Repo Market Functioning: The Role of Capital Regulation

by

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Abstract

Exploiting a quasi-natural experiment in the UK, we show that a tightening of the leverage ratio does not reduce repo market activity. Our results indicate a temporary reduction in bilateral repos by leverage constrained dealers, primarily affecting their smaller clients, which is offset by foreign dealers who step in to fill the void. Constrained dealers recapture smaller clients by applying over time higher haircuts in reverse repo contracts. In other words, dealers generate liquidity through rehypothecation neutralizing the cost of regulation. In contrast to conventional wisdom, the leverage ratio does not seem to affect collateral re-use in the repo market.

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1. Introduction

The multi-trillion dollar sale-and-repurchase ("repo") market is a vital part of the financial system. It is a key source of short-term funding and offers a low-risk and liquid investment for cash. And by supporting liquidity in other markets it contributes to the efficient allocation of capital to the real economy (De Fiore, Hoerova and Uhlig, 2018). A well-functioning repo market is thus crucial for financial stability (Cœuré, 2017) and for the efficient transmission of monetary policy (Draghi, 2012).[1] Yet despite its importance much of its workings are still not well-understood, including how the market reacts to changes in banking regulation.

This paper contributes to our understanding of the repo market by examining how the market reacts to one of the key changes in capital regulation in the wake of the global financial crisis: the leverage ratio. Exploiting a unique quasi-natural experiment in combination with novel transaction-level data, we show that dealers immediately react to a tightening of the leverage ratio by reducing bilateral repos primarily affecting their smaller clients. At the same time, competition dynamics ensure that, as long as unconstrained dealers are present, aggregate effects are minimal. The withdrawal from small clients by constrained dealers is only temporary, however. By increasing haircuts on reverse repo contracts, constrained dealers generate a cash surplus which is sufficient to justify the use of balance sheet space for repos with small clients and thus neutralize the cost of regulation.

The Basel III leverage ratio regulation is expected to affect repo market activities. 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.[2] Repos expand a bank's balance sheet and therefore attract a capital charge under the leverage ratio (Figure 1). As the margin on repos is low a binding leverage ratio makes it more costly for banks to engage in repo compared to engaging in activities with higher margins (but equal capital charge), providing them with an incentive to reduce their activity (Krishnamurthy and Duffie, 2016; Duffie, 2018).[3]

[1] The importance of the market is exemplified by the Fed's immediate injection of $75 bn. cash in the market in response to a sharp hike in repo rates on 17 September 2019.

[2] 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.

[3] 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.

However, the empirical evidence on the impact of the leverage ratio on repo market activity is at best mixed. Studies focusing on the tri-party repo market indicate that leverage constrained dealers reduced repo borrowing after the announcement of the leverage ratio in the US (Allahrakha, Cetina and Munjan, 2018; Anbil and Senyuz, 2018). By contrast, using a sample of European banks, Baldo, Bucalossi and Scalia (2018) show that repo activity outside the leverage ratio reporting dates has not decreased. Bicu, Chen and Elliott (2017) also find no statistically significant evidence of a reduction in repo liquidity after the announcement of the leverage ratio in the UK.

To provide compelling evidence on the impact of the leverage ratio on repo markets is challenging. The key challenge is to find exogenous variation in leverage ratio requirements. Regulatory changes often affect all banks at the same time, leaving no cross-sectional variation to exploit. And when regulators impose bank-specific requirements they tend to be correlated with (unobserved) bank characteristics. Furthermore, banks typically adjust their operations before new regulations are enforced. In its technical report, the Financial Stability Board stresses the importance of quasi- or natural experiments for the evaluation of the impact of post-crisis regulatory reforms. But these are hard to come by, especially as there are often concurrent developments that confound inferences (FSB, 2017a). This is especially relevant in the context of Basel III regulation as after the global financial crisis many regulatory changes were imposed around the same time.

In this paper, we revisit the question how the leverage ratio affects repo market activity and bring novel insights by exploiting a unique quasi-natural experiment. Instead of focusing on the announcement or implementation of the leverage ratio, we analyse a change in the *reporting* requirements that took place in the UK and that effectively tightened the leverage ratio. 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.[4] 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").[5] This switch from monthly to daily averaging reduced the ability of banks to window-dress their balance sheet at period-ends and effectively made the leverage ratio more binding.

[4] These are Barclays, HSBC, Nationwide, Lloyds, RBS, Santander UK and Standard Chartered.
[5] Both the capital measure as well as the *off*-balance sheet assets continued to be measured at month-end.

The regulatory change affected the four UK dealers in the gilt repo market, but not the remaining twelve non-UK dealers, providing us with a natural treatment and control group.[6] Importantly, the policy change did not coincide with any other regulatory change or adjustment in (unconventional) monetary policy in the UK potentially affecting the repo market. Furthermore, all UK dealers had an incentive to react even those with a leverage ratio above the 3 percent regulatory requirement in order to avoid the market reacting to a change in the leverage ratio. Finally, even though the change in reporting was already announced in November 2015, dealers had no incentive to change their behaviour ahead of implementation. Indeed, as is apparent from the top panel of Figure 2, the four UK dealers affected by the regulatory change eliminated their window-dressing behaviour after the transition from monthly to daily averaging. By contrast, the non-affected dealers did not change their behaviour (Figure 2, bottom panel).

We use this policy change to study the impact of the leverage ratio on the bilateral segment of the repo market. Despite its central role during the 2007-08 financial crisis, its functioning is still not well understood (Gorton and Metrick, 2012; Gorton, Laartis and Metrick, 2017). It is a key part of the repo market globally and captures almost 70 percent of total transaction volume in the UK and about 50 percent in the US (Martin, Skeie and Von Thadden, 2014; Baklanova, Caglio, Cipriani and Copeland, 2017). However, due to lack of detailed data it has been difficult to analyse how the bilateral segment of repo market reacts to shocks such as leverage ratio regulation.[7,8]

The bilateral market differs from the tri-party segment, which is the focus of most of the literature, in a number of important ways. First, cash lenders in the tri-party market are usually sophisticated financial intermediaries such as money market funds. By contrast, cash lenders in the bilateral market are very diverse and include hedge funds, pension funds, insurance companies and corporates who participate in order to hedge risk and invest cash. Second, the bilateral market facilitates both cash- and securities-driven transactions, meaning that cash lenders also participate in order to obtain specific securities. The tri-party market, on the other hand, is set up to facilitate only transactions against general collateral. Third, the bilateral market allows for rehypothecation, the practice by dealers to re-use an asset obtained when lending cash to one client as collateral when

[6] The four UK dealers in the gilt repo market are Barclays, HSBC, Lloyds and Santander UK.
[7] Only recently, in 2014, the Office of Financial Research and the Federal Reserve launched a voluntary pilot data collection that focuses on the US bilateral repo market (Baklanova, Caglio, Cipriani and Copeland, 2016). Krishnamurthy, Nagel and Orlov (2014) also acknowledge that the lack of data on the bilateral repo market has prevented them to assemble a full picture of repo markets.
[8] An exception is the paper by Gorton and Metrick (2012) who examine the run on repos at the start of the global financial crisis.

borrowing cash from another client. This is an important source of financing and profits as dealers can set different contracting terms in these transactions exploiting their role as market intermediaries (Figure 3) (Duffie, 2010; Eremen, 2015; Infante, 2019; Infante and Vardoulakis, 2019).[9] This practice is unique to the bilateral repo market and played a central role during the 2007-08 financial panic.[10]

We exploit a new supervisory database: the Sterling Money Market Database (SMMD). This dataset has a number of unique features. First, it covers the near-universe of bilateral repo market transactions in the UK. Second, besides detailed information on repo volumes it also includes information on pricing, maturity, haircuts and collateral used in each transaction. This allows us to assess in detail on which margins leverage constrained dealers adjust their repo intermediation. Finally, for each transaction we know the reporting dealer (the cash borrower) and the client (the cash lender). This allows us not only to isolate a dealer-driven from a client-driven effect, but also to analyse any heterogeneous behaviour of leverage constrained dealers across client types.

We start by analysing the immediate effect of the leverage ratio tightening in a standard difference-in-differences setting. We compare repo intermediation by affected dealers (treatment group) and non-affected dealers (control group) with the same client in the month before and in the month after the policy change.[11] We focus on clients with at least two dealers. This allows us to control for any observed and unobserved heterogeneity in repo demand and credit risk by employing client fixed effects (Kwaja and Mian, 2008).

We find that affected dealers on average accepted 48 percentage points less cash from the same client relative to non-affected dealers in the first month after the shift from monthly to daily averaging. Distinguishing between small and large clients based on their trading size, we find that affected dealers reduced repo volume only to their small and not to their large clients. In addition, affected dealers lowered repo rates they were willing to pay to small clients and reduced the

[9] It is estimated that rehypothecation (or collateral re-use) peaked at around 4.3 trillion euro just before the financial crisis in 2006. An implication of rehypothecation is that long collateral chains can develop within the financial system, which may increase financial fragility (FSB, 2017b).

[10] In a tri-party repo transaction, settlement occurs on the books of a third party – usually a clearing bank – who manages the collateral received. The cash lender cannot take possession of the collateral and the collateral cannot be re-used outside the tri-party platform (Adrian, Begalle, Copeland and Martin, 2013). As a result, the tri-party repo market does not contribute to the formation of collateral chains.

[11] Note that for the identification to be valid it does not have to be the case that non-affected dealers are not subject to a binding leverage ratio. It only requires that these dealers are not subject to the policy change that we exploit and are not affected by another shock that makes them behave differently in the post period.

frequency of interacting with them.[12] Other client characteristics such as strength of relationship, being foreign or being more active in term repo did not seem to influence the behavior of the dealer.

The differential adjustment with respect to the size of the client can be explained by the fact that dealers have – as intermediaries between cash lenders and cash borrowers – the ability to net out repo with reverse repo transactions. Netting of bilateral trades with the same counterparty and same maturity does not attract a capital charge under the leverage ratio. Indeed, we show that small clients are relatively less likely to engage in both repo and reverse repo transactions across all dealers but also with the same dealer. In addition, dealers want to protect other sources of revenue from their clients. Therefore they will be more willing to open up their balance sheet for clients that provide profitable ancillary business. These tend to be large clients (CGFS, 2017).

A simple back of the envelope calculation suggests that small clients were able to place 23 percent less cash with affected dealers in the first month after the policy change. However, the ability of small clients to place cash and obtain securities in the bilateral market was only marginally hampered by the tightening of the leverage ratio as foreign, non-affected dealers stepped in and increased their market share. The withdrawal of affected dealers from small clients and the corresponding reduction in repo rates offered improved potential revenue streams for foreign dealers and increased their willingness to compete. If this change in the market is permanent it can increase fragility as foreigners tend to be more flighty in times of stress (Giannetti and Laeven, 2012; De Haas and Van Horen, 2013).

A key question is to what extent these initial adjustments were temporary or persistent. We find that adjustments were only temporary and that a quarter after the initial impact the differential effect in terms of volume, prices as well as frequency of interaction had disappeared. In other words, after the initial shock subsided affected dealers again opened up their balance sheet for small clients. We show that a potential explanation for this finding lies in an adjustment in reverse repo contracts supported by the ability to rehypothecate collateral in the bilateral market. Theory suggests that dealers can overcome the costs of stricter regulation by extracting profits from their trading counterparties (Andersen, Duffie and Song, 2019). In line with this, we find that affected dealers

[12] The trade size is shown to be significant in other contexts too. For example, Edwards, Harris and Piwowar (2007) studying OTC secondary trades in corporate bonds in the US show that transaction costs decrease significantly with the size of the trade. More recently, Chen, Hanson and Stein (2017) argue that, in the aftermath of the 2007-08 financial crisis, big US banks cut small business lending because they view it as being peripheral in their overall business strategies.

seem to have neutralized the cost of the regulation by over time applying higher haircuts on reverse repo contracts they have with small clients while keeping haircuts on repo contracts stable and therefore generating a cash surplus. In other words, exploiting their role as market intermediaries, affected dealers seem to have generated profit through rehypothecation, which was sufficient to overcome the cost of a tightening of the leverage ratio and thus allowed them to recapture their small clients.

An implication of this novel result is that a binding leverage ratio can make borrowing cash on the repo market riskier for small, liability driven investors such as pension funds and insurers. Cash lenders have immediate access to the collateral re-used, in effect insulating them from the dealer's default. Cash borrowers, by contrast, are exposed to the dealer through the loss of their collateral. As haircuts in reverse repo contracts increase, the collateral pledged by cash borrowers is worth more than the loan they receive potentially exposing them to a loss if the dealer defaults. In addition, as recently modeled by Infante and Vardoulakis (2019), higher haircuts create an incentive for cash borrowers to withdraw their collateral and can expose dealers to collateral runs as was the case with the collapse of Bear Sterns in March 2008. To the best of our knowledge, our paper is the first to document that the leverage ratio not only affects repo but also reverse repo contracts, not in terms of volume but in terms of haircuts.

One important question remains open: How does the leverage ratio affect collateral re-use? This question is only relevant to the bilateral segment of the repo market where collateral rehypothecation is allowed.[13] On the one hand, it is expected that the leverage ratio will reduce collateral re-use by disincentivizing banks to engage in repo activities. On the other hand, the leverage ratio should not have to impact collateral re-use if leverage constrained dealers continue to engage with large clients and, in addition, start to manage their collateral better and recover the cost of a tighter leverage ratio through an increase in reverse repo haircuts. A precise analysis of this question requires transaction level data, which to the best of our knowledge does not exist. Using – for the first time – supervisory data on collateral re-use at the dealer-quarter level, we show that affected dealers did not reduce the re-use of their collateral. While this evidence is suggestive, it indicates that the leverage ratio does not need to lead to a reduction in collateral re-use in the repo market which is in contrast to the conventional wisdom among policymakers (FSB, 2017b)

[13] High collateral re-use contributed to the amplification of the 2007-08 financial panic, diminished since then, but it has recently started rebounding (Singh and Aitken, 2010; Singh, 2011; 2017)

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 related to the immediate impact of the leverage ratio tightening. Section 6 analyses the longer term effects and studies adjustments in reverse repo contracts and collateral re-use. Section 7 concludes and discusses the policy implications of our findings.

2. Contribution to the literature

Our paper contributes to several strands of the literature. First, it adds to the literature that studies the repo market. Most recent studies have focused on the functioning of the repo market during crisis episodes. Studying the US tri-party market during the global financial crisis Krishnamurthy, Nagel, and Orlov (2014) and Copeland, Martin, and Walker (2014) find that the market resisted the stress fairly well with limited declines in volume and haircuts. Also the central counterparty (CCP)-based euro interbank repo market showed resilience, except when sovereign stress was very high (Mancini, Ranaldo and Wrampelmeyer, 2016; Boissel, Derrien, Ors and Thesmar, 2017). By contrast, the US bilateral market was much more susceptible to repo runs with haircuts increasing sharply during the crisis (Gorton and Metrick, 2012). These differences in run dynamics can be rationalized by differences in market microstructures (Martin Skeie and Von Thadden, 2014) with the option to re-hypothecate in bilateral repo playing a crucial role (Infante, 2019). We add to this literature by analyzing the dynamics of the repo market in quiet times abstracting from developments during crisis episodes.

A more nascent part of this literature focuses explicitly on how regulation affects repo markets, with a special focus on the leverage ratio. Theory predicts that the leverage ratio as a non-risk weighted measure disincentivizes banks to reserve balance sheet space for low-margin activities such as repos (Krishnamurthy and Duffie, 2016; Duffie, 2018; Andersen, Duffie and Song, 2019). However, empirical evidence is mixed. 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.[14] Allahrakha, Cettina and Munyan

[14] 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

(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. By contrast, 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.

We contribute to this literature by providing causal evidence as to how a *tightening* of the leverage ratio affects the repo market, studying – for the first time – the bilateral segment of the market. Exploiting a quasi-natural experiment and transaction-level data we provide a comprehensive assessment as to how dealers react to a tightening of the leverage ratio. Our unique quasi-experimental design allows us to examine not only the initial reaction of leverage constrained dealers and the response of other dealers in the market, but also how behavior adjusts over time Furthermore, we highlight that the leverage ratio not only affects repo but also reverse repo contracts and explore its impact on collateral re-use due to dealers' ability to rehypothecate in the bilateral repo market.

Consequently, our paper also adds to the literature that focuses on the causes and consequences of rehypothecation. On the one hand, rehypothecation can lubricate transactions in the financial system (Singh and Aitken, 2010; Singh 2011) and can improve resource allocation (Andolfatto, Martin and Zhang, 2017). On the other hand, it can generate risk in case the cash lender does not return the collateral when due (Monnet, 2011). Infante and Vardoulakis (2019) model how dealers expose themselves to collateral runs by hedge funds when they generate profits through rehypothecation. Despite the growing theoretical work, empirical evidence on the causes and consequences of rehypothecation is lagging behind. We contribute by showing that rehypothecation can act as a channel through which dealers can overcome the costs of stricter capital regulation.

Finally, our paper adds to the literature that studies the consequences of capital regulation. Not surprisingly, given its early introduction, most of this literature has focused on the capital ratio, but recently attention has shifted to the leverage ratio.[15] Adrian, Boyarchenko and Shachar (2017)

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.

[15] Papers studying the impact of the capital ratio have found that an increase in capital requirements (or costs) 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

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. In addition, recent papers show 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) or to participate in spread-narrowing trades (Boyarchenko, Eisenback, Gupta, Shachar and Van Tassel, 2018). We contribute to this literature by providing causal evidence on the impact of the leverage ratio on the (bilateral) repo market.

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 can affect 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.

and Wix, 2019) and that it induces credit re-allocation towards non-bank financial intermediation (Irani, Iyer, Meisenzahl and Peydro, 2018).

Repo markets are an essential part of the financial system. They play a key role in facilitating the flow of cash and securities around the system. They create and support opportunities for the low-risk investment of cash, as well as efficient management of liquidity and collateral, benefitting both 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 counterparty (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.[16] 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 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.

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

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 largest banks (Barclays, HSBC, Nationwide, Lloyds, RBS, Santander UK 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 Internet Appendix Table 1.[17]

4. Empirical methodology and data

4.1 Quasi-natural experiment: Change in regulatory reporting requirements

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.

As of January 2016 four dealers in the gilt repo market, Barclays, HSBC, Lloyds and Santander UK, became formally subject to a 3 percent leverage ratio which had 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

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

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.[18]

The policy change provides us with an ideal quasi-natural experiment. First, it offers us a natural treatment and control group. For the non-UK dealers to qualify as a valid control group it is irrelevant whether they are themselves subject to a binding leverage ratio or not. It is only necessary that these dealers are not subject to the policy change that we exploit and are not affected by another shock that makes them behave differently in the post period. This is not the case. Second, the policy change did not coincide with any other regulatory change or adjustment in (unconventional) monetary policy in the UK potentially affecting the repo market. Third, different from the *introduction* of the leverage ratio, dealers had no incentive to adjust their balance sheet ahead of the change in reporting requirements. 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 any 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), but as the vast majority of repo transactions are very short-term dealers do not have to adjust their repo rates or volumes until the daily average requirement comes into effect. This makes it possible to pinpoint exactly the impact of the leverage ratio tightening on repo intermediation. Finally, all UK dealers had an incentive to adjust their repo activity even without a binding leverage ratio in order to avoid the market reacting to a change in their leverage ratio.

The change in regulatory reporting thus provides us with a suitable exogenous policy shock that affects some dealers in the gilt repo market, while leaving others unaffected. Figure 2 shows that the policy change 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

[18] 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.

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.

Table 1 tests more formally the existence of this differential behaviour. We create a dummy variable for each day for the period September 28, 2016 – February 28, 2017 and run simple OLS regressions for the sample of UK and non-UK regulated dealers (column 1), for UK regulated dealers only (column 2) and for non-UK regulated dealers only (column 3).[19] The dependent variable is the (log of the) total repo volume accepted by dealer *i* on date *t*. When we consider the full sample of dealers no window-dressing behaviour is observed before or after the change in the reporting requirements of the leverage ratio (i.e. January 01). When we separate the dealers in two sub-samples we find a striking difference. UK regulated dealers on the one hand clearly engaged in window-dressing behaviour prior to the policy change. After the switch to "daily averaging" they immediately stopped window-dressing their balance sheet (column 2). By contrast, non-UK regulated dealers did not engage in such regulatory arbitrage neither before nor after the tightening of the leverage ratio. Taken together, the evidence suggests our quasi-natural experiment is appropriate to study the impact of a tightening of the leverage ratio on repo market activities.

4.2 Identification strategy

Having identified exogenous variation in the tightening 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.

To assess the immediate impact of the policy change we compare the behaviour of the two types of dealers in the month before with the month after the regulatory change. The market is very short term, often overnight, and clients tend to use the market repeatedly during a short time window, so any adjustment in the market is expected to materialize quickly. To avoid any bias from increased volatility resulting from dealers' practices to window-dress their balance sheets at year-end (see Figure 2), we drop the last two business weeks of December 2016 and the first business days of January 2017. We ensure that both the pre and post periods have the same number of week days as

[19] For exposition purposes, we only report estimates +/- 2 days around month ends.

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).

To isolate the dealer-driven from the client-driven effect, we focus only 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.[20] This allows us to saturate the specification with client fixed effects and to control for any observed and unobserved heterogeneity in client demand and risk (Khwaja and Mian, 2008). 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*. 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 and our standard errors will be conservative. The variable is winsorized at the 1 and 99th percentile. $Affected\ Dealer_i$ 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* [21]; μ_j is a vector of client fixed effects; and ε_{ij} is the error term. The model is estimated using OLS and 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 1 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

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

[21] 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.

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. This way 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.

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 exclusively on the latter segment of the market.

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 client (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

[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.

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 percent in terms of repo volumes). Second, our clients include banks or non-bank financial institutions, such as pension funds, hedge funds and insurance companies, as well as non-financial corporates that place cash in the repo market. 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 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 16 dealers, 37 clients and 128 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.

[23] This mainly affects transactions reported from institutions based in France.
[24] Transactions with these characteristics represent less than 5 percent of total transactions.
[25] A similar consolidation procedure is applied by the Office of Financial Research in the U.S. Money Market Fund Monitor data.

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. Leverage ratio tightening and repo market activity: immediate effect

In this section we examine how dealers affected by the tightening of the leverage ratio adjust their repo market activity immediately after the policy change and how the market adjusts.

5.1 Baseline effect

We start by examining whether affected dealers indeed reduced bilateral repo after the policy change. The result in Table 2, column (1) indicates that affected dealers indeed on average reduced the repo volume 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 32 percent, while non-affected dealers on average increase it by 13 percent.[26]

One could be concerned that some of the clients placing cash with affected dealers 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 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. In column (3) we also control for the strength of the pre-shock relationship between dealer and client. The coefficient for *Affected Dealer* remains negative and is significant at the five percent level.

The economic magnitude of the change we document is substantial. The most saturated and therefore preferred model in column (3) shows that affected dealers accept 48 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

[26] As the dependent variable is the log difference, the economic effects are derived by taking the exponential of the respective parameters minus one.

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[27]. This average effect might however hide some important heterogeneous effects. An issue we turn to in the next section.

5.2 Heterogeneous effects

The tightening of the leverage ratio makes it more costly for dealers to engage in repo but does not prevent them from doing so. As long as the dealer can either avoid the repo trade to count towards its balance sheet and therefore does not have to hold capital against it or can make a large enough (indirect) profit from the trade it will still be willing to engage in repo even when faced with a binding leverage ratio.[28] This suggests that dealers likely behave differently towards large compared to small clients.

First, dealers have – as intermediaries between cash lenders and cash borrowers – the ability to net out repo with reverse repo transactions. Under the leverage ratio regulation a dealer can net out a repo with a reverse repo transaction when both trades are with the same counterparty, have the same maturity and are completed in the same settlement system. When a repo trade is netted out a dealer does not have to hold capital against it. As large clients tend to trade more and tend to engage in both repo and reverse repo, the possibility of netting is higher.

In Table 3 we formally test for this. We take as dependent variable either the client's share of reverse repo in total repo market activity or a dummy that is equal to 1 if a client does not engage in reverse repo conditioning on doing repo. We then differentiate between small and large clients, where *Small* is a dummy variable equal to 1 if the client engaged in below median volume of repo transactions in the pre-period, and 0 otherwise. The results clearly indicate that small clients are less likely to engage in both repo and reverse repo across all dealers (columns 1 and 3) but also with the same dealer (columns 2 and 4).

Second, larger clients are more likely to provide ancillary business which justifies use of balance sheet (CGFS, 2017). As a result indirect profits to be gained when accepting repo from large

[27] To ensure that our estimated effect in first-differences reflects a differential *decrease* in bilateral repos, we also run these regressions in levels. The coefficient in levels remains virtually unchanged (-0.621*) when we compare it with the most saturated and therefore preferred model in first-differences in column 3.

[28] Even when the leverage ratio requirement does not bind, which is the case for all UK dealers, banks prefer to maintain a buffer over the minimum leverage ratio requirement. In addition, banks prefer to avoid increases in their leverage ratio as markets tend to react to this.

clients are likely much larger than those from small clients. Finally, large clients have more negotiating power over contract terms.

As such, for all the above reasons, 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 by interacting *Affected Dealer* with *Small*. 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.

As in Table 2 we first show results without any controls (Table 4, 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 47 percent, while non-affected dealers increase it by 61 percent with the difference being statistically significant. For large clients, affected dealers also reduce repo volume accepted, but by 14 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.

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 (2) the differential effect remains highly significant at the 1 percent level. In column (3) 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. Finally we control for relationship strength (column 4). This slightly reduces the coefficient, but it remains highly significant.

In terms of economic magnitude, we find (using the most saturated specification in column 4) that affected dealers are willing to accept 67 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.[29]

While there is a clear rationale why leverage constrained dealers would differentiate between small and large clients, it is possible that these dealers also react differently with respect to other client characteristics. Furthermore, one could be worried that being small is a proxy for another client characteristic and that this might be driving our results. Therefore we set out to examine a number of alternative client characteristics. First, the strength of the relationship between dealer and client to test whether relationship matters more than size. Second, the maturity of repo contracts to test if dealers are more likely to withdraw from clients that want to place cash at longer maturities. And, finally, the nationality of the client to test if affected (UK) dealers might be more willing to continue lending to domestic as opposed to foreign clients

To this end we create three dummy variables. 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.[30,31] 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. A dummy variable *Foreign* which is one if the client if headquartered outside the UK, zero otherwise.

The results are provided in Table 5. We use the same specification as in Table 4, column 3, 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. We find that none of the alternative client characteristics seem to influence an affected dealer's decision to withdraw from a particular client. The interaction with *Small*, however, remains large and statistically significant at the 1 percent level in all cases, even when we add all four interaction terms together (column 7).[32]

Summarizing, our results show that the defining client characteristic which determines whether a dealer faced with a tightening of the leverage ratio adjusts its repo intermediation seems

[29] As earlier, we run our preferred specification (column 4) also in levels and confirm that the coefficient remains virtually unchanged (-1.016**).
[30] 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.
[31] The correlation between the relationship and the small dummy is below 0.5.
[32] The fact that size matters more than relationships is consistent with the arguments put forth in Adrian and Shin (2010). Dealers tend to operate on the margin and as such they are less likely to engage in relationship-based trading.

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.

5.3 Other margins of adjustment

Up till now we focused our attention on how leverage constrained dealers adjusted with respect to repo volumes. 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 a tightening 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.

As a way to recapture costs associated with a tightening of the leverage ratio dealers can 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 results in Table 6, column 1 show that following the change in reporting requirements affected dealers were on average not adjusting repo rates to their clients relative to non-affected dealers (Panel A). However, when we allow for heterogeneous effects (Panel B) 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 approximately a 9 basis points lower repo rate to their smaller clients relative to their larger clients compared to non-affected dealers. By adjusting their repo rates and making it less attractive for small clients to place cash, dealers widen their bid-ask spreads – the difference between the rates at which they borrow and lend cash in return for securities – following a tightening of the leverage ratio (Huh and Infante, 2017).

Next, 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 (column 2).

Another 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 client is often a function of its 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 the dealer only had to include it if it had not matured at month-end. Our third 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 (column 3).

Finally, we examine the adjustment on the extensive margin using three alternative definitions. We create the dependent variable *Δlog(#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 changes in volume capture 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 also consider two alternative definitions to test the effects on the extensive margin. *Exit (Access)* is a dummy variable that equals 1 if the total number of repo transactions accepted by dealer *i* from client *j* in the post (pre) period is smaller than the total number of repo transactions accepted by dealer *i* from client *j* in the pre (post) period. In other words, these variables are meant to capture the probability of terminating and entering a new repo trade at the dealer-client level respectively in response to the tightening of the leverage ratio regulation. In line with our expectation, we find (Table 6, columns 4-6) that affected dealers after the policy 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. Also, they were more likely to terminate and

less likely to enter a transaction with a smaller relative to a larger client compared to non-affected dealers after the policy change.[33]

5.4 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 (Figure 1) so we do not expect an impact of the tightening of the leverage ratio. Indeed, the results in Table 7 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 tightening of the leverage ratio.[34]

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. We show (Appendix Table 3) that our results are not sensitive to using alternative definitions. 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 of) 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.

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

[33] All findings are robust to using WLS (using as weights the log of repo volume by dealer-client before the regulatory change) instead of OLS. See Appendix Table 2.

[34] 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, 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.

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. 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 our sample period along several dimensions: we only exclude the last day of the year, 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, we expand the pre-period and have it start on October 31, 2016 and we extend the post-period and have it end on February 22, 2017. Regardless of the time period we exploit, our results indicate that dealer banks subject to the regulatory change reduced repo volume from smaller clients compared to dealer banks not affected by the change (Appendix Table 4).

5.5 Aggregate effect and market adjustment

We show that dealers that were subject to a tightening of the leverage ratio moved away from their small clients. A conservative back of the envelope calculation can shed light on how much small end-users were affected in aggregate. Using the OLS estimates of Table 4, column 1 we estimate that affected banks on average reduced repo volume to their small clients with 38 percent.[35] 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 23 percent 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 were experiencing lower growth rates compared to large clients after the regulatory change. 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 (1).[36] The model we estimate is as follows:

[35] This is the combined effect of the constant, the affected dummy, the small dummy and the affected*small interaction.
[36] 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 (2019), where a numerical correction of the difference of the OLS and FE estimate is applied.

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

where $\Delta log(AggrVolume)_j$ is the pre-post change in the (log of) the total repo volume accepted by *all* dealers from client *j*, winsorized at the 1 and 99 percentiles. $Small_j$ 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_j is the error term.

The results in Table 8 suggest that small end-users are not experiencing lower growth rates in their total repos relative to large clients after the regulatory change. This suggests that small clients were able to immediately switch to non-affected dealers to place cash in the repo market and is consistent with our previous finding that non-affected dealers were on average accepting more repo from their small clients after the policy change. This evidence is also confirmed when we look at the change in market share of affected and non-affected dealers after the tightening of the leverage ratio. The non-affected dealers increased their market share of the small clients from 39 to 49 percent.

6. Leverage ratio tightening and repo market activity: permanent or transitory?

The results presented in Section 5 indicate that leverage constrained dealers reduced bilateral repo in the first month after the tightening of the leverage ratio, which primarily affected their smaller clients. The impact on those clients was offset by foreign dealers who stepped in to fill the void. A key question is to what extent these initial adjustments were temporary or persistent.

6.1 Dynamic effect

To examine how persistent the change in the market is, we lengthen the sample period with a quarter until April, 28. In addition we extend the sample backwards with one month in order to make sure that our results are not driven by any pre-event trends. This enables us to see how the parameter on our main interaction effect (*Affected Dealer* * *Small*) behaves over time. We re-estimate model (2) (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 solid green line in Figure 4 depicts the estimate of β_1 for the different periods and the two dotted

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 2016m11) 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 tightening of the leverage ratio affected and non-affected dealers did not behave differently, reducing concerns that our results are driven by different pre-event trends between the two types of dealers.[37]

As shown in the previous section, in the first month after the leverage ratio tightening the two groups of dealers start diverging (labelled as 2017m1). Going forward in time, the results show that this differential effect persists into February (labelled 2017m2) and March (labelled 2017m3) but the magnitude of the coefficient becomes smaller over time. By April (labelled 2017m4) the differential effect has disappeared. In other words, about a quarter after the initial shock affected dealers again opened up their balance sheet for small clients.

Next we examine the aggregate impact on small clients in a dynamic setting by re-estimating model (3). The coefficient estimates as depicted by the solid red line in Figure 4 show that throughout the whole sample period small clients did not experience a reduction in their total repos indicating that the aggregate effects of the leverage ratio tightening were minimal.

In the first month after the change in reporting requirements affected dealers not only reduced the volume of bilateral repo they were willing to accept from their small clients, but also lowered repo rates and the frequency of interactions. When we re-estimate our main interaction effect (*Affected Dealer* * *Small*) for rolling symmetric windows for these dependent variables as well, we see a very similar pattern emerging as we observe for repo volumes (Figure 5). Both the coefficients for *ΔRate* and *Δlog(#Transactions)* remain negative and significant until March 2017, but become insignificant afterwards. For *Exit* and *Access* the coefficient already becomes insignificant in March 2017.

[37] To further mitigate such concerns, we run a second placebo experiment comparing the period {October 03 - October 21} to the period {October 24 - November 18}. The results from this exercise also confirm that there are no pre-event trends between treatment and control group. Results are available upon request.

Overall, these results consistently show that the impact of a tightening of the leverage ratio on bilateral repo market activity of affected dealers was only temporary. After about a quarter the leverage constrained dealers are again opening up their balance sheet for all clients regardless of their trading size. This raises the important question why this is the case. While likely several factors are behind this effect, we next turn to one potential explanation: an adjustment in reverse repo contracts motivated by the ability to rehypothecate in the bilateral repo market.

6.2 Adjustment in reverse repo contracts

The recent theoretical work of Andersen, Duffie and Song (2019) suggests that dealers overcome the cost of stricter regulation by extracting profits from their trading counterparties. In other words, leverage constrained dealers seek for compensation in order to open up space in their balance sheets for repo transactions. We test whether these motives can explain why leverage constrained dealers recapture their smaller clients a quarter after the initial market dislocation.

We focus our attention on the role of rehypothecation, the practice by dealers to re-use an asset obtained when lending cash to one client as collateral when borrowing cash from another client. This practice is unique to the bilateral repo market. Exploiting their role as market intermediaries, dealers can set different contracting terms (in particular haircuts) in their repo and reverse repo contracts when they rehypothecate collateral and this allows them to extract a significant amount of profits (Duffie, 2010; Eremen, 2015; Infante, 2019; Infante and Vardoulakis, 2019). Figure 3 depicts how this works.

Our hypothesis is that dealers recapture their smaller clients when they can generate sufficient profits from them in order to justify the use of balance sheet space for repos with them. In other words, constrained dealers will engage in costly repo transactions with their smaller clients as long as they can generate cash surplus to compensate. A way to achieve this is for the dealer to increase haircuts on reverse repo contracts while leaving haircuts on repo contracts unchanged.[38] Similar to the decision to reduce repo volume accepted from small but not from large clients, an affected dealer will likely also differentiate between clients when deciding for which clients haircuts on reverse repo should be raised. Again, clients most likely to face a higher haircut are those clients that have less

[38] Generating a cash surplus through rehypothecation also expands the balance sheet and as such the dealer has to hold capital against it. However, as long as the profits generated jointly by the reverse repo trade, the repo trade and the returns gained on the cash surplus outweigh the cost of additional capital it will be optimal for a dealer to engage.

market power, are less likely to engage in both repo and reverse repo contracts and are less likely to provide ancillary business to the dealer, i.e. the smaller clients. In other words, we expect dealers that were affected by a tightening of the leverage ratio to increase haircuts on reverse repo contracts for small relative to large clients, but leave them unchanged on repo contracts.

We test for this by employing a similar model as model 2. As our dependent variable we consider the *level* (not changes) of haircuts in the post period as our hypothesis predicts that the *level* of reverse repo haircuts imposed on small clients (relative to large) increases in order for dealers to generate a cash surplus as compensation for the use of balance sheet space for repos. Importantly, we include as control the level of haircuts in the pre-period. Haircuts are then regressed on the interaction of *Affected Dealer* * *Small* in a dynamic setting similar to the one we applied in the previous section, the level of haircuts in our pre-period, as well as a full set of dealer and client fixed effects.

The results are presented in Figure 6. The top figure presents dynamic estimates for haircuts in the repo contracts of leverage constrained dealers with their small relative to their large clients, while the bottom figure presents dynamic estimates for haircuts in the reverse repo contracts of leverage constrained dealers with their small relative to their large clients. The top figure suggests that dealers do not set different repo haircuts to small versus large clients in the market throughout the entire period. This is intuitive and consistent with the findings in Table 6. The bottom figure suggests that dealers set substantially higher reverse repo haircuts to small relative to large clients in April 2017, which is exactly when they again open up their balance sheets for repos from small clients (Figures 4 and 5). A potential explanation why haircuts are not adjusted directly after the change in regulatory reporting is that they are determined at a dealer's credit department and not at the dealer's trading desk (Julliard, Liu, Seyedan, Todorov and Yuan, 2019). This introduces some rigidity in the updating of contracts. While repo rates tend to quickly adjust to changes in the market, changes in collateral management tend to be more sluggish.

An alternative way dealers can compensate for the costs associated with the use of balance sheet space for small clients is to increase reverse repo rates when repo rates revert back to normal. This way the dealer can continue to profit from a higher bid-ask spread, but now resulting from

higher reverse repo and not a lower repo rate. We find no evidence in support of this adjustment in the long-run.[39]

Our evidence suggests that dealers not only adjust repo contracts but also reverse repo contracts in order to overcome the costs associated with the changes in their capital structure when leverage regulation tightens. To the best of our knowledge, this is the first paper to document how dealers respond over time to stricter capital regulation focusing both on repo and reverse repo contracts. An implication of our novel result is that a binding leverage ratio can make borrowing cash on the repo market riskier for small, liability driven investors such as pension funds and insurers. Cash lenders have immediate access to the collateral re-used, in effect insulating them from the dealer's default. Cash borrowers, by contrast, are exposed to the dealer through the loss of their collateral and as reverse repo haircuts increase, the collateral pledged is worth more than the initial loan. As such, cash borrowers are exposed to the loss of the collateral if the dealer defaults. In turn, this might give rise to incentives to run on collateral as was the case with the collapse of Bear Stearns in March 2008.

6.3 Leverage ratio and collateral re-use

An important question remains open. How does the leverage ratio affect collateral re-use? Policymakers share the view that by disincentivizing repo intermediation, the leverage ratio regulation will reduce collateral re-use in the repo market (FSB, 2017b). On the other hand, if leverage constrained dealers start to manage their collateral better and recover the cost of a tighter leverage ratio through an increase in reverse repo haircuts as our results suggest, the leverage ratio should not have to impact collateral re-use. The importance of collateral re-use is straightforward: when dealers re-use the same set of securities as collateral with multiple counterparties it can lead to the existence of long collateral chains. This can potentially create systemic fragility when these securities lose value. Despite its policy relevance, to the best of our knowledge, there is no empirical evidence as to whether the leverage ratio reduces collateral re-use or not. This is mainly due to lack of transaction-level data required to carefully analyse this question.

[39] Dealers could also adjust by reducing the size of their overall balance sheet by substituting other assets for repo. We do find some evidence of deleveraging in March 2017, which becomes more significant in April 2017, but with the aggregate balance sheet items that we have access to, it is difficult to attribute this exclusively to the leverage ratio effect.

We try to shed some light on this question by analyzing – for the first time – supervisory data on collateral re-use at the dealer-quarter level.[40] For each dealer, we obtain data on the collateral re-used in repos and the total collateral received from reverse repos which is available to be re-used. We obtain these data at two points in time; the fourth quarter of 2016 and the first quarter of 2017. These two time points represent the pre and post periods of our quasi-natural experiment throughout the paper. Our variables of interest are *Δlog(Re-use)*, which is defined as the quarterly change in the log of collateral re-used by dealers in repos as well as *ΔVelocity,* which captures the change in collateral velocity and is defined as a dealer's quarterly change in the collateral re-used in repos to the total collateral received from reverse repos which is available to be re-used.

Table 9 presents our results when we regress these variables on the dummy *Affected*, which equals one if dealer is constrained by the tightening of the leverage ratio, zero otherwise. In both specifications (columns 1 and 2), we fail to detect statistically significant evidence that point to a differential re-use of collateral by the two groups of dealers in response to a tightening of the leverage ratio. These results are fully in line with our findings. First, our results indicate that dealers affected by a tightening of the leverage ratio do not adjust repo accepted from their large clients, presumably as enough profits can be generated in order to justify the use of balance sheet and hold extra capital against it. Dealers can thus re-use collateral received via reverse repo when engaging in repo with these clients. Second, our findings suggest that once dealers start increasing haircuts in reverse repo contracts they are willing to recapture their small clients and open up their balance sheets for them. This in turn allows more collateral to circulate. Our evidence thus suggest that the leverage ratio does not need to lead to a reduction in collateral re-use, which is in contrast to the conventional wisdom among policymakers.

7. Conclusion

Exploiting a unique quasi-natural experiment that allows us to address major identification challenges in combination with novel transaction-level data this paper provides a comprehensive evaluation of how a tightening of the leverage ratio affects the bilateral repo market. All in all, our results show that a tightening of the leverage ratio does not affect liquidity in the repo market. First, leverage constrained dealers isolate their large clients from the impact of the regulation, presumably

[40] The data come from FINREP's template F32.04 on asset encumbrance and are available for 12 out of 16 dealers.

as these clients can either generate enough profits for the dealer to justify the use of balance sheet or because repo trades with them can be netted out with reverse repo trades and as a result the dealer does not have to hold capital against them. Second, while leverage constrained dealers do step away from their small clients, as long as unconstrained dealers are willing to step in, as was the case in the UK, these clients can switch dealers. As a result their ability to invest cash and source collateral is not impeded. If this change in the market is permanent this could potentially imply more fragility as foreigners tend to be more flighty in times of stress.

The reluctance affecting repo from small clients by constrained dealers is only temporary, however. Dealers seem to exploit their role as market intermediaries and neutralize the cost of leverage ratio regulation by increasing haircuts on the reverse repo contracts they have with small clients. Thus, the ability to rehypothecate in the bilateral repo market allows them to generate a cash surplus which is sufficient to justify the use of balance sheet for repos despite the stricter capital regulation. An implication of these results is that a binding leverage ratio can make borrowing cash on the repo market riskier for small, liability driven investors such as pension funds and insurers, as they will become more exposed to the possibility that a dealer defaults.

Our paper highlights a number of important issues to keep in mind when studying the impact of Basel III regulations on the repo market. First, analyzing detailed transaction-level data is key. Aggregate data will hide important adjustments that can take place in the market as changes in aggregates are naturally driven by large players in the market. Second, as regulation is not implemented in isolation and competition dynamics can play a role, it is important to examine, using quasi-natural experiments, how all dealers in the market react including those not affected by the regulation. Third, adjustments to the new steady state can take some time and initial adjustments might be reversed. To fully understand the impact on the market both need to be studied. Fourth, focusing solely on repo contracts without studying reverse repo contracts can conceal alternative ways in which dealers overcome the cost of regulation. Finally, both the bilateral and the tri-party segment are key parts of the repo market, but they differ in important ways. This can influence how changes in regulation affect each market. It is therefore important to study both segments of the market as one cannot assume that findings in one market will apply to the other one as well, as recent studies focusing on the 2007-08 financial crisis clearly show.

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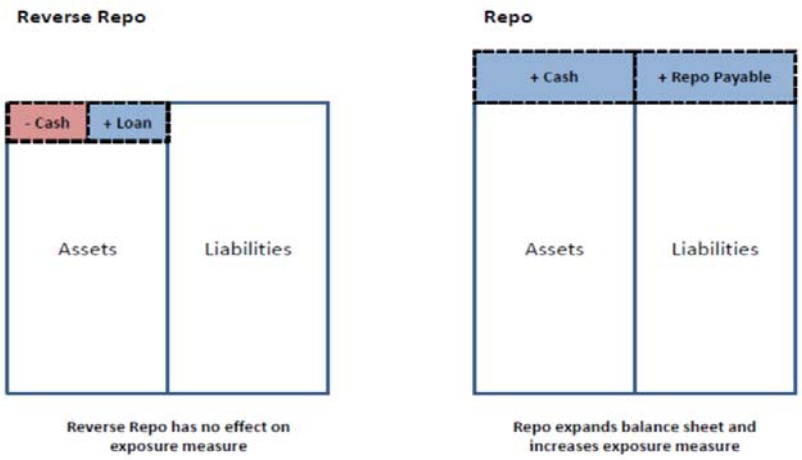
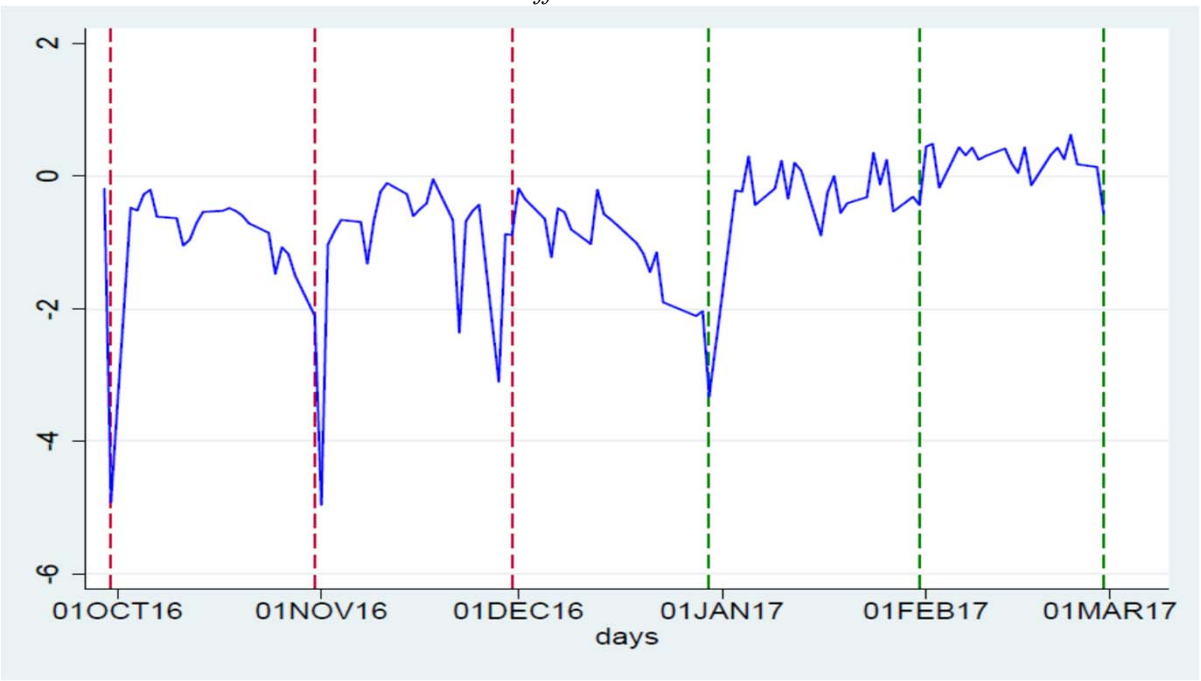
Figure 1: Balance Sheet Effects of Repo Market Transactions



Note: The figure presents the impact of reverse repo and repo transaction on a bank's balance sheet.

Figure 2: Daily Repo Volume around the Policy Change

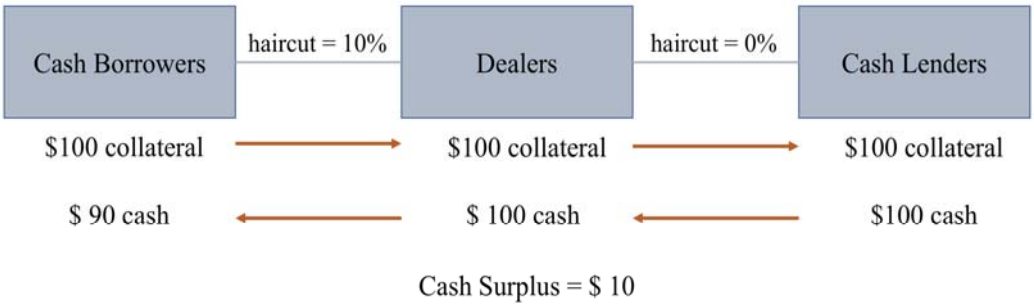
2a: Affected Dealers



2b: Non-Affected Dealers

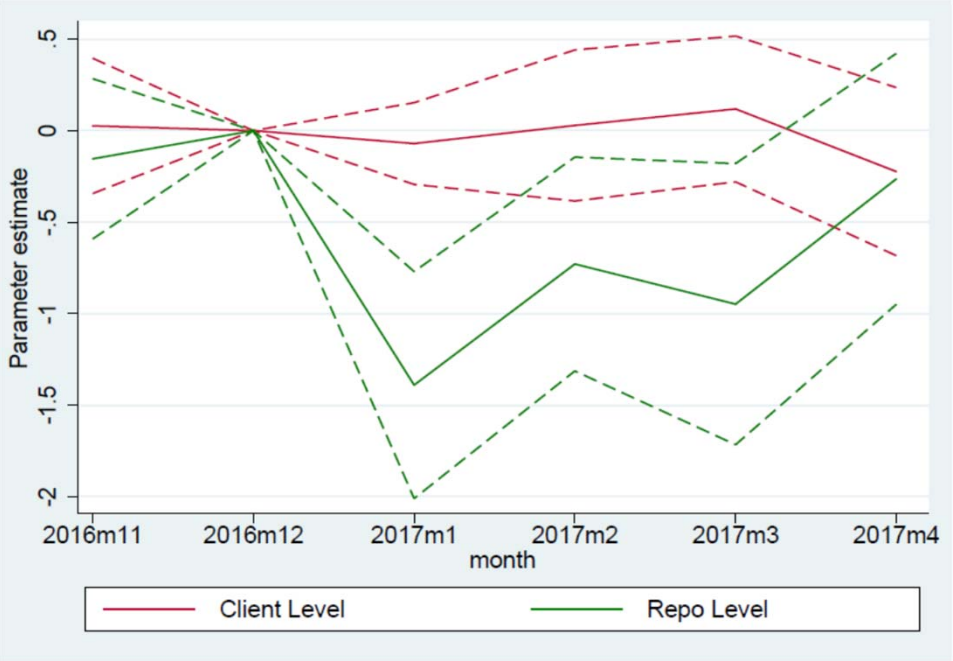
Note: The figures present the evolution of (standardized) repo volume by affected dealers (top figure) and non-affected dealers (bottom figure) over the period October 2016 - February 2017. The vertical dashed lines correspond to month-ends before (red) and after (green) the regulatory change in the reporting requirement of the leverage ratio.

Figure 3: Liquidity Creation through Rehypothecation



Note: The figure presents how dealers generate liquidty through rehypothecation. Dealers intermediate cash from cash lenders to cash borrowers by repledging cash borrowers' collateral. If dealers charge higher haircuts to cash borrowers, they generate liquidity for their own purposes.

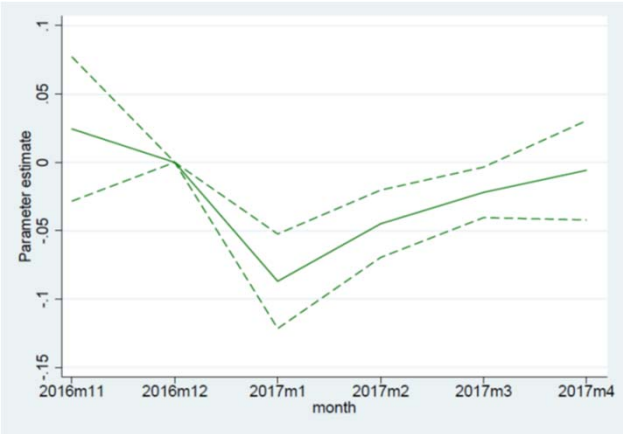
Figure 4: Dynamic Effect for Repo Volume



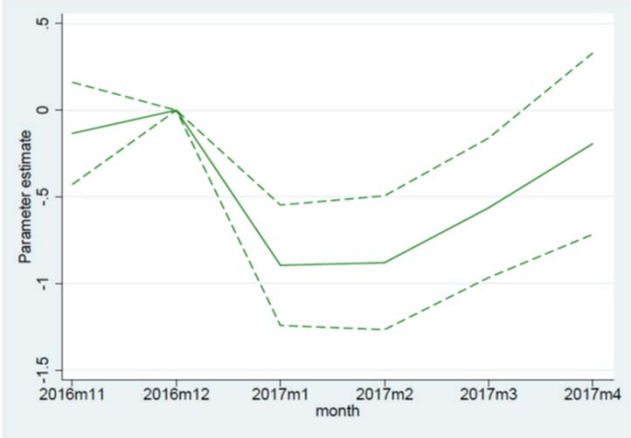
Note: The figure presents the time-varying estimates of the variable *Affected Dealer * Small.* The dependent variable is Δ*log(Volume)* which at the repo level (green) is defined as the pre-post change in the (log of) the total repo volume accepted by dealer *i* from client *j* and at the client level (red) is defined as the pre-post change in the (log of) the total repo volume accepted by all dealers from client *j*. In both cases the dependent variable is winsorized at 1 and 99 percentiles. Coefficients are estimated with rolling symmetric time-windows that end or start in 2016m12. The repo level regressions include client and dealer fixed effects and the client level regressions client-level estimated dummies capturing demand. The plot uses 90% confidence intervals, where standard errors allow for correlation at the dealer level for repo level regressions and robust standard errors are reported for client level regressions.

Figure 5: Dynamic Effect for Other Margins

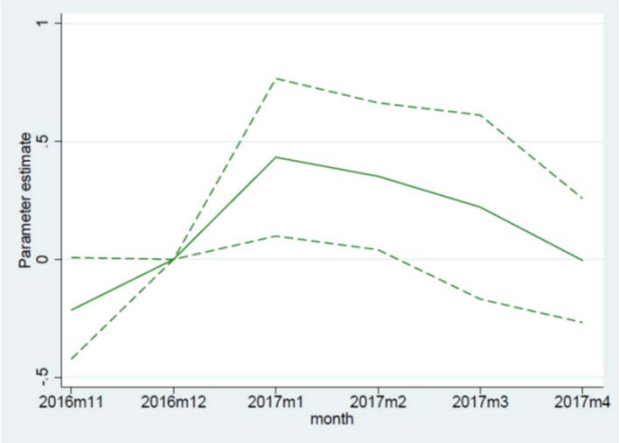
5a. Repo rate



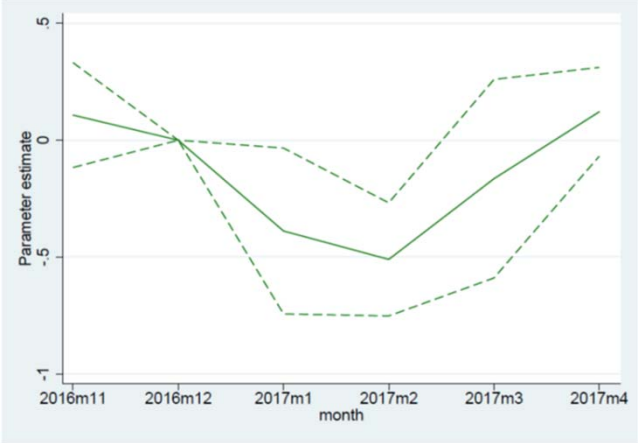
5b. Frequency transactions



5c. Exit



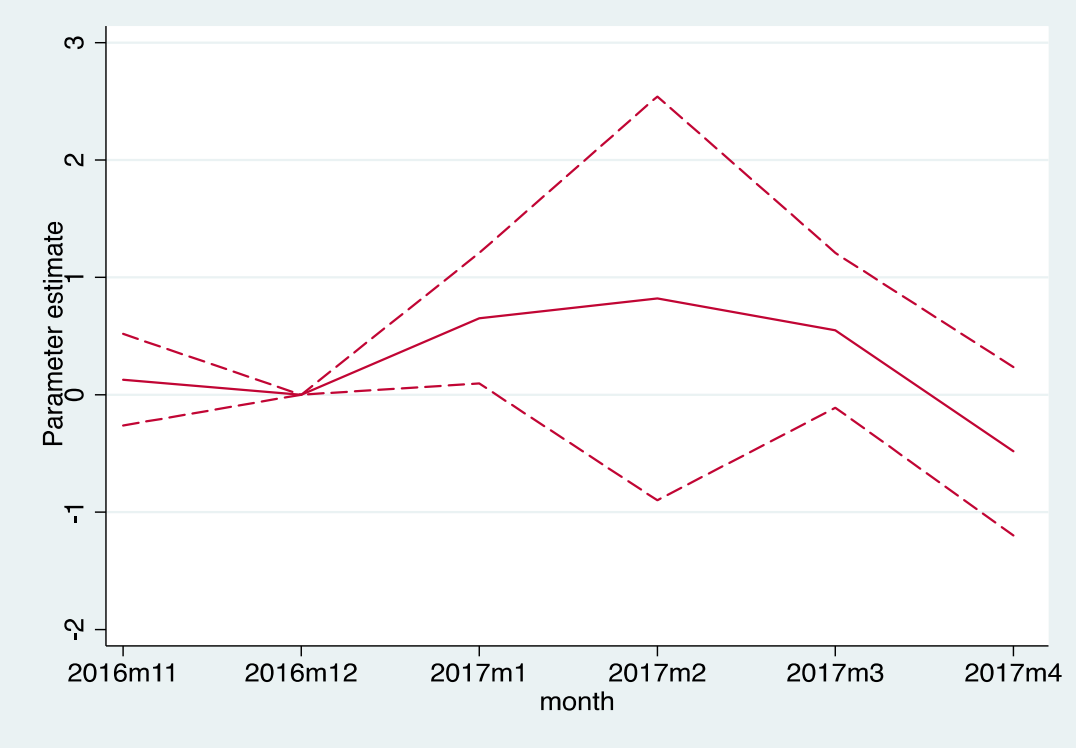
5d. Access



Note: The figures present the time-varying estimates of the variable *Affected Dealer* * *Small,* where the dependent variable is Δ*Rate* (5a), Δ*log(#Transactions)* (5b), *Exit* (5c) and *Access* (5d). *ΔRate* and Δ*log(#Transactions)* denote the pre-post change in the average repo rate and the number of transactions between dealer *j* and client *i* and both and are winsorized at 1 and 99 percentiles. *Exit* and *Access* denote the probability of termination of an existing repo trade and the probability of setting up a new repo transaction in the post period respectively. Coefficients are estimated with rolling symmetric time-windows that end or start in 2016m12. The plot uses 90% confidence intervals, where standard errors allow for correlation at the dealer level.

Figure 6: Adjustment of Haircuts in Repo and Reverse Repo Contracts

6a: Repo Haircuts



6b: Reverse Repo Haircuts

Note: The figure presents the time-varying estimates of the variable *Affected Dealer* * *Small,* where the dependent variable *Haircut* denotes the average haircut that dealer *j* imposes on client *i* in each month before and after the regulatory change in the reporting requirement of the leverage ratio (i.e. the level of haircuts in the respective month). All models control for the level of haircuts in the pre period (2016m12). The top figure presents coefficients for repo haircuts, while the bottom figure presents coefficients for reverse repo haircuts. All regressions include client and dealer fixed effects. Coefficients are estimated with rolling symmetric time-windows that end or start in 2016m12. All regressions include dealer and client fixed effects. The plot uses 90% confidence intervals, where standard errors allow for correlation at the dealer level.

Table 1: Month-End Window-Dressing in Repo Market around the Policy Change

	Log(Volume)		
	All Dealers	Affected Dealers	Non-Affected Dealers
Sep-28	-0.193	-0.273	-0.184
	0.733	0.205	0.693
Sep-29	-0.093	-0.111	-0.124
	0.733	0.205	0.693
Sep-30	-0.539	-1.285***	-0.269
	0.733	0.205	0.693
Oct-03	-0.061	-0.103	-0.076
	0.733	0.205	0.693
Oct-04	0.14	-0.095	0.234
	0.733	0.205	0.693
Oct-28	0.063	-0.408*	0.237
	0.733	0.205	0.693
Oct-31	-0.095	-0.729***	0.035
	0.733	0.205	0.693
Nov-01	-0.574	-1.393***	-0.522
	0.733	0.205	0.693
Nov-02	-0.609	-0.264	-0.331
	0.733	0.205	0.693
Nov-03	0.056	0.063	0.188
	0.733	0.205	0.693
Nov-28	-0.085	-0.674***	0.143
	0.733	0.205	0.693
Nov-29	0.21	-0.113	0.344
	0.733	0.205	0.693
Nov-30	0.151	-0.049	0.228
	0.733	0.205	0.693
Dec-01	0.275	0.151	0.31
	0.733	0.205	0.693
Dec-02	0.089	0.12	0.024
	0.733	0.205	0.693
Dec-28	-0.518	-0.657***	-0.475
	0.733	0.205	0.693
Dec-29	-0.565	-0.668***	-0.541
	0.733	0.205	0.693
Dec-30	-0.585	-1.056***	-0.395
	0.733	0.205	0.693
Jan-03	-0.185	-0.054	-0.33
	0.733	0.205	0.693
Jan-04	0.12	0.075	0.108
	0.733	0.205	0.693
Jan-30	-0.061	-0.048	-0.057
	0.733	0.205	0.693
Jan-31	-0.007	0.149	-0.022
	0.733	0.205	0.693
Feb-01	0.104	0.318	0.029
	0.733	0.205	0.693

Table 1 (cont'd)

	Log(Volume)		
	All Dealers	Affected Dealers	Non-Affected Dealers
Feb-02	0.232	0.22	0.125
	0.733	0.205	0.693
Feb-03	0.193	-0.038	0.13
	0.733	0.205	0.693
Feb-24	0.093	0.312	-0.138
	0.733	0.205	0.693
Feb-27	0.106	0.112	0.059
	0.733	0.205	0.693
Feb-28	0.164	0.019	0.212
	0.733	0.205	0.693
Constant	23.964***	23.075***	23.478***
	0.081	0.023	0.077
N	108	108	108
R^2	0.052	0.679	0.047

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

Note: The table presents results from OLS regressions. *Log(Volume)* is defined as the total repo volume accepted by dealer i on date *t.* The regressors are indicator variables for each day over the period {September 28 - February 28}. The table reports month-ends along with -/+ 2 days around them. The regulatory change in the reporting requirement of the leverage ratio takes place on January 01.

Table 2: The Impact of the Leverage Ratio on Repo Market

	Δlog(Volume)		
	[1]	[2]	[3]
Affected Dealer	-0.387**	-0.568*	-0.656**
	0.168	0.318	0.295
Relationship			-2.667***
			0.777
Constant	0.126		
	0.110		
Client FE	no	yes	yes
N	128	128	128
R^2	0.027	0.340	0.392

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 of dealer-client pair to the total number of repo transactions of the dealer. Standard errors allow for correlation at the dealer level.

Table 3: Client's Size and Balance Sheet Netting

	Reverse Repos/(Repos+Reverse Repos)		Pr(Reverse Repos=0 | Repos>0)	
	[1]	[2]	[3]	[4]
Small Client	-0.069**	-0.070**	0.264**	0.263***
	0.028	0.026	0.085	0.078
Dealer FE	no	yes	no	yes
N	128	128	128	128
R^2	0.016	0.217	0.081	0.207

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

Note: The table presents results from OLS regressions. In columns 1 and 2, the dependent variable is defined as the share of reverse repos in all repo and reverse repo transactions of client *j* in the pre-period. In columns 3 and 4, the dependent variable is the probability client *j* does no reverse repo transactions given he does repo transactions in the pre-period. The pre-period ranges from November 21 to December 16, 2016. *Small* is a pre-determined dummy variable, defined as client with log volume of repo transactions below the median client in the market. Standard errors allow for correlation at the dealer level.

Table 4: Heterogeneous Effects of the Leverage Ratio: Small versus Large Clients

	Δlog(Volume)			
	[1]	[2]	[3]	[4]
Affected Dealer * Small	-0.784***	-1.332***	-1.252***	-1.112***
	0.243	0.37	0.307	0.303
Affected Dealer	-0.165	-0.256		
	0.211	0.294		
Small	0.463**			
	0.174			
Relationship				-2.225**
				0.896
Constant	0.015			
	0.136			
Client FE	no	yes	yes	yes
Dealer FE	no	no	yes	yes
N	128	128	128	128
R^2	0.053	0.383	0.469	0.501

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 5: Heterogeneous Effects of the Leverage Ratio: Other Client Types

	Δlog(Volume)						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Affected Dealer * Relationship	0.256	-2.321					-1.545
	3.091	3.164					4.212
Affected Dealer * Long-Term Repos			0.346	0.393			0.475
			0.501	0.514			0.66
Affected Dealer * Foreign					-0.098	-0.003	-0.216
					0.452	0.418	0.513
Affected Dealer * Small		-1.387***		-1.407***		-1.390***	-1.348***
		0.304		0.398		0.384	0.289
Client FE	yes	yes	yes	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes	yes	yes	yes
N	128	128	128	128	128	128	128
R^2	0.455	0.493	0.422	0.465	0.419	0.461	0.498

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. In columns 1 and 2, *Relationship* is a 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 (the level effect is included in the regression, but omitted from reporting). In columns 3 and 4, *Long-Term Repos* is a pre-determined dummy variable, defined as client with average repo maturity above the median client in the market. In columns 5 and 6, *Foreign* is a dummy variable, defined as client with headquarters outside the UK. *Small* is a pre-determined dummy variable, defined as client with log volume of repo transactions below the median client in the market. Standard errors allow for correlation at the dealer level.

Table 6: The Impact of the Leverage Ratio on Other Margins of Adjustment

	Intensive Margin			Extensive Margin		
	ΔRate	ΔHaircut	Δlog(Maturity)	Δlog(#Transactions)	Exit	Access
	[1]	[2]	[3]	[4]	[5]	[6]
Panel A: Baseline						
Affected Dealer	-0.005	0.497	0.327	-0.331	0.139	-0.124
	0.025	0.409	0.209	0.199	0.167	0.207
Client FE	yes	yes	yes	yes	yes	yes
N	128	128	128	128	128	128
R^2	0.402	0.409	0.310	0.295	0.264	0.254
Panel B: Heterogeneous						
Affected Dealer * Small	-0.087***	1.045	-0.114	-0.895***	0.433*	-0.389*
	0.021	0.797	0.248	0.211	0.203	0.216
Client FE	yes	yes	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes	yes	yes
N	128	128	128	128	128	128
R^2	0.523	0.555	0.451	0.461	0.400	0.428

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}. *ΔRate, ΔHaircut* and *Δlog(Maturity)* (intensive margin) denote the pre-post change in the average repo rate, average collateral haircut and average maturity (in days) respectively and are winsorized at 1 and 99 percentiles. *Δlog(#Transactions), Exit* and *Access* (extensive margin) denote the pre-post change in the (log of) number of repo transactions, the probability of termination of an existing repo transaction and the probability of setting up a new repo transaction in the post period respectively. *Small* is a pre-determined dummy variable, defined as client with log volume of repo transactions below the median client in the market. Standard errors allow for correlation at the dealer level.

Table 7: Leverage Ratio and Reverse Repos

	Δlog(Volume)	
	Baseline	Heterogeneous
	[1]	[2]
Affected Dealer	-0.114	
	0.228	
Affected Dealer * Small		0.640
		0.725
Client FE	yes	yes
Dealer FE	no	yes
N	139	139
R^2	0.294	0.464

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 reverse 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. Standard errors allow for correlation at the dealer level.

Table 8: Substitution with Foreign Dealers and Market Adjustment

	Δlog(AggrVolume)	
	[1]	[2]
Small	0.214	-0.071
	0.235	0.136
Constant	-0.179	0.077
	0.156	0.075
Client Demand	no	yes
N	37	37
R^2	0.023	0.702

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. *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. Robust standard errors are reported.

Table 9: The Impact of the Leverage Ratio on Collateral Re-use

	ΔVelocity	Δlog(Re-use)
	[1]	[2]
Affected	0.033	0.093
	0.023	0.074
Constant	-0.014	0.071
	0.016	0.056
N	12	12
R^2	0.023	0.702

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

Note: The table presents results from OLS regressions. *ΔVelocity* is defined as a dealer's quarterly change (2017q1 - 2016q4) in the collateral re-used in repos to the total collateral received from reverse repos which is available to be re-used in repos. *Δlog(Re-use)* is defined as a dealer's quarterly change (2017q1 - 2016q4) in the (log of) collateral re-used in repos. Robust standard errors are reported.

Appendix Table 1: Summary Statistics

Variable	*Definiton*	*N*	*mean*	*median*	*sd*
Δlog(Volume)	The pre-post change in the (log of) the total repo volume accepted by dealer i from client j	128	-0.02	0.04	1.14
ΔRate	The pre-post change in the average repo rate offered by dealer i to client j	128	0.03	0.02	0.10
ΔHaircut	The pre-post change in the average collateral haircut offered by dealer i to client j	128	0.18	0	1.46
Δlog(Maturity)	The pre-post change in the average maturity (in days) offered by dealer i to client j	128	0.01	0	0.90
Δlog(# Transactions)	The pre-post change in the (log of) number of repo transactions between dealer i and client j	128	-0.05	0	0.70
Exit	The probability of termination of an existing repo trade between dealer i and client j	128	0.41	0	0.49
Access	The probability of setting up a new repo transaction in the post-period between dealer i and client j	128	0.44	0	0.49
Affected dealer	Dealer in gilt repo market subject to the regulatory change	128	0.38	0	0.48
Small	Client with volume of repo transactions below the median client in the market in the pre-period	128	0.28	0	0.45
Small (frequency dummy)	Client with (log) frequency of repo transactions below the median client in the market in the pre-period	128	0.29	0	0.45
Small (volume)	The (log) volume of repo transactions of client in the market in the pre-period	128	22.13	22.23	1.77
Small (frequency)	The (log) frequency of repo transactions of client in the market in the pre-period	128	4.42	4.87	1.36
Small (volume per transaction)	The (log of) volume to frequency of repo transactions of client in the market in the pre-period	128	17.73	17.78	0.74
Relationship	The ratio of frequency of repo transactions between dealer i and client j to total number of repo transactions of the dealer in the pre-period	128	0.01	-0.03	0.12
Long-Term Repos	Client with average repo maturity above the median client in the market in the pre-period	128	0.50	1	0.50
Foreign	Client with headquarters outside the UK	128	0.81	1	0.39
Reverse Repos/(Repos+Reverse Repos)	The share of reverse repos in all repo and reverse repo transactions of client j in the pre-period.	128	0.30	0.39	0.24
Pr(Reverse Repos=0 | Repos>0)	The probability client j does no reverse repo transactions given he does repo transactions in the pre-period.	128	0.22	0.00	0.42
Δlog(AggrVolume)	The pre-post change in the (log of) the total repo volume accepted by all dealers from client j	37	-0.06	0.07	0.71
ΔVelocity	The change of a dealer's collateral re-used in repos to the total collateral received from reverse repos	12	0.00	0.00	0.05
Δlog(Re-use)	The change of a dealer's (log of) collateral re-used in repos	12	0.12	0.12	0.15

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

Internet Appendix

Internet 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 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.

Internet Appendix Table 2: Weighted Least Squares for Other Margins of Adjustment

	Intensive Margin			Extensive Margin		
	ΔRate	ΔHaircut	Δlog(Maturity)	Δlog(#Transactions)	Exit	Access
	[1]	[2]	[3]	[4]	[5]	[6]
Panel A: Baseline						
Affected Dealer	-0.002	0.51	0.302	-0.291	0.122	-0.1
	0.021	0.417	0.2	0.205	0.177	0.212
Client FE	yes	yes	yes	yes	yes	yes
N	128	128	128	128	128	128
R^2	0.35	0.432	0.309	0.275	0.262	0.251
Panel B: Heterogeneous						
Affected Dealer * Small	-0.089***	1.096	-0.087	-0.891***	0.437*	-0.395*
	0.019	0.829	0.275	0.218	0.214	0.223
Client FE	yes	yes	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes	yes	yes
N	128	128	128	128	128	128
R^2	0.48	0.58	0.438	0.45	0.402	0.426

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

Note: The table presents results from WLS 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}. *ΔRate, ΔHaircut* and *Δlog(Maturity)* (intensive margin) denote the pre-post change in the average repo rate, average collateral haircut and average maturity (in days) respectively and are winsorized at 1 and 99 percentiles. *Δlog(#Transactions), Exit* and *Access* (extensive margin) denote the pre-post change in the (log of) number of repo transactions, the probability of termination of an existing repo transaction and the probability of setting up a new repo transaction in the post period respectively. Regressions are weighted by dealer-client log of repo volume before the regulatory change. *Small* is a pre-determined dummy variable, defined as client with log volume of repo transactions below the median client in the market. Standard errors allow for correlation at the dealer level.

Internet Appendix Table 3: Alternative Definitions for Small Client

	Δlog(Volume)			
	Frequency (dummy)	*Volume (continuous)*	*Frequency (continuous)*	*Volume/Trans.*
	[1]	[2]	[3]	[4]
Affected Dealer * Small	-1.390***	0.385***	0.454**	0.518**
	0.377	0.124	0.169	0.182
Client FE	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes
N	128	128	128	128
R^2	0.461	0.468	0.459	0.436

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 of) volume to frequency of repo transactions of client in the market. Standard errors allow for correlation at the dealer level.

Internet Appendix Table 4: Alternative Time-Windows

	Δlog(Volume)			
	Drop Year-End Day Only	*Drop November Adjustment*	*Expand Pre-Period*	*Expand Post-Period*
	[1]	[2]	[3]	[4]
Panel A: Baseline				
Affected Dealer	-0.531*	-0.828*	-0.548*	-0.312
	0.303	0.383	0.313	0.279
Client FE	yes	yes	yes	yes
N	136	111	141	144
R^2	0.265	0.329	0.464	0.385
Panel B: Heterogeneous				
Affected Dealer * Small	-0.833*	-1.227**	-0.838**	-0.871**
	0.408	0.417	0.371	0.357
Client FE	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes
N	136	111	141	144
R^2	0.397	0.468	0.558	0.452

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

Note: The table presents results from OLS regressions. In column 1 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 column 2 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 column 3 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 column 4 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. Standard errors allow for correlation at the dealer level.