Small (volume)	continuous	Log repo volume of client in month before the regulatory change	126	22.13	1.79	19.48	21.12	22.24	23.34	24.44
Small (frequency)	continuous	Log number of transactions of client in month before the regulatory change	126	4.43	1.37	2.30	3.14	4.88	5.20	6.15
Small (volume per transaction)	continuous	Log volume per transaction of client in month before the regulatory change	126	17.74	0.76	16.9	17.34	17.79	18.24	18.65
Relationship	continuous	Ratio of number of repo transactions between dealer - client to total number of repo transactions of the dealer in month before the regulatory change	126	0.02	0.10	-0.05	-0.04	-0.02	0.02	0.13
Δlog(AggrVolume)	%	Log change in repo volume accepted by all dealers from client *j* in the month after the regulatory change compared to the month before, winsorized at 1 and 99th percentile	38	-0.06	0.73	-1.04	-0.26	0.08	0.41	0.57
New Repo Relationship	0/1	Dummy that is one if the client established a new relationship with a dealer after the regulatory change, zero otherwise	38	0.39	0.5	0	0	0	1	1
Highly Exposed	0/1	Client with above median share of repos intermediated by affected dealers to total repos intermediated by all dealers in the market	38	0.50	0.51	0	0	0.50	1	1

Note: The table presents the definitions and summary statistics of all variables used in our regressions.