Collateral Demand in Wholesale Funding Markets*

Jamie Coen[†] Patrick Coen[‡] Anne-Caroline Hüser[§]

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Repo markets are systemically important funding markets, but are also used by firms to obtain the assets provided as collateral. Do these two functions complement each other? We build and estimate a model of repo trade between heterogeneous firms, and find that the answer is no: volumes and gains to trade would both be higher absent collateral demand. This is because on average the firms that need funding are also those that value the collateral to speculate or hedge interest rate risk. These results have implications for policies that affect collateral demand in repo markets, including rules on short selling.

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[†]Imperial College London, w.coen@imperial.ac.uk.
[‡]Toulouse School of Economics, patrick.coen@tse-fr.eu.
[§]Bank of England, anne-caroline.huser@bankofengland.co.uk.

1 Introduction

Repurchase agreements (repo) serve two important functions. The borrowing firm may trade to obtain funding (liquidity demand), whereas the lender may trade to temporarily obtain the asset provided as collateral (collateral demand), including in order to short it. Together, liquidity demand and collateral demand determine repo market outcomes, which in turn shape funding market conditions, financial stability, and asset prices.

Our focus in this paper is on how these two functions interact. What drives firms' demand for collateral? How is the ability of firms to fund themselves affected by collateral demand, both in normal times and in times of stress? Does this have implications for policy that affects collateral demand, including rules on short selling?

Recent empirical work has shown that collateral demand can be material, varies across assets, time and countries, and responds to monetary policy.[1] We argue that it is the as yet unstudied variation in collateral demand *across firms* that determines gains to trade in repo markets, and so is the key to understanding how collateral demand shapes outcomes in repo markets. Our contribution is thus based on three innovations involving this variation. First, we make use of detailed transaction data on the Sterling gilt repo market[2] that include firm identifiers. This allows us to track empirical variation across firms, assets and time, and so document new empirical facts on collateral demand. Second, we set out a model of repo trading in which firms are heterogeneous in their funding needs and their collateral demand, and show that market outcomes are driven by the joint distribution of these two features across firms. Third, we structurally estimate this model in order to recover this joint distribution from transaction data. This allows us to empirically interrogate this joint distribution, quantify its effect on market outcomes, and perform counterfactual analysis of regulation. It is, to our knowledge, the first structural model of collateral demand or specialness.

Our primary finding is that collateral demand makes it harder for firms to fund themselves via repo: if collateral demand were removed from repo markets, quantities and realised gains from trade would increase. The size of the increase would be particularly large in times of financial stress, precisely when funding demand is likely to be most important. This surprising result is driven by the fact that funding and collateral demand are positively correlated across firms: firms that need funding in relative terms also care more about giving

[1] Arrata et al. (2020); Mancini et al. (2016); Roh (2019); Schaffner et al. (2019).

[2] The repo market using UK government bonds (gilts) as collateral.

up the underlying collateral. Importantly, this is not driven just by hedge funds seeking to short to speculate, but also by dealer-banks seeking to hedge their underlying interest rate risk. These firms sit at the heart of the repo market whilst simultaneously intermediating, managing their own funding needs and their own collateral demand in order to hedge risk. Our results speak to the inability of banks to simultaneously do all of these things using repo.

The starting point for our work is transaction data on close to the universe of repo lending and borrowing backed by UK government bonds, from January 2017 to March 2023. We begin by describing three empirical facts in support of collateral demand as a key motive for trading in the Sterling repo market. First, lending banks frequently charge a lower rate than the risk-free rate (Arrata et al., 2020). Second, there is material heterogeneity across firms. Hedge funds, for example, charge lower interest rates when lending than money market funds, whose limited mandates preclude a motive to demand specific gilts as collateral, and these rates are more sensitive to the precise gilt chosen as collateral. Third, interest rates are higher when the lender does not specify exactly which gilt it requires as collateral (Ballensiefen et al., 2023). These facts are difficult to rationalise if the collateral is valued only as insurance against default, and instead suggest that certain traders have demand for specific gilts and are willing to lend at lower rates in return for being provided these "special" gilts Duffie (1996).

These facts establish the presence of collateral demand, but naturally raise further questions. What else could vary across transactions and confound these effects, including firms' unobserved funding needs, their position within the trading network or the funding needs of their other counterparties? Does it matter that some firms appear to have collateral demand and some do not? Collateral demand may exist, but what is its scale and how does it affect equilibrium trade? To help with each of these we build and estimate a model of repo trading.

In the model, repo is a temporary exchange of cash for an asset. Firms use the cash they obtain to fund a risky project, but also use any assets they obtain as collateral to obtain a risky return (from shorting the asset, for example). There are multiple assets, representing each of the gilts, and the firms simultaneously write repos against any of these assets. There are two types of firms, dealers and customers, connected by an exogenous trading network that governs the set of customers with which each dealer can trade. Dealers also have access to a competitive inter-dealer market. Beyond their type and position in the network, firms are heterogeneous in the expected return they earn from cash (their funding demand) and the expected return they earn from each of the different types of collateral (their collateral demand).

The model pins down a unique equilibrium in which a firm's portfolio choices – its repo borrowing and lending against each asset – depend on its demands for cash and collateral, and those of its counterparties. The effect of collateral demand on market outcomes depends on the size of the collateral demand motive, but also on its joint distribution with funding demand across firms. If collateral demand is negatively correlated with funding demand, then collateral demand increases trading volumes as it provides an additional motive for lenders to lend. If the two are positively correlated, then the reverse is true and collateral demand can reduce trading volumes.

We then estimate our model. Our objective is to use our model and the transaction data to recover the joint distribution of funding demand and collateral demand across firms, assets and time as flexibly as possible. Our estimation involves two steps. In the first step, we estimate the net inverse demand of each firm. We include firm-gilt-time fixed effects and as an instrument for trading quantity we use shocks to the prices of the bonds commonly used as collateral by firm j to trace out the net demand of firm i. In the second step, we decompose this estimated firm-gilt-time fixed effect between funding and collateral demand by making use of the general collateral asset for which collateral demand must be zero. This semi-parametric estimation procedure gives us variation in funding demand across firms and time, and collateral demand across firms, time and gilts, whilst making very few assumptions about their joint distribution.

We interrogate this estimated joint distribution and report three novel results about how repo markets work. First, we find that collateral demand and funding demand do not co-move over time: funding demand closely follows the UK's monetary policy stance, whereas collateral demand co-moves closely with forward implied volatility in secondary gilt markets. Collateral demand spiked during the dash-for-cash in March 2020, and during the gilt market turmoil in autumn 2022, consistent with demand for short selling. The effect of collateral demand on repo market functioning is thus particularly important in times of financial stress.

Second, collateral demand varies significantly across firms, and is not limited to hedge funds seeking to speculate. Hedge funds and dealer-banks have particularly high collateral demand, whereas mutual funds, money market funds and pension funds have relatively low collateral demand. Collateral demand and funding demand are positively correlated across firms, which through the lens of our model suggests that collateral demand might impede the ability of firms to fund themselves.

Third, collateral demand predicts future changes in gilt prices. We sort gilts into long-short portfolios based on estimated collateral demand, and find that gilts for which hedge funds have relatively high collateral demand fall in price in the future, consistent with hedge funds using repo markets to speculate. Importantly, this is not true for gilts for which dealer-banks have high collateral demand, indicating that they are not using repo markets to speculate, but instead to hedge interest rate risk in their business.

Finally, we simulate a counterfactual equilibrium in which we remove any collateral demand in repo markets. This quantifies exactly how collateral demand affects repo market functioning, and is also relevant for any policy that could reduce or remove collateral demand in repo (including bans on short selling or on naked short selling). We find that quantities and gains to trade in repo markets would increase in this counterfactual, very materially so in periods of financial stress when estimated collateral demand was high. Removing the existing prohibition on naked short selling of gilts could, therefore, enhance repo market functioning.[3]

The negative effect of collateral demand on repo market functioning stems from the fact that collateral and funding demand are positively correlated across firms – the firms that desire funding tend to be the same as the firms that value collateral. We illustrate this in a second counterfactual in which we first reallocate estimated collateral across firms such that they are *negatively* correlated, and compare this to the first counterfactual scenario in which collateral demand is removed. In this alternative, removing collateral demand would decrease quantities and gains to trade, confirming that it is indeed the correlation of collateral and funding demand across firms that drives our results.

In conclusion, collateral demand appears to impede the ability of firms to finance themselves via repo, rather than 'lubricating' it as suggested by Singh (2011), and particularly so in times of financial stress. A key driver of this result is that dealer-banks have both high funding demand and high collateral demand, as they need to hedge underlying interest rate risk. The structure of repo markets makes it difficult for dealer-banks to simultaneously do these two things: acquiring liquidity requires them to give up gilts, when both are relatively more valuable to dealer-banks than to other firms. Collateral demand, and its regulation, is thus of central importance to the most important wholesale funding market.

[3]The UK is currently considering lifting a prohibition on naked shorting of gilts (Short Selling Regulation Review (July 2023), HM Treasury). This would allow banks to sell gilts without first acquiring them temporarily through repo markets.

In Section 2, we describe the relevant institutional detail of the UK repo market and our data. In Section 3, we set out empirical facts, including general summary statistics and specific facts about collateral demand. In Section 4, we describe our model. In Section 5, we describe our estimation. In Section 6, we set out our results. In Section 7, we describe counterfactual analysis of the importance of collateral demand. In Section 8, we conclude.

1.1 Related literature

Our primary contribution is to the empirical literature on repo markets. Important papers in this literature include Copeland et al. (2014); Gorton and Metrick (2012); Hu et al. (2021); Krishnamurthy et al. (2014) on the US repo market and Mancini et al. (2016) and Boissel et al. (2017) on European repo markets. Within this growing field, we contribute to three specific strands.

The first strand studies the role of collateral demand in the repo market. Duffie (1996) defines a special as a repo rate significantly below prevailing market riskless interest rates. This can occur when competition to buy or borrow a particular bond causes buyers in the repo market to accept a lower interest rate in exchange for cash in the transaction. Recently, several empirical analyses have looked into specialness in the repo market, also against the backdrop of quantitative easing policies in major financial markets (Arrata et al., 2020; Jappelli et al., 2023; Mancini et al., 2016; Roh, 2019). Of particular relevance to our work are the findings by Ballensiefen et al. (2023) and Schaffner et al. (2019), who document that the euro money market is more segmented when the collateral motive prevails. Repo rates lent by banks with access to the deposit facility and secured by QE eligible assets are more collateral-driven and disconnected from funding-based money market rates. Our contribution to this literature is (1) to leverage novel data on how collateral demand varies across firms, (2) formalise in a model why such variation matters and (3) structurally estimate a model of collateral demand and document its equilibrium effects on repo markets.

The second strand of literature seeks to build and estimate structural models of the repo market. Two particularly relevant papers here are Eisenschmidt et al. (2022) and Huber (2023), who build structural models of the European and tri-party US repo market, respectively. Eisenschmidt et al. (2022) seek to understand the impact of market power on the pass-through of monetary policy. Huber (2023) shows that market power has a material impact on spreads earned by dealers when trading with cash lenders. We are the first in this structural literature to study and quantify the importance of collateral demand for repo market outcomes.

The third focuses on how collateral moves through the repo market. Andolfatto et al. (2017), Gottardi et al. (2019) and Infante (2019), for example, focus on rehypothecation in repo markets from a theoretical perspective. Empirical work by Singh (2011) and Aitken and Singh (2010) describe the possibility of collateral rehypothecation as a lubricant to repo market functioning. Our contribution is to show theoretically that collateral demand can have a positive or negative impact on the financing role of repo markets, and to show that empirically this impact is negative.

There is also a literature on the market for lending assets, including for the purposes of shorting (Foley-Fisher et al., 2019, 2016; Sikorskaya, 2023). D'Avolio (2002) and Asquith et al. (2013) look at depository institutions that lend equities or corporate bonds, respectively, and study what that implies for the constraints faced by arbitrageurs. Similarly, Chen et al. (2022) estimate a structural model and demonstrate how market power in the market for equities lending affects asset prices, through the effect on short sellers. We examine asset lending in the context of repo, and quantify how that relates to liquidity demand.

Finally, there is a broad literature on why repo markets exist, given the possibility of uncollaterized lending and asset sales. Explanations include asymmetric information Bigio (2015) and differences of opinion Geanakoplos (2010). Our model is in the spirit of the latter, in that firms have different uses for cash and the bonds. Our structural model allows us to quantify such differences, and show how complementarities between funding demand and collateral demand are an important driver of repo market outcomes.

2 Institutional setting and data

2.1 Institutional setting

In a repo transaction, a firm sells an asset to a counterparty with a commitment to buy it back at a future date. Repo is thus collateralised lending, where the initial seller of the asset is the borrower and the buyer is the lender. The repo rate is the percentage difference between the price at which the lender buys the asset initially and the price at which they sell it back, and can be thought of as the rate of interest on the cash lent. The lender in a repo contract obtains temporary ownership of the asset for the life of the repo contract. They can then use this asset in other transactions, for example lending it to someone else, using it as collateral in another repo transaction or using it to short. This aspect of repo transactions – the fact that the collateral is useful for the lender – and its implications for market functioning is the focus of our paper.

Our setting is the Sterling gilt repo market, where financial institutions write repos with each other backed by UK government bonds (gilts).[4] Participants in these markets include banks, hedge funds, money market funds, mutual funds, insurers, pension funds, governments and central banks. These markets are typically intermediated by dealer-banks, who borrow from lending institutions and lend to borrowing institutions.

Repo trades can take place over-the-counter or on centralised exchanges. In the UK, almost all repos between dealer-banks and non-banks are cleared bilaterally, whilst almost all inter-dealer trades are centrally cleared. In contrast to the US market, triparty repo is rare. See Hüser et al. (2021) for a fuller discussion of the institutional details of repo in the UK.

2.2 The role of liquidity and collateral demand

Market participants access repo markets for two broad reasons. The first reason is to cheaply and efficiently obtain short-term funding without selling assets, or 'liquidity without liquidation'. Regulation post the Great Financial Crisis incentivised collateralised borrowing rather than uncollateralised borrowing. Repo markets are more stable and more likely to be rolled over than uncollateralised markets, as well as more diversified in that liquidity is supplied by a broad range of firms and not just commercial banks. Repo is arguably the most important source of short-term financing for a broad range of financial firm types.[5]

The second reason is to temporarily obtain the underlying assets provided as collateral. Firms may want to do this, as opposed to purchasing the underlying asset, for one of three broad reasons:

- Speculation: borrowing the collateral through repo markets or through securities dealers is the first part of a shorting trade. Market participants, and hedge funds in

[4] For a broader background on this market, there have been several recent empirical studies on the Sterling gilt repo market. Key topics included the relationship between dealer intermediation and the regulatory framework (Bicu-Lieb et al., 2020; Erten et al., 2022; Kotidis and Van Horen, 2019; Noss and Patel, 2019), the liquidity stress cause by the COVID-19 pandemic (Czech et al., 2021a; Hüser et al., 2021), the LDI stress (Pinter, 2023), the impact of central clearing counterparties on repo rates (Benos et al., 2022) and the analysis of repo terms Julliard et al. (2023).

[5] This sub-section is based primarily on a detailed overview of how repo markets are used in practice by the International Capital Markets Association (ICMA). https://www.icmagroup.org/market-practice-and-regulatory-policy/repo-and-collateral-markets/icma-ercc-publications/frequently-asked-questions-on-repo/3-what-is-the-role-of-repo-in-the-financial-markets/.

particular, may therefore supply liquidity in repo markets in order to bet against particular assets. Repo is the primary way of obtaining gilts temporarily, as securities lending focuses on equities.[6]

- Hedging: participants may seek to short the underlying assets not for speculative reasons, but in order to hedge risk. This applies in particular to banks, whose other activities result in material risk related to the underlying bonds: "[h]*edging the interest rate risk on inventory means taking an off-setting short position in another security with a similar duration, which means borrowing the other security in the repo market*" (ICMA).[7]

- Speed/convenience: firms that require a particular bond may find it faster, cheaper or more convenient to temporarily acquire the bond through repo markets. For example, a market-maker in the secondary bond market that receives a buy order for a bond that it does not hold in inventory may choose to temporarily acquire via repo, sell it, and then acquire it at a later date to settle the repo trade.

2.3 Policy

The repo market is affected by a broad range of policy and regulatory decisions. We focus on one in particular: the prohibition of naked short selling in UK government bonds. This requires a firm wishing to short a given gilt to first temporarily acquire the bond through the repo market or a securities dealer. Lifting this prohibition could materially reduce collateral demand in repo markets.

In July 2023 the UK government launched a consultation on lifting this prohibition, with the aim of improving liquidity in secondary government bond markets.[8] As well as potentially affecting secondary bond markets, this policy change would have an impact on the functioning of the repo market, depending on the scale and distribution of collateral demand related to shorting and how it affects outcomes. We consider the impact of this policy change on the repo market in counterfactual simulations below.

[6]https://www.icmagroup.org/market-practice-and-regulatory-policy/repo-and-collateral-markets/icma-ercc-publications/frequently-asked-questions-on-repo/13-what-is-the-difference-between-repo-and-securities-lending/.

[7]https://www.icmagroup.org/market-practice-and-regulatory-policy/repo-and-collateral-markets/icma-ercc-publications/frequently-asked-questions-on-repo/3-what-is-the-role-of-repo-in-the-financial-markets/.

[8]https://assets.publishing.service.gov.uk/media/64abfc4e112104000cee65a5/Short_Selling_Regulation_Review_-_sovereign_debt_and_CDS_consultation_document__1_.pdf.

2.4 Data

The Bank of England Sterling Money Market data contain detailed transaction data on repo and reverse repo for which the collateral is UK government bonds. Our data include trades reported by banks and major broker dealers between 2017 and 2023. Transactions in which neither party is a bank or major broker dealer are omitted in the data, but in practice such transactions are immaterial (Hüser et al., 2021). The data include counterparty identifiers, the amount lent, the repo rate, the maturity and the gilt provided as collateral. The data also include various characteristics of the trade, such as whether it took place via a brokerage platform and if it was centrally cleared. The data also identify where collateral for a trade was "general collateral": in such trades, a clearing house monitors the value of the collateral pledged, and where necessary tops it up by transferring extra collateral from a pre-specified pool of gilts from the cash borrower.[9] In these trades the collateral is therefore not a pre-specified gilt, but is an unspecified single gilt or combination of gilts from a set of eligible gilts. In some transactions the haircut is also reported.

The primary advantage of this dataset relative to others used in the literature is its granular transaction-level detail including complete firm identifiers. This detail allows us to leverage variation across different types of collateral but *within firm*, and then comprehensively track how behaviour in the repo market varies across firms and firm types. We also make use of transactions that have general collateral and so do not specify the bond to be supplied as collateral, as do Schaffner et al. (2019) and Mancini et al. (2016). Variation within firms but across transactions that do and do not specify the underlying collateral drive the identification of collateral demand in our structural model.

We supplement this data with end-of-day prices of the 50 most popular gilts in our dataset, from Bloomberg. We report summary statistics in the following section.

3 Empirical facts

In this section we document two sets of facts on repo. We first describe summary statistics on the structure of the Sterling gilt repo market that drive our modeling approach. The second set of facts establishes the role played by collateral demand in driving trading in this

[9]General collateral repo transactions against gilts are cleared via the delivery-by-value (DBV) trading mechanism. For further details see https://www.bankofengland.co.uk/-/media/boe/files/news/2013/january/joint-initiative-to-introduce-a-cleared-term-delivery-by-value-service.pdf.

market.

3.1 Summary statistics

Transaction characteristics. We describe mean transaction characteristics in Table 1. Repos are frequently traded and in large volumes: each week there are over 20,000 trades and a total trading volume of £900bn. The majority of repo transactions are short maturity, as set out in Table 1: 40% are overnight and a further 36% are one week or less. Dealers and banks trade with each other and with customers, and there is no inter-customer trade. Our data on haircuts is incomplete and relatively low quality, but over 80% of the observations are reported as involving a haircut of 0.

Collateral heterogeneity. There is significant variation in the collateral against which firms borrow. In our dataset 209 distinct bonds appear as part of a repo transaction at least 50 times. In an average week 80 of these bonds are used as collateral in a repo transaction.

Figure 1 summarises the variation in the collateral against which firms borrow. For each week, we compute the fraction of active borrowing firms that use each gilt as collateral, and ranks gilts from most used to least used. We then average this across weeks, such that, for example, the first bar shows the fraction of firms each week that on average borrow against the most used bond in each week. It's clear from Figure 1 that firms borrow against different collateral. In the average week, less than one third of firms are borrowing against the most popular gilt.

This variation in gilts used as collateral likely reflects the fact that not all firms hold all gilts. In section 5 we will use this variation in collateral to help identify exogenous variation in repo demand across firms.

Firm heterogeneity. Participants in the gilt repo market include dealers, banks, hedge funds, money market funds, mutual funds, insurers, pension funds and other types of firm. In Table 2 we show their trade shares, and their daily net lending in both percentage and absolute terms. In what follows we will highlight the differing behaviour of dealers, hedge funds and money market funds (MMFs). These three sets of firms are of particular interest to our analysis as their business models imply specific patterns of collateral demand. Table 2 summarises the net trading behaviours of these three types of firms.

- Dealers participate in this market to obtain both funding and collateral. Cash and securities may be used for the dealers' own activities or is being sourced for their clients. Dealers also intermediate on behalf of their clients. Table 3 shows the rates dealers earn on their repo lending vs their borrowing. Dealers earn a spread, both in aggregate and within assets and time periods. This is consistent with Huber (2023) and Eisenschmidt et al. (2022), who find that dealers enjoy market power in US and European repo markets respectively.

- MMFs are almost uniquely lenders in repo markets. MMFs are mutual funds that invest in low-risk, short-term (typically government) securities. MMFs keep a fraction of their assets invested in cash. They lend this cash out as repo as it earns them a return and but remains a safe investment as it is collateralized. This can be seen in Table 2: they are almost solely lenders in the gilt repo market. The collateral they receive is pure risk mitigation or insurance against the counterparty's default. They do not short sell assets and nor do they typically write derivatives assets. As a result the collateral demand motive for trading repo is missing for these firms.

- Hedge funds play a very different role. As shown in Table 2, their activities are roughly balanced between lending and borrowing. This is because repo serves a dual purpose for hedge funds: they use repos in order to fund their activities (Barth and Kahn, 2021), but also in order to obtain the asset, for example to short it (Adrian et al., 2013). For example, a hedge fund following a strategy of yield curve arbitrage looks to take long and short positions at different points on the yield curve, and may use repo to implement its short positions. For hedge funds, then, obtaining collateral is not just for risk mitigation, but also represents their demand for securities.

We will use the different trading motives of these firms to study the role of collateral demand in repo below.

Trading network. The network of trading relationships is sparse, and fixed through time. Fewer than 2% of counterparty pairs have non-zero trade in the whole sample. Over 95% of transactions after January 2022 onwards were between traders who had traded together before January 2022. As a result, in our model we will treat the network of links between firms as fixed.

3.2 Empirical facts on collateral demand

We present three facts about repo interest rates that establish the role of collateral demand in driving repo trading.

Fact 1. The demand for collateral plays a major role in driving repo trading. Figure 2 shows the rates dealers earn on their repo lending, together with the rate paid on reserves at the Bank of England. If the only benefit to repo lending for dealers was to earn a return, they should not lend at a lower rate than that which they can earn risk-free by placing their money with the central bank. As Figure 2 shows, dealers frequently lend in the repo market at rates below Bank rate, as documented by Arrata et al. (2020). This can only be rationalised if repo lending is about more than just earning a return, but is also about obtaining the collateral.[10]

Table 4 provides further support for this fact. We regress the repo rate (net of Bank rate) on various combinations of fixed effects. The first set describe the terms of the transaction taking place: the collateral being pledged and the maturity of the lending relationship. If two firms are offering to lend for the same maturity against the same gilt at the same time, they are in effecting offering the same contract. The second set of fixed effects describes who is writing the contract.

For trades in a given week, the repo rate is determined in large part by which gilt is provided as collateral. These gilts are claims on the same issuer – the UK government – who has essentially no risk of default, and the repo contracts themselves tend to be of very short maturity (Table 1) and thus themselves face very little risk of default. It is therefore unlikely that the differences in repo rates across different gilts capture differences in their value as insurance in case of default. It is much more consistent with the idea that at certain times certain gilts are desirable, that repo is a way to obtain these gilts, and traders are willing to pay higher rates to obtain them.

Fact 2. The demand for collateral varies across traders and assets. Different types of firm have different motives for trading in the repo market. To draw out the differences in the demand for repo as a means of getting a security we focus on the different trading activities of MMFs and hedge funds. As explained above, MMFs have little reason to prefer a specific gilt as collateral against another: both are claims on the same institutions. Hedge funds, by contrast, often trade in order to obtain a specific asset for use in short-selling or in derivatives contracts. The collateral demand motive is thus present for these firms.

This difference in the role of collateral for hedge funds and MMFs can be seen in Table 5. For each of these two types of firms, we take transactions in which they were lending via repo

[10] Note that the very narrow difference between repo rates and the central bank rate suggest concerns about creditworthiness are only minor determinants of repo rates.

and regress the repo rate they earn on various combinations of fixed effects. For each type of firm, the week in which the transaction took place and the maturity of the repo contract explains about 50% of the variation in rates. For MMFs, the rest of the rate variation can be almost entirely explained by interacting these week-maturity fixed effects with the identity of the borrower: two MMFs lending to the same borrower in the same week at the same maturity tend to do so at roughly the same rate, regardless of the identity of the MMFs, which gilt is used as collateral, or anything else. This is consistent with (Huber, 2023), who finds in the US that a given MMF lends to different dealers at different rates, but a given dealer borrows from different MMFs at roughly the same rate.

The identity of the borrower does not play a large role in determining hedge fund repo lending rates. Instead, the variation in hedge fund lending rates is explained by which gilt was provided as collateral. Two hedge funds lending in the same week at the same maturity against the same gilt tend to do so at roughly the same rate.

Together, this implies that collateral demand creates variation in demand across traders, and across specific assets.

Fact 3. Collateral demand lowers rates for borrowers. Table 7 shows how the repo rate depends on whether a repo is against a specific gilt as collateral, or against general gilt collateral.When a firm lends against a specific asset, the asset is potentially performing two functions for them: it provides them with collateral in case of counterparty default, and it gives them temporary ownership of a specific asset for the duration of the contract. If they desire this *specific* asset, for example to short sell it or to provide it to another counterparty, this second function is valuable for them. Where lending is collateralised by general gilt collateral rather than a specific gilt, this motive of lending in order to obtain a particular asset is absent (Ballensiefen et al., 2023).

Borrowing against a specific gilt is cheaper than borrowing against a set of gilts (Table 7). We interpret the coefficient on 7 in Table 7 as capturing the value of receiving specific collateral in a repo.

Table 6 provides further evidence on the relationship between repo rates and collateral demand. As discussed above, hedge funds have an incentive to demand specific assets as collateral whilst MMFs do not. Table 6 contrasts the repo rates that firms pay when borrowing from hedge funds and repos. As a result of the further benefit they get from receiving the collateral, hedge funds lend at a lower rate than MMFs.

Together, these facts suggest that where a borrower can offer useful collateral to a counterparty, they are able to obtain funding at a cheaper rate.

4 Model

Our reduced-form empirical facts about differences across trader types suggest a role for collateral demand in driving trade in repo markets. There are, however, limits to their interpretation. First, the observed differences across firm types could be due to unobserved differences in funding needs. That is, hedge funds could demand lower rates than money market funds when lending because they simply have lower funding needs, not because of collateral demand. Second, the observed differences could be to do with differences across firm types based on their network position, including the degree of market power they face or the funding needs of their counterparties. Third, the facts above relate to differences in the repo rate, which could be rationalised through differences in trade size. Fourth, it is hard to judge the scale of the observed differences, or put differently the precise *quantitative* effect of collateral demand on equilibrium trade. Fifth, naked shorting is currently prohibited and was throughout our sample period, meaning we cannot directly observe the effect of lifting this prohibition.

For these reasons, we set out a model that formalises the role of the network and the way in which the various elements of a repo transaction are determined in equilibrium. The model also formalises the roles of collateral demand and funding needs, such that the identifying assumptions to disentangle them are clear. Finally, a model allows us to demonstrate the magnitude of collateral demand and the effect of policy through counterfactual simulations.

4.1 Overview

Firms trade multiple assets on a network. In a repo transaction the borrower sells a given gilt with an obligation to repurchase it in the future: the borrower temporarily obtains cash in exchange for the gilt, whereas the lender obtains the gilt in exchange for cash. The transaction specifies the loan amount and the interest rate paid by the borrower to the lender. The assets are heterogeneous only in the gilt used as collateral (we abstract away from maturity, for example).

Firms may have a desire for cash (representing liquidity needs) and their desire for specific gilts as collateral (representing their collateral demand, including for shorting or delivery as part of a futures contract). The payoffs to cash or collateral are risky, but there is no default risk when transacting. Firms are heterogeneous in their liquidity needs, their collateral demand, their network position (the set of firms with whom they can trade) and their market power.

4.2 Setup

Let $\mathcal{A}$ denote the set of distinct assets, which we index by $a \in (0, 1, ..., N_a)$. Assets 1 to N_a each represent repo using a given bond as collateral. Asset 0 represents repo with general collateral that, as described in Section 2 above, does not specify a particular bond. We treat this asset 0 differently in estimation, but within the model it is an asset with its own characteristics like any of the others.

There are two types of firm: dealers and customers. Dealer i may transact with customer j or with an inter-dealer market which we index by D. Let q^a_{ijt} be the dollar amount borrowed by dealer i from customer j with asset a as collateral and q^a_{iDt} the amount borrowed from the inter-dealer market. The model is static, and so in the remainder of the model section we omit the t subscript for clarity. These amounts can be negative, indicating that i lends to j or D. The interest rate paid is r^a_{ij} and r^a_{iD}. We assume that a repo transaction in which \$10m is lent involves the same value of the bond being provided as collateral.[11]

There are N_d dealers and N_c customers, that for each asset a are connected within a network denoted by the $N_d \times N_c$ matrix $\mathbf{G}^a$. If element $G^a(i,j) = 1$ then dealer i and customer j can trade asset a, if $G^a(i,j) = 0$ then they cannot trade. Customers cannot trade with each other and do not have access to the inter-dealer market. This network of trading relationships is exogenous. Let $\mathcal{N}^a_i$ denote the set of counterparties to which firm i has access for asset a, including, if firm i is a dealer, the inter-dealer market.

Let $Q^a_i = \sum_{k \in \mathcal{N}^a_i} q^a_{ij}$ be the total net amount borrowed by firm i against asset a, and let $Q_i = \sum_a Q^a_i$ denote the total net amount borrowed by firm i across all assets. The firm uses this borrowed cash to fund a risky project with expected return ν_i and unit variance: firms are thus heterogeneous in their funding demand ν_i. Firm i may also obtain a risky payoff from the collateral that has expected return η^a_i and variance σ. Finally, firms may also earn a non-pecuniary payoff from the transaction, ϵ^a_{ij}, which is a structural error representing the importance of specific trading relationships and any other unmodelled shocks to individual transactions.

[11] This is the same as haircuts being 0, which is true for over 80% of the transactions in our sample.

Firms are thus heterogeneous in the returns to cash and to temporary ownership of the asset, as captured by ν_i and η_i^a. Importantly, this heterogeneity in collateral demand could come from at least two different sources: differences in beliefs about the returns to the underlying assets (which we term a "speculation motive") or differences in endowments/pre-existing exposures to those assets ("hedging motive"). We do not disaggregate collateral demand η_i^a between these two motives here, but consider such a disaggregation post-estimation.

Firms have mean-variance preferences, with risk aversion $\kappa/2$. The utility to firm i is:

$$\nu_i Q_i - \frac{\kappa}{2} Q_i^2 - \sum_a \eta_i^a Q_i^a - \sum_a \frac{\kappa}{2} \sigma (Q_i^a)^2 - \sum_a \sum_{m \in \mathcal{N}_i} q_{im}^a (r_{im}^a + \epsilon_{im}^a) \tag{1}$$

4.3 Solving the model

We first consider trades between dealers and customers, before considering inter-dealer trade. We assume that dealers have market power with respect to customers, whereas customers are price takers, in keeping with our empirical evidence and existing findings in the literature (Eisenschmidt et al., 2022; Huber, 2023).

The first order condition for customer j in the periphery with respect to q_{ij}^a is as follows, remembering that q_{ij}^a is the amount lent from j to i:

$$\underbrace{-\nu_j + \kappa Q_j}_{\text{- } j\text{'s MB from cash}} + \underbrace{\eta_j^a + \kappa \sigma Q_j^a}_{j\text{'s MB from collateral}} + r_{ij}^a = 0 \tag{2}$$

The first order condition for dealer i transacting with customer j with respect to q_{ij}^a has two additional term representing the price effect, which follow directly from the equilibrium condition in Equation 2: borrowing marginally more from j increases j's marginal value for cash and decreases its marginal value for collateral, both of which increase the rate at which j is willing to lend to i.

$$\underbrace{\nu_i - \kappa Q_i}_{i\text{'s MB from cash}} \underbrace{- \eta_i^a - \kappa \sigma Q_i^a}_{\text{- } i\text{'s MB from collateral}} \underbrace{- \kappa \sum_l q_{ij}^l - \kappa \sigma q_{ij}^a}_{\text{Price effect}} - \epsilon_{ij}^a - r_{ij}^a = 0 \tag{3}$$

These two first order conditions together pin down the equilibrium interest rate and trade, conditional on each firm's other trades. Turning to interdealer trade, we assume that the interdealer market is competitive and clears with a single interdealer rate such that aggregate interdealer trade in a given asset must sum to 0: $\sum_i q^a_{iD} = 0$. The first order condition for dealer i with respect to q^a_{iD} is as follows:

$$\underbrace{\nu_i - \kappa Q_i}_{i\text{'s MB from cash - }} \quad \underbrace{-\eta^a_i - \kappa\sigma Q^a_i}_{i\text{'s MB from collateral}} \quad -\epsilon^a_{iD} - r^a_D = 0 \tag{4}$$

To pin down the equilibrium interdealer interest rate, sum Equation 4 over all dealers and impose the market clearing condition that $\sum_i q^a_{iD} = 0$. It follows immediately that the equilibrium interdealer rate r^a_D is a function of the average ν_i and η^a_i across dealers and their average trades with customers. These first order conditions pin down the unique set of equilibrium portfolio choices by firms.

The model build on and adapts the model of Eisfeldt et al. (2023) on credit default swaps in the following ways to make it suitable for our setting. We include a role for collateral demand, and in doing so include multiple assets as we allow for differences across repos depending on the underlying collateral. We assume that the core of our network has market power, in keeping with the literature on repo (Eisenschmidt et al., 2022; Huber, 2023) and our empirical facts. Finally, we do not include reduced form concentration aversion, but instead obtain the necessary curvature to payoffs through risk on the collateral demand side.

4.4 Simplified example

To illustrate some of the mechanisms in the model, consider the case with a single dealer (indexed by i), a single hedge fund (j) and a single asset. Let $\Delta\nu \equiv \nu_i - \nu_j$ denote the relative difference in funding needs between them and $\Delta\eta \equiv \eta_i - \eta_j$ the relative difference in collateral demand. For ease of exposition, suppose ϵ_{ij} is equal to 0.

Equilibrium net borrowing by i from j follows immediately from the linear first order conditions:

$$q_{ij} = \frac{\Delta\nu - \Delta\eta}{3\kappa(1+\sigma)} \tag{5}$$

We make two points with this simple example. First, changes in collateral demand that are *common* to both traders do not affect the quantity traded: Equation 5 makes clear that all that matters is the difference in collateral demand across firms, such that common collateral demand drops out. If, for example, temporary ownership of the asset becomes more valuable to everyone, then this does not affect trade in repo because the increased desire of the lender to acquire the asset is offset by the decreased desire of the borrower to give it up.

The second point concerns the effect of collateral demand on trade volume. One way to think about this would be by reference to the case in which collateral demand is removed by setting $\eta_i = \eta_j = \Delta\eta = 0$. The effect of collateral demand on net borrowing by i from j is obvious from Equation 5: removing collateral demand decreases net borrowing by i if j had relatively greater collateral demand than i.

One minor complication is the fact net borrowing by i and trade volume are not the same thing: net borrowing can be positive or negative, whereas trade volume is *absolute* net borrowing by i, $abs(q_{ij})$. To illustrate the effect of collateral demand on volume, suppose that $\Delta\eta$ is positive, indicating i has greater demand for the asset. Consider two cases:

- Suppose $\Delta\nu$ is positive and q_{ij} is positive, indicating i is the borrower. In this case, trading volume would be *greater* absent collateral demand, as i's collateral demand decreases its desire to borrow.
- Suppose instead that $\Delta\nu$ and q_{ij} are negative, indicating i is the lender. In this case, trading volume would be *lower* absent collateral demand, as i's collateral demand increases its desire to lend.

In the first case, funding need and collateral demand are positively correlated, and collateral demand reduces volumes. In the second case, funding need and collateral demand are negatively correlated, and collateral demand increases volumes.

To show this more formally, we introduce squared net borrowing $(q_{ij})^2$ as a reasonable index for trade volumes that avoids the kink in the absolute function. To explicitly model the relationship between funding needs and collateral demand, suppose $\eta_k = \rho_{\eta\nu}\nu_k\bar{\eta}$ for $k \in \{i, j\}$, where $\rho_{\eta\nu}$ represents the correlation between a firm's funding needs and its collateral demand, $\bar{\eta}$ represents the level of collateral demand ($\bar{\eta} = 0$, for example, removes collateral demand entirely), and we have omitted any common intercept as it does not matter for trade. Let $\rho_{\eta\nu}\bar{\eta} < 1$, implying that collateral demand is not more sensitive to funding need than funding need itself. Squared trade is as follows:

$$(q_{ij})^2 = \left[\frac{\Delta\nu}{3\kappa(1+\sigma)}\right]^2 (1 - \rho_{\eta\nu}\bar{\eta})^2 \tag{6}$$

It follows immediately that trade volume is increasing in the level of collateral demand $\bar{\eta}$ if $\rho_{\eta\nu} < 0$ and is decreasing if $\rho_{\eta\nu} > 0$.

The implication is that the effect of collateral demand on market functioning depends on its joint distribution with funding needs. If firms with low funding needs have high collateral demand, then collateral demand lubricates the repo market: natural lenders have more reason to lend, implying that collateral demand increases the gains to trade. If, however, firms with high funding needs have high collateral demand, then collateral demand reduces trade in repo: natural borrowers have less reason to borrow. Thus the effect of collateral demand on repo market functioning is an empirical question.

In the section on counterfactual analysis below, we will undertake exactly this analysis for estimated collateral demand and funding needs across all traders, and show the effect of removing collateral demand on trade and payoffs.

5 Estimation

We now turn to estimating our model. As described above, the empirical facts suggest that collateral demand varies across firms and across time, and in the model we show how the effect of collateral demand on repo market functioning depends critically on its distribution across firms and time. Our task in estimation, therefore, is to infer firms' funding needs ν_{it} and collateral demand η_{it}^a with as much generality as possible, together with firms' risk aversion κ and the risk associated with collateral demand σ.

We limit our dataset to the 50 most frequently traded gilts. We aggregate our transactions data to the pair-asset-day level, such that for each pair of firms that write repos on a given day against a given gilt, we compute their net repo trading against that gilt on that day q_{ijt}^a, together with the average interest rate on these transactions r_{ijt}^a. This gives us a dataset that varies across pairs $i - j$, gilts a and days t.

We estimate a separate funding need ν_{it} for each firm i on day t, and a separate collateral demand η_{it}^a by firm i for asset a at time t. As a result, we need to find the unknown parameter vector $\mathbf{\Theta} = (\boldsymbol{\nu}, \boldsymbol{\eta}, \kappa, \sigma)$: respectively, the vector of firm funding needs across firms and days, the vector of collateral demand across firms, days and assets, risk aversion and the risk associated with collateral demand. We look to infer this parameter vector from transaction data on trading quantity $\mathbf{q}$ and the interest rate paid by the borrower $\mathbf{r}$, using estimating equations implied by our model. Equations 2 and 3 of our model imply the following estimating equation:

$$r^a_{ijt} = \delta^a_{it} - \left[\kappa \sum_l q^l_{ijt} + \kappa\sigma q^a_{ijt}\right] \mathbb{1}_{ij} + \underbrace{\delta_{ij} + u^a_{ijt}}_{\epsilon^a_{ijt}} \tag{7}$$

where $\mathbb{1}_{ij}$ is an indicator variable that takes the value 1 if i is a dealer in the core and j is in the periphery (indicating market power), and 0 otherwise, and where the $i \times t \times a$ fixed effect δ^a_{it} captures i's preferences over cash and the gilt:

$$\delta^a_{it} = \nu_{it} - \kappa Q_{it} - \eta^a_{it} - \kappa\sigma \sum_m q^a_{imt} \tag{8}$$

We have disaggregated the pairwise shock ϵ^a_{ijt} into an $i-j$ fixed effect and a residual u^a_{ijt}. All our identification thus takes place within firm pairs.

Our estimating approach involves two steps: first to estimate the curvature parameters κ and σ from estimating Equation 7, and second to estimate ν_{it} and η^a_{it} using Equation 8. We discuss each step in turn.

Step 1: Estimating curvature parameters

In estimating Equation 7, the primary challenge is that rates and quantities are jointly determined, so we need exogenous variation in trading quantity q^a_{ijt}.

We obtain this variation by making use of the facts that (a) firms differ in the gilts against which they borrow, as shown in Figure 1, (b) the prices of different gilts vary differentially through time, and (c) these prices are plausibly exogenous, in that they are unlikely to be affected by the repo transactions of individual pairs of banks. As a result, we can use variation in gilt prices to isolate exogenous variation in firm j's net demand for cash and collateral in Equation 7, and use this to identify the slope of i's net demand for cash and collateral, which gives us κ and σ.

Formally, we compute two instrumental variables for the two endogenous terms in Equation 7, which capture j's net demand for cash and asset a at time t. To do so, for each firm j at time t we construct a measure of their "wallet": the subset of gilts which they hold, and against which they can borrow. We look at the preceding 4 weeks, and identify the set of gilts ω_{jt} against which firm j borrowed, and the amount of their borrowing that was against each of these gilts s^a_{jt-1}, for all a in ω_{jt}. We then construct the sum of the prices of the bonds in j's wallet, weighted by their amount of borrowing against each asset s^a_{jt-1}:

$$z_{1,jt} = \sum_{a \in \omega_{jt}} s^a_{jt-1} \times \text{price}^a_t \tag{9}$$

If this decreases, this means j has a lower value of collateral against which they borrow, which means their ability to borrow is more constrained. As a result, we should see a positive relationship between j's borrowing and its instrument $z_{1,jt}$.

We then construct a second instrument as follows:

$$z^a_{2,jt} = z_{1,jt} - s^a_{jt-1} \times \text{price}^a_t \tag{10}$$

This is the change in the value of the gilts in j's wallet, *except asset a*. If this decreases then the other assets in j's wallet are less valuable, which means that – conditional on the value of a not changing – they will aim to borrow more heavily against gilt a to fill the shortfall. As a result, we should see a negative relationship between j's borrowing in a and its instrument $z^a_{2,jt}$.

We use these instruments in the following first-stage regressions for the two endogenous variables in our estimating Equation 7:

$$q^a_{ijt} = \alpha^a_{1,it} + \beta_1 z_{1,jt} + \beta_2 z^a_{2,jt} + \alpha_{1,ij} + e^a_{ijt} \tag{11}$$

$$\sum_l q^l_{ijt} = \alpha^a_{2,it} + \beta_3 z_{1,jt} + \beta_4 z^a_{2,jt} + \alpha_{2,ij} + e^a_{ijt} \tag{12}$$

These instruments are in effect shift-share instruments, where the shares are determined by the amount of borrowing of firm j against different gilts. The instruments shift j's net demand and thus identify the slope of i's net demand.

The identifying assumption is that these instruments are independent of the pairwise shocks u^a_{ijt}, which in turn requires that gilt prices and the shares used in computing our instrument are independent of these shocks.

The independence of pairwise shocks and gilt prices is – given the demanding fixed effects we include – a relatively mild assumption. It is highly likely that developments in repo markets impact gilt markets: for example, if the hedge fund sector wishes to borrow a gilt for shorting reasons, one would expect its price to go up. However, our regressions include firm-gilt-time fixed effects, so this variation is stripped out of our regressions. The pairwise shocks to repo u^a_{ijt} are unlikely to be of sufficient magnitude to impact prices in gilt markets.

The exogeneity of our instrumental variables then depend on firm j's wallet over the preceding four weeks being unrelated to the shocks u^a_{ijt}. By construction the makeup of the firm's wallet is predetermined, such that it cannot be conditioned on shocks at time t. However, any serial correlation of these shocks could potentially induce some confounding variation. If a firm constructs its wallet of bonds based on some exogenous characteristic – for example its business model or some preferred habitat approach whereby it prefers to hold bonds of a certain maturity – then any feedback between shares s^a_{jt} and future shocks will be minimal.

Step 2: Estimating funding and collateral demand

We solve the second challenge – the separation of ν_{it} from η^a_{it} – using firms' repo trading against general collateral. We estimate δ^a_{it} in the first stage in which we recover estimates of κ and σ. Given these estimates, the only unknowns are η^a_{it} and ν_{it}:

$$\delta^a_{it} + \kappa Q_{it} + \kappa\sigma \sum_m q^a_{imt} = \nu_{it} - \eta^a_{it} \tag{13}$$

Conditional on ν_{it} firm's collateral demands can be inferred using differences in $\hat{y}^a_{it}$ across assets. To infer ν_{it}, we assume that the collateral demand in general collateral repo is 0. In this case, funding and collateral demand are pinned down as follows:

$$\begin{aligned} \nu_{it} &= \delta^0_{it} + \kappa Q_{it} + \kappa\sigma \sum_m q^0_{imt} \\ \eta^a_{it} &= \delta^0_{it} - \delta^a_{it} + \kappa\sigma \sum_m (q^0_{imt} - q^a_{imt}) \end{aligned} \tag{14}$$

where a subscript of 0 denotes general collateral.

A firm therefore has high funding demand if it trades general collateral repo at a high rate, if it borrows a lot, and if it borrows a lot against general collateral repo. A firm has high collateral demand for a given asset if it trades that asset at a discount relative to general collateral, and if it lends a lot against that asset relative to its lending aganist general collateral.

6 Results

We first describe the results of our estimation. We then show how our estimated collateral and funding demand vary in the time series and the cross-section, with implications for repo market functioning.

6.1 Parameter Estimates

Table 8 shows the results of the first part of our estimation approach, which is to estimate Equation 7. We show results from an OLS regression in the first column, and from our two-stage least squares approach in the second. The signs are as expected, and the coefficients are highly statistically significant. The first coefficient provides an estimate of minus the risk aversion κ, whilst the second estimates $-\kappa \times \sigma$, where σ is the standard deviation of the return firms earn using the assets they demand as collateral.

Table 9 shows the results of regressing the endogenous regressors in our estimating equation on our two instruments, equivalent to the first stage of our two-stage least squares approach. The first stages are strong, with the the instruments showing high predictive power for the endogenous regressors. The signs are broadly intuitive: an increase in the value of j's collateral ($z_{1,jt}$) is associated with an increase in its net borrowing from i (or equivalently, a decrease in i's net borrowing from j). An increase in the value of j's collateral *except* asset a leads it to decrease its net borrowing from i (equivalent to increasing i's net borrowing from j) against a, as it needs to rely less on asset a in its borrowing.

The results of the two-stage least squares approach – our preferred approach as it does not suffer from simultaneity issues – imply values of 0.016 for risk aversion κ and 11.8 for the risk on the return to obtaining collateral σ.

We describe our estimates of collateral and funding demand in detail in the following sections. Here we summarise some key features of our estimation of these parameters, with details given in Appendix A:

- Identifying variation: We show the variation in repo rates and trading quantities that pins down collateral and funding demand. We do so by regressing our estimated parameters on the terms in equations 14, and showing their explanatory power. This makes clear, for example, the extent to which differences in trading volumes across firms drive identification relative to differences in rates.

- High-level variation: We regress our estimated parameters on various fixed effects to illustrate the dimensions along which they vary. We find that there is relatively little cross-sectional variation in funding demand, but very material variation across firms and assets in collateral demand.

- Having established how our model and estimation strategy map empirical variation in transaction terms into estimated variation in model parameters, one might reasonably ask what advantages this structural approach brings relative to simpler reduced-form approaches. We implement various simpler approaches, and show that they imply materially different empirical distributions of collateral and funding demand.

6.2 Collateral & funding demand

The key outputs of our estimation are estimates of funding demand ν_{it} and collateral demand η_{it}^{a}, which we estimate semi-parametrically as described in Section 5. In this section we document how funding and collateral demand vary in the time series and the cross-section, what are the economic variables that drives them, and their implications for asset prices.

6.2.1 Macro drivers

Our model showed that the joint distribution of funding and collateral demand determines repo market outcomes. What shapes this distribution? Here we establish how changes in the macroeconomy and financial markets drive time series variation in these variables.

Figure 3 shows how funding and collateral demand vary through time. We plot the 10^{th}, 50^{th} and 90^{th} percentiles of funding demand ν_{it} in the left panel and of collateral demand η_{it}^{a} in the right panel. Funding demand closely tracks the central bank's policy rate over this same period. This is intuitive: the net demand for funding via repo contracts should depend on the cost of alternative funding. As policy rates change, this is passed through into other funding markets. As a result, the monetary policy tightening from 2022 onwards led to an increase in the marginal cost of funding on the repo market.

Our estimated collateral demand follows a different trajectory to funding demand. It rises in March and April 2020 (the grey highlighted region) and from the end of 2021, reaching a peak in October 2022. These two periods coincide with two key moments of market turmoil in UK financial markets: the dash-for-cash in March 2020 (Czech et al., 2021a; Hüser et al., 2021) and the gilt market turmoil in the autumn of 2022 (Pinter, 2023).

We explore this further in Figures 4 and 5. Prior literature argues that short selling should be more prevalent in periods of greater disagreement (Sikorskaya, 2023). In Figure 4 we plot implied interest rate volatility through time. The time profile is strikingly similar to that of collateral demand in Figure 3. To formalise this, in Figure 5 we plot the daily levels of implied volatility against the mean and the dispersion of our estimated collateral demand. Implied interest rate volatility explains a large amount of time series variation in collateral demand.[12]

This suggests that short selling is quantitatively a key driver of repo market outcomes.[13] In stable periods with little disagreement, there is little incentive to engage in short selling. In this case, collateral demand is low and the repo market operates as a standard secured funding market. By contrast, when volatility increases so does the desire of market participants to short sell assets, and to use the repo market to do so. In this case the repo market serves two functions simultaneously: facilitating funding and the obtaining of collateral to short sell assets. Collateral demand thus endogenously increases in times of uncertainty, when funding needs may be most acute.

6.2.2 Variation across firms

A key contribution of our estimation is to produce estimates of collateral demand that vary across firms, relative to a literature that generally studies this at the asset level (Schaffner et al., 2019). In this section we study this dimension of variation to shed light on which types of firm contribute to demand for certain assets in repo markets, and how this co-moves with funding demand across firms.

Table 10 summarises variation in funding and collateral demand across firm types. In the first column we regress funding demand ν_{it} on dummies for the type of firm i. MMFs have lower funding demand, consistent with their role as lenders in these markets. Dealers, by constrast, have amongst the highest funding demand, consistent with their reliance on repo markets for funding.

In the second column of Table 10 we regress collateral demand η_{it}^{a} on dummies for firm

[12]This is in line with the findings for stocks in Sikorskaya (2023).

[13]We are in the process of merging our data with transaction-level data on trading in gilts. This will enable us to further demonstrate that short selling drives fluctuations in collateral demand in repo markets.

type. MMFs and pension funds have low collateral demand, suggesting they view the assets they receive as pure insurance in case of default rather than useful assets to obtain. Dealers, banks and hedge funds have high collateral demand. It is perhaps more surprising that dealers and banks have such high collateral demand, as these are less likely to be using repo to speculate in asset markets. Instead, their collateral demand is likely to represent them using repo to hedge exposures rather than speculate (which we discuss in more detail below), and to source assets cheaply for their clients.

Table 11 summarises the correlation between funding demand and collateral demand in the data. The first column shows the unconditional relationship between the two, the second shows the correlation within days across firms, and the third shows the correlation within firms across time. In each case, the two are positively correlated, indicating that a high demand for cash tends to be accompanied by a high demand for collateral. Given our results in Section 4, this would suggest that collateral demand might impede repo market functioning by reducing the gains to trade between firms. We formalise this in counterfactual simulations in Section 7.

6.2.3 Collateral demand and asset prices

A key motive for obtaining assets via repo is to short-sell the underlying asset, whether for speculation or hedging purposes. If this short-selling is undertaken by informed investors, then it follows that collateral demand in the repo market should be able to predict the prices of the underlying asset. In this section we test this hypothesis.

To do so, in each period we order assets from high to low based on their collateral demand. In the spirit of Czech et al. (2021b), we then construct a long-short portfolio on assets that goes long on the bottom tertile of assets in this ranking and short the top tertile, and track the cumulative returns on this portfolio in the days that follow. This approach makes use only of variation in collateral demand within time period, rather than across time periods, in order to control for confounding intertemporal variation.

We show the returns on this portfolio in the left panel of Figure 6. The returns to this strategy are negative in the short term, but turn positive after around 280 days.[14] This suggests that high collateral demand did predict declines in asset prices over our sample period, but only over a very long time horizon.

[14] There is anecdotal evidence that firms held short positions for long stretches of our sample: https://www.ft.com/content/e97731b2-8c52-4088-bdd1-21e39d60697a.

As discussed in Section 2.1, speculative short selling is only one of the motives for collateral demand. Some firms are largely precluded from undertaking this kind of activity. For example, MMF's mandates mean they do not short-sell whilst regulation limits banks' and dealers' ability to speculate. Hedge funds, by contrast, follow strategies that actively take positions on future asset prices, such as yield curve arbitrage. As a result, if there is information about price falls in collateral demand, hedge fund collateral demand is where it would most likely show up.

To test this, we again construct long-short portfolios, but this time based on how much a gilt is in demand by hedge funds relative to other traders. That is, we order assets according to the difference between hedge funds' collateral demand for the asset and all other firms' collateral demand for the asset. We then compute cumulative returns on portfolios that go long assets in the bottom tertile of this ranking and short assets in the top tertile. We then repeat the exercise for dealer-banks rather than hedge funds.

We show the returns on these portfolios in the second panel of Figure 6. The returns on the portfolio based on hedge fund collateral demand turn negative within days of the portfolio being constructed, and decrease montonically before levelling out after around 200 days. By contrast, the returns on the portfolio based on dealer-bank collateral demand are positive throughout.

Together, these results add a new dimension to the literature on informed trading in fixed income markets, and also shed light on the nature of collateral demand and how it varies across firms. Hedge funds have the ability to forecast asset prices on average – as shown in Czech et al. (2021b) – and this manifests itself in repo markets. Dealer-banks short selling as asset does not predict future asset price declines, and implies they are short selling assets for reasons other than informed speculation.

7 Counterfactuals

We run two counterfactual simulations. In the first, we quantify how repo market functioning would change if the collateral demand motive for trade did not exist. We calculate the counterfactual equilibrium in which collateral demand η_{it}^{a} is zero for all firms, assets and time periods. The sole motive for trade in the repo market is now to obtain funding.

We view this counterfactual as (a) quantifying the equilibrium impact of collateral demand and (b) showing the impact of changes to policies and financial market conditions that affect the collateral demand motive for trade. These include bans on short selling and the removal of the existing ban on naked short selling – short selling without having borrowed the asset. Both of these would likely reduce the extent to which repo markets are used for short selling – the former by reducing short selling, and the latter by reducing the necessity of repo in short selling. The UK government is currently considering lifting the existing prohibition on the naked short selling of gilts (Short Selling Regulation Review (July 2023), HM Treasury).

The results are shown in Figure 7. In panel (a) we show the impact of collateral demand on repo rates. The first panel shows the impact on the median repo rate on each day. Absent collateral demand, repo rates are higher as lenders no longer benefit from collateral demand and borrowers no longer need to forego their own collateral demand. Panel (b) of Figure 7 shows the impact on the variance of rates. Collateral demand creates a motive to acquire some assets, but not others, and hence creates variation in how valuable different gilts are to the trader that receives collateral. Removing collateral demand removes this source of heterogeneity, and hence reduces variation in rates across gilts. The remaining variation in rates comes from funding demand, network structure and market power.

Panels (c) and (d) of Figure 7 show the impact of collateral demand on trading quantities and the realised gains from trade. Both of these would be materially higher without collateral demand, particularly towards the end of our sample period in times of heightened volatility and collateral demand. It follows that any policy changes that reduce the role of collateral demand in repo markets – such as removing the current prohibition on naked short selling – could enhance repo market functioning, increasing trading and gains from trade in repo markets.

The main driver of this result is the positive correlation across firms between collateral demand and funding demand: in Section 4 we show in theory that such positive correlation implies that collateral demand impedes repo market functioning, and in Section 6 we show that empirically this correlation is indeed positive.

We shed further light on this mechanism in our second counterfactual. We first rearrange collateral demand across firms to exactly reverse the positive correlation we estimate in 11, such that there is instead negative correlation of the same magnitude. We then calculate the resulting equilibrium. In Figure 8, we compare these outcomes with those in our first counterfactual. We find that the sign of our results reverses: if collateral demand were negatively correlated across firms with funding demand, then its removal would decrease quantities traded and realised gains from trade. This confirms that the joint distribution of collateral demand and funding demand across firms is a key determinant of the impact of collateral demand on repo outcomes, and an important consideration in any regulatory change that would impact collateral demand.

These findings are at odds with the idea put forward by Singh (2011) that collateral demand can lubricate financing via repo. Instead collateral acquisition via repo in a sense crowds out financing via repo, as firms that need funding in relative terms also care more about giving up the underlying collateral. Importantly, these firms are not just hedge funds, but also the banks that sit at the heart of the repo market whilst simultaneously intermediating, managing their own funding needs and their own collateral demand in order to hedge risk. Our results speak to the inability of dealer-banks to simultaneously do all of these things using repo.

8 Conclusion

We document empirical facts that suggest that collateral demand is an important driver of outcomes in this market. We formalise this in a model of repo between firms with heterogeneous funding needs and collateral demand, and structurally estimate this using transaction-level repo data. We show that collateral demand is material, varies across firms, assets and time, and predicts asset prices. We show that the presence of collateral demand constrains trading and gains to trade in repo markets.

We leave for future work an assessment of how collateral demand impacts risk and financial stability, and a more comprehensive quantitative investigation of the feedbacks between repo markets and the markets for the underlying asset. More generally, this work forms part of a broader agenda in the literature to use new transaction data to examine the way in which financial markets are organised, and the implications of this for financial stability and policy.

References

Adrian, T., Begalle, B., Copeland, A., and Martin, A. (2013). Repo and securities lending. In *Risk topography: Systemic risk and macro modeling*, pages 131–148. University of Chicago Press.

Aitken, J. and Singh, M. M. (2010). *The (sizable) role of rehypothecation in the shadow* *banking system*. International Monetary Fund.

Andolfatto, D., Martin, F. M., and Zhang, S. (2017). Rehypothecation and liquidity. *European Economic Review*, 100:488–505.

Arrata, W., Nguyen, B., Rahmouni-Rousseau, I., and Vari, M. (2020). The scarcity effect of QE on repo rates: Evidence from the euro area. *Journal of Financial Economics*, 137(3):837–856.

Asquith, P., Au, A. S., Covert, T., and Pathak, P. A. (2013). The market for borrowing corporate bonds. *Journal of Financial Economics*, 107(1):155–182.

Ballensiefen, B., Ranaldo, A., and Winterberg, H. (2023). Money market disconnect. *The Review of Financial Studies*, page hhad022.

Barth, D. and Kahn, R. J. (2021). Hedge funds and the Treasury cash-futures disconnect. *OFR Working Paper*, pages 21–01.

Benos, E., Ferrara, G., and Ranaldo, A. (2022). Collateral cycles. *Bank of England Working Paper No. 966*.

Bicu-Lieb, A., Chen, L., and Elliott, D. (2020). The leverage ratio and liquidity in the gilt and gilt repo markets. *Journal of Financial Markets*, 48:100510.

Bigio, S. (2015). Endogenous liquidity and the business cycle. *American Economic Review*, 105(6):1883–1927.

Boissel, C., Derrien, F., Ors, E., and Thesmar, D. (2017). Systemic risk in clearing houses: Evidence from the European repo market. *Journal of Financial Economics*, 125(3):511–536.

Chen, S., Kaniel, R., and Opp, C. C. (2022). Market power in the securities lending market. *Available at SSRN 4100699*.

Copeland, A., Martin, A., and Walker, M. (2014). Repo runs: Evidence from the tri-party repo market. *The Journal of Finance*, 69(6):2343–2380.

Czech, R., Gual-Ricart, B., Lillis, J., and Worlidge, J. (2021a). The role of non-bank financial intermediaries in the 'dash for cash' in sterling markets.

Czech, R., Huang, S., Lou, D., and Wang, T. (2021b). Informed trading in government bond markets. *Journal of Financial Economics*, 142(3):1253–1274.

D'Avolio, G. (2002). The market for borrowing stock. *Journal of Financial Economics*, 66(2-3):271–306.

Duffie, D. (1996). Special repo rates. *The Journal of Finance*, 51(2):493–526.

Eisenschmidt, J., Ma, Y., and Zhang, A. L. (2022). Monetary policy transmission in segmented markets. *Working paper*.

Eisfeldt, A. L., Herskovic, B., Rajan, S., and Siriwardane, E. (2023). OTC intermediaries. *The Review of Financial Studies*, 36(2):615–677.

Erten, I., NeamÈu, I., and Thanassoulis, J. E. (2022). The ring-fencing bonus.

Foley-Fisher, N., Gissler, S., and Verani, S. (2019). Over-the-counter market liquidity and securities lending. *Review of Economic Dynamics*, 33:272–294.

Foley-Fisher, N., Narajabad, B., and Verani, S. (2016). Securities lending as wholesale funding: Evidence from the US life insurance industry. Technical report, National Bureau of Economic Research.

Geanakoplos, J. (2010). The leverage cycle. *NBER macroeconomics annual*, 24(1):1–66.

Gorton, G. and Metrick, A. (2012). Securitized banking and the run on repo. *Journal of Financial Economics*, 104(3):425–451.

Gottardi, P., Maurin, V., and Monnet, C. (2019). A theory of repurchase agreements, collateral re-use, and repo intermediation. *Review of Economic Dynamics*, 33:30–56.

Hu, G. X., Pan, J., and Wang, J. (2021). Tri-party repo pricing. *Journal of Financial and Quantitative Analysis*, 56(1):337–371.

Huber, A. W. (2023). Market power in wholesale funding: A structural perspective from the triparty repo market. *Journal of Financial Economics*, 149(2):235–259.

Hüser, A.-C., Lepore, C., and Veraart, L. A. M. (2021). How does the repo market behave under stress? Evidence from the COVID-19 crisis. *Bank of England Staff Working Paper No. 910*.

Infante, S. (2019). Liquidity windfalls: The consequences of repo rehypothecation. *Journal of Financial Economics*, 133(1):42–63.

Jappelli, R., Subrahmanyam, M. G., and Pelizzon, L. (2023). Quantitative easing, the repo market, and the term structure of interest rates.

Julliard, Gabor Pinter, G., Todorov, K., and Yuan, K. (2023). What drives repo haircuts? Evidence from the UK market. *Available at SSRN: https://ssrn.com/abstract=3374969 or http://dx.doi.org/10.2139/ssrn.3374969.*

Kotidis, A. and Van Horen, N. (2019). Repo market functioning: The role of capital regulation. *Bank of England Staff Working Paper No. 746.*

Krishnamurthy, A., Nagel, S., and Orlov, D. (2014). Sizing up repo. *The Journal of Finance*, 69(6):2381–2417.

Mancini, L., Ranaldo, A., and Wrampelmeyer, J. (2016). The euro interbank repo market. *The Review of Financial Studies*, 29(7):1747–1779.

Noss, J. and Patel, R. (2019). Decomposing changes in the functioning of the sterling repo market. *Bank of England Staff Working Paper No. 797.*

Pinter, G. (2023). An anatomy of the 2022 gilt market crisis. *Available at SSRN.*

Roh, H. S. (2019). Repo specialness in the transmission of quantitative easing. *Available at SSRN 3387085.*

Schaffner, P., Ranaldo, A., and Tsatsaronis, K. (2019). Euro repo market functioning: collateral is king. *BIS Quarterly Review, December.*

Sikorskaya, T. (2023). Institutional investors, securities lending and short-selling constraints. *Securities Lending, and Short-Selling Constraints (November 8, 2023).*

Singh, M. M. (2011). *Velocity of pledged collateral: analysis and implications.* International Monetary Fund.

Figures

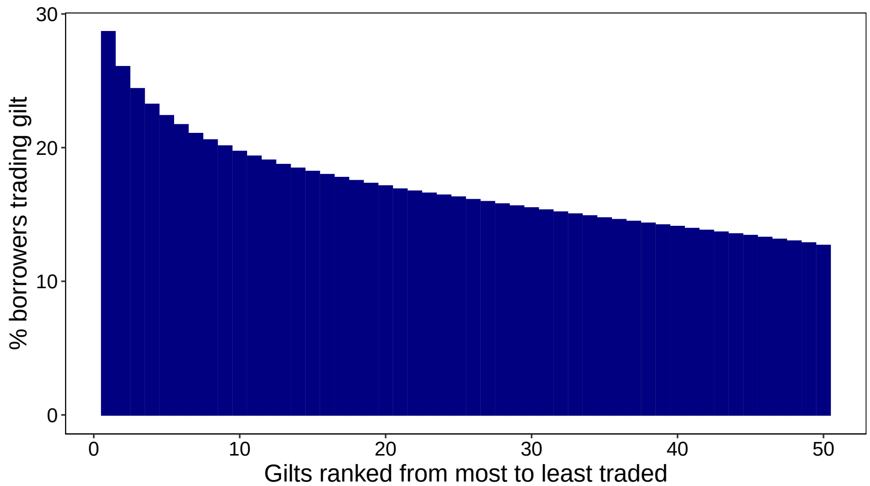

Figure 1: Variation in use of gilts in repo borrowing

Note: Figure summarises variation in the gilts used as collateral by firms. For each week we take the set of unique borrowers and gilts, and compute 'gilt share' as the fraction of borrowers that use each gilt as collateral in borrowing. We then rank gilts from most to least popular each week according to how many firms use them. For each rank (1 being the most popular gilt, 2 being the second most, etc) we compute the average of 'gilt share' across weeks. We plot these values for ranks 1 to 50.

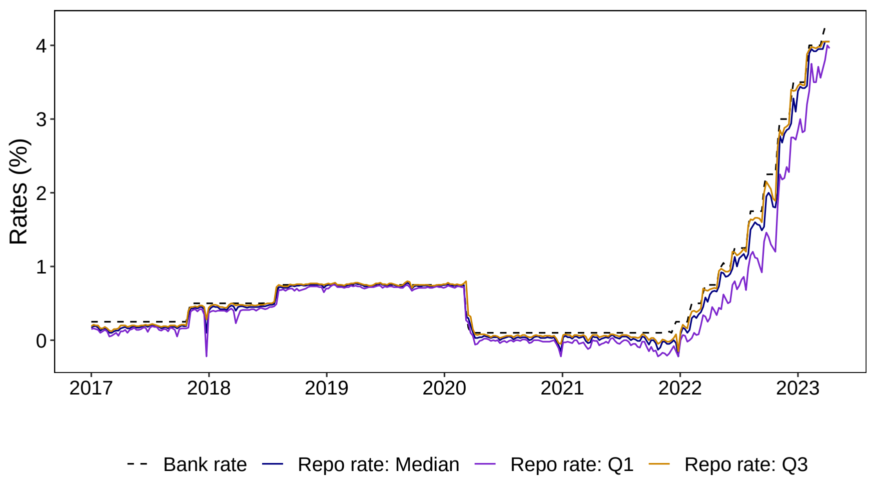

Figure 2: Rates through time on dealer repo lending

Note: Figure show the distribution of repo rates that dealers earn on their repo lending (solid lines), vs the central bank policy rate (dashed line), which banks can earn by holding money with the central bank.

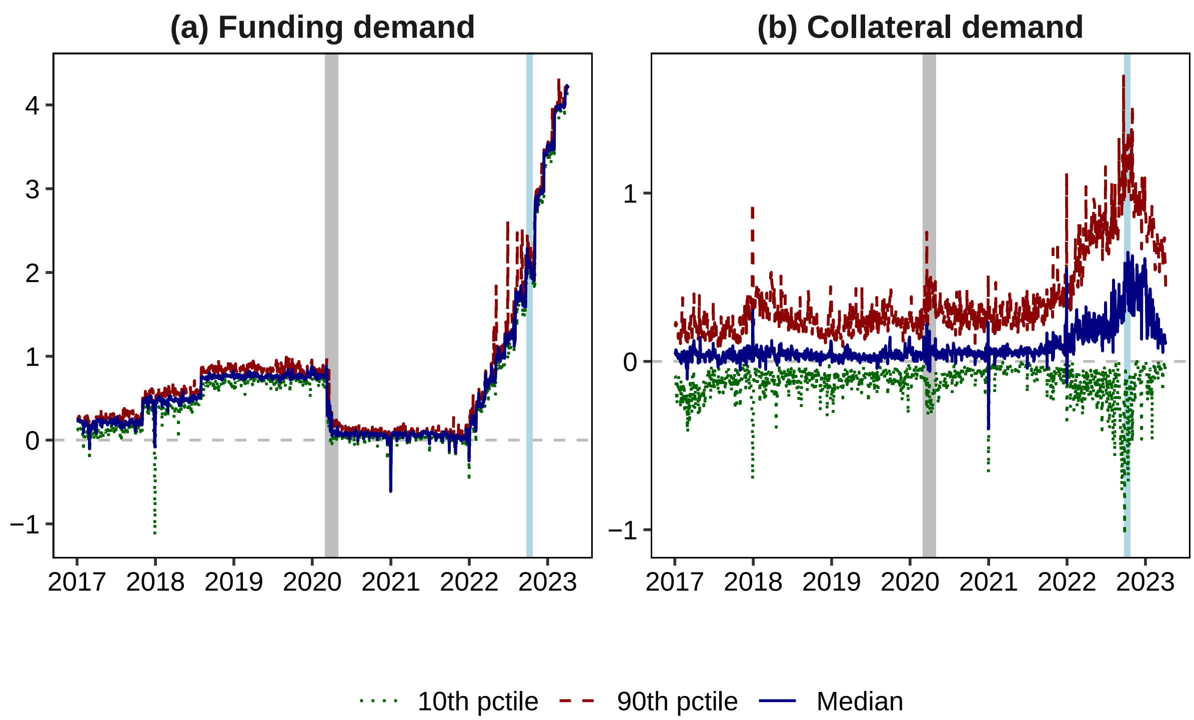

Figure 3: Funding & collateral demand through time

Note: Figure summarises the estimated distribution of funding demand ν_{it} across firms and time and of collateral demand η^a_{it} across firms, time and gilts. The grey region in the second panel highlights March & April 2020, around the 'dash for cash'. The blue highlighted region in the second panel shows the month following 23$^{\text{rd}}$ September 2022, which marked the beginning of the LDI crisis in the UK (Pinter, 2023).

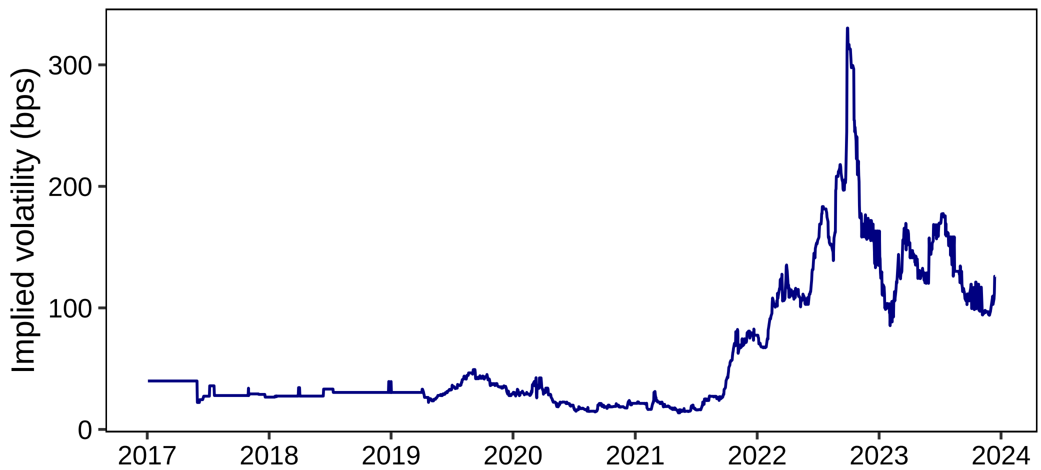

Figure 4: Gilt market volatility

Note: Figure plots the swaption-implied volatility of interest rates through time. The series is the daily implied volatility of 1-year interest rates over a 3 month horizon, derived from UK interest rate swaption prices and taken from Bloomberg.

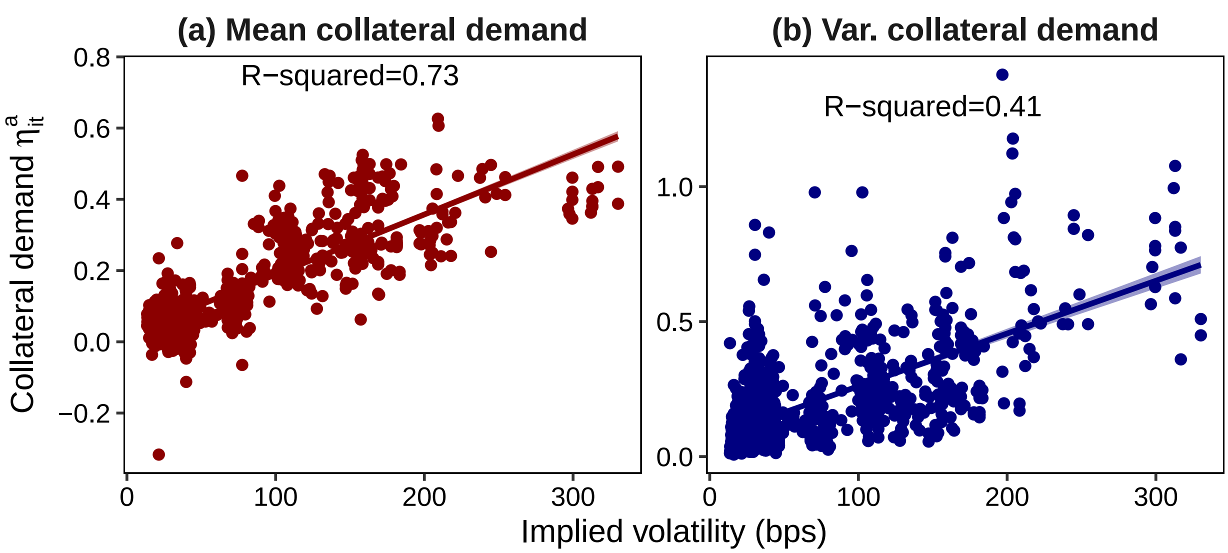

Figure 5: Gilt market volatility and collateral demand

Note: Figure plots the relationship between the daily implied volatility of interest rates shown in Figure 4, and the mean (left panel) and variance (right panel) of collateral demand η^a_{it} each day. The line shows a linear regression of the variable on the y axis on implied volatility, with 95% confidence intervals shown around this line of best fit. The R-squareds of these time series regressions are displayed on each panel.

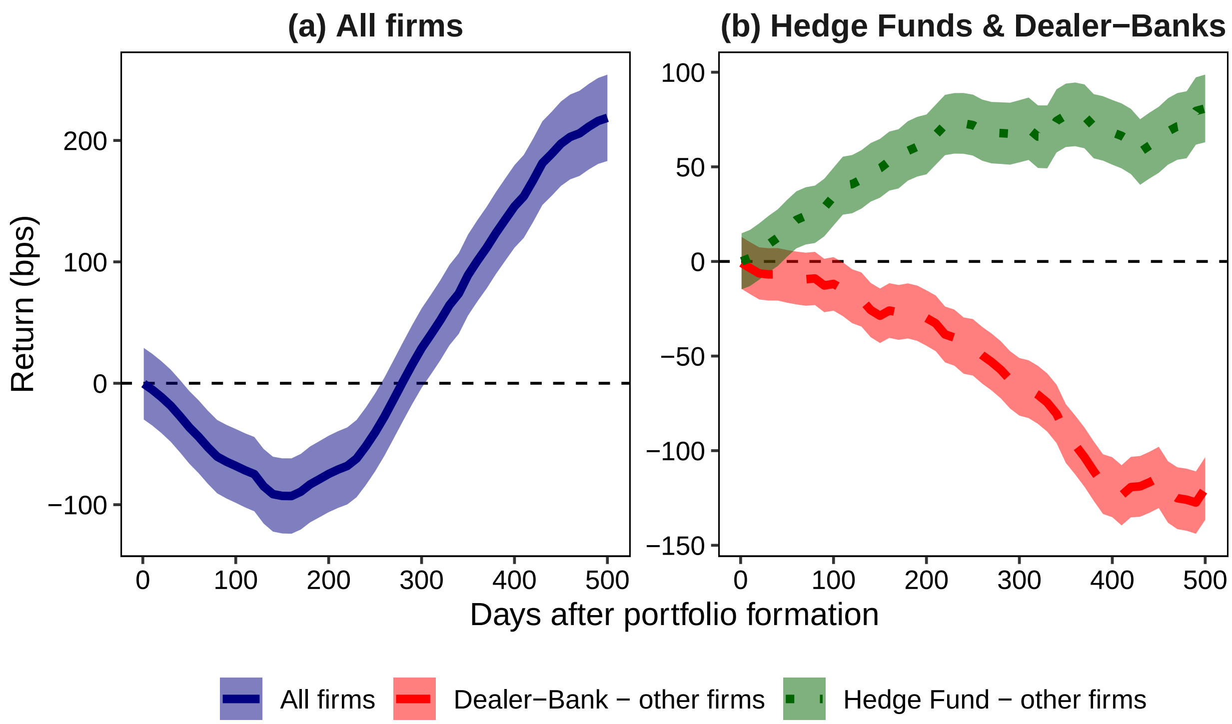

Figure 6: Long-short portfolio returns - sorted by collateral demand

Note: Figure shows the relationship between collateral demand and future gilt prices. In the first panel, for each time period t we order bonds from high to low based on their average estimated collateral demand η^a_{it}. We then compute a portfolio that goes long in the top tertile of bonds according to this ranking, and short the bottom tertile. We then compute the returns on this long-short portfolio over the coming 1 to 500 days. The line shows the average of these returns taken over t, whilst the shaded area is a 95% confidence interval computed based on boostrapping. The right panel does the same, but orders bonds based on the difference between hedge funds' collateral demand and other firms' collateral demands (green) and dealer-banks' collateral demands and other firms' collateral demands (red).

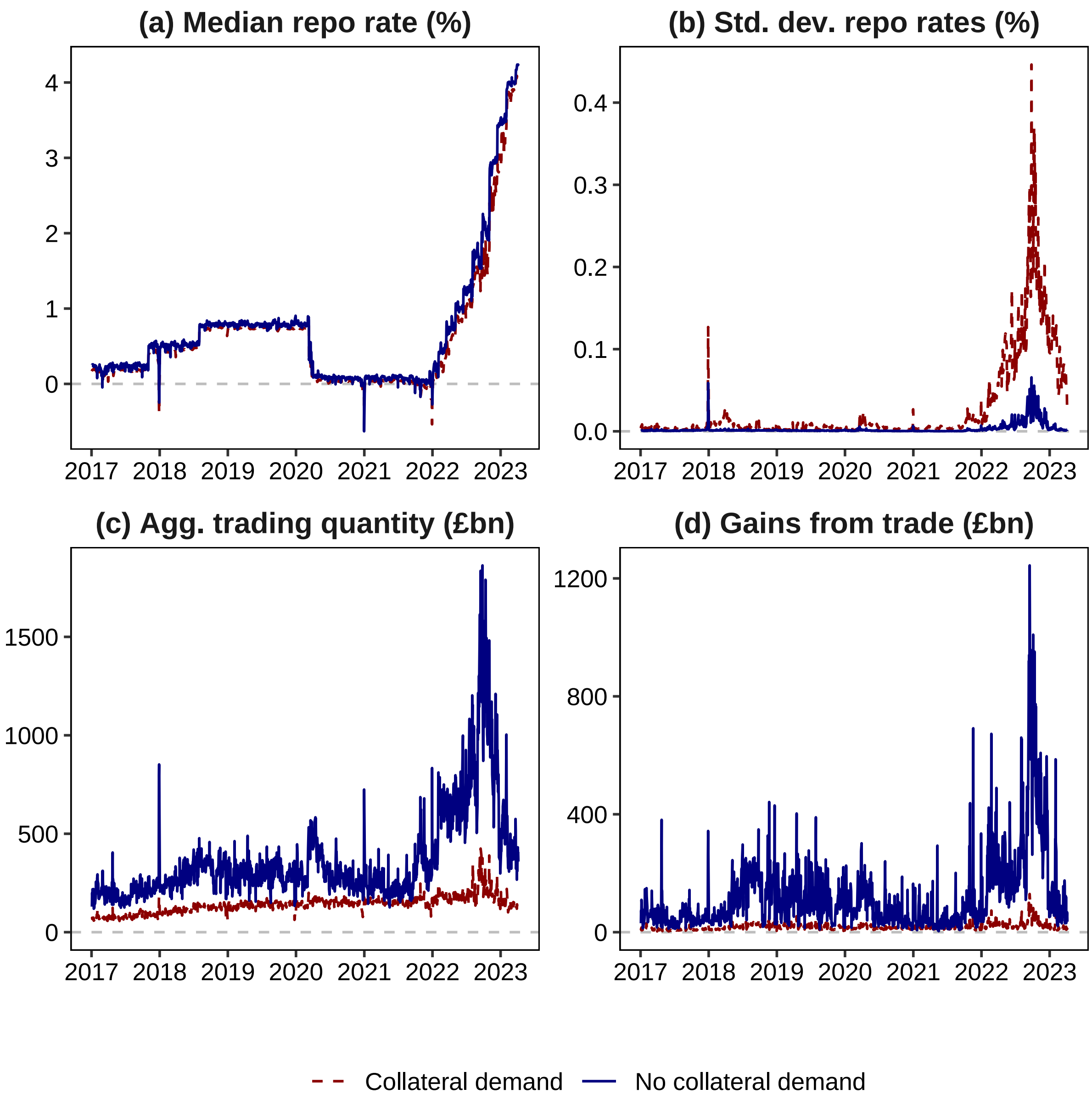

Figure 7: Counterfactual: impact of collateral demand

Note: Figure summarises the impact of collateral demand on repo rates and quantities and the gains from trading repo. The red dashed line in the panel (a) shows the median repo rate across all traders and gilts each day for our estimated model. The blue line shows the median rate in a counterfactual equilibrium where all η^a_{it} parameters capturing collateral demand are set to 0. Panels (b), (c) and (d) replicate the analysis for the variance of repo rates, aggregate daily trading quantity, and the gains from trading repo, given by evaluating Equation 1 at equilibrium quantities and rates

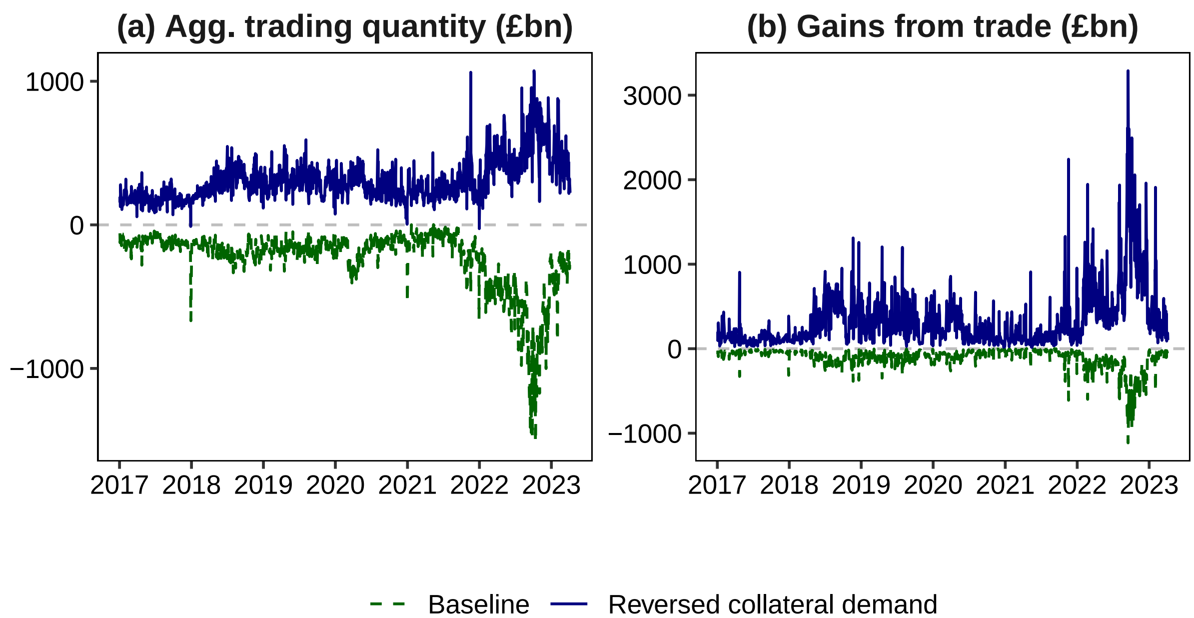

Figure 8: Impact of collateral demand: role of correlation between collateral and liquidity demand

Note: Figure shows how the impact of collateral demand on repo quantities and the gains from trading repo depend on the correlation between collateral demand η^a_{it} and funding demand ν_{it} across firms. The green dashed line shows the impact of collateral demand on aggregate trading quantity for our estimated parameters. This is the difference between two lines in panel (c) of Figure 7. The blue line shows what the impact of collateral demand would be if – contrary to our findings – the correlation between funding and collateral demand were negative. The second panel summarises the change in the gains from trading repo, as defined above, due to collateral demand under the same assumptions.

Tables

Table 1: Summary Statistics

	Share (%)
Maturity	
Overnight	40
Less than 1 week	36
2 weeks - 1 month	16
1 month plus	7
Clearing	
Cleared	54
Bilateral	46
Triparty	0
Segment	
Dealer-Bank to Dealer-Bank	56
Dealer-Bank to Customer	44

Notes: Share shows percentage of total volume in each category. Cleared trades are cleared via a central counterparty. In this table trades with central counterparties are counted as a single trade between two end users rather than two offsetting trades with the central counterparty. Dealer-banks include both dealers and banks.

Table 2: Trading activity by sector

	Trade Share (%)	Daily net lending (%)	Daily net lending (£bn)
Dealer	66.1	-3.8	-4.6
Bank	11.7	-31.4	-7.5
Hedge Fund	10.3	-0.2	-0.4
Fund	4.2	62.5	5.2
MMF	2.9	97.4	6.2
PFLDI	2.8	18.9	0.9
Other	2.0	0.6	0.5

Notes: Table summarises the lending behaviour of different sectors. The first numeric column shows the volume-weighted trade shares of each sector. The second and third numeric columns summarise the average daily net lending of each sector, in % and £bn respectively. The net lending figures only include days when a given sector traded at least once. In this table trades with central counterparties are counted as a single trade between two end users rather than two offsetting trades with the central counterparty.

Table 3: Dealer rates on borrowing & lending

	Repo rate (%)		
	(1)	(2)	(3)
Dealer lending	0.155***	0.149***	0.092***
	(0.007)	(0.002)	(0.0006)
R^2	0.23	0.35	0.81
Observations	1,003,270	1,003,270	1,003,270
Week fixed effects	Yes		
Week-Dealer fixed effects		Yes	
Week-Dealer-Asset fixed effects			Yes

Notes: Table shows how the rates dealers charge on their repo lending exceed those they pay on their borrowing. The table shows regressions of repo rates (net of Bank rate) on a dummy for whether a dealer is lending in that transaction along with a set of fixed effects, where the sample includes only dealer-client trades and dealers lending is the the excluded category. Transactions with CCPs, governments and central banks are excluded here. Standard errors are clustered at the level of the fixed effect. ***, ** and * respectively denote significance at the 0.1%, 1% and 5% levels of significance.

Table 4: Rate variation

Fixed effects	R-squared
Deal characteristics	
Week	0.37
Week-Asset	0.86
Week-Maturity	0.42
Week-Asset-Maturity	0.90
Trader characteristics	
Week-Borrower	0.51
Week-Lender	0.45
Week-Borrower-Lender	0.59

Notes: Table shows the R-squared of a regression of repo rates (net of Bank rate) on the fixed effects shown in each row. Week-Asset means that fixed effects with the interaction of the gilt provided as collateral and the week of the transaction are included as regressors.

Table 5: Rate variation: MMFs vs hedge funds lending

Fixed effects	Hedge fund	MMF
Week-Maturity	0.50	0.31
Week-Maturity-Borrower	0.56	0.98
Week-Maturity-Lender	0.62	0.42
Week-Maturity-Asset	0.94	0.73

Notes: Table summarises the variables that explain repo rates (net of Bank rate) for lending by hedge funds and lending by MMFs. The first numeric column takes all transactions in our sample where hedge funds are lending cash, regresses the repo rate on the listed fixed effects, and displays the R-squared from this regression. The second numeric column does the same for transactions by MMFs. Maturity denotes the maturity of the repo contract and week-maturity, for example, means that fixed effects with the interaction of the maturity of the repo and the week of the transaction are included as regressors.

Table 6: Repo rates & security demand: MMFs vs hedge funds lending

	Repo rate (%)			
	(1)	(2)	(3)	(4)
Lender: Hedge fund	-0.06***	-0.08***	-0.003***	-0.002**
	(0.006)	(0.003)	(0.001)	(0.001)
R^2	0.38	0.58	0.94	0.97
Observations	371,649	371,649	371,649	371,649
Week fixed effects	Yes			
Borrower-Week fixed effects		Yes		
Borrower-Asset-Week fixed effects			Yes	
Borr-Asset-Mat-Week fixed effects				Yes

Notes: Table summarises the difference between the rates at which hedge funds and mutual funds lend. Each column shows the results of a regression of the repo rate on the identity of the lender and a set of fixed effects, where the dataset consists only of transactions where the lender was either a hedge fund or a MMF. Standard errors are clustered at the level of the fixed effect. ***, ** and * respectively denote significance at the 0.1%, 1% and 5% levels of significance.

Table 7: Repo rates & collateralisation type

	Spread				
	(1)	(2)	(3)	(4)	(5)
General Collateral	0.09***	0.09***	0.09***	0.10***	0.09***
	(0.006)	(0.01)	(0.003)	(0.004)	(0.005)
R^2	0.30	0.20	0.55	0.43	0.40
Observations	6,095,617	6,095,617	6,095,617	6,095,617	6,095,617
Week fixed effects	Yes				
Borrower-Lender fixed effects		Yes			
Borrower-Week fixed effects			Yes		
Lender-Week fixed effects				Yes	
Maturity-Week fixed effects					Yes

Notes: Table shows how repo rates vary according to whether collateral is exchanged via 'Delivery by Value' – denoted general collateral – or otherwise. The table shows the results of regressions on a dummy for whether the transaction involved general collateral and the listed fixed effects. Standard errors are clustered at the level of the fixed effect. ***, ** and * respectively denote significance at the 0.1%, 1% and 5% levels of significance.

Table 8: Parameter estimates: OLS and TSLS

	Repo rate r^a_{ijt} (%)	
	OLS	2SLS
	(1)	(2)
$\sum_l q^l_{ijt}$	-0.01***	-0.02***
	(0.0009)	(0.002)
q^a_{ijt}	-0.12***	-0.18***
	(0.002)	(0.003)
Wald (1st stage), $\sum_l q^l_{ijt}$		6,377.2
Wald (1st stage), q^a_{ijt}		2,170.8
R^2	0.996	0.997
Within R^2	0.027	0.037
Observations	599,384	527,295
Firm-asset-day fixed effects	Yes	Yes
Firm-counterparty fixed effects	Yes	Yes

Notes: Table shows the results of estimating Equation 7 by OLS and two-stage least squares. Standard errors are clustered at the firm-asset-week level. ***, ** and * respectively denote significance at the 0.1%, 1% and 5% levels of significance.

Table 9: First stage results

	q^a_{ijt}	$\sum_l q^l_{ijt}$
	(1)	(2)
$z_{1,jt}$	-0.01***	-0.007***
	(0.0002)	(0.0002)
$z^a_{2,jt}$	0.01***	0.0009***
	(0.0002)	(0.0002)
R^2	0.80	0.87
F-test	535.2	879.0
Observations	527,295	527,295
Firm-asset-day fixed effects	Yes	Yes
Firm-counterparty fixed effects	Yes	Yes

Notes: Table shows the results of regressing the endogenous terms in Equation 7 on our instrumental variables, equivalent to the first stage in two-stage least squares estimation. $z_{1,jt}$ and $z^a_{2,jt}$ are the instruments detailed in Section 5. Standard errors are clustered at the firm-asset-week level. ***, ** and * respectively denote significance at the 0.1%, 1% and 5% levels of significance.

Table 10: Funding and collateral demand by sector

	Funding demand ν_{it}	Collateral demand η^a_{it}
	(1)	(2)
Bank	0.68***	0.13***
	(0.007)	(0.0007)
Dealer	0.81***	0.23***
	(0.006)	(0.0004)
Fund	0.84***	0.07***
	(0.005)	(0.001)
Hedge Fund	0.70***	0.11***
	(0.004)	(0.0007)
MMF	0.61***	0.05***
	(0.01)	(0.003)
Other	0.77***	0.13***
	(0.008)	(0.002)
PFLDI	0.71***	-0.08***
	(0.006)	(0.001)
R^2	0.005	0.05
Observations	167,037	1,490,509

Notes: Table shows variation in funding and liquidity demand across firms. We regress our panel of estimated values of funding demand ν_{it} (first column) and collateral demand η^a_{it} (second column) on dummies for the type of firm i.'Other' includes insurers, principal trading firms and central banks, along with other firm types.

Table 11: Collateral & Funding Demand

	Collateral demand η^a_{it}		
	(1)	(2)	(3)
Funding demand ν_{it}	0.20***	0.95***	0.12***
	(0.0003)	(0.001)	(0.02)
R^2	0.22	0.74	0.57
Observations	1,563,051	1,563,051	1,563,051
Day fixed effects		Yes	
Firm fixed effects			Yes

Notes: Table summarises the co-movement between collateral demand and funding demand. We regress our panel of estimated values of collateral demand η^a_{it} on funding demand ν_{it}, together with the relevant fixed effects. Standard errors are clustered at the level of the fixed effect, and are unclustered in the first column. ***, ** and * respectively denote significance at the 0.1%, 1% and 5% levels of significance.

A Further detail on results

A.1 Identifying variation

The way in which our estimation approach maps empirical variation in transaction characteristics into estimated variation in structural parameters is clear from Equation 14. Both collateral demand and funding demand are pinned down by variation in repo rates and variation in repo quantities. We now demonstrate empirically the extent to which our estimates are driven by rate variation vs. quantity variation.

To do so, we regress our empirical estimates of funding demand ν_{it} and collateral demand η^a_{it} on variables involving repo rates and quantities motivated by Equation 14, along with fixed effects. We then show the proportion of the variation in our parameter estimates – after stripping out the fixed effects – that can be explained by the regressors. Table A1 shows the variables and fixed effects we include, together with the within-R-squared, defined as the proportion of the variation in the dependent variable left over after stripping out the fixed effect that can be explained by the regressor.

The time series variation in funding demand is overwhelmingly driven by changes in the rates at which firms trade general collateral repo. By contrast the across-firm variation is driven by differences in firms' net borrowing: firms with high collateral demand are those that borrow large amounts via repo. The across-asset variation in collateral demand is largely driven by repo rates: assets that in aggregate have high collateral demand are those that trade at a discount relative to the general collateral rate. By contrast, most of the across-firm variation is driven by trading quantities: firms with high collateral demand for a given asset a are those that lend large amounts against a relative to their lending against general collateral. Time series variation is driven by both rate and quantity variation

A.2 High-level variation in funding and collateral demand

Table A2 summarises the variation of collateral demand η^a_{it} and funding demand ν_{it} across firms, time and assets. The bulk of variation in funding demand is through time. This is in line with the results in Figure 3: funding demand is in effect the marginal cost of obtaining funding, and this driven in large part by the central bank policy rate. Much of the variation in collateral demand is at the firm and firm-time level. This highlights the importance of understanding heterogeneity across firms in understanding collateral demand.

A.3 Comparison of reduced-form and structural results

The standard approach to studying collateral demand – alternatively specialness or segmentation – is to compare rates on repos for specific assets to rates on repos for a more general basket of collateral. If repo for a specific asset trades at a discounted rate relative to general collateral, this indicates there is an unusually high level of demand for that asset as collateral.

Our estimation of collateral demand has two innovations relative to this existing approach: it is firm-specific, and it is model-based. The advantage of the former is that it allows us to understand how asset-level collateral demand is driven by firm-level demands. The advantages of the latter are twofold: it allows us to control for confounding factors like market power or the structure of the network, and it allows us to use quantity data to identify collateral demand as well as rate data. For example, if firm A borrows a large amount against general collateral from firm B, but also lends to firm B against a specific gilt, this would suggest that firm A has collateral demand for that specific gilt. Our estimation approach harnesses this identifying variation as well as rate variation.

In Table A3 we summarise the extra information we get from our estimation approach relative to the approach taken in the literature. In the first column we regress our estimated collateral demand η_{it}^{a} on the average difference between the repo rates on asset a at time t and the general collateral repo rate at time t. This regressor is an example of the standard asset-level rate-based approach to estimating collateral demand. The coefficient estimate is 1: the two approaches are clearly capturing many of the same features. However, the R-squared is under 20%: the standard approach captures only a small proportion of the variation in our more granular estimates. This suggests that there is potentially significant value to estimating collateral demand at the firm level.

In the second column we regress our estimated collateral demand on a firm-level version of the standard approach. Here the regressor is the average difference between the repo rates on asset a by firm i at time t and the general collateral repo rate of firm i at time t. Once again, it's clear the two estimates share common variation, but our estimates contain a lot of variation that cannot be captured by the more standard approach, even when applied at the firm level. This suggests that there is potentially significant value to using repo quantities, as well as rates, to estimate collateral demand.

Appendix: Figures & Tables

Table A1: Identifying variation: rates & quantities

	Variables	% variation explained
Funding demand ν_{it}		
Within i, across t	r^0_{it}	91
Within i, across t	$Q_{it} + \sum_m q^0_{imt}$	2
Within t, across i	r^0_{it}	2
Within t, across i	$Q_{it} + \sum_m q^0_{imt}$	91
Collateral demand η^a_{it}		
Within ia, across t	$r^0_{it} - r^a_{it}$	43
Within ia, across t	$\sum_m (q^0_{imt} - q^a_{imt})$	54
Within it, across a	$r^0_{it} - r^a_{it}$	81
Within it, across a	$\sum_m (q^0_{imt} - q^a_{imt})$	19
Within at, across i	$r^0_{it} - r^a_{it}$	10
Within at, across i	$\sum_m (q^0_{imt} - q^a_{imt})$	86

Notes: Table shows the variation in the repo rates and quantities that pins down cross-sectional and time series variation in funding and collateral demand. In the first row, we regress our estimated values of ν_{it} on firm i's general collateral repo rate at time t r^0_{it} (for firms that trade against general collateral at time t), along with firm fixed effects. The third column shows the within-R squared from this regression, capturing the variation in across firm-within time funding demands that is explained by r^0_{it}. Subsequent rows repeat this for different fixed effects and explanatory variables, and collateral demand rather than funding demand.

Table A2: Variation in funding & collateral demand

Fixed Effects	Funding demand	Collateral demand
Time t	0.96	0.07
Firm i	0.14	0.49
Asset a		0.05
Firm-Asset ia		0.58
Firm-Time it		0.85
Asset-Time at		0.19

Notes: Table shows the cross-sectional and time series variation in collateral demand and funding demand. We regress funding demand ν_{it} on time fixed effects, and obtain an R squared of 96%. We repeat this procedure for the fixed effects given in the first column, and for collateral demand rather than funding demand in the third column.

Table A3: Estimating Collateral Demand: Model vs Reduced Form

	Firm collateral demand η_{it}^{a} (1)	(2)
Asset repo - GC repo rate	1.0***	
	(0.002)	
Firm asset repo - GC repo rate		0.97***
		(0.001)
R^2	0.19	0.27
Observations	1,563,051	1,563,051

Notes: Table summarises the relationship between our structural estimates of collateral demand η_{it}^{a} and reduced-form estimates based solely on repo rates. The first column regresses η_{it}^{a} on the difference betwen the general collateral repo rate r_{it}^{0} averaged across firms at time t and the repo rate for asset a averaged across firms at time t. The second column regresses η_{it}^{a} on the difference betwen firm i's general collateral repo rate r_{it}^{0} at time t and its repo rate for asset a at time t. Standard errors are iid. ***, ** and * respectively denote significance at the 0.1%, 1% and 5% levels of significance.