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Collateral demand in wholesale funding markets

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Abstract

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.

Key words: Repo, collateral demand, intermediation, financial crises.

JEL classification: G01, G21, G23, G11, L14.

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1 Introduction

Repurchase agreements (repo) serve two important functions. The borrowing firm may trade to obtain funding (funding demand), whereas the lender may trade to temporarily obtain the asset provided as collateral (collateral demand), including in order to short it. Together, funding 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 these 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 impedes repo market functioning: 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 up the underlying collateral.

[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.

Importantly, this is not driven just by hedge funds seeking to short to speculate, but also by dealers and 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 dealers and 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 show that lending dealers frequently charge a lower rate than the risk-free rate (Arrata et al., 2020) and that interest rates are higher for general collateral repo, where the lender does not specify exactly which bond it requires as collateral (Ballensiefen et al., 2023). We then set out various novel facts on how trading varies across firms. We show that hedge funds charge lower interest rates when lending than money market funds, whose limited mandates preclude a motive to demand specific bonds as collateral, and these rates are more sensitive to the precise bond chosen as collateral. 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 bonds and are willing to lend at lower rates in return for being provided these "special" bonds (Duffie, 1996).

These facts establish the presence of collateral demand and show it varies across firms, 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?[3] 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 bonds, 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

[3] Eisenschmidt et al. (2022) and Huber (2023), for example, find evidence of market power for dealers. The rates obtained by individual traders will therefore depend on the degree of market power they face, as well as their collateral demand.

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. Collateral demand decreases the payoff to borrowing (as the borrower has to give up valuable collateral), but increases the payoff to lending. The net effect of collateral demand on volumes and gains to trade can thus be positive or negative depending on which effect dominates. If collateral demand is negatively correlated with funding demand, then the additional payoff to lenders (that typically have low funding demand) dominates the reduced payoff to borrowers. In this case, collateral demand increases trading volumes and gains to trade. If instead the two are positively correlated, then the reverse is true and collateral demand reduces trading volumes and gains to trade. The effect of collateral demand thus depends on the joint distribution of collateral and funding demand across firms, which is exactly what our data are well suited to measure.

We then return to the data to structurally estimate our model (Eisenschmidt et al., 2022; Huber, 2023). 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-bond-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-bond-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 bonds, whilst making very few assumptions about their joint distribution.

This estimation allows us to set out three further sets of empirical results on 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 bond 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. Dealers, banks and hedge funds 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 bond prices. We sort bonds into long-short portfolios based on estimated collateral demand, and find that bonds 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 bonds for which dealers and 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, so as to quantify exactly how collateral demand affects repo market functioning. 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. A key driver of this result is that dealers and banks have both high funding demand and high collateral demand in financial stresses, as they need to hedge underlying interest rate risk. The structure of repo markets makes it difficult for dealers and banks to simultaneously do these two things: acquiring liquidity requires them to give up bonds, when both are relatively more valuable to dealers and banks than to other firms.

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 an additional 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.

Our findings have implications for various policies that affect how firms, and dealers and banks in particular, simultaneously fund themselves and fulfil their collateral demand. Such policies include how and when central banks intervene in repo markets, whether through repo lending facilities or collateral swap facilities. If such facilities accept collateral other than government bonds (at a reasonable rate and haircut), then this would allow dealers and banks to separate the way they manage interest rate risk from their liquidity management in a stress: our findings indicate this would improve repo market functioning. Rules regarding naked or uncovered short-selling – which is banned or limited in various jurisdictions – also affect the degree of collateral demand in repo markets, and so have implications for repo market functioning. More broadly, our findings suggest policy should be designed in a way that permits dealers and banks to manage their collateral demand and their interest rate risk in a stress, as well as their their liquidity risk.

In conclusion, collateral demand appears to impede repo market functioning, rather than lubricating it as suggested by Singh (2011), and particularly so in times of financial stress. Our data and setting are specific to the Sterling gilt repo market, but repo markets are important funding markets worldwide and there is evidence of collateral demand in both the US (Duffie, 1996) and in other European markets (Arrata et al., 2020; Ballensiefen et al., 2023), such that the issues we consider in this paper are of wider relevance. Collateral demand, and its regulation, is of central importance to the most important wholesale funding market.

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; Jank et al., 2022; 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. Ioannidou et al. (2022) and Taburet et al. (2024) estimate structural models in other lending markets. 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 lending markets (Chang, 2019; Chang and Chuan, 2023). 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 funding 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 complementarity between funding demand

and collateral demand is 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 an agreed price 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 dealers, who borrow from lending institutions and lend to borrowing institutions.[5]

Repo trades can take place over-the-counter or on centralised exchanges. In the UK, almost all repos between dealers or banks and non-banks are cleared bilaterally, whilst almost all trades between dealers and banks 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.

[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]Dealers in gilt markets are typically also banks. In general we will refer to dealers and (other) banks as distinct entities, except in estimating our model where we group them together.

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 banks. Repo is arguably the most important source of short-term financing for a broad range of financial firm types.[6]

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 four 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 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.[7]

- Hedging: participants may seek to short the underlying assets not for speculative reasons, but in order to hedge risk. This applies in particular to dealers and 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).[8] Banks may also hedge using interest rate swaps (Jiang et al., 2023).

- Leverage: firms may lend or borrow against particular bonds in order to leverage up, including when undertaking a basis trade. A basis trade is a relative value trade in which a firm sells a futures contract and buys a given bond (typically the cheapest-to-

[6]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/.

[7]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/.

[8]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/.

deliver under that futures contract). The firm finances this trade by lending that bond out on the repo market (Barth and Kahn, 2021).

- 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

Our focus is on collateral demand in repo markets. The benefits to obtaining collateral through repo markets are affected by a broad range of policy and regulatory decisions.

One of the sources of collateral demand in repo markets, as described above, is shorting. Policy on short-selling, and in particular the prohibition of uncovered (or naked) short selling in UK government bonds, therefore matters for repo market functioning. Current rules require a firm wishing to short a given bond to first temporarily acquire the bond through the repo market or a securities dealer. Market-makers are exempt from this prohibition, but need to give regulators 30 days' notice before engaging in naked short-selling.[9] In July 2023 the UK government launched a consultation on lifting this prohibition, with the aim of improving liquidity in secondary government bond markets.[10] 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.

Other relevant policy decisions include how and when central banks intervene in repo and in related markets. The Bank of England, for example, can choose to lend through a repo transaction in return for collateral (Breeden and Whisker, 2010), whilst UK authorities also offer the means to obtain and exchange collateral (DMO, 2004). The terms at which central banks do this, and critically the collateral that they accept, clearly affects the role of collateral demand in wholesale repo markets. We discuss the implications of our work for these policy decisions in Section 7.

[9] https://www.fca.org.uk/markets/short-selling/exemptions-requirements.

[10] 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 bond 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 bonds from the cash borrower.[11] In these trades the collateral is therefore not a pre-specified bond, but is an unspecified single bond or combination of bonds from a set of eligible bonds. 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 for government bonds 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 in quantitative terms the key features of the Sterling gilt repo market, which we use to explain how the market functions and motivate our modelling approach. In the second set of facts we consider

[11]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.

collateral demand, and in particular the extent to which it varies across firms.

3.1 Repo market features

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 bond as collateral, and rank bonds 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 is 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 bond.

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

Rate level. 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.[12]

Rate drivers. Table 2 provides evidence on the role of collateral demand. We regress the

[12]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.

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 bond 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 bond is provided as collateral. These bonds 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 bonds capture differences in their value as insurance in case of default. It is much more consistent with the idea that at certain times certain bonds are desirable, that repo is a way to obtain these bonds, and traders are willing to pay higher rates to obtain them.

Trading network. The network of trading relationships is sparse, and essentially 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.

General collateral. Firms trade repo against both general and specific collateral. Across our whole sample period, around 9% of aggregate repo trading is against general collateral, where the collateral exchanged can be any of a pre-specified set of bonds. We will use the simultaneous trading of general and specific collateral repo to separately identify funding demand and collateral demand in Section 5.

As in Ballensiefen et al. (2023), we find that rates differ for general and specific collateral in a way that is consistent with collateral demand: borrowing against a specific bond is cheaper than borrowing against a set of bonds (Table 3). We interpret the coefficient in Table 3 as capturing the value of receiving specific collateral in a repo.

3.2 Empirical facts on collateral demand

In the preceding subsection on summary statistics, we document the existence of collateral demand. In this subsection, we set out three novel facts on heterogeneity across firms: (1) on trading behaviour, (2) on the drivers of interest rates, and (3) on the level of interest rates.

Fact 1: Heterogeneity in trading behaviour

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 4 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 sets of firms are of particular interest to our analysis as their business models imply specific patterns of collateral demand. Table 4 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, thus trading with many more counterparties than any other type of firm. Table 5 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 4: 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. 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 4, 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.

Fact 2: Heterogeneity in the drivers of interest rates

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, dealers and hedge funds. As explained above, MMFs have little reason to prefer a specific bond as collateral against another, whereas hedge funds often trade in order to obtain a specific asset for use in short-selling or in derivatives contracts. Dealers play several roles: obtaining funding and collateral and intermediating for their clients.

This difference in the role of collateral for these three types of firm can be seen in Table 6. For each of these types of firm, 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 between 31% and 52% 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 bond is used as collateral, or anything else.

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 bond was provided as collateral. Two hedge funds lending in the same week at the same maturity against the same bond tend to do so at roughly the same rate.

Similar to hedge funds, the bulk of variation in dealers' repo rates is explained by which bond was provided as collateral, and not by the firm they were lending to. This is consistent with dealers, like hedge funds, exhibiting collateral demand.

Fact 3: Heterogeneity in the level of interest rates

The difference between hedge funds and MMFs in the level of the interest rates at which they lend is also informative about collateral demand. Table 7 contrasts the repo rates that firms pay when borrowing from hedge funds and MMFs. Hedge funds lend at a lower rate than MMFs, which is consistent with them receiving some additional benefit from the collateral that MMFs do not. This is true for various fixed effects, including those at the borrower-time level: in other words, the same borrower in the same week pays more to borrow from an MMF than from a hedge fund. We do not report similar results for dealers, as the level of their interest rates is affected by market power, as described in fact 1 above.

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 bond with an obligation to repurchase it in the future: the borrower temporarily obtains cash in exchange for the bond, whereas the lender obtains the bond 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 bond used as collateral (we abstract away from maturity of the repo, for example).

Firms may have a desire for cash (representing liquidity needs) and their desire for specific bonds 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.[13]

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, as in Eisfeldt et al. (2023). 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). 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 normally distributed 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 normally distributed risky payoff from the collateral that has expected return η^a_i and variance σ.[14] 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

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

[14] It would be straightforward to allow σ to vary across firms, time or assets. We consider such robustness checks in our empirical section below.

and any other unmodelled shocks to individual transactions.

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. We do not impose any assumptions about the distribution of these parameters across firms, assets or time, and instead estimate this distribution as flexibly as possible in Section 5 below. Heterogeneity in collateral demand could come from any of the possible motives described above in Section 2.4, including differences in beliefs about the returns to the underlying assets (speculation, in other words) and differences in endowments/pre-existing exposures to those assets (hedging). We do not disaggregate collateral demand η_i^a between these motives here, but consider such a disaggregation post-estimation.

Firms have mean-variance preferences, with risk aversion $\kappa/2$. The payoffs to a given firm from cash and collateral are normally distributed, such that this is equivalent to firms having CARA preferences.

$$\mathbb{E}[W_i] - \frac{\kappa}{2}\mathbb{V}[W_i] \tag{1}$$

where $W_i = Q_i\alpha_i - \sum_a Q_i^a\alpha_i^a$, and $\alpha_i \sim N(\nu_i, 1)$ is the payoff to the firm of cash and $\alpha_i^a \sim N(\eta_i^a, 1)$ the payoff to the firm of asset a. All payoffs are independent of each other. Given these preferences and the model of trade described above, the utility to firm i is:

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

Firms thus face a quadratic payoff function, with heterogeneity coming from their preferences over cash ν_i and collateral η_i^a, their network position $\mathcal{N}_i$, and whether they possess market power.

4.3 Solving the model

We first consider trades between dealers and customers, before considering inter-dealer trade. 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:

$$\underbrace{-\nu_j + \kappa Q_j}_{\text{- } j\text{'s MB from cash}} + \underbrace{\eta_j^a + \kappa\sigma Q_j^a}_{j\text{'s MB from collateral}} + r_{ij}^a = 0 \tag{3}$$

The first order condition for dealer i transacting with customer j with respect to q^a_{ij} has two additional term representing the price effect, which follow directly from the equilibrium condition in Equation 3: 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.

$$\underbrace{\nu_i - \kappa Q_i}_{i\text{'s MB from cash}} \underbrace{- \eta^a_i - \kappa\sigma Q^a_i}_{\text{- }i\text{'s MB from collateral}} \underbrace{-\kappa \sum_{l\in\mathcal{A}} q^l_{ij} - \kappa\sigma q^a_{ij}}_{\text{Price effect}} - \epsilon^a_{ij} - r^a_{ij} = 0 \tag{4}$$

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:

$$\underbrace{\nu_i - \kappa Q_i}_{i\text{'s MB from cash}} \underbrace{- \eta^a_i - \kappa\sigma Q^a_i}_{\text{- }i\text{'s MB from collateral}} - \epsilon^a_{iD} - r^a_D = 0 \tag{5}$$

To pin down the equilibrium interdealer interest rate, sum Equation 5 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.

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:

$$q_{ij} = \frac{\Delta\nu - \Delta\eta}{3\kappa(1+\sigma)} \tag{6}$$

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 6 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 6: 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, 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. The equilibrium gains to trade (GTT) across the two parties are as follows:

$$GTT = \left[\frac{2\Delta\nu}{9\kappa(1+\sigma)}\right]^2 (1 - \rho_{\eta\nu}\bar{\eta})^2 \tag{7}$$

Suppose that $\rho_{\eta\nu}\bar{\eta} < 1$, implying that collateral demand is not more sensitive to funding need than funding need itself.[15] It follows immediately that gains to trade are increasing in the level of collateral demand $\bar{\eta}$ if $\rho_{\eta\nu} < 0$ and are decreasing if $\rho_{\eta\nu} > 0$.

Collateral demand affects both demand and supply in repo markets. The presence of collateral demand shifts the demand curve of the borrower *inwards*, as the borrower has to give up collateral that it values. It shifts the supply curve of the lender *outwards*, as the lender obtains collateral that it values. This reduces rates, but the net effect on quantity and gains to trade depends on the relative magnitudes of the shifts in demand and supply. If the shift in demand is larger (which would imply collateral demand is positively correlated with funding demand, as the borrower has higher funding demand than the lender), then quantities and gains to trade go down, and vice versa.

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.

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.

4.5 The relationship between the model and the data

We emphasise two aspects of the relationship between our modelling choices and the data.

First, the model's features are closely informed by the patterns we observe in the data and describe in Section 3. The data clearly show that firms trade different repo assets, with evidence that some firms access repo for funding and some for the collateral. In Table 6, we show that rates vary materially across firms and across assets. The focus of the model is to allow general variation in firms' needs for funding and collateral, and to show how that variation drives trade across multiple assets. We also describe in Section 3 how the network is sparse and fixed over time, which informs how we allow for an exogenous trading network.

[15] Under this assumption, it is funding demand that determines the direction of trade, in that the firm with larger funding demand borrows and the firm with smaller funding demand lends. Repo is thus primarily a *funding market*. We discuss in our counterfactuals below what would happen if this assumption were not to hold, such that collateral demand drives the direction of trade and repo were primarily a *collateral market*.

Finally, we match empirical and institutional features regarding access to a competitive dealer to dealer market, a role for general collateral, and dealer market power.

Second, the model is intended to be structurally estimated. As described in the preceding subsection, the effect of collateral demand on repo market functioning can be positive or negative depending on the distribution of collateral and funding demand across firms. Thus the effect of collateral demand on repo market functioning is an empirical question. The model allows us to recover the joint distribution of funding and collateral demand as flexibly as possible, while controlling for other drives of trade including market power and network position.

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 bonds. 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 bond, we compute their net repo trading against that bond 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 $i-j$, bonds a and days t. The dealers in our model consist of dealers and banks in our data, whilst all other types of firm are taken to be customers.

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 3 and 4 of our model imply the following estimating equation:

$$r^a_{ijt} = \delta^a_{it} - \left[\kappa \sum_l q^l_{ijt} + \kappa\sigma q^a_{ijt}\right] \mathbb{1}_{ij} + \underbrace{\delta_{ij} + u^a_{ijt}}_{\epsilon^a_{ijt}} \tag{8}$$

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 we have disaggregated the pairwise shock ϵ^a_{ijt} into an $i-j$ fixed effect and a residual u^a_{ijt}. The $i \times t \times a$ fixed effect δ^a_{it} captures i's preferences over cash and the bond:

$$\delta^a_{it} = \nu_{it} - \kappa Q_{it} - \eta^a_{it} - \kappa\sigma \sum_m q^a_{imt} \tag{9}$$

Our estimating approach involves two steps: first to estimate the curvature parameters κ and σ from estimating Equation 8, and second to estimate ν_{it} and η^a_{it} using Equation 9. We discuss each step in turn, including our baseline approach and various robustness tests.

Step 1: Estimating curvature parameters

In estimating Equation 8, 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 bonds against which they borrow, as shown in Figure 1, (b) the prices of different bonds 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 firms - we emphasise here that we include firm-time-bond fixed effects δ^a_{it} within step 1 of our estimation, so the only remaining variation is within individual pairs of firms within the repo market. As a result, we can use variation in bond prices to isolate exogenous variation in firm j's net demand for cash and collateral in Equation 8, 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 8, 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 bonds which they hold, and against which they can borrow. We look at the preceding 4 weeks, and identify the set of bonds ω_{jt} against which firm j borrowed, and the amount of their borrowing that was against each of these bonds 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}:

$$z_{1,jt} = \sum_{a \in \omega_{jt}} s^a_{jt-1} \times \text{price}^a_t \tag{10}$$

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:

$$z^a_{2,jt} = z_{1,jt} - s^a_{jt-1} \times \text{price}^a_t \tag{11}$$

This is the change in the value of the bonds 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 bond 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 8:

$$q^a_{ijt} = \alpha^a_{1,it} + \beta_1 z_{1,jt} + \beta_2 z^a_{2,jt} + \alpha_{1,ij} + e^a_{ijt} \tag{12}$$
$$\sum_l q^l_{ijt} = \alpha^a_{2,it} + \beta_3 z_{1,jt} + \beta_4 z^a_{2,jt} + \alpha_{2,ij} + e^a_{ijt} \tag{13}$$

These instruments are in effect shift-share instruments, where the shares are determined by the amount of borrowing of firm j against different bonds. 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 bond prices and the shares used in computing our instrument are independent of these shocks.

The independence of pairwise shocks and bond prices is – given the demanding fixed effects we include – a relatively mild assumption. It is highly likely that developments in repo markets impact bond markets, and indeed in our results section below we show how our collateral demand estimates are correlated with bond prices. If, for example, the hedge fund sector wishes to borrow a bond for shorting reasons, one would expect its price to go up. However, our regressions include firm-bond-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 bond markets.

We lag the firm's wallet so as to remove any contemporaneous correlation between firm trading and the unobserved shocks. If these unobserved shocks are not serially correlated, then our instrumental variable is valid.

In Appendix A we set out various robustness tests that guard against the possibility of serial correlation in these errors biasing our results. We include more stringent fixed effects, including at the $i - j - a$ level, which control for any fixed preference by j for any particular bonds (in the sense of a preferred habitat or some business-related reason why a firm systematically obtains particular types of bond for use in the repo market). We also include fixed effects at the $i - j - t$ level, which control for time-varying relationship-specific shocks. Finally, we also equal-weight the bond prices in the wallet, instead of relying on their shares within the wallet. In all cases our results are robust.

Step 2: Estimating funding and collateral demand

In the first step, we estimate δ^a_{it} and we recover estimates of κ and σ. In the second step of our estimation, we use these estimates to recover funding and collateral demand. Given Equation 9 and the estimates from the first step, the only remaining unknowns are η^a_{it} and ν_{it}, as everything on the left-hand side of the following equation is known:

$$\delta^a_{it} + \kappa Q_{it} + \kappa\sigma \sum_m q^a_{imt} = \nu_{it} - \eta^a_{it} \tag{14}$$

Variation across assets clearly pins down variation across η^a_{it}, as ν_{it} does not vary across assets. The only remaining complication is to separately identify the level of ν_{it} and the average level of η^a_{it}. To do so, we make use of the general collateral asset: as described in Section 2.1, when trading this asset the lender does not require a particular bond in return. We therefore assume that the collateral demand for this particular asset is equal to 0, which then allows us to pin down ν_{it} and η^a_{it} by re-arranging Equation 14 as follows (noting again that all variables and coefficients on the right-hand side are known):

$$\begin{aligned}\nu_{it} &= \delta^0_{it} + \kappa Q_{it} + \kappa\sigma \sum_m q^0_{imt} \\ \eta^a_{it} &= \delta^0_{it} - \delta^a_{it} + \kappa\sigma \sum_m (q^0_{imt} - q^a_{imt})\end{aligned} \tag{15}$$

where a subscript of 0 denotes general collateral.

This approach allows us to semi-parametrically recover the joint distribution of collateral demand across assets, firms and time from variation in rates and quantities (semi-parametric in the sense that we impose that $\eta^0_{it} = 0$ for general collateral, but otherwise make no assumptions about the shape of that distribution across firms, times or assets that are not general collateral).

We set out a cross-check providing further detail on the nature of our identifying variation in Appendix A. In general terms, we conclude that a firm 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 against general collateral.

We discuss in the following section and in Appendix A various robustness tests that we run. In one of them, we allow for further heterogeneity in collateral demand depending on the direction of trade, and thus whether the firm involved is temporarily obtaining or giving up collateral.

As discussed in Section 4, we estimate a single homogeneous σ and κ across time, firms, and assets. We do this for parsimony, and it ensures that collateral demand is captured in a single parameter η^a_{it}. It is straightforward in both modelling and estimation to allow these parameters to vary. As a robustness check, we re-estimate our model allowing these parameters to vary across months, and summarise the results of this robustness test in Appendix A.

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. We then discuss various cross-checks and tests for robustness.

6.1 Parameter Estimates

Table 8 shows the results of the first part of our estimation approach, which is to estimate Equation 8. 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 curvature parameter κ and 11.8 for the risk on the return to obtaining collateral σ. In other words, the model implies that the risk associated with collateral demand is materially larger than that associated with funding.

6.2 Collateral demand and funding demand

The key outputs of our estimation are estimates of funding demand ν_{it} and collateral demand η^a_{it}, 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}, 50th and 90th percentiles of funding demand ν_{it} in the left panel and of collateral demand η^a_{it} 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 (D'Avolio, 2002; 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.[16]

This suggests that short selling is quantitatively a key driver of repo market outcomes. 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). Our model shows that this variation across firms is a key driver of repo market outcomes. We first show how funding demand and collateral demand vary separately across

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

and within firm types, before examining their co-movement.

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 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.

As well as variation across types, we also examine variation within types. In Table 11, we regress estimated collateral demand on firm type-time-asset fixed effects for various firm types, and report the R^2. A high R^2 indicates that there is little disagreement within firm type. We find that there is relatively little disagreement amongst hedge funds (the R^2 is 83%), but material disagreement amongst dealers (23%). This could reflect homogeneity amongst hedge funds in the shorting strategies that they pursue, whereas dealers face more idiosyncratic hedging needs depending on their activities elsewhere.

Finally, we consider what the variation across firms implies for the correlation between funding demand and collateral demand. In Table 12 we regress collateral demand on funding demand with various fixed effects: 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 coefficient is positive, 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

In this section, we document the close links between our estimates for the repo market and the secondary bond market.

We first consider the *contemporaneous* relationship between estimated collateral demand for a given bond and the price of that bond in the secondary market. In Table 13, we regress collateral demand on price, with various combinations of fixed effect. We find that collateral demand and prices are negatively correlated across time periods, in that in times of stress bond prices fall and collateral demand goes up as firms look to short. Conversely, we find that the two are positively correlated within time period, confirming that certain bonds are desirable in both markets (Duffie, 1996).

We then consider the relationship between estimated collateral demand and *future* bond prices. A key motive for obtaining assets via repo is to short-sell the underlying asset. If this short-selling is undertaken by informed investors looking to speculate, then it follows that collateral demand in the repo market should be able to predict the prices of the underlying asset.

To test this hypothesis, 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.[17] This suggests that high collateral demand did predict declines in asset prices over our sample period, but only over a very long time horizon.

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.

[17] 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.

To test this, we again construct long-short portfolios, but this time based on how much a bond 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 dealers and banks rather than hedge funds. Importantly, we are not testing whether hedge funds do in fact earn abnormal returns from their shorting activities, we are instead testing whether the prices that hedge funds are willing to pay, as reflected in their collateral demand, can predict asset prices.

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 positive within days of the portfolio being constructed, and increase montonically before levelling out after around 200 days. 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. By contrast, the returns on the portfolio based on dealers' and banks' collateral demand are negative 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. Dealers and 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 (hedging interest rate risk, for example (Begenau et al., 2015; Khetan et al., 2023; McPhail et al., 2023)).

6.3 Cross-checks and robustness

We run two cross-checks on our results and describe the results in Appendix A. First, we illustrate our identifying variation by regressing our estimated parameters on the terms in Equation 15, and showing their incremental explanatory power. This makes clear, for example, the extent to which differences in trading volumes across firms drive identification relative to differences in rates. Second, 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. This suggests that there is potentially significant added value to our structural approach.

We also show the key features of our results are robust to alternative specifications regarding (1) whether collateral demand varies depending on whether it is incoming or outgoing for a given firm, (2) how we weight the bonds in our instrumental variable and the fixed effects we include, and (3) allowing risk aversion κ and the riskiness of collateral σ to vary through time. We set out the results in Appendix A.

7 Counterfactuals

We run various counterfactual analyses in which we change collateral demand and quantify the resulting equilibrium effect on rates, volumes and gains to trade. Our objective is to quantify exactly how collateral demand affects repo market functioning. We discuss four counterfactuals in turn, before discussing their policy implications.

Counterfactual 1: Removing collateral demand

In the first counterfactual 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.

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 bonds are to the trader that receives collateral. Removing collateral demand removes this source of heterogeneity, and hence reduces variation in rates across bonds. 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. 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.

Counterfactual 2: The impact of correlation

The main driver of our first counterfactual 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 Table 12, 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.

Counterfactual 3: Removing dealer and bank collateral demand

We show in our results section that dealers and banks have material collateral demand, that relates not to speculation but more likely to hedging. The way in and extent to which banks hedge is the subject of recent academic interest (Granja et al., 2024; Jiang et al., 2023). In the third counterfactual we decompose the first counterfactual between firm types, and in particular show the importance of collateral demand by dealers and banks. We set collateral demand for any dealer or bank in any time period to 0, and leave collateral demand for all other firms unchanged from their estimated values. We quantify the resulting change in trading quantities, and find that this is on average 95% of the effect of all collateral demand in our first counterfactual. In other words, dealers and banks are the primary drivers of our main counterfactual results.

Dealers and 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 dealers and banks to simultaneously do all of these things using repo.

Counterfactual 4: Continuous changes in collateral demand

In the final counterfactual we multiply all estimates of collateral demand by a scalar between 0 (corresponding to our first counterfactual in which we remove collateral demand completely) and 1.25 (such that collateral demand is higher than our estimated values). In Figure 9 we plot the resulting equilibrium volume and gains to trade for various such multipliers.

We draw two conclusions from this counterfactual. First, a partial decrease in collateral demand increases gains to trade: in other words, the effect of collateral demand is directionally the same as in our first counterfactual. Second, the effect of collateral demand on gains to trade is convex and can be non-monotonic, in that an increase in collateral demand from its estimated values by 25% would actually *increase* gains to trade. By way of intuition for this result, consider what happens in the limit when this scalar gets large: in this case differences in funding demand across firms would be immaterial, and the direction of trade would be determined only by differences in collateral demand. In other words, repo would be a *collateral market*. Any further increase in the factor would simply magnify differences between firms, and so gains to trade must be increasing in this scalar asymptotically. The point at which gains to trade start increasing in collateral demand depends on the relative values of funding demand and collateral demand.

This can also be understood in the context of the simplified model set out in Section 4.4, in which our results depended on whether $\rho\bar{\eta}$ was less than 1 (such that repo is primarily a funding market) or greater than 1 (such that repo is primarily a collateral market). In practice, our estimates indicate that repo is primarily a funding market, and so decreases in collateral demand increase gains to trade. We leave for further work a fuller investigation about whether there are circumstances under which repo could become primarily a collateral market.

7.1 Policy implications

Our results and counterfactuals indicate that the two functions of the repo market – to obtain funding and to obtain collateral – do not complement each other, particularly in times of stress. Dealers and banks, in particular, need to be long on government bonds in order to fund themselves on the repo market, which impedes their ability to manage their inventory risk. Our work has implications for various regulatory policies that affect how firms fund themselves and hedge risk. We discuss three in particular: (1) short-selling rules, (2) central bank repo facilities and (3) collateral swap facilities.

Short-selling rules. Major financial jurisdictions (including the EU,[18] the UK[19] and the US)[20] currently have rules either banning or limiting naked short selling, such that participants do typically need to borrow the bond through repo before they agree to sell. We find that permitting uncovered short-selling may improve repo market functioning (in the sense of increasing trading quantities and realised gains from trade), as it makes repo markets less important for firms looking to short, and so would likely reduce collateral demand. Our counterfactuals show that were this to significantly reduce collateral demand across all firms, repo market activity would increase.[21] Relatedly, the rules could allow only dealers to naked short, in which case it would be informative to understand how repo market functioning would change if collateral demand for dealers only were to reduce. We simulate this in our third counterfactual, and find that permitting short-selling for dealers only may be sufficient to materially improve repo market functioning.

Central bank repo facilities. Many central banks offer repo lending facilities both under normal market conditions and in times of stress.[22] Typically this borrowing is collateralised against government bonds, but major central banks such as the Federal Reserve, the ECB, and the Bank of England[23] accept other types of collateral in certain circumstances. We find that collateral demand is a very large determinant of repo market functioning in times of stress, and our findings suggest that accepting collateral other than government bonds (at a reasonable price and haircut) and thereby allowing dealers and banks to fund themselves without having to be long on government bonds could improve repo market functioning. This suggests that regulators should take into account bank risk management in stresses, as well as their access to liquidity.

Collateral swap facilities. Central bank repo facilities that allow dealers and banks to obtain liquidity using a broad range of collateral can improve repo market functioning. A swap facility, on the other hand, would achieve the same thing by allowing dealers and banks to hedge their inventory risk using other types of collateral (that is, by swapping their

[18]https://www.esma.europa.eu/esmas-activities/markets-and-infrastructure/short-selling

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

[20]https://www.sec.gov/investor/pubs/regsho.htm

[21]We consider the possible effect of short-selling rules and repo market functioning, but naturally such rules would have wider impacts of interest to policymakers in other markets.

[22]https://www.bankofengland.co.uk/markets/bank-of-england-market-operations-guide/our-tools.

[23]See https://www.sec.gov/investor/pubs/regsho.htm for the US, Pelizzon et al. (2024) for the EU, and https://www.bankofengland.co.uk/markets/bank-of-england-market-operations-guide/our-tools for the UK.

other collateral for government bonds that they then short). The UK's Debt Management Office operates such a facility for government bonds only, in a scheme designed to be used to avoid delivery failures in their market-making business (DMO, 2004). Eurosystem central banks offer securities lending facilities to their counterparties for the assets they hold on their balance sheets, with cash or other securities posted as collateral.[24] Our findings suggest that a swap facility that is aimed at allowing dealers and banks to separate their inventory risk management from their liquidity needs would have large positive effects, particularly in times of stress.

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. Furthermore, we show that the presence of collateral demand constrains trading and gains to trade in repo markets, relative to a counterfactual in which there is no collateral demand. This sheds new light on how this key funding markets functions, and has implications for any regulation that affects collateral demand.

Our data and setting are specific to the Sterling gilt repo market, but repo markets are important funding markets worldwide and there is evidence of collateral demand both in the US (Duffie, 1996) and in other European markets (Arrata et al., 2020; Ballensiefen et al., 2023), such that the issues we consider in this paper are of wider relevance.

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.

[24]See https://www.ecb.europa.eu/mopo/implement/app/lending/html/index.en.html.

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Figures

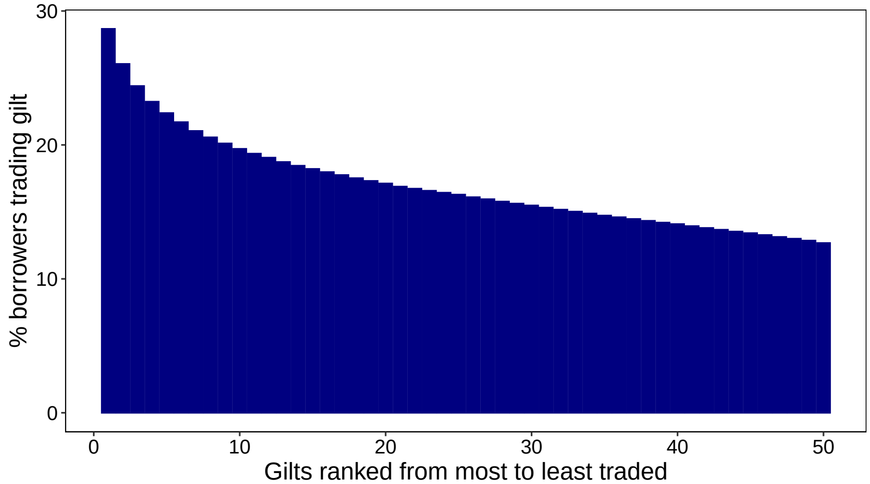


Figure 1: Variation in use of gilts in repo borrowing

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.

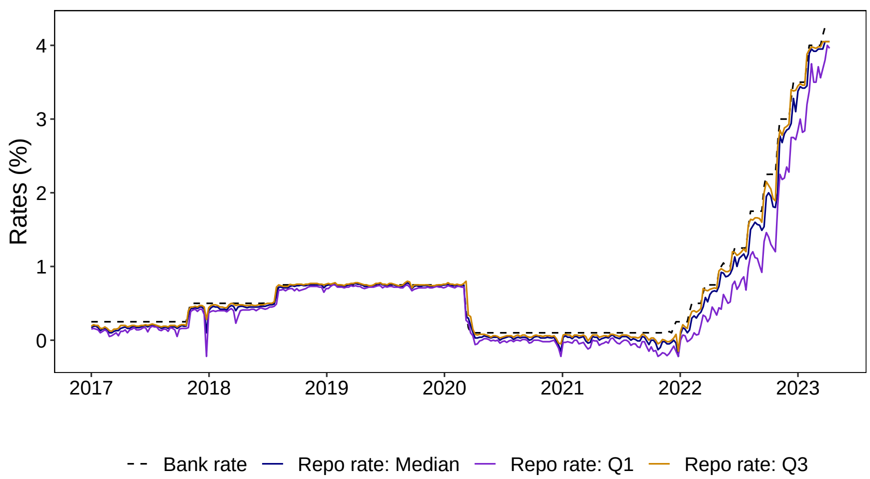


Figure 2: Rates through time on dealer repo lending

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.

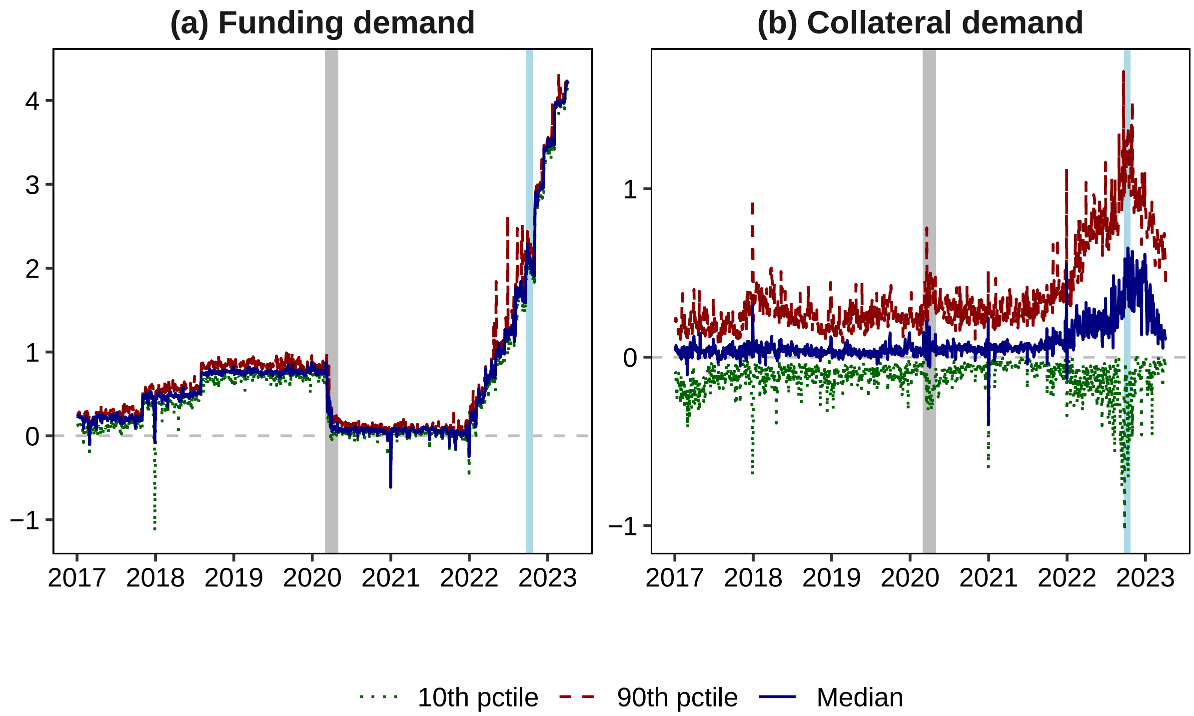


Figure 3: Funding & collateral demand through time

Note: Figure summarises the estimated distribution of funding demand ν_{it} across firms and time and of collateral demand η_{it}^{a} 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).

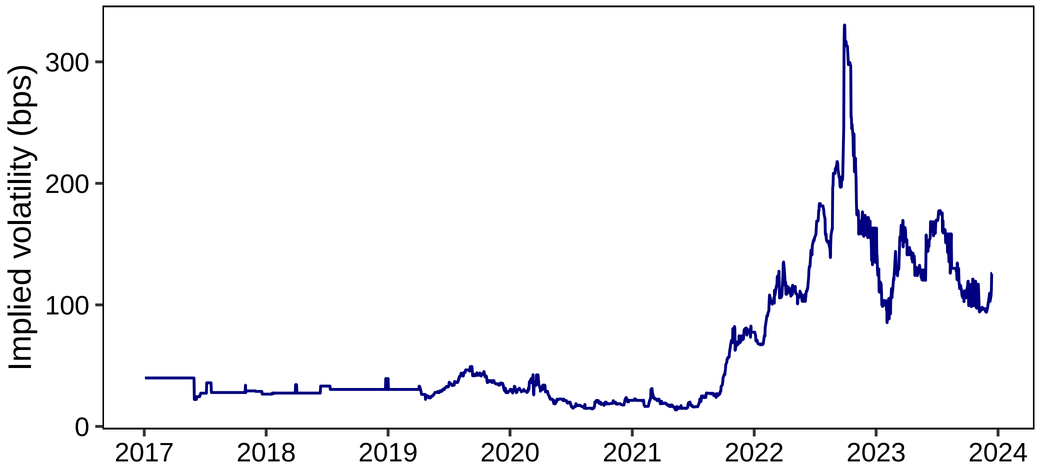


Figure 4: Gilt market volatility

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.

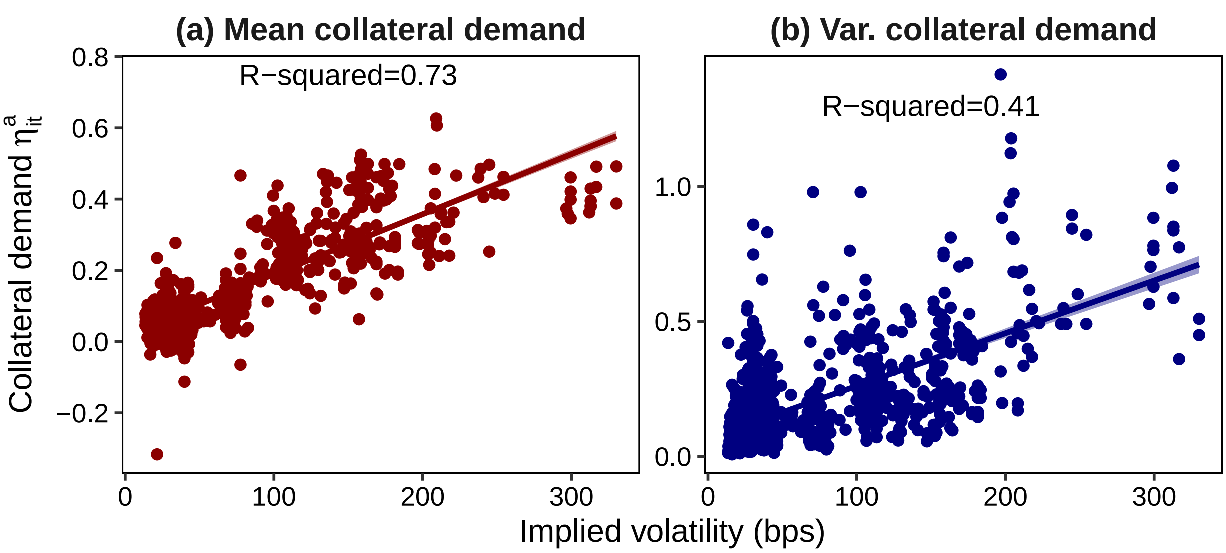


Figure 5: Gilt market volatility and collateral demand

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.

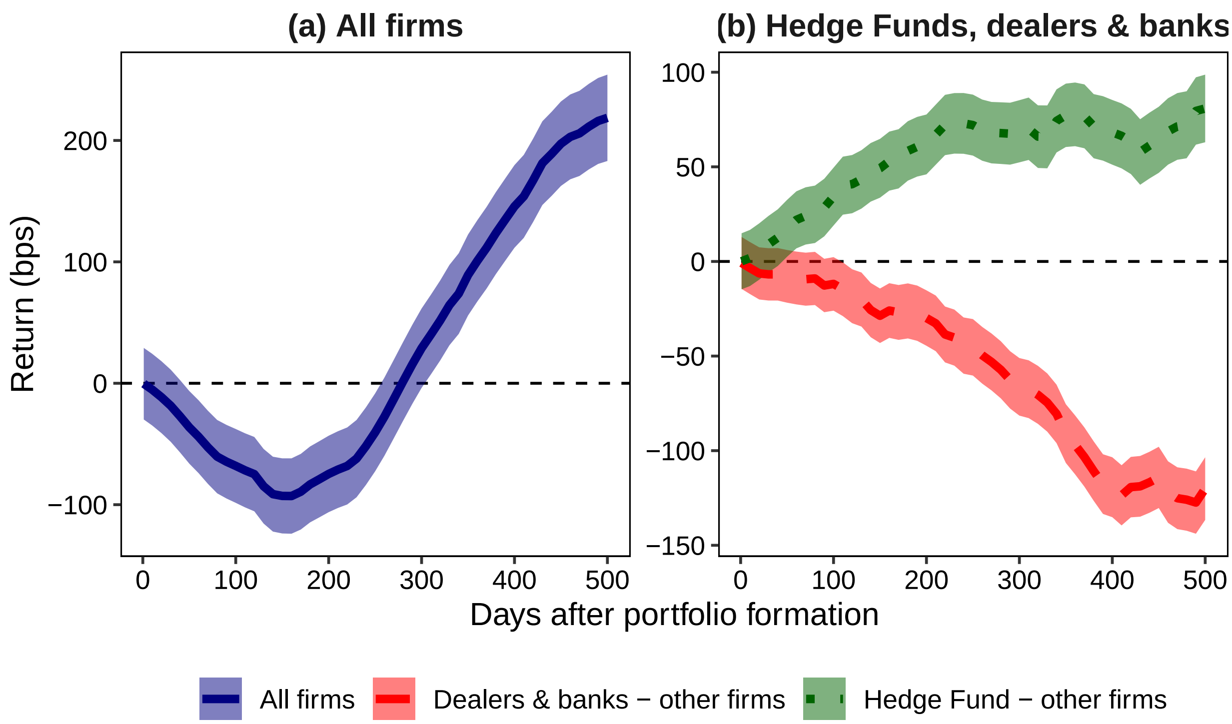


Figure 6: Long-short portfolio returns - sorted by collateral demand

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 dealers' and banks' collateral demands and other firms' collateral demands (red).

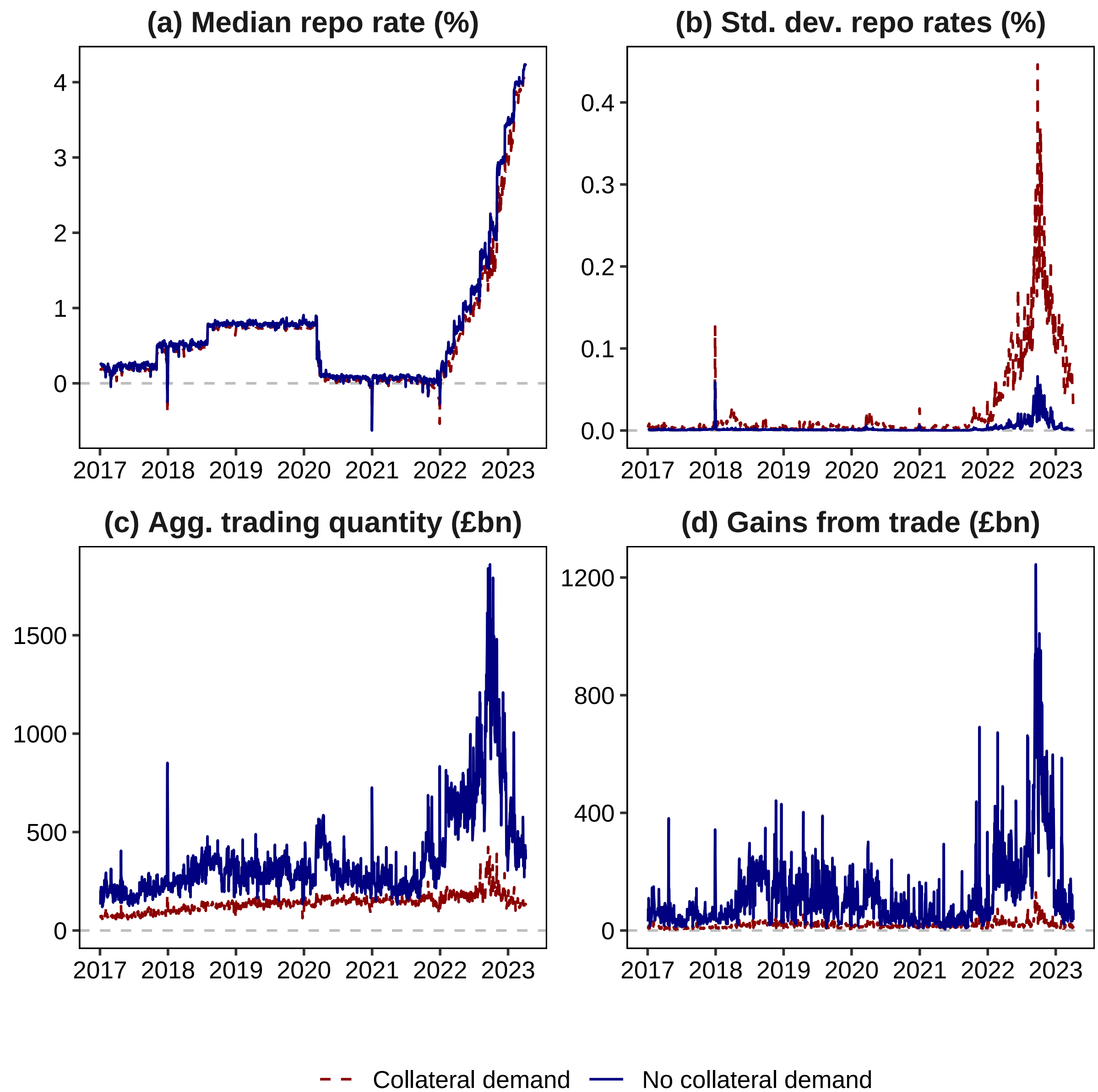


Figure 7: Counterfactual: impact of collateral demand

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_{it}^{a} 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 2 at equilibrium quantities and rates

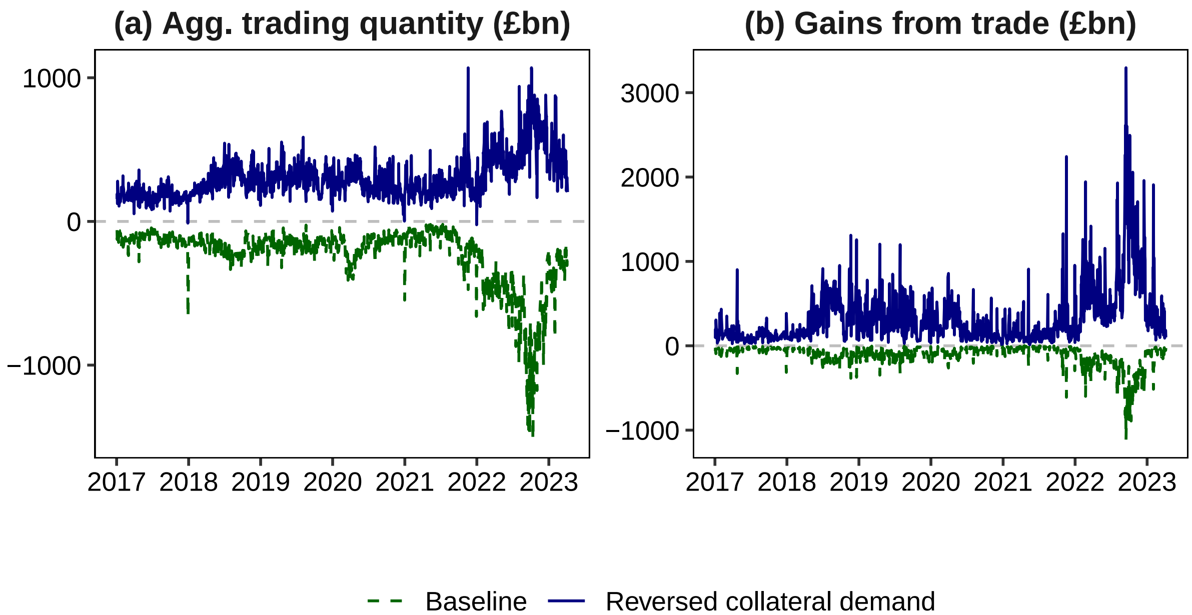


Figure 8: Impact of collateral demand: role of correlation between collateral and liquidity demand

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_{it}^{a} 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.

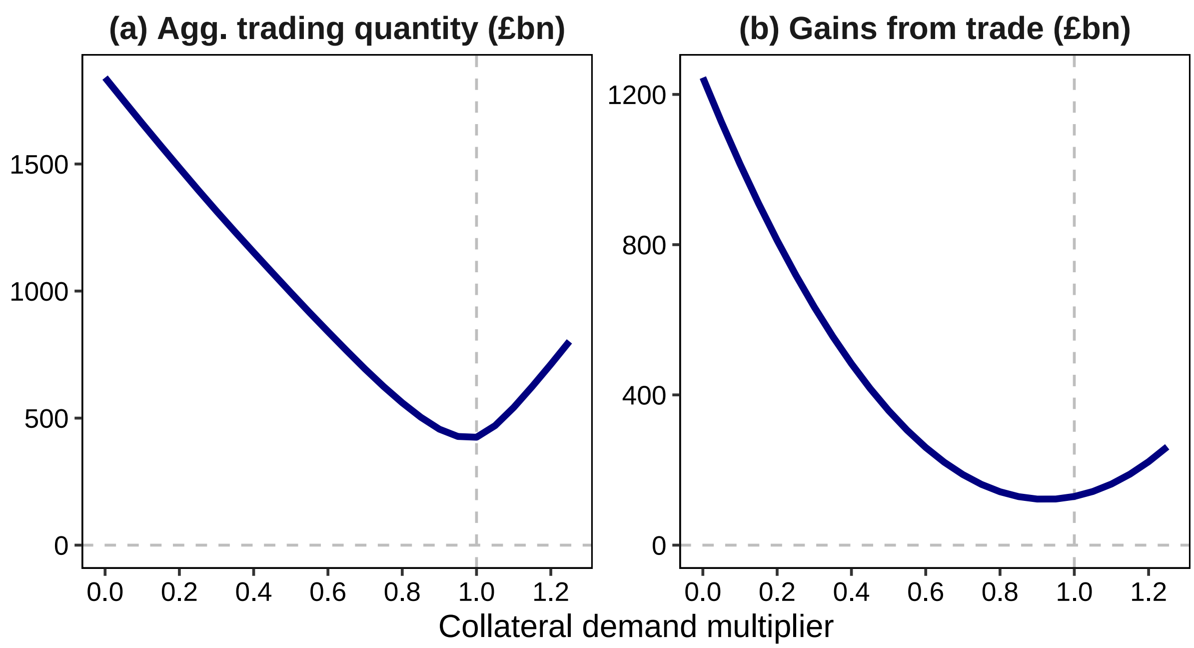


Figure 9: Marginal impact of collateral demand

Note: Figure shows the impact of scaling collateral between 0 and our estimated level of collateral demand. For a single date where collateral demand was high – September 16^{th} 2022 – we set collateral demand equal to some scalar α times our estimated collateral η^{a}_{it}, recompute the equilibrium, and compute aggregate trading quantities and gains from trade. We plot these figures above, for α ranging from 0 to 1.25.

Tables

Table 1: Summary Statistics

	Share (%)
Maturity	
Overnight	39
Less than 1 week	37
2 weeks - 1 month	16
1 month plus	8
Clearing	
Cleared	53
Bilateral	47
Triparty	0
Segment	
Dealer-Bank to Dealer-Bank	55
Dealer-Bank to Customer	45

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: Rate variation

Fixed effects	R-squared
Deal characteristics	
Week	0.30
Week-Asset	0.69
Week-Maturity	0.40
Week-Asset-Maturity	0.79
Trader characteristics	
Week-Borrower	0.54
Week-Lender	0.43
Week-Borrower-Lender	0.67

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 3: Repo rates & collateralisation type

	Repo rate (%)				
	(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 of rates (net of Bank rate) 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 4: Trading activity by sector

	Trade Share (%)	Daily net lending (%)	Daily net lending (£bn)	Counterparties per firm
Dealer	66.1	-3.8	-4.6	206.2
Bank	11.7	-31.4	-7.5	14.8
Hedge Fund	10.3	-0.2	-0.4	4.3
Fund	4.2	62.5	5.2	3.3
MMF	2.9	97.4	6.2	3.8
PFLDI	2.8	18.9	0.9	5.5
Other	2.0	0.6	0.5	2.8

Notes: Table summarises the 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. The fourth column shows the number of counterparties that the average firm of each sector trades with in our sample. For computing trade shares and net lending trades with central counterparties are counted as a single trade between two end users rather than two offsetting trades with the central counterparty. All trades with central counterparties are removed when computing the number of counterparties per firm.

Table 5: 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 6: Rate variation: MMFs, hedge funds and dealers lending

Fixed effects	Hedge Fund	MMF	Dealer
Week-Maturity	0.50	0.31	0.52
Week-Maturity-Borrower	0.56	0.98	0.59
Week-Maturity-Lender	0.62	0.42	0.59
Week-Maturity-Asset	0.94	0.73	0.93

Notes: Table summarises the variables that explain repo rates (net of Bank rate) for lending by hedge funds, dealers and 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, and the third does it for dealers. 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 7: 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 (net of Bank 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 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 8 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)
$z_{1,jt}$	-0.02***	-0.01***
	(0.0007)	(0.0008)
$z^a_{2,jt}$	0.02***	0.006***
	(0.0008)	(0.0008)
R^2	0.78	0.87
F-test	481.4	882.1
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 8 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} (1)	Collateral demand η^a_{it} (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. We exclude central counterparties from these regressions.

Table 11: Collateral Demand: disagreement by sector

	Collateral Demand η^a_{it}		
	All sectors	Hedge Funds	Dealers
R^2	0.39	0.83	0.23
Observations	1,490,509	266,075	753,290
Day-Sector-Asset fixed effects	Yes	Yes	Yes

Notes: Tables summarises the extent of variation in collateral demand that can be explained by day-sector-asset fixed effects. In the first column we regress our estimated collateral demand η^a_{it} on day-sector-asset fixed effects, and show the R-squared. In the second and third column we repeat this exercise restricting out sample to hedge funds and dealers respectively. We exclude central counterparties from these regressions.

Table 12: 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.

Table 13: Collateral demand and bond prices

	Collateral demand η^a_{it}		
	(1)	(2)	(3)
Bond price	-0.32***	0.69***	0.67***
	(0.11)	(0.02)	(0.02)
R^2	0.06	0.13	0.62
Observations	1,484,821	1,484,821	1,484,821
Asset fixed effects	Yes	Yes	Yes
Day fixed effects		Yes	Yes
Firm fixed effects			Yes

Notes: Tables shows the relationship between collateral demand and the price of the underlying collateral. We regress our panel of estimated collateral demands η^a_{it} on the price of asset a at time t, together with the fixed effects shown at the bottom. Standard errors are clustered at the level of the fixed effect.

A Cross-checks and robustness

A.1 Cross-check: 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 15. 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_{it}^a on variables involving repo rates and quantities motivated by Equation 15, 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 Cross-check: Reduced-form vs 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 supported by a model. 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 is 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.

A.3 Robustness: Incoming and outgoing collateral

In our baseline approach we allow collateral demand to vary at the time-firm-asset level, but not to vary according to whether the firm is borrowing or lending. In this robustness test, we examine whether collateral demand varies along this dimension in a way that matters for our results.

We do this by including a firm-direction dummy variable in the first step of our estimation, Equation 8:

$$r^a_{ijt} = \delta^a_{it} + \underbrace{\delta_i \times \mathbb{1}_{q^a_{ijt}>0}}_{\text{Outgoing dummy}} - \left[\kappa \sum_l q^l_{ijt} + \kappa\sigma q^a_{ijt}\right] \mathbb{1}_{ij} + \delta_{ij} + u^a_{ijt} \tag{16}$$

where $\mathbb{1}_{q^a_{ijt}>0}$ is a dummy variable that takes the value 1 if firm i is borrowing (indicating that the collateral is outgoing) and δ_i is the firm-specific parameter on that dummy variable. This effectively asks whether a given firm systematically lends and borrows against the same asset at different rates, holding constant the determinants of the intermediation spread.

In Figure A1a we show the distribution of estimated collateral demand conditional on whether a firm is borrowing or lending cash. The distributions are very similar. In Figure A1b we plot the time series of collateral demand. The patterns are very similar to our baseline estimates in Figure 3. Finally, in Table A4 we plot the estimated average collateral demand across firm types, replicating the analysis shown in Table 10. Again, the results are qualitatively unchanged.

A.4 Robustness: Instrumental variables and fixed effects

In this section, we set out results that use more stringent fixed effects and different instrumental variables. Identification of step 1 of our baseline estimation requires that the unobserved, non-pecuniary shocks are independent of our instrumental variable constructed by interacting bond prices with firm-specific lagged trading across bonds (which, as described in Section 5, we term the firm's wallet). The motivation for this approach is that firms trade specific bonds for exogenous reasons related to their business or preferred habitat, and that changes in price to these specific bonds shock a given firm's trading independently of unobserved shocks in the repo market.

We include in our baseline $i-t-a$ and $i-j$ fixed effects. In this section, we show that our results our robust to the inclusion of additional fixed effects. First, we include $i-j-a$ fixed effects, allowing for pairs to consistently trade a particular bond for unobserved reasons outside of our model. Second, we $i-j-t$ fixed effects, allowing for pairs to trade more in a given period for unobserved reasons outside of our model. In this case we cannot separately identify the curvature parameters κ and σ, only their product.

As well as these more stringent fixed effects, we change how we weight bond prices in our instrumental variables. In our baseline, we calculate the sum of firm j's borrowing in time $t-1$ against asset j, which we denote s^a_{jt-1}. We use this variable to weight bond prices $price^a_t$ and calculate our instrumental variables, as set out in Equations 10 and 11. In this robustness test, we homogenise the weighting across bonds:

$$\tilde{s}_{jt-1} = \frac{\sum_a s^a_{jt-1}}{\sum_a 1} \tag{17}$$

$\tilde{s}_{jt-1}$ is thus the average amount traded by j across bonds. We then use this in place of s^a_{jt-1} to construct our instruments in Equations 10 and 11. This alternative approach guards against serial correlation in bond-specific unobservable reasons for trade.

In Table A5 we show four sets of results: the two additional fixed effect specifications with our baseline instrumental variables, and then again with the alternative, equal-weighted instrumental variables. We show that our estimated curvature parameters are robust to these alternative specifications.

A.5 Robustness: Heterogeneous risk and risk aversion

In our baseline specification the risk associated with temporary use of the collateral, σ, is constant across firms, time and assets, and so is risk aversion κ. In principle, variation along these dimensions is identifiable. Here we allow κ and σ to vary through time by estimating our model separately each month. We plot the times series of funding and collateral demand in Figure A2. The shape of the two time series is the same as in our baseline results: funding demand tracks the central bank policy rate whilst the level and dispersion of collateral demand spike during times of stress and in particular in the gilt market turmoil in 2022. The magnitude of collateral demand increases, whilst the volatility of funding demand at year-ends increases somewhat, but the key features of the baseline results continue to hold.

In Table A6 we show funding and collateral demand across firms under this alternative approach. Once again, the key results remain: there is significant variation in collateral demand across firms, with dealers and banks exhibiting the highest collateral demand.

Appendix: Figures & Tables

Table A1: Identifying variation: rates & quantities

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

Table A4: Funding and collateral demand by sector: robustness

	Funding demand ν_{it} (1)	Collateral demand η^a_{it} (2)
Bank	0.67***	0.13***
	(0.007)	(0.0005)
Dealer	0.75***	0.16***
	(0.006)	(0.0003)
Fund	0.84***	0.07***
	(0.005)	(0.0009)
Hedge Fund	0.69***	0.10***
	(0.004)	(0.0005)
MMF	0.64***	0.05***
	(0.01)	(0.002)
Other	0.76***	0.13***
	(0.008)	(0.001)
PFLDI	0.72***	-0.07***
	(0.006)	(0.001)
R^2	0.004	0.04
Observations	167,037	1,681,080

Notes: Table shows the differences in collateral and funding demand across firms where we allow a firm's collateral demand η^a_{it} to differ according to whether it is lending or borrowing. We estimate collateral demand as described in Section A.3, and then replicate the analysis in Table 10.

Table A5: Parameter estimates: robustness

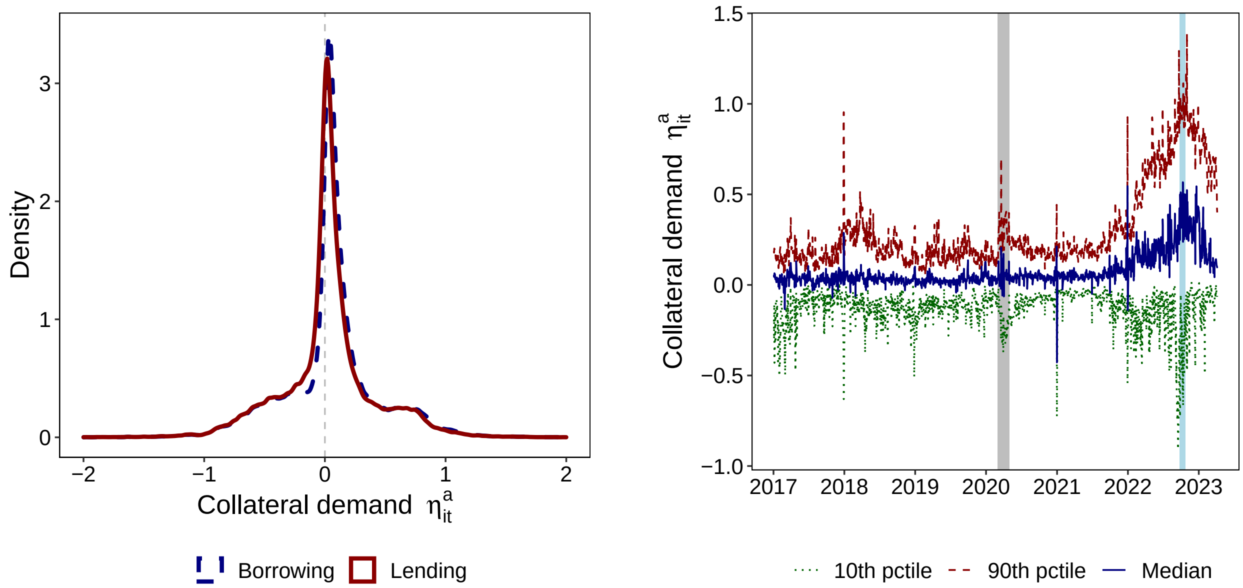
	Repo rate r^a_{ijt} (%)			
	Weighted		Unweighted	
	(1)	(2)	(3)	(4)
$\sum_l q^l_{ijt}$	-0.02***		-0.005**	
	(0.002)		(0.002)	
q^a_{ijt}	-0.17***	-0.16***	-0.33***	-0.30***
	(0.006)	(0.003)	(0.02)	(0.006)
Wald (1st stage), $\sum_l q^l_{ijt}$	3,376.2		3,451.8	
Wald (1st stage), q^a_{ijt}	1,137.4	2,594.9	274.9	1,434.6
Observations	527,295	538,593	527,295	538,593
Firm-asset-day fixed effects	Yes	Yes	Yes	Yes
Firm-counterparty-asset fixed effects	Yes	No	Yes	No
Firm-counterparty-day fixed effects	No	Yes	No	Yes

Notes: Table shows the robustness of our two-stage least squares regressions to including more stringent fixed effects and changing the definition of our instrumental variable. The first column shows our two-stage least squares estimates when we include firm-counterparty-asset fixed effects rather than firm-counterparty fixed effects. The second shows our estimates when we instead include firm-counterparty-day fixed effects. The third and fourth column repeat the analysis when we compute firm wallets based on unweighted, rather than weighted, borrowing against assets in the past four weeks.

Table A6: Funding and collateral demand by sector: risk robustness

	Funding demand ν_{it} (1)	Collateral demand η^{a}_{it} (2)
Bank	0.69***	0.21***
	(0.008)	(0.0008)
Dealer	0.92***	0.34***
	(0.007)	(0.0005)
Fund	0.88***	0.16***
	(0.007)	(0.002)
Hedge Fund	0.68***	0.16***
	(0.005)	(0.0008)
MMF	0.61***	0.06***
	(0.02)	(0.006)
Other	0.78***	0.16***
	(0.010)	(0.002)
PFLDI	0.83***	0.14***
	(0.006)	(0.002)
R^2	0.008	0.04
Observations	150,301	1,458,167

Notes: Table shows the differences in collateral and funding demand across firms where we allow risk aversion κ and collateral risk σ to vary across months. We estimate our model separately for each month, and then replicate the analysis in Table 10.



(a) Collateral demand density **(b) Collateral demand through time**

Figure A1: Collateral demand on borrowing vs. lending

Note: Figures summarises the distribution of collateral demand where we allow a firm's collateral demand η_{it}^{a} to differ according to whether it is lending or borrowing. We estimate collateral demand as described in Section A.3. We then plot the distribution of our estimates of collateral demand for borrowing and lending in the first panel above. We then replicate the second panel of Figure 3 with these new estimates in the second panel of this Figure.

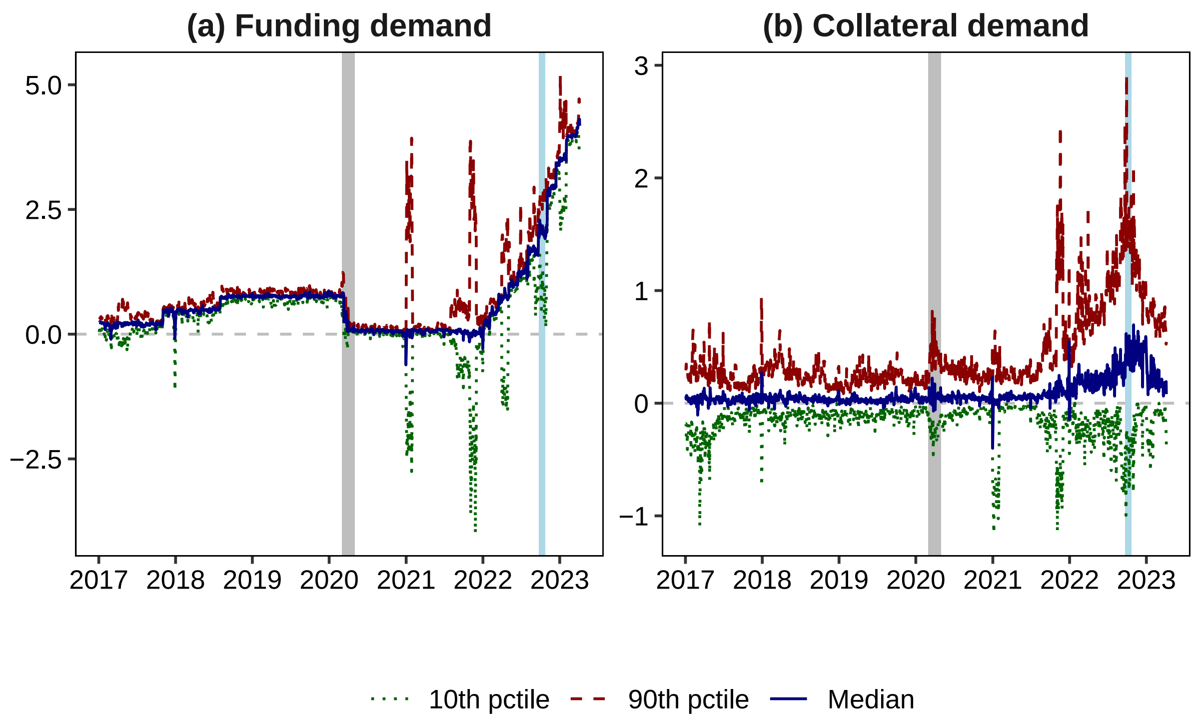


Figure A2: Funding & collateral demand through time: risk robustness

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, where we allow our estimates of risk aversin κ and collateral risk σ to vary across months. 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 23rd September 2022, which marked the beginning of the LDI crisis in the UK (Pinter, 2023).