Collateral demand and liquidity demand in wholesale funding markets*

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We study the role of collateral demand in repo markets. Using transaction-level data on Sterling gilt repo markets, we provide evidence that firms use repo markets to obtain assets as collateral as well as funding. We build and structurally estimate a model of repo trading to study and quantify this collateral demand. Our estimates indicate that collateral demand varies materially in the cross-section and in the time series. We show through counterfactual analysis of our estimated model that collateral demand is a key driver of repo market functioning, in that in its absence trading volumes would be smaller, interest rates would be greater and firm payoffs would be lower.

Keywords: Repo, collateral demand, intermediation, portfolio allocation.
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1 Introduction

Repurchase agreements (repos) are the main source of wholesale funding for financial institutions. As a result, repo markets plays a key role in shaping financial crises, market liquidity, and the transmission of monetary policy. A repo transaction serves two functions: firms may trade to obtain funding (liquidity demand), but they may also trade to temporarily obtain the asset provided as collateral (collateral demand). The funding dimension of repo is relatively well understood.[1] The empirical importance of collateral demand, and how it interacts with funding demand, is less well understood. How does collateral demand vary in the cross-section and in the time series? How does it interact with funding demand? What is the contribution of collateral demand to repo market functioning?

We answer these questions based on the Sterling gilt repo market, where we have transaction data on close to the universe of repo lending and borrowing backed by UK government bonds, from January 2017 to March 2023. We use these data to establish new facts on the role of demand for collateral, and to build and structurally estimate a model of the repo market. We use our estimated model to quantify the contribution of collateral demand to trade quantities, interest rates and firm payoffs. We find that removing collateral demand would significantly increase the cost of repo funding, decrease repo activity and decrease welfare, demonstrating that collateral demand is key to understanding repo markets.

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. Second, hedge funds 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.

These facts are difficult to rationalise if the collateral is valued only as insurance against risk, and instead suggest that certain traders have collateral demand for specific gilts and are willing to lend at lower rates in return for being provided these gilts. This naturally raises further questions about (1) the scale of this collateral demand motive, and the extent to which it affects equilibrium trade and (2) what else could vary across transactions and confound these effects, including firms' unobserved funding needs, their position within the

[1] See for example Julliard, Todorov, and Yuan (2023) and Brunnermeier and Pedersen (2009).

trading network or the funding needs of their other counterparties. To help with both of these we build and estimate a model of repo trading.

In the model, repos are 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. Firms have mean-variance preferences and dealers have market power in their transactions with customers. 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 all assets – depend on its demands for cash and collateral, and those of its counterparties. Firms with low funding demand and high collateral demand are natural lenders. Dealers intermediate between natural lenders and borrowers and earn a spread, but also have their own demand for cash and collateral. 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: 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 time and across firms as flexibly as possible. Our model gives us equilibrium net demand curves, which govern how a given firm's net lending varies with the interest rate and other lending choices across the rest of the network. We estimate these net demand curves in two steps. First, our model implies that a given dealer charges its counterparties different interest rates depending on risk aversion, volatility and the size of the trade. We estimate this model-implied regression of interest rates to recover risk aversion and volatility. 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 to our estimation, we use these estimated fixed effects and parameters to back out the gilt-firm-time-specific intercepts of the net demand functions. This is analogous to stripping out the effect of network position and counterparty demand on interest rates, and leaving only a given firm's funding and collateral demand. Importantly, funding demand is common across assets (a firm's demand for cash does not depend on the underlying collateral), whereas collateral demand is specific to assets. Thus using variation in interest rates within firm-time but across gilts we can separately identify collateral and funding demand whilst making relatively few assumptions about their joint distribution.

Our estimates give us variation in the demand for funding across firms and time, and for collateral across firms, time and gilts. The time path of repo funding demand is closely related to the UK's monetary policy stance. As monetary policy tightened from 2022 onwards, the marginal cost of repo funding rose too. Collateral demand, by contrast, rises during times of stress in financial markets. In particular, collateral demand spiked during the dash-for-cash in March 2020, and during the gilt market turmoil in autumn 2022. This suggests that collateral demand is highest during times of stress, consistent with demand for short selling being a key driver of repo trading.

We quantitatively study the role of collateral demand in a counterfactual analysis in which we set the parameters governing collateral demand equal to zero. We find that, relative to our baseline estimated collateral demand parameters, this increases the average interest rate by 16%, as it removes an important motivation for lenders to lend. This causes overall trading volumes to shrink by 70% and aggregate firm utilities to decrease by over half. These results highlight the importance of collateral demand for repo markets. Collateral demand has a major impact on repo markets, and there are significant complementarities between collateral demand and the ability of firms' to access cheap funding in large quantity via the repo market. Treating repo markets purely as funding markets, and ignoring the collateral-driven motive for trade, thus omits something of fundamental importance to repo markets.

Our work suggests that collateral demand is of first-order importance in shaping how repo markets function. Collateral demand varies across firms, assets and time, and the nature of collateral demand determines the quantity and price of funding that firms can obtain via repo.

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. Copeland, Martin, and Walker (2014); Gorton and Metrick (2012); Krishnamurthy, Nagel, and Orlov (2014) study the role of the US repo market during the financial crisis. Mancini, Ranaldo, and Wrampelmeyer (2016) and Boissel, Derrien, Ors, and Thesmar (2017) study European repo markets during the financial crisis and during the European sovereign debt crisis, respectively. Hüser, Lepore, and Veraart (2021) use a subset of the same UK data as us to track repo market performance during the Covid 19 pandemic. Julliard, Todorov, and Yuan (2023) use a series of snapshots of similar UK data to document patterns in repo contract terms and to test different theories of why repo exists. Two particularly relevant papers in this literature are Eisenschmidt, Ma, and Zhang (2022) and Huber (2023), who build structural models of the European and tri-party US repo market, respectively. Eisenschmidt, Ma, and Zhang (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.

Our contribution is to show that collateral demand is an important and under-explored feature of repo markets, and to quantify its importance using structural estimation. We show how collateral demand affects market outcomes in the cross-section and inter-temporally, including during periods of financial stress.

There is also a literature on the market for lending assets, including for the purposes of shorting. D'Avolio (2002) and Asquith, Au, Covert, and Pathak (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, Kaniel, and Opp (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.

Our work is also related to the mostly theoretical literature on rehypothecation in repo markets, including Andolfatto, Martin, and Zhang (2017) and Gottardi, Maurin, and Monnet (2019). Singh (2011) and Aitken and Singh (2010) describe the possibility of collateral rehypothecation as a lubricant to repo market functioning. Our objective is to quantify the extent to which collateral demand, in the words of Singh (2011), lubricates repo market functioning.

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). 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, Lepore, and Veraart (2021) for a fuller discussion of the institutional details of repo in the UK.

2.2 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, commonly known as gilts. 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, Lepore, and Veraart, 2021). The data include counterparty ids, 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 exchanged 'Delivery by Value'. 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. 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.

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 Patterns

In this section we document two sets of facts on repo. We first describe some 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 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 36% are one week or less. Our data on haircuts is incomplete and (for now) low quality, but over 80% of the reported observations involve 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. On 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. Repo markets are used by many different types of financial firm, as we set out in Table 1.[2] In what follows we will highlight the differing behaviour of three sets of firms: dealers, hedge funds and money market funds (MMFs). Table 2 summarises the net trading behaviours of these types of firms. Dealers are involved in all trades, as the market is intermediated without material customer-to-customer trade. 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, Ma, and Zhang (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

[2] In our analysis we group together gilt dealers and banks under the category 'dealer-banks', as many institutions are both banks and gilt dealers. For brevity, we often refer to dealer-banks simply as dealers.

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 is a very safe investment. 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 securities demand motive for obtaining collateral 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, Begalle, Copeland, and Martin, 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 Collateral demand

We present 3 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. This can only be rationalised if repo lending is about more than just earning a return, but is also about obtaining the collateral.[3]

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 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

[3] 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.

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. The supply of cash and the demand for collateral are complements. Table 7 shows how the repo rate depends on whether a repo is against a specific gilt as collateral, or against a set of interchangeable gilts.[4] 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 an interchangeable set of gilt rather than a specific gilt, this motive of lending in order to obtain a particular asset is absent.

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 suggests a complementarity between the dual roles of repo. The fact that a borrower can offer useful collateral to a counterparty enables them to obtain funding at a cheaper rate.

[4]Here 'interchangeable gilts' denotes trades collateralised using CREST's delivery-by-value settlement system. For futher information, see https://www.euroclear.com/services/en/collateral-management/collateral-management-euroclear-uk-international.html.

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 observed differences could be rationalised through differences in trade size. Finally, it is hard to judge the scale of the observed differences, or put differently the exact effect of collateral demand on equilibrium trade.

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 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 and of which there are N_a. Each of these represents repo using a given bond as collateral. 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.[5]

There are N_d dealers and N_c customers, connected within a network denoted by the $N_d \times N_c$ matrix $\mathbf{G}$. If element $G(i,j) = 1$ then dealer i and customer j can trade, if $G(i,j) = 0$ 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 $\mathcal{N}_k$ denote the set of counterparties to which firm k has access, including, if firm k is a dealer, the inter-dealer market.

Let $Q^a_i = \sum_{k \in \mathcal{N}i} q^a_{ij}$ 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. Firm i may also obtain a risky payoff from the collateral that has expected return η^a_i and variance σ. Firms are thus heterogeneous in the returns to cash and to temporary ownership of the asset, as captured by ν_i and η^a_i, where this heterogeneity could come from individual liquidity needs, expectations about the returns to shorting the underlying bonds or individual endowments of cash or the bonds. Finally, firms may also earn a non-pecuniary payoff from the transaction, ϵ^a_{ij}, which is a reduced form representation of the importance of specific trading relationships.

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

$$\nu_i Q_i - \frac{\kappa}{2} Q_i^2 - \sum_a \eta^a_i Q^a_i - \sum_a \frac{\kappa}{2} \sigma (Q^a_i)^2 - \sum_a \sum_{m \in \mathcal{N}_i} q^a_{im}(r^a_{im} + \epsilon^a_{im}) \tag{1}$$

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

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 the customers, whereas customers are price takers, in keeping with our empirical evidence and existing findings in the literature (Eisenschmidt, Ma, and Zhang, 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: $\sum_i q_{iD}^a = 0$. The first order condition for dealer i with respect to q_{iD}^a is as follows:

$$\underbrace{\nu_i - \kappa Q_i}_{i\text{'s MB from cash}} \underbrace{-\eta_i^a - \kappa\sigma Q_i^a}_{\text{- } i\text{'s MB from collateral}} - \epsilon_{iD}^a - r_D^a = 0 \tag{4}$$

To pin down the equilibrium interdealer interest rate, sum Equation 4 over all dealers and impose the market clearing condition that $\sum_i q_{iD}^a = 0$. It follows immediately that the equilibrium interdealer rate r_D^a is a function of the average ν_i and η_i^a 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, Herskovic, Rajan, and Siriwardane (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, Ma, and Zhang, 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, a single hedge fund and two assets. Suppose the dealer (indexed by i) does not have collateral demand, such that $\eta_i^1 = \eta_i^2 = 0$. The hedge fund (indexed by j) does have collateral demand, where $\eta_j^1 > \eta_j^2 > 0$ (indicating a preference for asset 1). Suppose all ϵ are equal to 0.

It is straightforward from the linear first order conditions to pin down aggregate lending between the two firms (Equation 5) and its distribution across the two assets (Equation 6):

$$q_{ij}^1 + q_{ij}^2 = \frac{\nu_i - \nu_j + 0.5(\eta_j^1 + \eta_j^2)}{3\kappa(1+\sigma)} \tag{5}$$

$$q_{ij}^1 - q_{ij}^2 = \frac{\eta_j^1 - \eta_j^2}{3\kappa\sigma} \tag{6}$$

The distribution of aggregate lending across the assets depends on the hedge fund's relative preferences over them, as the dealer is indifferent between them. The importance of collateral demand for aggregate trading depends on the size of η_j^1 and η_j^2: the bigger they are, the greater the net lending from the hedge fund to the dealer.

Note that the direction of this effect on trading volumes, $abs(q_{ij}^1 + q_{ij}^2)$, depends on the firms' relative funding needs, $\nu_i - \nu_j$. If this is positive, then collateral demand complements funding needs, such that its presence increases trading volumes. Suppose, on the other hand, that $\nu_i << \nu_j$, such that in equilibrium the dealer lends to the hedge fund. In this case, trading volumes are *decreasing* in collateral demand, as it limits the extent to which the hedge fund is willing to give up its collateral in order to borrow.

The implication is that the effect of collateral demand on repo market functioning depends not just on its size, but also on its joint distribution with funding needs. That is, collateral demand only lubricates (in the words of Singh (2011)) repo market functioning if it is distributed in the right way relative to funding needs.

5 Estimation

We now turn to estimating our model, where our task 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 aggregate our transactions data to the pair-asset-week level, such that for each pair of firms that write repos in a given week against a given gilt, we compute their net repo trading against that gilt in that week 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 weeks t.

We estimate a separate funding need ν_{it} for each firm i in week 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 $\boldsymbol{\Theta} = (\boldsymbol{\nu}, \boldsymbol{\eta}, \kappa, \sigma)$: respectively, the vector of firm funding needs across firms and weeks, the vector of collateral demand across firms, weeks 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 $\mathbf{r}$.[6]

Equations 2 and 3 of our model imply the following estimating equation:

$$r_{ijt}^a = \delta_{it}^a - \left[\kappa \sum_l q_{ijt}^l + \kappa\sigma q_{ijt}^a\right] \mathbb{1}_{ij} + \epsilon_{ijt}^a \tag{7}$$

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 $i \times t \times g$ fixed

[6]The haircut data to which we have access is (for now) incomplete and of low quality. Given what we do observe with reasonable accuracy, it seems that over 80% of transactions involve zero haircut (or, in the notation of our model, haircut multipliers of 1). In what follows we assume that this haircut multipliers are 1 for all transactions.

effect δ_{it}^a captures i's preferences over cash and the gilt:

$$\delta_{it}^a = \nu_{it} - \kappa Q_{it} - \eta_{it}^a - \kappa\sigma \sum_m q_{imt}^a \tag{8}$$

Our estimating approach is to estimate κ and σ from estimating Equation 7, and then to estimate ν_{it} and η_{it}^a using Equation 8.

In doing this, we face two challenges. First, rates and quantities are jointly determined, so we need exogenous variation in trading quantity q_{ijt}^a in order to estimate Equation 7. Second, we need to separately identify ν_{it} and η_{it}.

We solve the first challenge 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 demand 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 against which they hold, and against which they can borrow. To do so, we look at the preceding 4 weeks, and identify the set of gilts ω_j against which firm j borrowed, and the percentage of their net borrowing that was against each of these gilts s_{jt}^a, for all a in ω_j. We then construct the sum of the prices of the bonds in j's wallet, weighted by the shares s_{jt}^a:

$$z_{1,jt} = \sum_{a\in\omega_j} s_{jt}^a \times \text{price}_t^a \tag{9}$$

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:

$$z_{2,jt}^a = z_{1,jt} - s_{jt}^a \times \text{price}_t^a \tag{10}$$

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:

$$\begin{aligned} q^a_{ijt} &= \alpha^a_{it} + \beta_1 z_{1,jt} + \beta_2 z^a_{2,jt} + e^a_{ijt} \\ \sum_l q^l_{ijt} &= \alpha^a_{it} + \beta_3 z_{1,jt} + \beta_4 z^a_{2,jt} + e^a_{ijt} \end{aligned}$$

We solve the second challenge by making use of variation across gilts. 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}:

$$\hat{\delta}^a_{it} + \hat{\kappa} Q_{it} + \hat{\kappa}\hat{\sigma} \sum_m q^a_{imt} \equiv \hat{y}^a_{it} = \nu_{it} - \eta^a_{it} \tag{11}$$

where for notational simplicity we aggregate the known combinations of estimated parameters from the first stage and data in to the term $\hat{y}^a_{it}$. This term can be interpreted as the average interest rate paid by firm i at time t adjusted for trade-size and network position, such that any remaining heterogeneity across firms and time comes from their funding need and collateral demand.

Variation in $\hat{y}^a_{it}$ across a pins down differences in η^a_{it}. To separately pin down the level of η^a_{it} and v_{it}, we assume that $min_a \eta^a_{it} = 0$ within i and t: that is, collateral demand for $a^{'}$ is the incremental value ascribed by firm i to $a^{'}$ over its least valued a. This gives us a semi-parametric approach to recovering η^a_{it} and ν_{it} across i and t, in that the only restrictions we impose are on the smallest collateral demands across a and within i and t.

Any benefit to the gilt that is not collateral demand and that is common to all gilts (such as its use as collateral in the sense of insurance against default) is captured under what we call funding needs ν_{it}. If, on the other hand, agent i has strictly positive collateral demand for all gilts (for example, if the agent wants to short all gilts), then this approach would misidentify some of this as funding needs. Thus we interpret this as a lower bound on the true collateral demand parameters.

6 Results

We describe the results of our estimation in this section. For now, we only use data on the 30 most frequently traded gilts.

Table 8 shows the results of the first part of our estimation approach, which is to estimate Equation 7. We show results from OLS regressions 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 0.16 for risk aversion κ and 1.47 for the risk on the return to obtaining collateral σ.

Figure 3 shows the results of the second part of our estimation, where we infer semi-parameterically the values of collateral demand and funding demand from the fixed effects of the regression in Table 8. We plot the distribution of the estimates of funding demand ν_i in the left panel and collateral demand η_i^a in the second panel.

Our estimated funding demand (solid lines in Figure 3a) closely tracks the central bank's policy rate (dashed line). This is intuitive: the net demand for funding via repo contracts should be in part determined by the cost of alternative available funding. As policy rates change, this is passed through into other funding markets. As a result, the monetary policy tightening from 2022 onwards has 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, as shown in Figure 3b. It rose in March & 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, Gual-Ricart, Lillis, and Worlidge, 2021) and the gilt market turmoil in the autumn of 2022 (Pinter, 2023).

This suggests that the demand for collateral tends to spike during times of uncertainty and disagreement in underlying asset markets. Each of these periods involved large movements in UK yield curves and uncertainty about the future path of interest rates. This creates a motive for firms to look to speculate on future movements or hedge against them, as the gains to these strategies are potentially large. As a result, the demand for collateral via repo contracts – potentially to short specific assets – spikes during times of stress.

7 Counterfactuals

Our goal in this section is to use our estimated model to quantitatively study the impact of collateral demand on the repo market. To do so, we compare our estimated equilibrium outcomes to a counterfactual equilibrium where collateral demand η_{it}^{a} is zero for all firms, assets and time periods. We then compare repo rates, trading quantities and welfare in the counterfactual and the baseline. Table 10 shows the change in these quantities in the counterfactual for a single week, beginning 22$^{\text{nd}}$ January 2017.

Absent collateral demand, repo rates are higher, trading quantity is lower, and utility is higher. The magnitudes of these differences are large: the increase in the repo rate is 16%. This large increase in the marginal cost of funding leads to major reductions in trading activity in the market (70%), and in traders' welfare (53%).

Economically, removing collateral demand is a reduction in the benefit that the firm receiving collateral gets from a repo contract, which reduces the gains from trade. This reduction in firms' net demand for collateral impacts firms' ability to gain funding via the repo market. A firm that previously could borrow at a low rate by providing their counterparty with an asset they desired now has less to offer their counterparty, and so must pay a higher rate. This in turn shrinks overall trading volumes and utility.

The large magnitudes of these results are driven by the data in the following way. Our empirical patterns showed that repo rates varied significantly across different bonds (Table 10). Our model showed that – controlling for firms' positions in the network – this variation could be explained by variation in collateral demand as captured by η_i^a across firms and assets. Our estimation showed significant variation in collateral demand across firms and bonds, and produced estimates of risk aversion κ and σ that pinned down the elasticity of firms' net demands for cash and collateral. In the counterfactual where we turn off collateral demand, the magnitudes of the estimated collateral demand mean this represents a big shock to collateral demand and the elasticities of firms' net demands mean this has major impacts on rates, quantities and welfare.

These results highlight the importance of collateral demand for repo markets. Collateral demand has a major impact on repo markets, and there are significant complementarities between collateral demand and the ability of firms' to access cheap funding in large quantity via the repo market. Treating repo markets purely as funding markets, and ignoring the collateral-driven motive for trade, thus omits something of fundamental importance in repo markets.

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 that we structurally estimate. We leave for future work an assessment of how collateral demand might affect bond prices through its effect on shorting, a more complete treatment of how haircuts relate to collateral demand, and an assessment of how this impacts risk. More generally, this work forms part of a broader agenda in the literature to use new transaction data to examine the way in which markets are organised.

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Figures

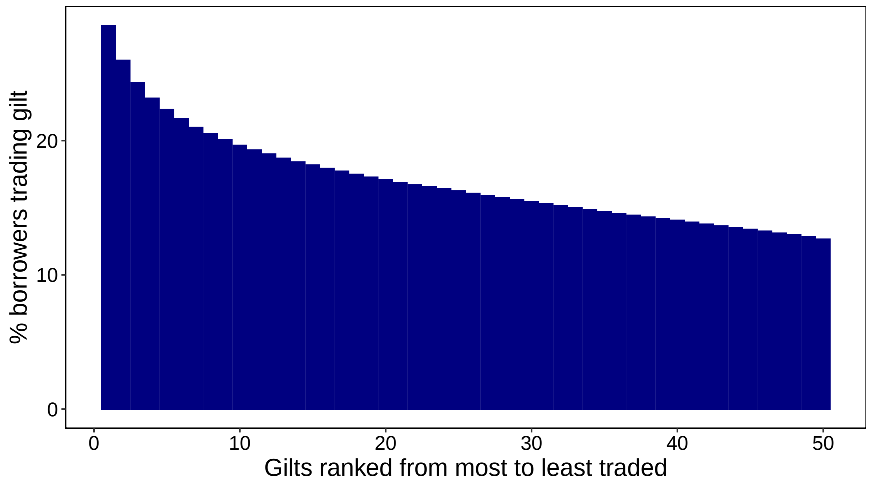


Figure 1: Variation in use of gilts in repo borrowing

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.

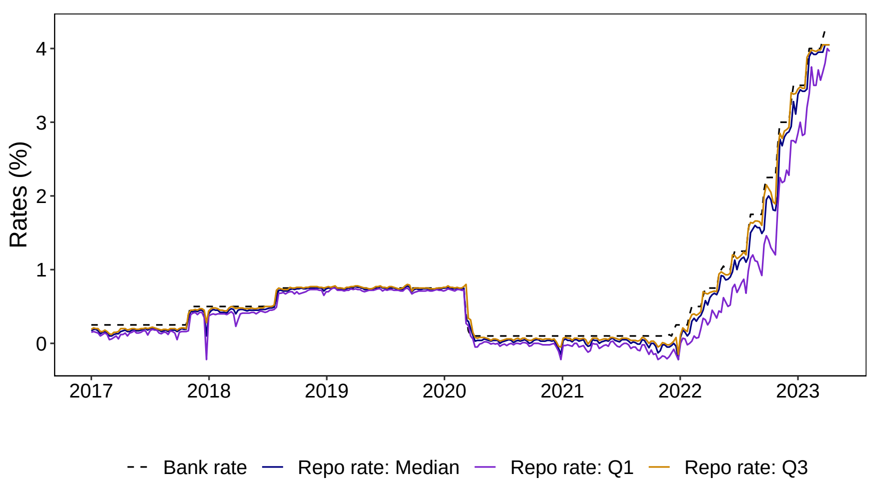
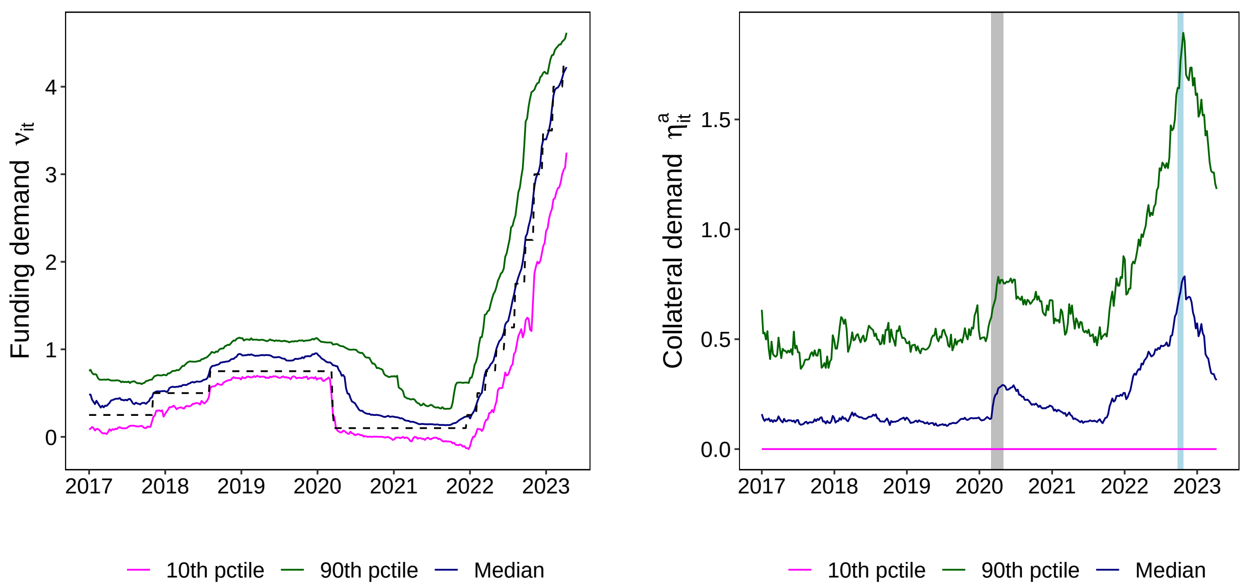


Figure 2: Rates through time on dealer repo lending

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.



(a) Funding demand **(b) Collateral demand**

Figure 3: Estimated funding & collateral demand through time

Note: Figure summarises the estimated distribution of funding demand ν_{it} across firms and weeks and of collateral demand η^a_{it} across firms, weeks and gilts. The dashed line in the first panel shows Bank of England base rate. 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).

Tables

Table 1: Summary Statistics

	Share (%)
Maturity	
Overnight	40
Less than 1 week	36
2 weeks - 1 month	16
1 month plus	8
Clearing	
Cleared	53
Bilateral	46
Triparty	0
Segment	
Interdealer	56
Dealer-Customer	44
Trader Type	
Dealer-Bank	78
Hedge Fund	10
Fund	4
PFLDI	3
MMF	3
Other	2

Notes: Share shows percentage of total volume in each category. MMFs are money market funds, and PFLDI denotes pension funds & liability-driven investments. Banks and dealers are grouped together as dealer-banks, and the interdealer segment is the set of trades between these firms. 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 2: Net lending by sector

	Mean net lending (%)	% days net lending
Dealer	-8	5
Hedge Fund	-1	50
MMF	98	99
Other	6	87

Notes: Table summarises the lending behaviour of various sectors. The first column shows the average daily net lending of each sector, computed as 100 times the difference between the sector's lending and borrowing divided by the sum of its lending and borrowing. The second column shows the % of days on which the sector lends more than it borrows. This table includes only days when a given sector traded at least once.

Table 3: Dealers rates on borrowing & lending

	Repo rate (%)		
	(1)	(2)	(3)
Dealer lending	0.158***	0.152***	0.099***
	(0.007)	(0.002)	(0.0007)
R^2	0.13	0.29	0.59
Observations	1,254,802	1,254,802	1,254,802
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.

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)	(5)
Lender: Hedge fund	-0.06***	-0.05***	0.03***	-0.08***	-0.002**
	(0.005)	(0.005)	(0.003)	(0.003)	(0.001)
R^2	0.38	0.45	0.80	0.57	0.97
Observations	380,282	380,282	380,282	380,282	380,282
Week fixed effects	Yes				
Maturity-Week fixed effects		Yes			
Asset-Week fixed effects			Yes		
Borrower-Week fixed effects				Yes	
Asset-Mat-Borr-Week fixed effects					Yes

Notes: Table summarises the difference between the rates (net of Bank rate) 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.

Table 7: Repo rates & collateralisation type

	Spread				
	(1)	(2)	(3)	(4)	(5)
Interchangeable Collateral	0.08***	0.09***	0.09***	0.09***	0.09***
	(0.005)	(0.010)	(0.002)	(0.004)	(0.004)
R^2	0.26	0.17	0.53	0.37	0.35
Observations	6,390,842	6,390,842	6,390,842	6,390,842	6,390,842
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 (net of Bank rate) vary according to whether collateral is exchanged via ‘Delivery by Value’ – here denoted interchangeable collateral – or otherwise. The table shows the results of regressions on a dummy for whether the transaction involved interchangeable collateral and the listed fixed effects. Repo rates are measured net of Bank rate. Standard errors are clustered at the level of the fixed effect. For further details on delivery by value, see https://www.euroclear.com/services/en/collateral-management/collateral-management-euroclear-uk-international.html.

Table 8: Parameter estimates: OLS and TSLS

	Repo rate (%)	
	OLS	2SLS
	(1)	(2)
$\sum_l q^l_{ijt}$	-0.02***	-0.16***
	(0.0003)	(0.002)
q^a_{ijt}	-0.05***	-0.23***
	(0.002)	(0.009)
R^2	0.94	0.95
Observations	2,922,678	2,512,141
Firm-asset-week fixed effects	Yes	Yes

Notes: Table shows the results of estimating Equation 7 by OLS and two-stage least squares. The coefficient on $\sum_l q^l_{ijt}$ gives an estimate of (minus) risk aversion κ, whilst the coefficient on q^a_{ijt} gives an estimate of $-\kappa \times \sigma$, where σ is the standard deviation of the return firms get using the asset they obtain as collateral. Standard errors are clustered at the firm-asset-week level.

Table 9: First stage results

	q^a_{ijt}	$\sum_l q^l_{ijt}$
	(1)	(2)
$z_{1,jt}$	-0.002***	-0.008***
	(5.6×10^{-5})	(0.0002)
$z^a_{2,jt}$	0.002***	0.0004***
	(3.6×10^{-5})	(7.7×10^{-5})
R^2	0.28	0.25
Observations	2,513,340	2,513,340
Wald (joint nullity)	1,646.3	922.8
Firm-asset-week 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 both instruments based on the prices of the gilts that firm j typically uses as collateral, with the details given in Section 5. Standard errors are clustered at the firm-asset-week level.

Table 10: Changes in key quantities in counterfactual

	Percentage change in counterfactual
Mean repo rate	16
Aggregate trading quantity	-70
Aggregate welfare	-53

Notes: Table shows the effect on key quantities of a counterfactual scenario in which collateral demand is set to 0. For a single week in 2017 we compute the mean repo rate, aggregate trading quantity and firm welfare based on our actual estimated parameters. We then set all counterfactual demand parameters η^a_{it} to zero, recompute these three quantities, and display in the table their percentage change relative to the baseline.