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Quantitative easing and the functioning of the gilt repo market

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Abstract

We assess the impact of quantitative easing (QE) on the provisioning of liquidity and the pricing in the UK gilt repo market. We compare the behaviour of banks that received reserves injections via QE operations to other similar banks in terms of the amounts lent and pricing. We also investigate whether leverage ratio capital requirements affected the amounts of liquidity supplied by broker-dealers and the spreads they charged. We find that QE interventions can improve liquidity provision, and that their size determines how this is attained. QE can also reduce the cost of borrowing in the repo market unless it was associated with spikes in demand for liquidity. Our findings further indicate that the leverage ratio supports the provision of liquidity during stress, as it prompts banks to become less leveraged. However, the larger capital charge repo transactions attract under the leverage ratio requirement is reflected in their spreads.

Key words: Monetary policy, quantitative easing, gilt repo market, leverage ratio.

JEL classification: G10, G21, G23.

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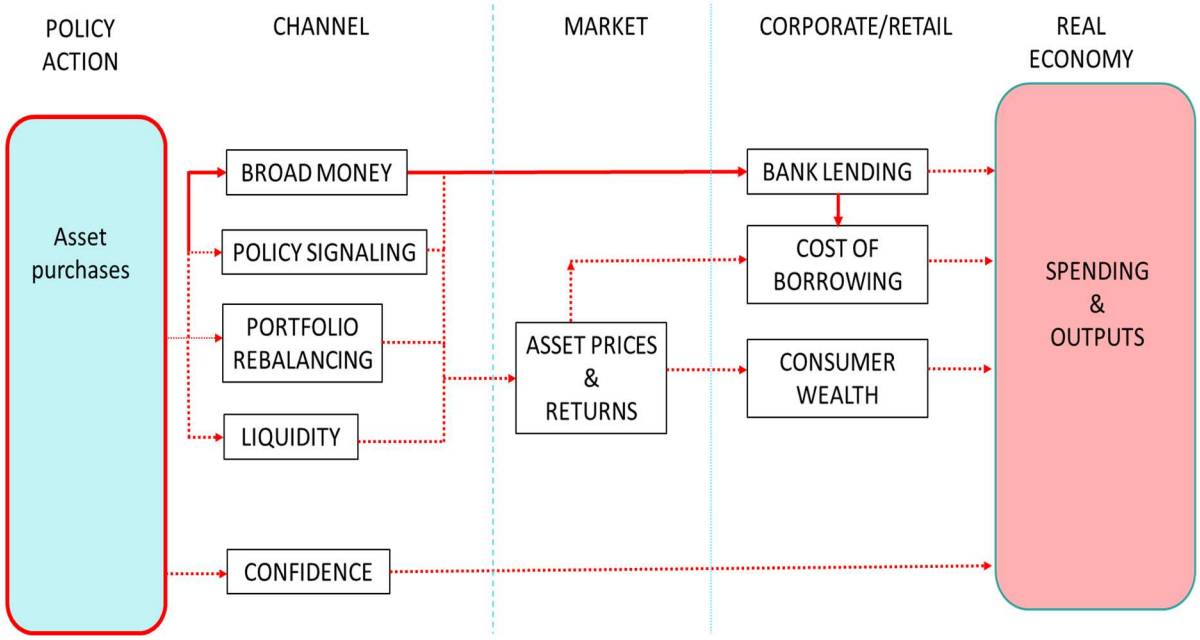
1. Introduction

Repo markets represent an essential source of short-term funding and an outlet for low-risk investment (Kotidis and van Horen, 2018). They are a key ingredient of healthy and stable financial systems (Cœuré, 2017). Changes in the conditions of these markets can have strong implications for the availability of liquidity (Brunnermeier and Pedersen, 2009) and financial stability, as seen in the Great Financial Crisis of 2007-08 (Gorton and Metrick, 2012). Functioning repo markets also support efficient allocation of resources (De Fiore et al, 2018) and orderly monetary policy transmission (Draghi, 2012). Quantitative easing (QE) operations involve purchasing large amounts of assets (mainly gilts in the UK), creating large amounts of reserves. QE impact transmits through several channels, shown in Figure 1 (Joyce et al., 2011).[1]

Figure 1: QE transmission channels



Our focus in this paper is on the broad money channel, where the additional liquidity banks receive leads to an increase in bank lending generally, and lending in the gilt repo market specifically. The

[1] Most QE transmission channels operate through prices and returns in the asset markets. Changes in asset prices and returns result from the response of different investors to the change in relative yields on different assets and the additional liquidity created by the program. For instance, lower gilt yields induce portfolio rebalancing towards other alternatives with relative higher (risk-adjusted) yields. See Joyce et al. (2011) or Fatouh et al. (2021a) for more details about QE transmission channels.

literature suggests that the transmission through this channel is affected by capital requirements and positions of banks (Repullo and Suarez, 2013, and Fatouh et al., 2021a), and other factors that affect banks' ability or incentives to lend, such as government lending support schemes during the Covid-19 pandemic (Fatouh et al., 2021b). The additional liquidity banks receive, in the form of central bank reserves, may encourage banks to increase lending. If banks relayed some of this additional liquidity into the repo market, this could improve liquidity conditions in repo markets.

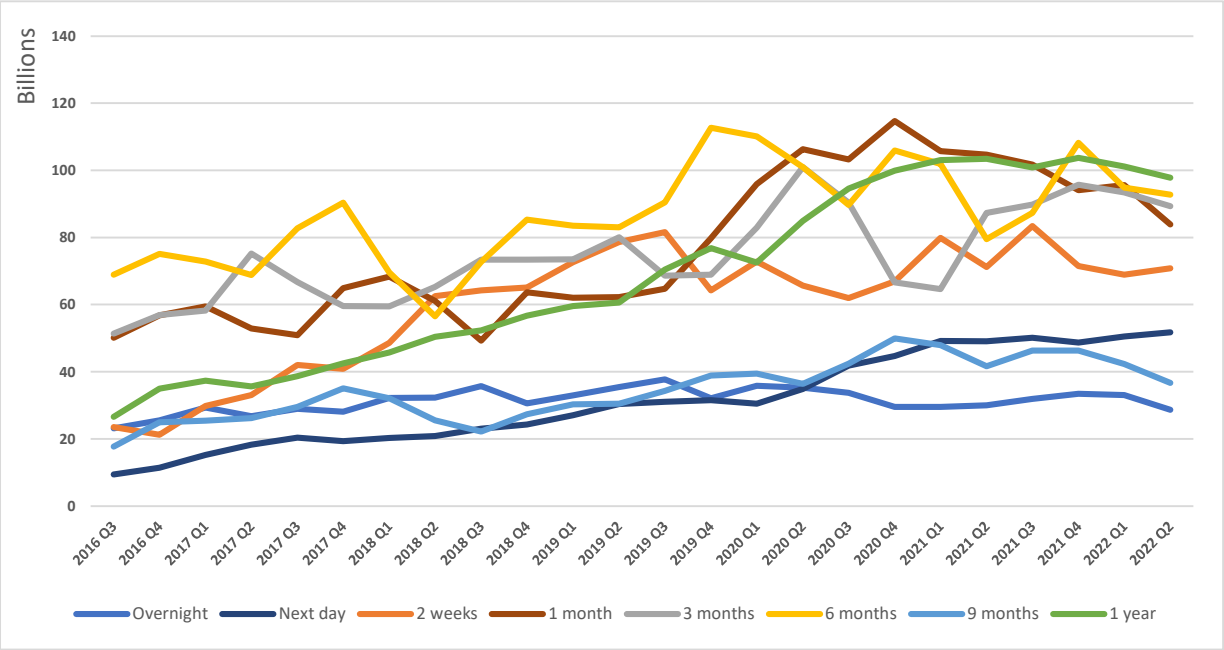
While assessing the impact of the Bank of England's (the Bank) QE on banks', Fatouh et al. (2021b) suggest that reserves injections increased recipient banks' engagement in the repo market during the COVID stress period. QE purchases are generally initiated at times central banks deem as turbulent, during which repo markets, in particular the overnight market, tend to show signs of strain (Hüser et al., 2021). Hence, by improving the provision of liquidity, QE operations can help stabilise and improve the functioning of repo market in stress. Additionally, banks' incentives to do so are largely affected by capital requirements they are subject to, especially the leverage ratio capital requirements. The leverage ratio is a risk-agnostic requirement, under which no risk weights are assigned to exposures with different levels of risk. As such, it can affect low-risk activities (such as repo lending) disproportionally more (for example, Acosta-Smith et al., 2020).

This paper aims to assess the impact of UK QE on liquidity and funding conditions in the gilt repo market through the additional central bank reserves injected to the banking system in the two most recent QE waves following the Brexit vote (QE_{Brexit}) and during the Covid-19 stress (QE_{Covid}). Our analysis also considers the possible effects of the UK leverage ratio on the banks' incentives to engage in repo transactions (see for example, Kotidis and van Horen, 2018, and Gerba and Katsoulis, 2021).

We implement a difference-in-differences (DiD) setup, relying on a confidential Bank of England's dataset, which identifies banks that received reserves injections through the asset purchase programme (APP). The setup follows Giansante et al. (2022) by using a propensity score matching to avoid the QE treatment effect being contaminated by differences in bank characteristics between the treatment and control groups. The dataset combines three confidential data sources, including data

on APP operations, gilt repo data from the Sterling Money Market Database (SMMD), and balance sheet data from regulatory returns. We focus on the gilt repo market, the fourth largest repo market in the world, in terms of amounts outstanding (Committee on the Global Financial System, 2017). Figure 2 shows the average daily volumes of reverse repo (lending) transactions in the market between 2016 Q3 and 2022 Q2.

Figure 2: Average daily amounts outstanding of reverse repo in the gilt repo market



Source: Bank of England Database: https://www.bankofengland.co.uk/boeapps/database/default.asp. Series codes: YWQZM5L YWQZM5M YWQZM5O YWQZM5P YWQZM5Q YWQZM5R YWQZM5S YWQZM5T YWQZM6E.

We aim to assess the impact of QE reserve injections on spreads and the amounts borrowed and lent in the gilt repo market, the pricing of individual transactions, and the effects of leverage ratio on amounts and pricing in that market.

Our results suggest that QE can improve liquidity provision in the gilt repo market, but the manner through which this is attained relies on the size of QE injection. While banks rely on the substantial liquidity large QE injections (e.g., QE_{Covid}) to increase repo lending,[2] they tend to intermediate (i.e., borrow and lend) more when reserves injections are relatively smaller (e.g., QE_{Brexit}). QE can also reduce the cost of borrowing in the repo market, but this effect can disappear if demand in the market

[2] Throughout the paper, we use lending, repo lending and reverse repo interchangeably. We also use borrowing, repo borrowing and repo interchangeably.

is quite strong, in the manner seen during the "dash for cash" in March 2020. The period saw steep rises in demand for liquidity, especially by non-financial corporates concerned about their ability to withstand the shock caused by the pandemic, with many pre-emptively drawing-down existing credit lines to build cash reserves (Basel Committee on Banking Supervision, 2021).

Lastly, the results indicate that the leverage ratio supports the provision of liquidity in repo market in stress, as it prompts banks to become less leveraged and hence enter stress with better balance sheet capacity. However, due to its risk insensitivity, the leverage ratio increases the amount of capital needed to support repo transactions relative to other activities. This effect reflects on the spreads of these transactions. We find evidence that banks subject to the ratio charged more on repo lending and paid less on repo borrowing.[3]

We contribute to the literature in several ways. Our analysis contributes to the literature assessing the repo market behaviour in stress. Earlier studies included assessment for repo markets in the US (Copeland et al., 2014; Krishnamurthy et al., 2014; Avalos et al., 2019; and Correa et al., 2020), the Euro Area (Mancini et al., 2016; and Boissel et al., 2017), and the UK (Hüser et al., 2021). Nevertheless, to the best of our knowledge, we are the first to investigate the impact of Bank of England response measures on the repo market. Similar to what He et al. (2022), who investigate the effects of the Fed's purchases of treasuries in the US during COVID, we aim to assess the impact of APP gilt purchases in the UK. We also contribute to the literature assessing QE transmission channels, specifically the impact on bank lending and bank balance sheets (for instance, Fatouh et al., 2021a; Fatouh et al., 2021b; and Giansante et al., 2022). Lastly, we contribute to the growing literature examining the effects of the post Great Financial Crisis (GFC) regulatory reforms (the leverage ratio in particular) on the liquidity and pricing in the repo market (for example, Kotidis and van Horen, 2018; Noss and Patel, 2019; Bicu-Lieb et al., 2020; Fatouh et al., 2021b; and Gerba and Katsoulis, 2021).

[3] Both repo lending and borrowing transactions can attract capital charges under the leverage ratio requirements. The leverage ratio rules also allow reverse repo and repo transactions that meet certain conditions (e.g., they have the same counterparty and similar maturities) to be calculated on net basis (*nettable)*.

The remainder of the paper is as follows. Section 2 describes the data used; Section 3 explains the empirical design; Section 4 presents the results; Section 5 includes robustness checks; and Section 6 concludes.

2. Data

We use multiple confidential datasets held by the Bank. First, we rely on data on QE operations to determine banks that received reserves for difference-in-differences (DiD) empirical identification (Giansante et al., 2022). Second, we use data on gilt repo transactions from the Sterling Money Market Database (SMMD). SMMD covers secured and unsecured lending and borrowing transactions carried out by the 33 most active dealers in the sterling money market, representing more than 90% of all transactions. It contains transaction-level details on volumes, spreads, counterparties, and collateral types. Our dataset spans from January 2016 to April 2021, with about 4.11mn transactions, of which 1.97mn were lending (reverse repo) and the remainder were borrowing (repo) transactions. Lastly, we use internal regulatory data submitted by banks to collect data on bank-level controls. Table 1 provides an overview of our dataset.

Out of the 33 broker-dealer banks in our sample, 22 received reserves injections via QE operations, and are hence designated as treated banks (QE banks). The remaining 11 are control banks (non-QE-banks). Lastly, 11 banks are subject to leverage ratio requirements.[4] Note that, as we will discuss in the empirical section, QE banks tend to be riskier than non-QE banks. In other words, non-QE banks show lower risk weight density. QE banks also have stronger capitalisation and hold repo portfolios with relatively shorter maturities. To alleviate these differences, we employ a propensity score matching using these dimensions as covariates as well as controlling for them in the DiD empirical exercises.

[4] Until 2023, the UK leverage ratio was applied at the group-consolidation level. However, there has been evidence (e.g., Bank of England, 2018) suggesting that banking groups cascade their capital requirements to their subsidiaries. Thus, we assume that a broker-dealer is subject to UK leverage ratio if its parent group is subject to it.

Table 1: Descriptive Statistics of the Dataset

Variable		Obs.	mean	St. dev	min	P25	median	P75	Max
Trade-level									
amount	Log of amount borrowed or lent (cash leg of the trade)	4,109,107	16.91378	1.301885	12.27746	16.1159	17.07136	17.78374	22.1519
Spread* (%)	Spread over the reference rate index (to calculate interest rate at issuance)	4,109,107	-0.0169279	0.1354192	-3.1665	-0.0501	-0.008	0.03	182.542
maturity bucket	Maturity of the trade at issuance in years	4,109,107	0.0161702	0.0741871	0.0013699	0.0013699	0.0013699	0.0013699	1
Bank-level									
totAssets	Log of total assets	352	25.16366	2.714524	13.91972	23.98957	25.92452	27.22304	28.22435
rwa	Log of risk weighted assets	352	24.27514	3.021395	9.977574	23.64253	25.24683	25.99111	27.41535
lem	Log of leverage ratio exposure measure	352	25.65179	2.632744	13.91972	25.10503	26.48531	27.35131	28.47689
cet1Cap	Log of core tier 1 capital	352	22.58127	2.359405	12.4285	22.01448	23.2494	24.106	25.36766
tier1Cap	Log of tier 1 capital	352	22.69106	2.389325	12.4285	22.01448	23.44739	24.21319	25.53545
trdAssets	Log of total trading assets	285	23.59532	3.308831	9.283219	22.72902	24.77246	25.3961	27.82987
securitiesAssets	Log of total securities holdings	349	22.83931	3.071773	9.92564	21.67911	23.60409	25.08148	27.05477
loansBanks	Log of total lending to banks	343	22.10879	3.101762	9.828926	20.0111	22.6904	24.53215	27.1546
totLoans	Log of total loans	346	23.83968	2.959396	11.9591	21.92683	24.96898	26.27623	27.4483
npl	Non-performing loans/total loans		0.0367954	0.1163406	0	0.0030009	0.0139795	0.0298776	0.0929210
totLiabs	Log of total liabilities	351	25.06824	2.945941	8.994103	23.96959	25.87486	27.18127	28.17011
totDeposits	Log of total deposits	169	24.7924	3.320296	6.907755	24.0883	25.94362	26.96937	27.58602
amount	Log of total amount lent/borrowed by a bank in a day per maturity bucket, LR nettability and collateral type	195,589	19.42061	1.752594	13.81551	18.30774	19.48539	20.74307	23.98591
Spread (%)	Weighted average spread on lending/borrowing by a bank in a day per maturity bucket, LR nettability and collateral type	195,589	0.0112572	0.1953133	-2.374435	-0.0414	0.003	0.0491144	53.5329

Source: Bank of England Sterling Money Market database, asset purchase facility operations database, and internal regulatory data.

* Spread: the difference between the rate charged and the relevant reference rates. Amounts are in logarithmic scale.

3. Empirical design

To assess QE effects on the pricing and amounts in the gilt repo market, we implement a DiD model that compares QE banks to similar banks that did not receive reserves injections (non-QE banks). Our baseline DiD model is:

$$Y_{i,t} = \beta_i + \omega_j + \delta_1(Treated_i\ \boldsymbol{QE}_t) + \delta_2(Treated_i\ \boldsymbol{QE}_t LR_i) + \gamma_1 \boldsymbol{QE}_t + \theta X_{i,t} + \varsigma(X_{i,t}\ \boldsymbol{QE}_t) + \upsilon_{i,t} \quad \textbf{(1)}$$

where, $Y_{i,t}$: spread or log of lending amount; $\beta_i\ and\ \omega_j$: bank and counterparty sector fixed effects; $Treated_i$: treatment dummy, set to 1 for QE banks and 0 otherwise; $\boldsymbol{QE}_t = [QE_{Brexit,t}, QE_{Covid,t}]$: Brexit and Covid treatment time dummies, which are set to 0 before 4 August 2016 and 19 March 2020, respectively, and 1 afterwards; LR_i: leverage ratio dummy, set to 1 for banks subject to the leverage ratio framework and 0 otherwise; $Treated_i\ \boldsymbol{QE}_t$: interaction term of treatment and QE episode; $Treated_i\ \boldsymbol{QE}_t\ LR_i$: interaction term of treatment, QE episode and leverage ratio requirements; $X_{i,t}$: a matrix of controls, including bank-level and transaction level controls. As shown in Table 1, bank-level controls include balance sheet assets and liabilities, capitalisation metrics, and risk measures (risk-weighted assets and non-performing loans). Transaction-level controls include maturity, collateral type, central clearing dummy (set to 1 for transactions cleared with a central counterparty (CCP) and 0 otherwise), and leverage ratio *nettability* dummy (set to 1 for transactions eligible for netting under the leverage ratio rules and 0 for ineligible transactions);[5] $X_{i,t} * \boldsymbol{QE}_t$: interaction terms to account for possible heterogeneous responses by banks. We apply Equation (1) at both the bank-level, where we assess effects on daily total amounts and weighted average spreads charged and paid by banks, and the transaction-level, where we assess impact on spreads of individual transactions. In both analyses, we categorise transactions into three maturity buckets, overnight (we refer to as short-term), two weeks to one month (we refer to as medium-term), and three months to one year (we refer to as long-term)[6].

The selection of QE banks (i.e., selection into the treatment group) is most likely not random. It would probably reflect specific bank characteristics, such as bank size and the structure of assets and

[5] The leverage ratio rules allow reverse repo and repo transactions that meet certain conditions (e.g., they have the same counterparty and similar maturities) to be calculated on net basis (*nettable)*.

[6] Worth noting that our analysis focuses on standard maturities and excludes non-standard maturities.

liabilities. Hence, our analysis and results would be subject to the effects of selection bias. To mitigate this and create comparable treatment and control groups, we use a propensity score matching approach. We implement the matching in three stages. First, we check whether selection to treatment is correlated with certain bank and repo portfolio characteristics. To do so, we regress the treatment status (dummy) before the treatment (i.e., QE waves) on a set of bank-level variables, reflecting business model, risk, and capitalisation, as well as repo portfolio-level variables, reflecting size and maturity. We do that for lending (reverse repo) and borrowing (repo) separately, and for the total lending and borrowing portfolios as well as sub-portfolios/maturity buckets (short-term, medium-term, and long-term). We also do this assessment before the Brexit and Covid waves separately, unlike Giansante et al. (2022), who do the assessment just before the first two waves. This is because bank-level data coverage is somewhat less complete before the QE_{Brexit}, which affects our ability to do comprehensive matching. In the next step, we use characteristics correlated with the treatment status to match each bank in the treatment group with those in the control group that are most similar based on these characteristics. Lastly, we re-run the regressions we did in the first step (treatment on characteristics) using the matched sample, to verify whether the matching has reduced differences between the treatment and control groups.

4. Analysis and results

4.1. Propensity score matching

As mentioned above, we regress treatment status on a set of bank-level and portfolio-level variables, separately for lending and borrowing portfolios, as well as for total portfolios and sub-portfolios (short-term, medium-term, and long-term). For the total portfolios, the portfolio-level variables include the log of total amount (lent/borrowed) and the weighted average maturity of all (lending/borrowing) transactions. Meanwhile, for the sub-portfolios, they include the log of the amounts in the sub-portfolios and the percentages of the amounts in the sub-portfolios out of the amounts in the total portfolios. The bank-level variables include size (total assets), risk-weighted assets (RWAs), and capitalisation (core equity tier 1, CET1, ratio). The results of the regressions are presented under model (1) in Table 2 and Table 3.

Table 2: Propensity score matching (pre Brexit QE)

	Lending (reverse repo)								Borrowing (repo)							
	All maturities		Overnight		2 weeks to 1 month		3 months or more		All maturities		Overnight		2 weeks to 1 month		3 months or more	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
VARIABLES	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat
Total amount	-0.495	-0.057	-14.443	-2.408	-1.343	-1.202	0.050	-0.396	0.182	0.080	0.255	0.062	-0.257	-0.491*	-0.463	-0.688
	(0.303)	(0.200)	(19.972)	(1.973)	(1.089)	(1.657)	(0.190)	(0.411)	(0.179)	(0.180)	(0.174)	(0.169)	(0.231)	(0.286)	(0.368)	(0.488)
w. avg. maturity	-22.642	2.548							-13.379***	-7.885						
	(15.940)	(14.380)							(4.725)	(29.879)						
pct. Of total portfolio			157.854	22.484	-6.141*	-2.626	-5.263	-0.261			0.258	0.548	3.468	4.968*	13.907	21.223
			(220.803)	(15.317)	(3.236)	(4.350)	(8.013)	(10.664)			(0.169)	(0.337)	(2.431)	(2.661)	(12.193)	(15.022)
Total assets	-0.806***	-0.724*	-21.692	-3.463	-2.014*	-1.920	-0.662***	-0.500	-0.125	-0.153	0.059	-0.080	0.365	0.497*	0.220	0.386
	(0.302)	(0.439)	(30.499)	(1.942)	(1.059)	(1.818)	(0.218)	(0.385)	(0.121)	(0.202)	(0.123)	(0.161)	(0.285)	(0.271)	(0.217)	(0.296)
RWAs	1.365**	2.440**	37.062	6.695	4.322	4.078	1.107**	2.144*								
	(0.642)	(1.133)	(51.809)	(3.335)	(2.726)	(3.930)	(0.505)	(1.199)								
CET1 ratio	13.628	65.345	77.036	61.118	49.267	48.434	9.183	62.038								
	(11.477)	(40.846)	(76.983)	(41.781)	(47.046)	(62.553)	(6.782)	(45.579)								
Constant	-2.037	-30.212*	-141.664	-44.790**	-30.965	-32.095	-13.781	-40.927*	-0.726	1.258	-7.590	-0.649	-1.364	0.107	6.425	6.727
	(15.448)	(18.366)	(194.956)	(18.494)	(27.054)	(28.914)	(11.227)	(23.686)	(5.510)	(8.353)	(5.350)	(6.733)	(8.981)	(6.101)	(9.138)	(9.883)
Matching	-pre	-post	-pre	-post	-pre	-post	-pre	-post	-pre	-post	-pre	-post	-pre	-post	-pre	-post
$Adj\ R^2$	0.498	0.494	0.669	0.598	0.586	0.442	0.430	0.340	0.355	0.126	0.338	0.244	0.242	0.364	0.291	0.432
p-value	0.000	0.101	0.688	0.151	0.002	0.333	0.007	0.489	0.027	0.619	0.046	0.115	0.368	0.233	0.496	0.473
N	17	14	17	13	16	12	16	13	13	12	13	13	12	12	11	11

Probit regressing the treatment on lending/borrowing (reverse repo/repo) portfolio characteristics and bank characteristics. The dependent variable is QE treatment status treat for QE banks. Model (1) reports the pre-matching results while model (2) reports the post matching results with matching ratio 1:2. Coefficients and standard errors are reported for each variable. Standard errors are robust and reported in brackets, * p<0.10 ** p<0.05 *** p<0.01

Table 3: Propensity score matching (pre Covid QE)

	Lending (reverse repo)								Borrowing (repo)							
	All maturities		Overnight		2 weeks to 1 month		3 months or more		All maturities		Overnight		2 weeks to 1 month		3 months or more	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
VARIABLES	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat	treat
Total amount	0.050	-0.189	0.059	-0.212	0.001	-0.169	-0.074	0.103	0.080	-1.352***	0.117	-0.029	-0.005	-0.119	-0.024	-0.101
	(0.171)	(0.172)	(0.164)	(0.176)	(0.215)	(0.272)	(0.218)	(0.236)	(0.127)	(0.422)	(0.107)	(0.132)	(0.155)	(0.177)	(0.128)	(0.146)
w. avg. maturity	-23.157**	-9.880							-5.720	413.900						
	(11.559)	(16.021)							(8.014)	(172.524)						
pct. Of total portfolio			4.647**	1.191	-6.003	1.183	-10.392*	-9.771*			-0.041	-0.009	-1.487	0.334	-4.041	6.796
			(2.289)	(2.786)	(3.834)	(3.274)	(5.786)	(5.341)			(0.074)	(0.063)	(2.681)	(2.337)	(7.919)	(9.241)
Total assets	-3.026***	-2.783*	-3.259***	-2.594*	-3.187**	-2.210**	-2.699***	-1.941**	-2.199***	-1.183	-2.160***	-2.516***	-2.072***	-2.295***	-2.026***	-2.335***
	(0.842)	(1.457)	(1.047)	(1.400)	(1.322)	(0.912)	(0.793)	(0.835)	(0.814)	(0.893)	(0.733)	(0.956)	(0.676)	(0.695)	(0.686)	(0.860)
RWAs	3.370***	2.683*	3.595***	2.487*	3.491**	2.119**	3.028***	1.813**	2.319***	2.244*	2.392***	2.427**	2.343***	2.360***	2.269***	2.339**
	(0.924)	(1.405)	(1.135)	(1.367)	(1.439)	(0.947)	(0.914)	(0.802)	(0.826)	(1.254)	(0.775)	(0.986)	(0.723)	(0.742)	(0.732)	(0.926)
CET1 ratio	10.964	20.929	13.785	22.331	14.644	20.694	10.865	32.142	4.067***	63.367**	4.671***	5.506	6.681	9.260	5.264	5.799
	(7.097)	(18.458)	(9.761)	(18.338)	(11.567)	(16.546)	(7.196)	(24.323)	(1.360)	(25.104)	(1.310)	(8.314)	(6.455)	(6.201)	(5.743)	(5.821)
Constant	-7.754	6.906	-12.456*	6.033	-5.640	4.818	-4.737	-2.157	-2.998	-0.427	-6.937	4.443	-4.820	1.729	-3.630	3.189
	(6.750)	(13.684)	(7.350)	(12.329)	(6.038)	(13.952)	(4.546)	(5.392)	(8.794)	(11.803)	(4.231)	(9.482)	(5.757)	(5.990)	(5.424)	(6.477)
Matching	-pre	-post	-pre	-post	-pre	-post	-pre	-post	-pre	-post	-pre	-post	-pre	-post	-pre	-post
$Adj\ R^2$	0.550	0.483	0.563	0.475	0.545	0.487	0.530	0.439	0.465	0.675	0.465	0.489	0.445	0.446	0.434	0.468
p-value	0.008	0.257	0.031	0.383	0.109	0.152	0.019	0.206	0.003	0.022	0.008	0.149	0.033	0.026	0.032	0.032
N	33	28	33	28	31	26	31	26	30	26	30	29	29	29	28	28

Probit regressing the treatment on lending/borrowing (reverse repo/repo) portfolio characteristics and bank characteristics. The dependent variable is QE treatment status treat for QE banks. Model (1) reports the pre-matching results while model (2) reports the post matching results with matching ratio 1:2. Coefficients and standard errors are reported for each variable. Standard errors are robust and reported in brackets, * p<0.10 ** p<0.05 *** p<0.01

As the two tables show, on average, treated banks are smaller, and have higher risk weight density (i.e., higher RWAs), stronger capitalisation, and repo portfolios with relatively shorter maturities. We then match each bank in the treatment group with the most similar banks in terms of these characteristics in the control group. We use a 1:2 matching ratio in our baseline to better balance the two groups. That is, each treated bank is matched with the most similar two banks in the control group based on the abovementioned characteristics.[7] After the matching, we re-run the same (pre-matching) regressions, but using the matched sample, and results are shown in model (2) in Table 2 and Table 3. Comparing the results of model (1) and model (2) regressions indicates that the matching generally reduces differences between the treatment and control groups,[8] and hence we can proceed to the baseline regressions (Equation (1)) at both the bank-level and the transaction-level.

4.2. Bank-level analysis

We start our analysis by running Equation (1) at the bank-level, where we assess the treatment effects on the daily amounts lent and borrowed and the spreads charged and paid by QE banks, compared to the control group. Amounts are the sums of amounts lent and borrowed in the total and sub portfolios, as indicated earlier. Spreads are weighted averages of spreads on individual transactions within each maturity bucket on each date, using transaction amounts as weights. Table 4 presents the DiD results for the bank-level models.

4.2.1. QE effects

As the top part of Panel (a) shows, relative to the control group, QE banks did not increase their total lending post QE_{Brexit}. They, however, restructured reverse repo portfolios towards significantly less long-term lending and significantly more short-term lending. Meanwhile, post QE_{Covid}, QE banks total repo lending was 33.6% higher than that of non-QE banks. The effects are clearer for short-term lending, which was 38.3% higher for QE banks. A weaker and less significant increase is seen for long-term lending, and no statistically significant effects can be documented for medium-term lending.

[7] We try other matching ratios (1:1, 1:3 and 1:4), and results of the matching are generally consistent. We chose 1:2 matching ratio as it minimises difference between the treatment and control groups post matching (model (2) in Tables Table 2 and Table 3).

[8] In the context of these regressions, differences between the treatment and control groups decrease with smaller coefficients on the regressors, lower level of significance and higher p-value.

Table 4: QE treatment effect --- bank-level

Panel (a): reverse repo (lending) amounts and pricing

Variables	Amounts				Spreads			
	All 1(a)	**Overnight** 1(b)	**2 weeks to 1 month** 1(c)	**3 months or more** 1(d)	**All** 1(a)	**Overnight** 1(b)	**2 weeks to 1 month** 1(c)	**3 months or more** 1(d)
$\boldsymbol{Treated \times QE_{Brexit,t}}$	-0.149	1.852**	-0.149	**-0.528*** **	**-0.0879** **	**-0.133*** **	**-0.0661*** **	**-0.0310*** **
	(0.519)	(0.915)	(0.0139)	(0.162)	(0.0428)	(0.00755)	(0.0140)	(0.00723)
$Treated \times QE_{Brexit,t} \times LR_t$	0.253	0.547	-0.0648	0.195	**-0.0662*** **	**-0.0927*** **	**-0.0242*** **	**0.0265*** **
	(1.0797)	(1.115)	(0.129)	(0.253)	(0.0162)	(0.00895)	(0.00261)	(0.00590)
Obs.	33,679	16,428	10,956	5,468	33,679	16,428	10,956	5,007
R-squared	0.117	0.111	0.124	0.111	0.021	0.198	0.012	0.094
$Treated \times QE_{Covid,t}$	**0.336*** **	**0.383*** **	-0.297	0.376*	0.0120	0.0000384	-0.0210	0.00780
	(0.157)	(0.0817)	(0.256)	(0.203)	(0.0145)	(0.0222)	(0.0237)	(0.0204)
$Treated \times QE_{Covid,t} \times LR_t$	**0.684*** **	0.975**	-0.0493	**0.699*** **	0.000850	-0.00322	-0.00616	0.0121
	(0.254)	(0.385)	(0.222)	(0.159)	(0.0129)	(0.0246)	(0.0182)	(0.0150)
Obs.	8,978	4,382	2,881	1,654	8,978	4,382	2,881	1,654
R-squared	0.269	0.576	0.260	0.348	0.178	0.663	0.232	0.141
QE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls $*$ **QE**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Coefficient estimates of amounts and spreads on reverse repo (lending) on daily basis (Jan 2016 to Apr 2021). $Treated_i$ equals to 1 for QE banks and 0 for non-QE banks. Controls include bank-level controls (e.g., total assets, RWAs) and portfolio-level controls (e.g., maturity bucket, collateral type). Robust standard errors reported between parentheses, * p<0.10 ** p<0.05 *** p<0.01.

Panel (b): repo (borrowing) amounts and pricing

	Amounts				Spreads			
Variables	**All 1(a)**	**Overnight 1(b)**	**2 weeks to 1 month 1(c)**	**3 months or more 1(d)**	**All 1(a)**	**Overnight 1(b)**	**2 weeks to 1 month 1(c)**	**3 months or more 1(d)**
$Treated \times QE_{Brexit,t}$	**0.428***** (0.143)	**0.900***** (0.162)	**-1.538***** (0.209)	-0.0725 (0.550)	0.0000424 (0.0263)	0.00899 (0.00760)	-0.0709* (0.0395)	0.0532 (0.0597)
$Treated \times QE_{Brexit,t} \times LR_t$	-0.170* (0.0999)	-0.158 (0.126)	**0.659***** **(0.125)**	**0.808***** **(0.171)**	**-0.0753***** **(0.0222)**	**-0.0578***** **(0.00564)**	**-0.131***** **(0.0469)**	**-0.0781***** **(0.00698)**
Obs.	13,847	24,952	16,623	8,748	49,246	24,952	16,623	8,748
R-squared	0.295	0.233	0.141	0.101	0.017	0.065	0.013	0.068
$Treated \times QE_{Covid,t}$	0.122 (0.117)	-0.0378 (0.172)	0.329 (0.225)	0.134 (0.220)	**0.0373***** (0.00852)	**0.0409***** (0.0130)	0.0186 (0.0130)	-0.0109 (0.0130)
$Treated \times QE_{Covid,t} \times LR_t$	0.128 (0.100)	0.0914 (0.174)	0.0520 (0.186)	0.125 (0.212)	-0.00200 (0.00521)	**-0.0422***** (0.00851)	0.0116 (0.00746)	**0.0320***** (0.00983)
Obs.	19,692	10,126	6,520	3,877	19,692	10,126	6,520	3,877
R-squared	0.380	0.403	0.382	0.490	0.600	0.662	0.609	0.706
QE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls $*$ **QE**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Coefficient estimates of amounts and spreads on repo (borrowing) on daily basis (Jan 2016 to Apr 2021). $Treated_i$ equals to 1 for QE banks and 0 for non-QE banks. Controls include bank-level controls (e.g., total assets, RWAs) and portfolio-level controls (e.g., maturity bucket, collateral type). Robust standard errors reported between parentheses, * p<0.10 ** p<0.05 *** p<0.01.

In contrary to QE_{Brexit}, the ample size of reserves injections through the large QE purchases during QE_{Covid} allowed QE banks to satisfy the very high demand for short-term liquidity during the March 2020 dash-for-cash without rationing longer-term lending. During QE_{Brexit}, the increased lending by QE banks was supported by rationing longer-term lending, as well as increased borrowing. As Panel (b) suggests, total and especially short-term borrowing of QE banks increased by 42.8% and 90% (respectively) post QE_{Brexit}, but shows no statistically significant change post QE_{Covid}, relative to the control group. Thus, QE operations helped improve provision of liquidity in the gilt repo market by injecting additional reserves and incentivising banks that received those reserves to increase the level of intermediation in the market (borrowing and lending more). The latter is more apparent in the QE_{Brexit} and less so in QE_{Covid} due to the larger reserves injections during QE_{Covid}. In terms of pricing, spreads charged by QE banks were about 8.8bps lower than those of non-QE banks post QE_{Brexit}. However, the spreads of the two groups of banks show no statistically significant differences after QE_{Covid}, probably due to the very strong demand at the time when that wave was introduced.

In summary, we find evidence that QE can improve liquidity provision in the gilt repo market, the short-term overnight liquidity in particular. However, the size of QE injection dictates how this increased provision is attained. When injections are sufficiently large (e.g., QE_{Covid}), the sizeable liquidity provided by QE purchases support the increased liquidity provision. Meanwhile, the higher provision following smaller injections (e.g., QE_{Brexit}) would be funded by a mix of rationing of longer-term lending and increased repo borrowing. In other words, smaller QE injection can increase intermediation in the short-term gilt repo market. The additional cheaper liquidity received via QE operations can reduce the cost of funding in the gilt repo market, but demand factors can reduce this effect or wipe it out entirely.

4.2.2. Leverage ratio effects

The total lending of QE banks subject to the leverage ratio was 68.4% higher than the control group during QE_{Covid} but shows an increase only for the medium-term bucket during QE_{Brexit}. This indicates that the leverage ratio did not have a negative impact on bank lending in the gilt repo market. On the

contrary, by comparing to the treatment effect of all QE banks during QE_{Covid}, the leverage ratio had a net positive effect on that lending.[9] Nevertheless, the difference in effects between the two waves is likely arising from the chronical sequence of the leverage ratio implementation. The ratio was introduced in 2016 as a risk agnostic measure into a regulatory framework characterised by risk-weighted capital requirements. Hence, at its introduction, the leverage ratio would have had some effects on banks' incentives to engage in low-risk activities (with low capital requirements), such as repo lending, as it leads to an increase in the capital base required to support these activities compared to riskier activities. This explains why QE banks subject to the leverage ratio lending did not increase lending and charged higher spreads during QE_{Brexit}, which came only 8 months after the leverage ratio introduction. In terms of pricing, QE banks subject to leverage ratio charged relatively more on repo lending compared to other QE banks, but still less than the control group.[10] The clearer effects during QE_{Brexit} are likely due to the lower liquidity injected into the system via QE, and the possible effects of the recent introduction of the leverage ratio on low-risk activities. Moreover, QE banks subject to the leverage ratio paid less on repo borrowing compared to the control group as well as other QE banks. This is because repo borrowing transactions attract capital charges in the leverage ratio, making this source of funding relatively more costly (economically) for banks subject to the ratio, and reducing the spreads they are willing to pay to attain it.

To sum up, our results suggest that the leverage ratio not only does not have negative effects on the provision of liquidity in the gilt repo market but can also have positive effects in stress. Yet, the ratio increases the economic cost of repo lending for banks subject to it, increasing the spreads they charge on this lending. Our results are in line with those of Gerba and Katsoulis (2021). They, however, contrast with earlier studies that indicate negative effects of the leverage ratio on the provision of low-risk activities (for instance, Kotidis and van Horen, 2018, and Acosta-Smith et al., 2020). The two

[9] QE banks increased lending by 33.6% during QE_{Covid}, compared to the control group. The 33.6% is the average effect across all the treatment group. A sub-sample of that group (those subject to the leverage ratio) show a stronger treatment effect (68.4%). We argue that the difference indicates a positive effect of the leverage ratio on lending amounts.

[10] QE banks subject to the leverage ratio reduced spreads they charge by about 5.7 bps compared to the control group. However, that reduction is significantly smaller than the average reduction for the entire treatment group (QE banks). The difference is likely due to the leverage ratio requirements.

views can be reconciled. Earlier studies mostly cover the early stages after the introduction of the leverage ratio, where banks where still adjusting to the changes in the regulatory regime that would disproportionally affect low-risk activities, as discussed above. However, over time, after banks had adjusted to the new regulatory regime, leverage ratio effects would appear in the pricing of low-risk activities rather than their amounts. In fact, the leverage ratio can have 'positive' effects on the provision of low-risk activities in stress, as banks subject to it to enter the stress with stronger capital positions. This likely explains the larger increase in lending by QE banks subject to the leverage ratio compared to both the control group and other QE banks not subject to the ratio.

4.3. Transaction-level analysis

In this section, we run the model in Equation (1) at the transaction-level, to assess whether the trends we document for spreads at the bank-level flow into the pricing of individual trades. Specifically, we assess whether the spreads charged on individual repo transactions by QE banks changed relative to similar transactions offered by the control group post QE episodes. We do that for each of the sub-portfolios (short-term, medium-term, and long-term) separately. Regression results are presented in models (a) of Table 5 and Table 6.

In line with the bank-level results, spreads charged on individual lending transactions of QE banks fell relative to spreads on similar transactions provided by non-QE banks during QE_{Brexit} across different maturity buckets, although the coefficients for the medium and long term regression are statistically insignificant. Meanwhile, no evidence of statistically significant differences between the spreads on the transactions of QE banks and non-QE banks during QE_{Covid} is documented. Leverage ratio effects are generally consistent with the bank-level results. Spreads on lending transactions of QE banks subject to the leverage ratio were lower than the control group, but higher than the rest of the treatment group during QE_{Brexit}. However, the spreads on lending transactions of these banks were marginally lower than the control group and other QE banks, but this does not reflect on the aggregate pricing; that is, it was not cheaper to borrow from these banks on average, as the bank-level analysis shows.

Table 5: QE treatment effect on spreads and amounts of reverse repos --- transaction-level

Panel (a): Spreads

	Overnight			2 weeks to 1 month			3 months or more		
Variables	1(a)	1(b)	1(c)	2(a)	2(b)	2(c)	3(a)	3(b)	3(c)
$Treated \times QE_{Brexit,t}$	-0.0989***	-0.0868***	-0.0868***	-0.828	-1.375	-1.375	-0.500	-0.0554	-0.0554
	(0.0215)	(0.0213)	(0.0213)	(0.605)	(0.982)	(0.982)	(0.546)	(0.251)	(0.251)
$Treated \times QE_{Brexit,t} \times LR_t$	-0.0399***	-0.0281***	-0.0281***	0.880	1.190	1.190	0.0456	0.0526	0.0526
	(0.00170)	(0.00165)	(0.00165)	(0.772)	(1.896)	(1.896)	(0.0735)	(0.205)	(0.205)
$Transaction\ amount$	0.00132***	0.00169***	0.00169***	-0.00547***	-0.00179	-0.00179	-0.00894***	-0.00274***	-0.00274***
	(0.0000905)	(0.0000795)	(0.0000795)	(0.000216)	(0.00131)	(0.00131)	(0.00191)	(0.000497)	(0.000497)
Obs.	43,591	43,591	43,591	221,523	221,523	221,523	43,591	752	752
R-squared	0.079	0.147	0.147	0.113	0.169	0.169	0.241	0.296	0.296
$Treated \times QE_{Covid,t}$	0.00334	0.00426	0.00426	-0.00216	0.00689	0.00689	-0.0714	-0.204***	-0.204***
	(0.00511)	(0.00506)	(0.00506)	(0.00790)	(0.00665)	(0.00665)	(0.0596)	(0.0596)	(0.0596)
$Treated \times QE_{Covid,t} \times LR_t$	**-0.0316*** **	**-0.0328*** **	**-0.0328*** **	**-0.0157*** **	-0.00216	-0.00216	**-0.147*** **	**-0.149*** **	**-0.149*** **
	(0.00566)	(0.00558)	(0.00558)	(0.00436)	(0.00410)	(0.00410)	(0.0443)	(0.0391)	(0.0391)
$Transaction\ amount$	**0.00223*** **	**0.00225*** **	**0.00225*** **	**-0.00527*** **	0.00132*	0.00132*	**-0.0173*** **	-0.00555	-0.00555
	(0.000736)	(0.000738)	(0.000738)	(0.000237)	(0.000759)	(0.000759)	(0.00584)	(0.00611)	(0.00611)
Obs.	43,591	43,591	43,591	221,523	221,523	221,523	43,591	752	752
R-squared	0.192	0.194	0.194	0.006	0.013	0.013	0.192	0.254	0.254
QE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls $*$ **QE**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CP sec. FEs	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
LR nettability	No	Yes	No	No	Yes	No	No	Yes	No

Coefficient estimates of spreads on reverse repo transactions on daily basis (Jan 2016 to Apr 2021). Model specifications: (a) bank fixed-effect only; (b) bank, counterparty sector and LR nettability fixed-effects; and (c) bank and counterparty sector fixed-effects and LR nettability as a control. Treatment status $Treated_i$ equals to 1 for QE-banks and 0 for non-QE-banks. Controls include collateral type and central clearing status. Robust standard errors reported between parentheses, * p<0.10 ** p<0.05 *** p<0.01.

Panel (b): Amounts

	Overnight			2 weeks to 1 month			3 months or more		
Variables	1(a)	1(b)	1(c)	2(a)	2(b)	2(c)	3(a)	3(b)	3(c)
$Treated \times QE_{Brexit,t}$	-0.587	**-1.849*** **	**-1.849*** **	-7.777**	-3.308	-3.308	0.386	0.392	0.3858684
	(0.466)	(0.461)	(0.461)	(3.500)	(4.791)	(4.791)	(0.751)	(0.700)	(0.708254)
$Treated \times QE_{Brexit,t} \times LR_t$	**-0.639*** **	**-0.927*** **	**-0.927*** **	-0.00913	0.294	0.294	1.434	-1.012	-0.9687634
	(0.0656)	(0.0645)	(0.0645)	(0.362)	(0.350)	(0.350)	(1.351)	(1.293)	(1.321237)
Obs.	567,711	567,711	567,711	57,536	57,536	57,536	34,168	34,168	34,168
R-squared	0.069	0.118	0.118	0.076	0.205	0.205	0.043	0.141	0.141
$Treated \times QE_{Covid,t}$	**0.303*** **	**0.305*** **	**0.305*** **	**1.223*** **	**1.074*** **	**1.074*** **	0.109	0.127	0.127
	(0.0565)	(0.0564)	(0.0564)	(0.0941)	(0.0918)	(0.0918)	(0.807)	(0.602)	(0.602)
$Treated \times QE_{Covid,t} \times LR_t$	0.0674	0.0566	0.0566	**-0.243*** **	**-0.295*** **	**-0.295*** **	0.109	0.203	0.203
	(0.0614)	(0.0614)	(0.0614)	(0.0378)	(0.0346)	(0.0346)	(0.455)	(0.360)	(0.360)
Obs.	43,591	43,591	43,591	221,523	221,523	221,523	752	752	752
R-squared	0.143	0.145	0.145	0.093	0.247	0.247	0.276	0.432	0.432
QE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls $*$ **QE**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CP sec. FEs	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
LR nettability	No	Yes	No	No	Yes	No	No	Yes	No

Coefficient estimates of amounts of reverse repo transactions on daily basis (Jan 2016 to Apr 2021). Model specifications: (a) bank fixed-effect only; (b) bank, counterparty sector and LR nettability fixed-effects; and (c) bank and counterparty sector fixed-effects and LR nettability as a control. Treatment status $Treated_i$ equals to 1 for QE-banks and 0 for non-QE-banks. Controls include collateral type and central clearing status. Robust standard errors reported between parentheses, * p<0.10 ** p<0.05 *** p<0.01.

Table 6: QE treatment effect on spreads and amounts of repos (borrowing) --- transaction-level

Panel (a): Spreads

	Overnight			2 weeks to 1 month			3 months or more		
Variables	1(a)	1(b)	1(c)	2(a)	2(b)	2(c)	3(a)	3(b)	3(c)
$Treated \times QE_{Brexit,t}$	**0.0143*** **	**0.0156*** **	**0.0156*** **	**-0.0751*** **	**-0.0732*** **	**-0.0732*** **	**-0.150*** **	**-0.146*** **	**-0.146*** **
	(0.00242)	(0.00245)	(0.00245)	(0.0186)	(0.0184)	(0.0184)	(0.0571)	(0.0435)	(0.0435)
$Treated \times QE_{Brexit,t} \times LR_t$	**-0.0338*** **	**-0.0385*** **	**-0.0385*** **	**-0.0920*** **	**-0.0829*** **	**-0.0829*** **	**-0.120*** **	**-0.0715*** **	**-0.0715*** **
	(0.00144)	(0.00138)	(0.00138)	(0.00331)	(0.00328)	(0.00328)	(0.0189)	(0.0161)	(0.0161)
$Transaction\ amount$	**0.00181*** **	**0.00224*** **	**0.00224*** **	**-0.000891*** **	**-0.00581*** **	**-0.00581*** **	**0.0108*** **	-0.0000914	-0.0000914
	(0.0000971)	(0.0000999)	(0.0000999)	(0.000241)	(0.000255)	(0.000255)	(0.000826)	(0.000835)	(0.000835)
Obs.	1,174,064	1,174,064	1,174,064	168,563	168,563	168,563	11,897	11,897	11,897
R-squared	0.059	0.068	0.068	0.053	0.110	0.110	0.157	0.298	0.298
$Treated \times QE_{Covid,t}$	**-0.258*** **	0.00443	0.00443	**-0.117*** **	-0.0220	-0.0220	**-0.474*** **	**0.0518*** **	**0.0518*** **
	(0.0190)	(0.00273)	(0.00273)	(0.0421)	(0.0157)	(0.0157)	(0.0490)	(0.0112)	(0.0112)
$Treated \times QE_{Covid,t} \times LR_t$	0.00672**	**-0.00746*** **	**-0.00746*** **	-0.0198	-0.0134*	-0.0134*	**0.0496*** **	**-0.0369*** **	**-0.0369*** **
	(0.00275)	(0.00197)	(0.00197)	(0.0155)	(0.00736)	(0.00736)	(0.0120)	(0.00783)	(0.00783)
$Transaction\ amount$	**0.00506*** **	**0.00448*** **	**0.00448*** **	**0.00161*** **	-0.000531	-0.000531	**0.0113*** **	0.000468	0.000468
	(0.000198)	(0.000207)	(0.000207)	(0.000518)	(0.000618)	(0.000618)	(0.000666)	(0.000716)	(0.000716)
Obs.	130,763	130,763	130,763	14,332	14,332	14,332	19,337	19,337	19,337
R-squared	0.153	0.167	0.167	0.198	0.219	0.219	0.164	0.273	0.273
QE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls $*$ **QE**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CP sec. FEs	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
LR nettability	No	Yes	No	No	Yes	No	No	Yes	No

Coefficient estimates of spreads on repo transactions on daily basis (Jan 2016 to Apr 2021). Model specifications: (a) bank fixed-effect only; (b) bank, counterparty sector and LR nettability fixed-effects; and (c) bank and counterparty sector fixed-effects and LR nettability as a control. Treatment status $Treated_i$ equals to 1 for QE-banks and 0 for non-QE-banks. Controls include collateral type and central clearing status. Robust standard errors reported between parentheses, * p<0.10 ** p<0.05 *** p<0.01.

Panel (b): Amounts

	Overnight			2 weeks to 1 month			3 months or more		
Variables	1(a)	1(b)	1(c)	2(a)	2(b)	2(c)	3(a)	3(b)	3(c)
$Treated \times QE_{Brexit,t}$	0.0161	**0.112*** **	**0.112*** **	-0.506**	-0.344*	-0.344*	**1.974*** **	**1.225*** **	**1.225*** **
	(0.0318)	(0.0316)	(0.0316)	(0.221)	(0.199)	(0.199)	(0.350)	(0.360)	(0.360)
$Treated \times QE_{Brexit,t} \times LR_t$	**0.0588*** **	**0.121*** **	**0.121*** **	0.0316	-0.0245	-0.0245	**-0.743*** **	**-0.538** **	**-0.538** **
	(0.0189)	(0.0180)	(0.0180)	(0.0540)	(0.0489)	(0.0489)	(0.276)	(0.223)	(0.223)
Obs.	1,174,064	1,174,064	1,174,064	168,563	168,563	168,563	11,897	11,897	11,897
R-squared	0.110	0.149	0.149	0.073	0.205	0.205	0.162	0.345	0.345
$Treated \times QE_{Covid,t}$	0.00474	**-0.136*** **	**-0.136*** **	**0.719*** **	**0.293*** **	**0.293*** **	**0.683*** **	0.341**	0.341**
	(0.0346)	(0.0352)	(0.0352)	(0.105)	(0.0955)	(0.0955)	(0.171)	(0.138)	(0.138)
$Treated \times QE_{Covid,t} \times LR_t$	**0.416*** **	**0.274*** **	**0.274*** **	**-0.309*** **	-0.0924	-0.0924	**0.340*** **	-0.189**	-0.189**
	(0.0346)	(0.0332)	(0.0332)	(0.105)	(0.0977)	(0.0977)	(0.113)	(0.0963)	(0.0963)
Obs.	130,763	130,763	130,763	14,332	14,332	14,332	19,337	19,337	19,337
R-squared	0.169	0.262	0.262	0.233	0.377	0.377	0.175	0.420	0.420
QE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls $*$ **QE**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CP sec. FEs	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
LR nettability	No	Yes	No	No	Yes	No	No	Yes	No

Coefficient estimates of amounts of repo transactions on daily basis (Jan 2016 to Apr 2021). Model specifications: (a) bank fixed-effect only; (b) bank, counterparty sector and LR nettability fixed-effects; and (c) bank and counterparty sector fixed-effects and LR nettability as a control. Treatment status $Treated_i$ equals to 1 for QE-banks and 0 for non-QE-banks. Controls include collateral type and central clearing status. Robust standard errors reported between parentheses, * p<0.10 ** p<0.05 *** p<0.01.

5. Robustness checks

In this section, we describe the experiments we carried out to ensure robustness of our results. This includes falsifying the two main dimensions of DiD, treatment timing (using synthetic treatment time) and treatment status (using an alternative treatment group), as well as ensuring the results are not demand-driven.

5.1. Timing effects

In this experiment, we trim our sample to avoid QE periods to generate a sample from February 2017 to January 2020 (36 months). We then create a synthetic QE treatment at the middle of that period (1 August 2018) and rerun our bank-level (Section 4.2) regressions on the new sample. Results of this experiment are in Table 7. As the results suggest, almost all treatment effects disappear, and even for the only exception, the coefficient becomes negative, suggesting a reduction in short-term lending, contrary to what we see for the two QE waves in Table 4.

5.2. Using an alternative treatment group

This experiment focuses on the treatment status rather than timing in the bank-level regressions bank-level (Section 4.2). We drop the treated banks completely from the sample, and create an alternative treatment group, based on the results on the propensity score matching we did in the baseline analysis. That is, we select the most matched banks from the control group with the treated banks in the matching exercise, and create an alternative treatment group, which we then compare to the reminder of the control group using DiD.

The idea here is that banks in the alternative treatment group are the most similar to the actual treated banks and would have been the most likely to be in the treatment group had the treatment banks not existed. Due to data limitation, we are able to implement this exercise only for QE_{Covid}. Results are shown in Table 8. Like with the timing effect, treatment effects either disappear or change directionality, as we see for long-term lending amounts and spreads.

Table 7: Synthetic QE treatment effect --- reverse repo (lending) amounts and pricing

Variables	Amounts				Spreads			
	All	**Overnight**	**2 weeks to 1 month**	**3 months or more**	**All**	**Overnight**	**2 weeks to 1 month**	**3 months or more**
	1(a)	**1(b)**	**1(c)**	**1(d)**	**1(a)**	**1(b)**	**1(c)**	**1(d)**
$Treated \times QE_{Synth,t}$	-0.785	-0.901**	0.285	-0.876	0.0150	-0.00515	0.129**	-0.0178
	(0.510)	(0.425)	(0.694)	(0.713)	(0.0325)	(0.0186)	(0.0560)	(0.0472)
Obs.	5,562	2,942	1,546	1,070	5,562	2,942	1,546	1,070
R-squared	0.335	0.605	0.316	0.394	0.257	0.589	0.337	0.193
QE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls $*$ **QE**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Coefficient estimates of amounts and spreads on reverse repo on daily basis (Feb 2017 to Jan 2020, treatment on 1 Aug 2018). $Treated_i$ equals to 1 for QE banks and 0 for non-QE banks. Controls include bank-level controls and portfolio-level controls. Robust standard errors reported between parentheses, * p<0.10 ** p<0.05 *** p<0.01.

Table 8: Alternative QE treatment effect --- reverse repo (lending) amounts and pricing

Variables	Amounts				Spreads			
	All	**Overnight**	**2 weeks to 1 month**	**3 months or more**	**All**	**Overnight**	**2 weeks to 1 month**	**3 months or more**
	1(a)	**1(b)**	**1(c)**	**1(d)**	**1(a)**	**1(b)**	**1(c)**	**1(d)**
$Treated \times QE_{Synth,t}$	1.802	137.4	2.577	-5.881***	-0.174	30.52	0.0251	0.250**
	(3.365)	(392.916)	(2.778)	(1.672)	(0.271)	(28.04)	(0.188)	(0.107)
Obs.	779	240	1,366	3,259	779	240	1,366	3,259
R-squared	0.106	0.377	0.293	0.186	0.153	0.283	0.187	0.132
QE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctrls $*$ **QE**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Coefficient estimates of amounts and spreads on reverse repo on daily basis (Jan 2016 to Apr 2021). $Treated_i$ equals to 1 for alternative treatment banks and 0 otherwise. Controls include bank-level controls and portfolio-level controls. Robust standard errors reported between parentheses, * p<0.10 ** p<0.05 *** p<0.01.

5.3. Demand effects

To ensure our results are not driven by differences in demand QE banks and non-QE banks face, we re-run our transaction-level analyses (Section 4.3) controlling for the counterparty sector. The results are shown in models (b) and (c) in Table 5 and Table 6, and are generally consistent with the baseline regressions in models (a), suggesting that differences between the treatment and control groups are more likely to reflect differences in behaviour of banks rather than the demand they face.

6. Conclusions

We assessed the impact of quantitative easing (QE) in the UK on liquidity and funding conditions in the gilt repo market. We also considered implications of the *leverage ratio* (LR) requirements on banks' incentives to engage in the low-risk repo activity. Our results suggest that QE improved liquidity provision in the gilt repo market, but the manner through which this is attained relies on the size of QE injection. While banks rely on the substantial liquidity large QE injections (e.g., QE_{Covid}) to increase repo lending, they tend to intermediate (i.e., borrow and lend) more with relatively smaller injections (e.g., QE_{Brexit}). The results also suggest that QE reduced the cost of borrowing in the gilt repo market, unless it was accompanied with a spike in demand, like that during the "dash for cash" in March 2020. Lastly, the results point out that the leverage ratio supported the provision of liquidity in gilt repo market in stress, as banks entered stress with better balance sheet capacity. However, banks subject to the ratio charged more on repo lending and paid less on repo borrowing, due to the larger capital charge repo transactions attract under the leverage ratio requirements.

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