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QE and the Bank Lending Channel in the United Kingdom*†

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Abstract

We test whether quantitative easing (QE), in addition to boosting aggregate demand and inflation via portfolio rebalancing channels, operated through a bank lending channel (BLC) in the UK. Using Bank of England data together with an instrumental variables approach, we find no evidence of a traditional BLC associated with QE. We show, in a simple framework, that the traditional BLC is diminished if the bank receives 'flighty' deposits (deposits that are likely to quickly leave the bank). We show that QE gave rise to such flighty deposits which may explain why we find no evidence of a BLC.

Keywords: Monetary policy; Bank lending channel; Quantitative Easing.

JEL Codes: E51, E52, G20

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1 Introduction

The Bank of England's Monetary Policy Committee (MPC) first voted to purchase gilts financed by the issuance of central bank reserves in March 2009 (widely referred to as quantitative easing (QE)). As the financial crisis had intensified, central banks around the world had taken action to support demand by loosening monetary policy. The MPC cut interest rates sharply to 0.5% but judged that additional 'unconventional measures' (King, 2009) were necessary to achieve their remit.[1] QE was designed to boost GDP and inflation. This would primarily happen via reducing gilt yields and increasing asset prices. This would occur as agents in the non-bank private sector would prefer to reinvest the newly created bank deposits into riskier assets such as corporate bonds and equities, absent a change in the price of those assets. This would lead to portfolio re-balancing and asset price changes, due to the imperfect substitutability of money and securities, as originally set out in Tobin (1963) and Brunner and Meltzer (1973).[2]

In this paper we examine whether those asset purchases by the Bank of England also gave rise to a traditional bank lending channel (BLC) in the UK. This channel can be understood as a supplementary channel of monetary policy which leads banks to increase their supply of lending. Although such a channel is not necessary for QE to boost demand and inflation, it is nevertheless valuable for our understanding of unconventional monetary policy to assess whether there was one. The BLC captures the idea that expansionary monetary policy leads to a shift out in banks' lending supply schedules. There are different versions of the BLC, but in this paper we follow an approach in the spirit of Kashyap and Stein (1995). In such a set-up, expansionary monetary policy increases reserves and transaction deposits. As a result, and because transactions deposits are a relatively cheap source of financing, the bank is willing to extend more loans at any given interest rate than previously. In QE, banks gain both new reserves and a corresponding new customer deposit which could lead to such a predicted increase in loan supply.

We take an empirical approach to the question using a dataset available to researchers at the Bank of England. This dataset has been constructed and used by other researchers in the Bank (see Bridges, Gregory, Nielsen, Pezzini, Radia, and Spaltro, 2014). The monthly dataset combines balance sheet, regulatory and market operations data for individual banking groups. A key challenge for empirical work on the bank lending channel is to isolate changes in lending caused by changes in deposits, from changes in deposits caused by new lending. We attempt

[1]Gilt purchases were the overwhelming focus of the policy of expanding the central bank's balance sheet through asset purchases (QE). Joyce, Tong, and Woods (2011) provide an excellent overview of these operations.

[2]For a short review of this literature see Joyce (2012).

to address this problem using an instrumental variable approach.[3] The key to this approach is that asset purchases by the Bank of England were intended to be made *from non-banks* (other financial corporations, OFC), but practically all of these transactions would, and indeed did, take place *via* banks. Since the decision to sell gilts to the Bank of England is exogenous to the individual bank's lending decision that period, the deposits created by such transactions are a useful exogenous source of variation to exploit. Our instrument is a monthly, bank-specific measure of the value of gilts sold as part of QE by each banks' customers which we calculate using market operations information on the transactions with the Bank of England.

At the time QE was launched, the MPC were not expecting or relying upon a large bank lending channel. The Minutes of their March 2009 meeting make clear that:

> 'The current strains in the financial system, and in particular the pressures on banks to reduce the size of their balance sheets, meant banks were less likely to increase their lending substantially following an increase in their reserves.'

And it was a deliberate aspect of the design of QE to target purchases at assets held by non-banks, by not buying gilts with short maturities (see Fisher (2010)). Asset price channels were, and are, thought to be the primary transmission mechanism of gilt purchases.

However, as set out in Benford, Berry, Nikolov, Young, and Robson (2009), other channels were conceived as possible at the time including a bank lending channel, and possible direct confidence/expectations effects.[4] And the BLC might have been expected to become more powerful over time, as banks improved their capital positions and were more able to lend. Moreover, Bowman, Cai, Davies, and Kamin (2011) have found a positive and statistically significant effect of Japanese banks' liquidity positions on their lending during 2000-09, suggesting that the expansion of reserves associated with QE may have boosted the flow of credit in Japan, albeit the estimated impact is small economically. Taken together, it seems important to ask to what extent QE in the UK has given rise to a BLC.

We find no statistically significant evidence that those banks who received increased deposits from QE lent more, all else equal. This does not prove that there was no bank lending channel from QE, but if the effect was very powerful it seems unlikely that there would be no evidence of it in our tests. It also does not rule out a boost to lending from the numerous other policies adopted by the UK authorities during this time; these include, for example, the Special Liquidity Scheme (SLS) and the Funding for Lending Scheme (FLS).[5] These are

[3] In an appendix we also present a second, difference-in-differences approach. The nature of the asset purchases gave rise to other financial corporations' (OFC) deposits (OFCs include pension funds and insurance companies). Our diff-in-diff exploits the fact that, as a result of historical strategy and for infrastructure reasons, not all banks are equally in a position to take very large OFC deposits. We use historical information on the share of OFC deposits held by individual banks to split the sample into those easily able to attract the newly-created OFC deposits and those less able to do so. We use this bank variable, together with time-series variation in the OFC deposits to examine whether those banks able to take advantage of increases in OFC deposits actually increased lending.

[4] It is also possible that the effect of QE on yields is caused by a signalling channel as investigated by Bauer and Rudebusch (2014).

[5] See John, Roberts, and Weeken (2012) and Churm, Radia, Leake, Srinivasan, and Whisker (2012) for details of the SLS and FLS, respectively.

complements to QE and operate through different channels.

Evidence suggests that QE boosted GDP and inflation materially via the portfolio rebalancing channel. For example, Joyce, Lasaosa, Stevens, and Tong (2011) and Joyce and Tong (2012) both used event study methodologies to estimate that the impact on gilt yields of the first tranche of £200bn of asset purchases in 2009-10 (QE1) was close to 100bps.[6]

The existing paper that is most closely related to ours is Joyce and Spaltro (2014). In that paper, the authors find, controlling for macro variables and other factors like capital, a small positive relationship between total deposits and lending using pre-crisis data for UK banks. They do not reject statistically a null hypothesis that the relationship was unchanged after the onset of the financial crisis in 2007. Drawing on work that shows that QE boosted deposits, they use the pre-crisis relationship to simulate the impact of QE on bank lending out of sample and find that the first round of QE purchases may have led to a small effect on bank lending growth. While we are also interested in the relationship between deposits and bank lending, our approach differs in three main respects. First, we focus on data during the QE period to directly estimate whether QE had an effect on bank lending. Second, we use an IV identification strategy to try to shed light on a causal relationship. Third, rather than examine total deposits, we focus on wholesale OFC deposits (the type created instantaneously by QE purchases).

The third difference is important as we show that the impact of deposits on lending is unlikely to be invariant to the deposits created. The importance of deposit characteristics has not previously been emphasised by the literature. In particular, we highlight that the extent of a BLC is conditional on whether the deposits created are 'flighty' (as opposed to 'sticky') in the sense that the individual bank receiving the new deposit can rely on having a higher level of deposits in the future too. If it is likely that deposits will not be around in future periods, banks will not choose to lend as much of the temporary boost. As we argue, and Butt, Domit, McLeay, Thomas, and Kirkham (2012) show, QE has mainly led to the creation of OFC deposits as these are the primary sellers of gilts. Moreover, if these OFCs begin to rebalance their portfolios, then this will result in a movement of deposits between banks when the transacting OFCs do not hold their deposits with the same bank. We show that QE has been associated with an increase in the variance of banks' reserves and OFC deposit positions. This is consistent with QE working through a portfolio rebalancing channel. Our BLC framework suggests that increased variance in deposits, by contributing

[6] Kapetanios, Mumtaz, Stevens, and Theodoridis (2012) used a variety of empirical methods to estimate the effect of that asset price change on the UK economy. Estimates of the impact varied considerably across different model specifications, but averaging them gave a central estimate of a peak boost to real GDP of 1.5% and a peak effect on annual CPI inflation of 1.25 percentage points. An alternative approach is followed by Bridges and Thomas (2012) who use a money supply and demand framework to estimate the impact of QE on asset prices and nominal spending in the UK. Their central case estimate is that QE1 boosted broad money by £122bn, or 8%. They apply this increase to a set of monetarist econometric models that articulate the extent to which asset prices and spending need to adjust to make demand for money consistent with that increased broad money supply. Their preferred, central case estimate is that QE1 may have boosted real GDP by a peak of 2%, with a peak impact on inflation of 1 percentage point.

to deposit flightiness, would diminish any bank lending channel, even if banks' balance sheets had been strong. Weakness of banks' balance sheets is only one reason why QE might not have generated substantial loan supply effects.

Our results are time and location specific and do not prove that there would not be a bank lending channel from QE in future or in other countries. And it is, of course, possible that broader credit channels other than the traditional bank lending channels that we examine here result from the effect of QE on asset prices. However, as the other central banks that expanded their balance sheets for similar reasons over roughly the same period also emphasise asset price channels as the primary transmission mechanism of QE, our analysis gives reasons to be pessimistic about a strong BLC. For example, the Federal Reserve in the US has undertaken many rounds of QE and there is evidence that it had some of its main effects on financial markets. Gagnon, Raskin, Remache, and Sack (2011) studies the financial market impact of Large-Scale Asset Purchases (LSAPs) by the Federal Reserve, suggesting that they let to economically meaningful and long-lasting reductions in longer-term interest rates.[7] If QE gives rise to increased financial market activity, it may be that QE is creating 'flighty' deposits in these other countries and our results caution against expecting a traditional BLC. This lends support to how QE was designed in the UK.

The rest of this paper is structured as follows. Section 2 develops a simple illustrative framework to highlight the type of BLC that we are examining in this paper. This section also highlights the conditions under which such a BLC can be expected to be stronger or weaker. Section 3 describes the data. Section 4 reviews descriptively the periods of asset purchases from 2009 to 2012 and changes in banks' balance sheets over that period. Section 5 covers our empirical specification strategy to test the null hypothesis that changes in OFC deposits led to increased lending, and the results. Section 6 concludes.

2 The Bank Lending Channel (BLC)

In the classic 'money view' of the transmission mechanism, monetary policy operations are likely to result in changes to lending, but such changes are *not* the bank lending channel.[8] Under a textbook money view, open market operations by the central bank increase reserves. Commercial banks, who are required to hold reserves proportional to their transactions deposits, are now holding more reserves than they are required to. To put these excess reserves to use, commercial banks make loans, which create deposits. They continue to create loans and deposits until they have created enough deposits to ensure that the new, higher level of reserves is no longer excessive. Higher transactions deposits mean that banks should hold more bonds and individuals less. If prices do not adjust immediately households will see an increase in real money balances and equilibrium will require a fall in real interest rates. In

[7] Chung, Laforte, Reifschneider, and Williams (2012) find that LSAPs significantly checked the rise in unemployment and prevented the US economy from falling into deflation.

[8] The money view can be represented in a number of different ways including the IS-LM framework.

this set-up the transmission affects the user cost of capital, as interest rates fall to equate money demand and supply.

The BLC is a separate, potentially additional, channel. Sometimes called the 'lending view', the BLC captures the idea that the increase in reserves, which results in an increase in transaction deposits as described above, leads to an additional shift in loan supply. The traditional approaches to the bank lending channel examine how banks' lending supply responds to monetary shocks which affect the level of liabilities held at commercial banks. Kashyap and Stein (1995) ('KS' hereafter), the framework that we follow most closely, present a two period, partial equilibrium model in which monetary policy is assumed to directly control the level of deposits; this means we can think about the effects of monetary policy after the 'money channel' has operated. A bank in this model must make an asset choice between holding liquid securities or earning a spread on lending; and a liability choice in terms of how much external financing they use at an increasing premium. The potential that next period the bank will have less deposits, and that the shortfall will need to be made up via expensive external financing, means banks choose to hold liquid securities as a buffer. Monetary policy, by shifting the level of (cheap) financing, leads to an increase in lending supply.

An alternative view of the BLC is presented by Peek and Rosengren (1995) in a one period, partial equilibrium bank lending model in which a bank may or may not be at its maximum leverage ratio (ratio of balance sheet assets to equity capital). They emphasise that whether or not a bank is capital constrained crucially determines how a bank responds to a monetary-policy-induced expansion of deposits. A capital constrained bank will offset the increase in deposits so as not to increase the size of the balance sheet and violate the maximum leverage ratio; lending supply is unaffected. An unconstrained bank allows total deposits to rise when monetary policy is loosened; the larger balance sheet allows for an expansion of loan supply.

The traditional bank lending channel that we investigate in this paper is part of a wider credit channel of monetary policy. In fact, the BLC, which focuses on changes in the balance sheet of banks, is considered by Gambacorta and Marques-Ibanez (2011) to be part of a narrow credit channel. The broad credit channel, which considers the impact of monetary policy on the balance sheets of firms and households, includes the financial accelerator concept in Bernanke and Gertler (1995). In the financial accelerator framework, monetary policy can affect the balance sheet condition of borrowers, such as the net worth of Public Non-Financial Corporations (PNFCs), which in turn affects the willingness of banks to lend to them.

Linking these two parts of the credit channel is Disyatat (2011). He is unconvinced by the traditional BLC. He argues that banks face an external finance premium which is determined by their balance sheet strength, and this balance sheet strength can be affected by monetary policy. In effect, he extends the financial accelerator effect of Bernanke and Gertler (1995) to banks' own balance sheets, linking their funding costs to their financial health.[9] The key mechanism in his model is that banks' financial strength affects the spread they charge on

[9]Bernanke (2007) discussed that banks and non-bank lenders may be subject to such effects but Disyatat (2011) formalises this view within a model.

loans to firms, and that this is affected by changes in the policy rate.

In this paper we test whether QE affects the supply of loans by commercial banks, i.e. a QE bank lending channel.[10] We are therefore concerned with the narrow bank lending channel rather than seeking to provide exposition of, and empirical evidence on, the broader credit channel. We build on the approach of KS to present a simple model of an individual bank to highlight the traditional BLC and its emphasis of the role of deposits. Before turning to the specifics of the framework, it is worth briefly outlining why we believe that this framework is suitable, and what analysis we add relative to KS.

Our main interest is the presence, or not, of a BLC in response to QE purchases. Given that the KS BLC framework emphasises the role of deposits, and that QE increases deposits, we believe it is a natural starting point for our analysis. However, our contribution is to modify the KS framework to illustrate the role of deposit 'flightiness' in weakening the BLC. This is important because the type of deposits that QE creates in the first instance are OFC deposits which are like more traditional household or PNFC deposits in some regards (such as the fact that they are a cheap funding source), but may be more flighty. Indeed, the portfolio rebalancing channel of QE may increase their flightiness even more. Our framework lays out the conditions for a QE BLC. We show that whether, or not, a significant BLC exists depends on the flightiness of the deposits created.

2.1 A simple bank lending channel framework

In this subsection we develop a bank lending channel (BLC) framework that is very similar to the framework in KS. Rather than explore the quantitative magnitude of the channel (we will explore this empirically in section 5), our objective in presenting the framework is simply to illustrate the nature of the channel which we investigate in this paper, and to show how QE might be expected to give rise to a bank lending channel. The basic narrative that we wish to capture in our simple framework is that QE increases the overall level of OFC deposits in the UK banking system. Though this aggregate level increase is known and persistent, any individual bank, the units that make the decision to extend loans in our framework, face uncertainty in the level and persistence of deposits on their balance sheet. Since we illustrate the type of BLC using a partial equilibrium model, we shall simplify our framework by modelling deposits at each individual bank as a stochastic variable.[11]

[10] As pointed out by Bernanke and Blinder (1988), even if we show the existence of greater bank lending in response to expansionary monetary policy, there are two more broad requirements necessary for such a channel to lead to changes in economic activity. First, it must be that changes in the supply of loans by banks matter for firm decisions.

In other words, for at least some subset of firms securities and bank loans must not be perfect substitutes such that changes in loan supply simply lead to costless switching between financing options by firms. Second, as usual, we require sticky prices for there to be a real effect on economic activity, rather than simply on prices. We do not explore these latter two points as we do not find evidence supportive of the necessary first step of a shift in lending supply.

[11] If, instead, we modelled the level of deposits in each individual bank as a function of the aggregate level of deposits, the framework becomes somewhat more complicated but the main insights of the analysis should not change.

We consider a 3-period ($t \in 0, 1, 2$), partial equilibrium analysis of the effect of monetary (deposit) shocks on the lending decisions of an *individual* commercial bank. The commercial bank chooses how to optimally manage its balance sheet in the first two periods; the last period, $t = 2$, is simply for accounting purposes when loans from earlier periods coming due are repaid. In terms of assets, the bank holds liquid assets (R), which include reserves and liquid securities, and loans (L). On the liabilities side, the bank can finance itself using either deposits (D) or wholesale borrowing (B). To simplify the analysis, the stylised bank balance sheet does not include capital as a liability. The commercial bank's balance sheet is given by:

Assets		Liabilities	
Liquid assets	R	Deposits	D
Illiquid Loans	L	Wholesale borrowing	B

The bank must manage both sides of its balance sheet. Loans are illiquid in the sense they make loans when $t = 0$ but these are not paid back until $t = 2$. Loans pay a return of r in each period, and are repaid when $t = 2$; there is no default and to ensure the simplest possible model we assume that no new lending is initiated in period 1.[12] Liquid assets can be sold at any time but the return on liquid assets is lower than the return on illiquid loans. As in KS, we normalise the return on liquid assets to zero which means that r effectively measures the spread of illiquid loans over liquid assets. We impose no requirement to hold liquid assets; the bank will optimally hold liquid assets to protect against negative payment shocks in period 1 which could necessitate costly wholesale borrowing.

Following KS, we assume for simplicity that deposits, D, are stochastic. We assume that the first round effects of monetary policy ultimately determine the level of deposits in the aggregate banking sector. Under conventional monetary policy, the level of interest rates leads households and firms to optimise their deposit holdings such that lower interest rates would typically lead to a decrease in the amount of deposits; under unconventional policy, asset purchases directly create deposits in the economy. Deposits are remunerated at the policy interest rate (which is normalised to zero). Given that we are interested in the effect of monetary policy on lending supply, we shall simply consider an expansionary monetary shock as higher than average deposits at $t = 0$:

$$D_0 = \bar{D} + \eta_0 \tag{1}$$

where η_0 represents the effects of monetary policy on the deposits at bank we are analysing.[13]

Unlike loans which are determined only in period 0, deposits may be added or withdrawn

[12] The model could be adapted to allow for negative shocks to the value of assets in period 1.

[13] The monetary policy shock is transient but the effects will be longer lasting given the time-series properties of D_1 described in equation (2). Alternatively, one could model a longer lasting monetary policy shock by assuming that monetary policy actually affects the average deposits $\bar{D}$.

in period 1. We assume that deposits in period $t = 1$ are given by:

$$D_1 = \rho D_0 + (1 - \rho)\bar{D} + \epsilon_1 \tag{2}$$

where ρ captures the persistence of deposits, and $\epsilon_1 \sim N(0, \sigma)$ represents a payment shock which either increases or decreases the level of deposits.

In addition to deposits, the bank can fund their activities by borrowing, at a cost, from wholesale funding markets. There are two maturities of borrowing allowed in the wholesale market; B_1 is the amount of 2-period borrowing in period 0, while B_2 is the amount of 1-period borrowing in period 1.[14] As they borrow more, banks are assumed to pay an increasing spread; this financing premium is asymmetric in the sense that excess funds lent on wholesale markets by the bank are assumed to be spread among many other banks and therefore do not yield a premium.[15] We model the cost of wholesale borrowing according to a convex function in each period; we allow the cost functions to potentially differ in each period - $S_0(B_0)$ and $S_1(B_1)$.

The idea that external finance has an increasing marginal cost could be micro-founded by assuming, for example, that there is an asymmetric information problem while, because of deposit insurance, deposits are not subject to such increasing marginal cost. However, this crucial assumption is not innocuous; Romer and Romer (1990) attack it using a Modigiliani-Miller irrelevance argument. They posit that banks can always finance themselves via non-reservable liabilities and so banks can costlessly offset falls in deposits by raising other liabilities. In one sense, the question of whether there is a traditional bank lending channel rests on whether, or not, deposits are a special form of financing for the bank.

2.2 Deposit 'flightiness'

In this section we discuss in more detail the behaviour of deposits and introduce the idea of deposit 'flightiness' which we later use to examine how the bank lending channel is affected by the flightiness of deposits. Deposits are important for two reasons. First, and foremost, this is the channel through which we assume that both conventional monetary policy and quantitative easing affect the bank balance sheet. Second, we will show that the extent of the BLC is affected by the 'flightiness' of deposits created by monetary policy. We argue, and later show empirically, that conventional and unconventional monetary policy may yield different forms of deposit creation.

Given (2), deposits in the bank at $t = 1$ are a random variable drawn from a distribution centred on $\rho D_0 + (1-\rho)\bar{D}$ and with dispersion dictated by the distribution of payment shocks: $D_1 \sim N(\rho D_0 + (1 - \rho)\bar{D}, \sigma)$. We capture the idea of flightiness as the likelihood that the

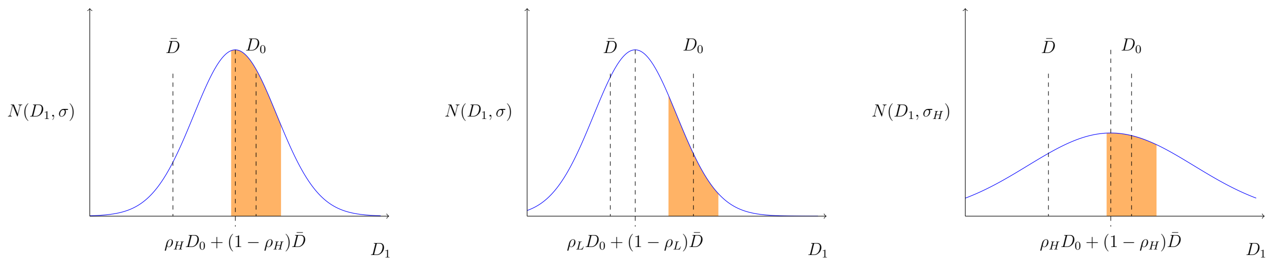
[14] Assuming that all wholesale borrowing was 1-period would affect the quantitative but not the qualitative nature of the results we describe below. A further complication would be to allow banks to choose a mix of 1-period and 2-period borrowing when $t = 0$.

[15] An alternative explanation is that there is a management time cost to arranging ever larger amounts of wholesale funding.

deposits created at $t = 0$ will still be in the bank at $t = 1$. This is affected by both the ρ persistence parameter, and the variance of the payment shocks; lower ρ, and more volatile payment shocks, increase the flightiness of deposits relative to our baseline case. Following a positive shock in period 0 (indicated by $D_0 > \bar{D}$), the extent to which deposits fall back toward $\bar{D}$ will depend partly on the persistence parameter ρ. Moreover, whether payment shocks can offset the tendency for mean-reversion and lead D_1 to be at, or above, D_0 relies on positive payment shocks; the likelihood of which depends on the variance of shocks.

We now illustrate these features using three comparative distributions. In **Figure 1a**, we first assume a high persistence (ρ_H) such that the mean of the D_1 distribution is only slightly below D_0. The orange shaded area indicates the probability that the level of deposits is within a reasonably narrow range around D_0. The expected value of D_1 actually falls within this range.

Figure 1: Distribution of D_1



(a) High Persistence (ρ_H) **(b)** Low Persistence (ρ_L) **(c)** Higher Variance (σ_H)

Notes: Theoretical example drawn to illustrate how persistence of deposits and variance of payment shocks affect the likelihood of having period 1 deposits at a level that is relatively similar to the period 0 level.

Relative to this baseline case, in **Figure 1b** we assume a lower persistence parameter (ρ) while maintaining the same distribution of shocks. The result is that the mean of the distribution is much closer to $\bar{D}$. This has the effect of reducing the probability that deposits are close to their elevated period 0 level.

Finally, in **Figure 1c** we return to the assumed high persistence of deposits (ρ_H) but assume that the payment shocks are more variable. This flattens the mass of probability at the mean, and pushes more mass toward the tails. As in **Figure 1a**, the expected value of deposits still falls close to D_0, but the probability that the realisation of D_1^j is close to D_0 is lower (as indicated by the smaller shaded area).

2.3 Equilibrium

To understand the equilibrium in this framework, we solve the model backwards. Consider a bank which enters period 1 with loans L and liquid assets R, having taken D_0 deposits and borrowed B_0 from wholesale markets. The key concern for the bank in period 1 is the possibility that negative payment shocks require expensive refinancing in wholesale markets. Of course, any declines in deposits can (and will) initially be met out of liquid assets; as in KS, this is the reason that banks do not only hold illiquid loans which pay a premium return.

In (3) we define the amount of external funding needed as F_1. This is determined when D_1 is realised. The bank may have excess funding, $F_1 < 0$, such as when there is a positive payment shock, or enough liquid assets to cover the negative payment shock. Or, if deposits decline so much that the fall in liabilities exceeds the bank's holding of liquid assets, a funding shortfall ($F_1 > 0$). If there is a shortfall, the bank must raise costly extra wholesale funding to finance its back-book of loans.

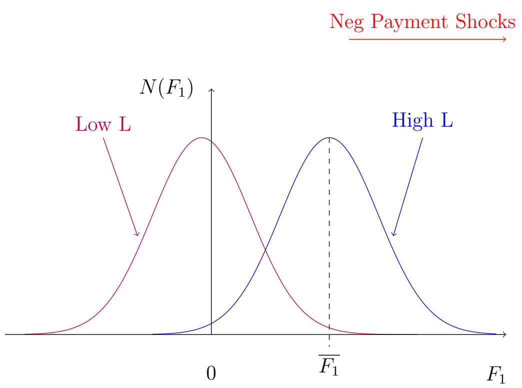
$$F_1 = \underbrace{(D_0 + B_0) - (D_1 + B_0)}_{\text{Fall in liabilities}} - \underbrace{R_0}_{\text{Liquid assets}} = L_0 - D_1 - B_0 \tag{3}$$

Since only D_1 is stochastic once we enter period 1, the distribution of the funding need is related to the payment shocks discussed above:

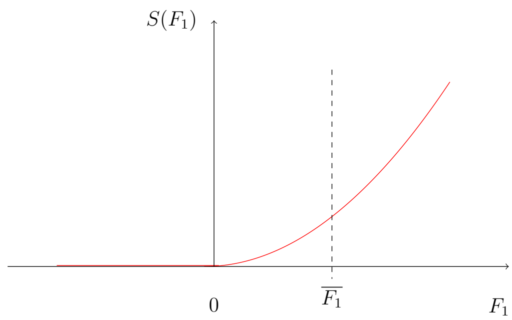
$$F_1 \sim N(L_0 - \rho D_0 - (1-\rho)\bar{D} - B_0, \sigma) \tag{4}$$

where negative (positive) payment shocks increase (reduce) the funding needs and the mean of the distribution is $\overline{F_1} \equiv L_0 - \rho D_0 - (1-\rho)\bar{D} - B_0$.

Figure 2: Funding Shortfalls in Period 1



(a) Distribution of Funding Needs (F_1)



(b) Shortfall funding costs ($S_1(F_1)$)

Notes: The top panel is a theoretical example drawn to illustrate how the choice of period 1 lending affects the distribution of future funding shortfall. The bottom panel illustrates that the cost of any funding shortfall increases according to a convex function.

Figure 2a illustrates the distribution of shortfall costs. If we hold fixed the level of B_0 and the time-series process for deposits, the 'High L' (blue) distribution illustrates the case of a bank which chooses a high amount of lending (L_0) while the 'Low L' (purple) distribution is shifted to the left showing the case of a bank which decides to hold more liquid assets. **Figure**

2b shows the costs, $S_1(F_1)$, associated with financing any level of funding shortfall.[16] As the bank holds higher L_0, the expected level of funding shortfall increases and the probability of having to pay increasing costs of financing also increases.

The funding shortfall is the key consideration in terms of expected costs in period 1 and banks in the model hold liquid assets R_0 to buffer these potential costs. Though the exact expression depends on precise distributional and functional form assumptions, we write the expected, at $t = 0$, period 1 funding costs as:

$$C(F_1) \equiv \mathrm{E}\left[S_1(F_1)\right] \tag{5}$$

with $F_1 \sim N(L_0 - \rho D_0 - (1-\rho)\bar{D} - B_0, \sigma)$ and, as before, $S(.)$ is a convex function.

The period 0 profit maximisation for the bank is:

$$\max_{\{L_0, B_0\}} rL_0 - S_0(B_0) - C(F_1) \tag{6}$$

which we can solve to give the following two first order conditions for period 0 (see appendix for details):

$$r = \frac{\partial S_0(B_0)}{\partial B_0} \tag{7}$$

$$r = \frac{\partial C}{\partial F_1} \tag{8}$$

Period 0 size of balance sheet is chosen such that the marginal cost of balance sheet expansion via wholesale funds equals the marginal benefit in terms of the loan spread (equation (7)). The asset allocation of how many loans to extend is chosen such that the marginal expected shortfall costs equals the marginal lending spread (equation (8)).[17]

2.4 Is there a bank lending channel of QE?

The model admits a BLC. As in KS, consider the effect of conventional monetary policy that leads to an increase in deposits, D_0. Given that (7) pins down the optimal amount of the external funding, the monetary-policy-induced additional liabilities allow the bank to expand its balance sheet in period 0. At least some of this expanded balance sheet is lent out. The extra lending represents the bank lending channel. The extent of extra lending is determined by the bank's desire to hold some liquid assets as a buffer against payment shocks in the second period as captured by (8). This channel is also present in the dynamic general equilibrium model of Bianchi and Bigio (2014) in which banks face a trade-off between costly liquidity risk and the benefits of further lending.

[16] In the figure, we draw $S_1(F_1)$ as a quadratic function though any increasing marginal cost function should deliver similar predictions.

[17] We shall, for simplicity, assume that the lending spread does not adjust. But the same qualitative results hold if we assume that the spread must fall to increase L_0.

If QE creates deposits then we should expect that there will be a traditional BLC as a result. But the key insight from this analysis is that extent to which the bank extends period 0 loans depends on the 'flightiness' of the deposits they receive. In **Figure 3** we consider an initial increase in deposits ($D_0 > \bar{D}$) but examine two scenarios. In both scenarios the initial deposit is considered to be the same, as well as the decision on loans, $\widetilde{L_0}$, and period 0 external funding, $\widetilde{B_0}$. However in one scenario the deposits created are sticky, while in the other the deposits created are flighty:

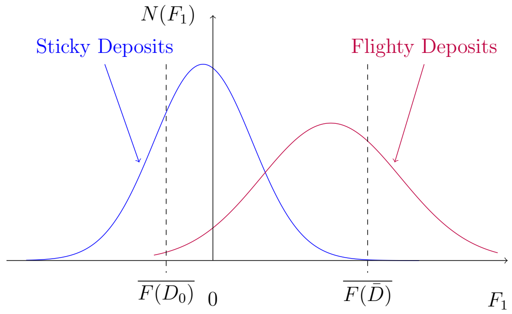
1. Sticky deposits

When the persistence of the deposits, ρ, is high and the variance of payment shocks is relatively low, the distribution of the shortfall given $\widetilde{L_0}$ is centred close to the mean shortfall if deposits remained at exactly their elevated period 0 level ($\overline{FN(D_0)}$). This scenario is represented by the distribution on the left for the period 1 shortfall in **Figure 3** and represents less need to finance an expensive shortfall. Imagine that $\widetilde{L_0}$ is optimal for the bank getting sticky deposits.

2. Flighty deposits

If deposits are flighty (lower ρ and higher σ), the expected value of D_1 is closer to $\bar{D}$ than D_0. In **Figure 3** this is the distribution on the right. This means that if the bank lends out $\widetilde{L_0}$, there is a higher expected shortfall and greater uncertainty. Given the asymmetric, convex costs of external funding, this leads to much higher expected costs of choosing that level of loans; the optimal response, consistent with (8) above, is to lower L_0 below $\widetilde{L_0}$.

Figure 3: Comparison of funding shortfalls for sticky and flighty deposits (with given $\widetilde{L_0}$)



Notes: Theoretical example drawn to illustrate how flighty deposits raise expected costs from a funding shortfall. Both the distributions for funding costs are drawn for the same decision on period 0 lending $\widetilde{L_0}$. Given that there was a positive shock to deposits in period 0, if deposits are more flighty then it is more likely that period 1 is one of lower deposits (as they revert more toward the mean $\bar{D}$). This means expected funding needs, and costs, are higher.

This highlights that the size of the BLC is conditional on the type of deposits that it creates. If the conditions for a traditional bank lending channel are in place, but the monetary policy action creates flighty deposits, then there is no reason to expect banks to expand their loan supply and expose themselves to potentially large loan-book financing costs in the future.

2.5 Does this bank-level argument aggregate well?

The preceding argument boils down to banks recognising that the created deposits are more flighty and they are, therefore, reluctant to expand lending in response. While this is clear at the level of an individual bank, there is a question of how, and under what conditions, this behaviour aggregates to the whole banking system such as to invalidate a possible BLC.

In particular, even if deposits are quickly moving from one individual bank to another, they should stay within the banking system. Individual banks, assuming that they are not myopic, either know that another deposit will appear very suddenly to replace the last transient deposit, or the banks know that other banks will have excess deposits which they will lend on an interbank market. In either case, if QE has created deposits in aggregate then this should lead them to recognise this and lend more.

Actually we don't believe that to be the case. A first reason is that volatility in deposits can still have an effect on how a bank manages its balance sheet. Even though there may be no volatility at the aggregate level, volatility at the individual bank level does still matter if, as in our framework, there is an increasing cost (convex cost function) to substitute funding. Indeed, during periods of stress when there may be greater liquidity hoarding, the convexity of the cost function is likely to increase markedly which would reduce the likelihood that an individual bank would lend out funds if it received flighty deposits.

Second, they may also be uncertain over the level of aggregate deposits after QE because some of the deposits 'leak' out of the system. This is because of a variety of reasons including transactions with non-resident institutions and purchases of bank capital and debt (which effectively remove deposits). Butt, Domit, McLeay, Thomas, and Kirkham (2012) provides some estimates of this effect.

Third, banks might be myopic. Observing 'flighty' deposits, banks might not realise that though subject to volatile inflows and outflows, the aggregate amount will be trapped in the system. While it is the case the Bank of England made clear the decision (and likely impact) of its QE purchases, it is plausible that, especially during a financial crisis, banks may think in partial, rather than general, equilibrium

Our arguments so far rely on flighty deposits. It is therefore crucial that we show empirically below that QE in the UK has mainly led to the creation of OFC deposits as these are the primary sellers of gilts (see Bridges and Thomas (2012) and Butt, Domit, McLeay, Thomas, and Kirkham (2012)), and that these deposits are more flighty than other deposits (figure 8 below). Moreover, with QE operating through a portfolio rebalancing channel, OFC deposits have been subject to increased volatility since the start of QE.

3 Data

We make use of a dataset available to researchers at the Bank, combining balance sheet, regulatory and market operations data for individual banking groups. The various datasets are merged at the bank group level and cover the time period 1990-2013. Markets operational data are available from May 2006, following the Money Market Review (MMR) changes to the Sterling Monetary Framework (SMF). As banks merge, fail, or join the reporting population the sample size varies, and so the panel is unbalanced; the number of banks (N) varies between 20, at the beginning of the sample in 1989, and 39.

We use of a range of variables within this dataset. In particular we are interested in studying the effects of changes in deposits on lending. The balance sheet data includes various deposit series, including the deposits of other financial corporations (OFCs), which are a good fit for the group of institutions who sold gilts during QE. We also make use of sectoral splits of bank lending as our dependent variable of interest. This means we can focus on 'real economy lending' to firms (PNFCs) and households. Unfortunately we cannot distinguish different maturities of lending (either in aggregate or within each class) and therefore we cannot examine whether there was any differential response of shorter and longer-term loans. A key innovation of this dataset is the inclusion of 'true lending flows' data. As discussed in Bridges, Gregory, Nielsen, Pezzini, Radia, and Spaltro (2014), differences in the stock of lending may not reflect economically meaningful lending transactions. Various factors, such as write-offs, exchange rate effects, reporting changes, changes to group structures, reclassifications and changes in the values of securities and repos will affect the stock of lending, and so distort lending flows if calculated as differences. The 'true lending flows' data used in our dataset strip out these effects at the individual bank level. In addition, we use data from the Bank of England's Markets division to study the impact of QE and other operations on reserves. As controls, we make use of regulatory data from the Prudential Regulation Authority (and previously the Financial Services Authority) on banks' capital positions (capital buffer) and liquidity (customer funding gap).

As in much of the bank lending channel literature we use changes in nominal lending and deposits in our estimation. This approach has a few advantages. First, the results are easily economically interpretable as regression estimates give a pound per pound marginal effect of changes in OFC deposit flows. Second, the IV estimation approach used in section 5 requires both gilts and OFC deposits to be in comparable units, and use of differences in the diff-in-diff estimation means that the results are comparable. And third, this approach allows us to control effectively for any deleveraging effects over the QE period.

The balance sheet data benefit from being validated by the Bank of England's Statistics and Regulatory Data Division, when they are submitted by reporting institutions. This process aims to reduce the probability of erroneous reporting affecting our datasets and it also helps ensure that we understand the drivers of large movements within the data.[18] The data are also adjusted for mergers and acquisitions. At the time of any M&A activity we create a new institution, and exclude an appropriate number of months, of data to remove balance sheet distortions that can occur during M&A. This adds to the unbalanced nature of the panel, but, following Bridges, Gregory, Nielsen, Pezzini, Radia, and Spaltro (2014) we think this is preferable to creating synthetic banking groups, as it is not clear that the different competitor banks with different balance sheet strategies can be treated as one bank prior to their merger.

4 The effect of QE on banks' balance sheets

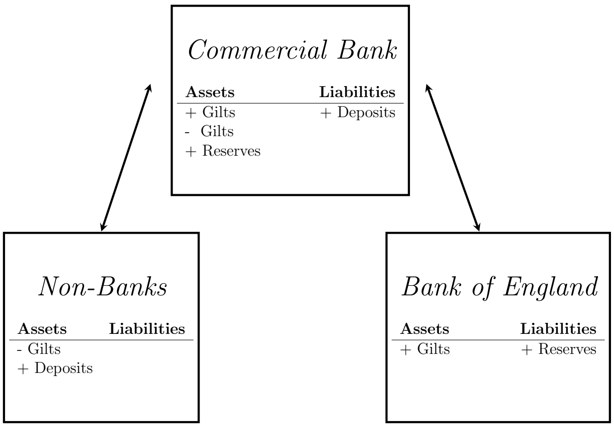
In this section we discuss the impact of QE on banks' balance sheets at both the aggregate level and also across banks. We find evidence that reserves increased for banks within the same month that they participated in auctions (on behalf of OFCs), with around half of the reserves sticking. Changes in OFC deposits are also well correlated with participation in QE operations. But reserves did not lie dormant on banks' balance sheets, we find evidence that the variability of banks' reserve positions actually increased, despite the increased level of reserves in the system. We find a similar pattern of increased variability for OFC deposits, and changes in OFC deposits are correlated with changes in reserves at the individual bank level. Taken together this evidence is consistent with the evidence for a portfolio rebalancing channel of QE. This section reviews these findings in more detail and describes how these motivate the estimation and identification strategies pursued in section 5.

Figure 4 shows schematically how QE operated in the UK and how it directly affected each participant's balance sheet. Bank of England QE purchases are made from the non-bank sector but *via* commercial banks (either retail or investment banks). The decision to sell in the QE auctions is taken by the non-bank sector, but the deposits are created at the commericial bank through which the sale is executed. In the first instance, QE increases reduced the amount of gilts in circulation, increased the amount of reserves in the banking system and increased the deposit holdings of OFCs with banks.

Over time QE may also lead to the creation of household and PNFC deposits, but the proximate and largest impact on banks' liabilities is to OFC deposits, as discussed in Bridges and Thomas (2012) and Butt, Domit, McLeay, Thomas, and Kirkham (2012). Perhaps surprisingly, however, the reserves impact of QE is not equal to the amount of purchases because of the impact of other factors. During QE1, the Bank made £200bn of purchases, but reserves

[18]It should be noted though that data definitions used within the panel differ somewhat to those used in published monetary statistics. In particular, our series for other financial corporations (OFC) deposits is closest to the OFC money series, rather than non-intermediate OFC money. The latter includes adjustments to exclude inter-bank payments that are sometimes reported as liabilities against OFCs due to payments made through clearing houses, for example. Since these payments can sometimes be large, we run robustness analysis of all our regressions on cleaned versions of the data in which we remove all observations where OFC deposits change by +/-100% and also +/-50%. We apply a similar cleaning routine to lending data to check that large observations do not unduly affect our results.

Figure 4: Schematic of the balance sheet effects of QE in the UK



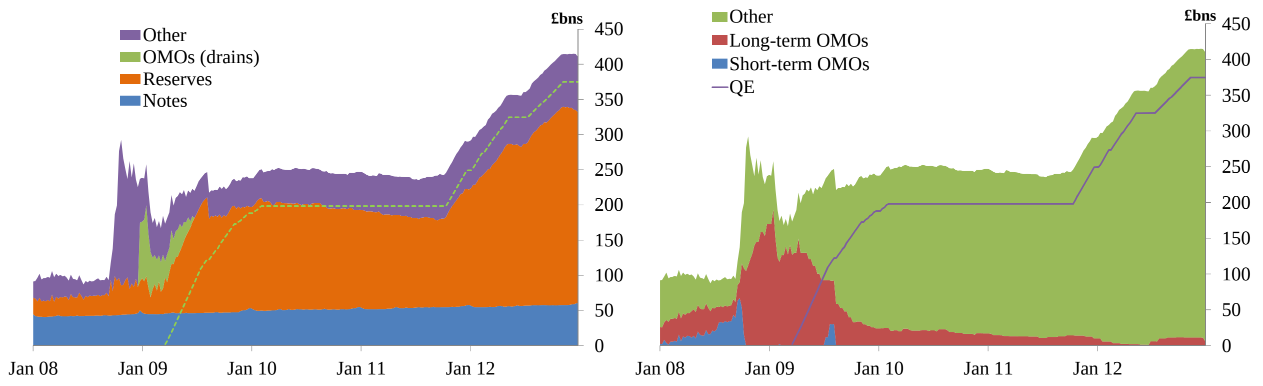
Notes: This schematic shows how Bank of England QE purchases are made from the non-bank sector but via financial institions who serve as gilt-edged market makers. The decision to sell in the QE auctions is taken by the non-bank sector, but is carried out by the commercial bank, which sees an increase, and then subsequent decrease, in its gilts holdings. As a result of the gilt transaction, the commerical bank through which the sale is executed gains central bank reserves as well as a deposit liability (the asset of the non-bank sector).

increased by only £130bn (**Figure 5a**). As only the Bank can create or destroy reserves this difference is accounted for by other changes to the Bank's balance sheet. A key development over this period was a reduction in the amount outstanding in open market operations (OMOs) as can be seen in **Figure 5b**. This destroyed reserves, resulting in a level of reserves lower than the value of asset purchases. The Bank conducted a second round of asset purchases between October 2011 and May 2012. The Bank purchased £125bn of gilts, and reserves increased by £104bn. Again the amount of purchases was less than the increase in reserves, reflecting factors such as reduced use of the Bank's long-term repo operations by banks over the period. During the final phase of asset purchases the link between asset purchases and reserves creation is closer, as there were few other factors affecting the Bank's balance sheet.

Our contribution is to add to this analysis by studying the effect of QE on individual banks balance sheets using the panel dimension of our dataset. There has been a popular tendency to believe that reserves created by QE sit on banks' balance sheets rather than being lent out. This characterisation misunderstands the role of reserves in the UK banking system in two ways. First, reserves are highly unlikely to have sat statically on banks' balance sheets. Reserves are the ultimate means of settlement, such that when payments are made by banks' customers, absent any offsetting payments, they are settled in reserves. Second, such a characterisation seems to assume there is a normal tight link between reserves, money and the quantity of lending via a money multiplier. But the UK sterling monetary framework has no such feature. This can be seen very clearly by examining the money reserves multiplier in the UK in **Figure 6**.[19]

[19] By contrast, the money multiplier in the US was relatively stable prior to October 2008 largely due to the system of reserve requirements.

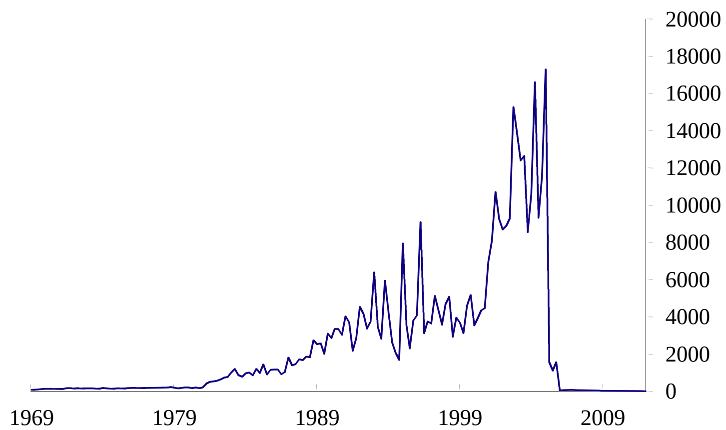
Figure 5: The Bank of England's balance sheet



(a) Liabilities **(b)** Assets

Notes: Bank of England balance sheet data.

Figure 6: Bank of England money multiplier



Notes: Multiplier is calculated as M4/reserves; M4 and M4ex are spliced. Data Source: Bank of England

Table 1: Factors explaining changes in reserves

	Reserves		OFC deposits	
APF gilt sales$_t$	0.304**	0.302**	0.236***	0.235**
	(0.129)	(0.115)	(0.060)	(0.078)
OMO$_{it}$	0.568***	0.530*		
	(0.185)	(0.251)		
Agg APF giltsales$_t$	0.0291	-		
	(0.0194)	-		
Constant	-171.2		-567.775***	
	(172.6)		(52.704)	
Bank fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	No	Yes	No	Yes
Observations	454	454	426	426
Banks	16	16	13	13
F	4.257	3.489	15.296	9.038

Notes: Standard errors clustered at the bank level are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Estimation period: March 2009 to October 2012

We estimate the following equation to investigate whether reserves in bank i had increased at the end of the month in which it conducted APF gilt sales:

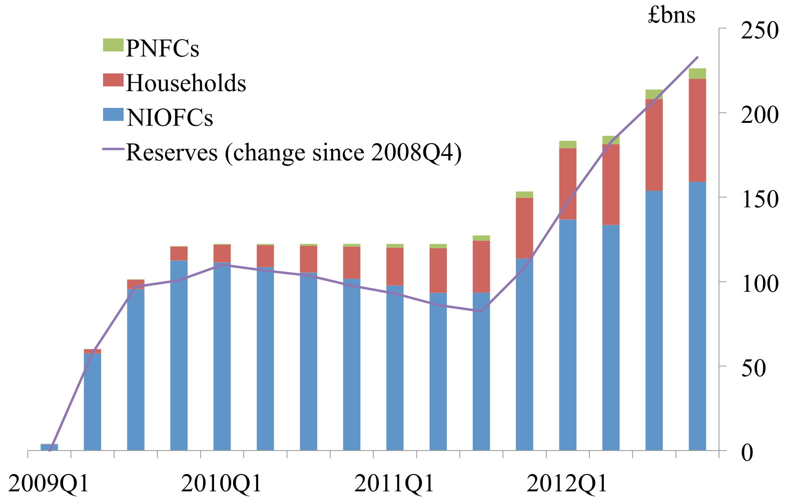
$$\Delta R_{i,t} = \beta_1 GS_{i,t} + \beta_2 APF_t + \beta_3 OMO_{i,t} + u_i + \epsilon_{i,t} \tag{9}$$

where $\Delta R_{i,t}$ is the change in the level of reserves at bank i at time t, $GS_{i,t}$ are APF gilt sales conducted through bank i at time t on behalf of their customers. We control for the aggregate level of gilt sales during a given month (APF_t). We also control for open market operations carried out by the Bank of England to supply or drain reserves. These operations account for important changes to banks' reserves over the period and we use information on the bank i specific operations in each month ($OMO_{i,t}$).

The first two columns of **Table 1** shows the results from estimating (9). Both the OMO flows and APF gilt sales coefficients are positive and statistically significant across QE periods. It therefore appears that reserves exhibited some stickiness, but that only a portion of reserves created by QE remained within a given bank by the end of the same month.

We also find a link between participation in QE operations and contemporaneous changes in deposits from OFCs. Accounting for the monetary impact of QE can be complicated when using aggregate data. A number of factors, that could be associated with QE, could reduce the monetary impact; and money may still appear weak, despite a substantial boost from policy, if the counterfactual path of money was very weak. This is particularly relevant during a period of deleveraging by banks. Bridges and Thomas (2012) and Butt, Domit, McLeay, Thomas, and Kirkham (2012) estimate the impact of QE on money and find that

Figure 7: Monetary impact of QE



Notes: Bank of England, Bridges and Thomas (2012) and Bank calculations. The aggregate impact reflects the estimates of the impact of QE net of the indirect leakages.

there is a boost to broad money of around 60% of the value of QE, and that much of this is concentrated in OFC deposits, at least initially, as they are the main sellers of gilts (**Figure 7**). Because we can introduce time and fixed effects to control for both institutional trends, and system-wide trends, the panel dimension of our data allows us to control for the effects of bank deleveraging. The last 2 columns of **Table 1** present the results of a regression of OFC deposits on APF gilt sales in the spirit of equation (9) but we drop the two reserves-specific controls. The coefficient on gilt sales indicates that there is a positive and significant correlation, with the results robust to the inclusion of time effects.[20] This tells us that in the first instance APF gilt sales led to increases in deposits at banks that participated in auctions. This finding is used to motivate an identification strategy in the following section.

A number of indicators point towards increased churn in OFC deposits and reserves during QE. Using daily data on reserve holdings we calculate a Herfindahl measure of concentration of reserve holdings across banks on a given day. A higher Herfindahl indicates that reserve holdings are concentrated within a smaller number of banks. During the QE period there was a small increase reserves concentration on average – the average value of the Herfindahl increased from 0.08 (May 2006 to February 2009) to 0.1 (March 2009 to July 2013). But there was especially an increase in the volatility of the Herfindahl. The standard deviation rose from 0.018 to 0.028, and the interquartile range (of the daily Herfindahl measures) almost doubles from 0.2 to 0.38. These data suggest that reserve holdings, rather than sitting idly within individual banks, were actually increasingly moving through the system such that from day to day, the holdings of reserves from bank to bank varied a great deal after QE had begun.

A number of indicators point towards increased churn in OFC deposits and reserves during QE. Using daily data on reserve holdings we calculate a Herfindahl measure of concentration

[20]The results are also robust to the inclusion of various controls, as shown in section 5.2.

of reserve holdings across banks on a given day. A higher Herfindahl indicates that reserve holdings are concentrated within a smaller number of banks. During the QE period there was a small increase in reserves concentration on average – the average value of the Herfindahl increased from 0.08 (May 2006 to February 2009) to 0.11 (March 2009 to October 2012). More notable was an increase in the volatility of the Herfindahl. The standard deviation rose from 0.018 to 0.027, and the interquartile range (of the daily Herfindahl measures) increased from 0.2 to 0.32. These data suggest that reserve holdings, rather than sitting idly within individual banks, were actually increasingly moving through the system such that, from day to day, the holdings of reserves from bank to bank varied a great deal after QE had begun.

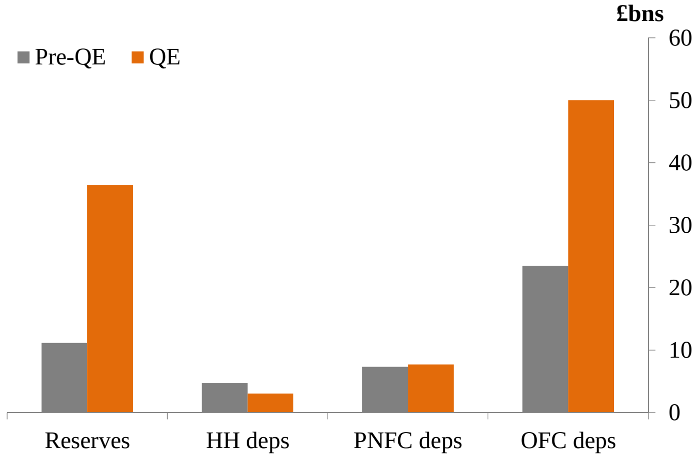
To further investigate evidence of increased churn, we develop a churn statistic which we can calculate for any time series variable X which is available across individual banks. To calculate this statistic, we sum the absolute value of changes in the variable of interest, X, across all i banks and subtract the sum changes in X across banks. Specifically, we calculate a gross versus net flows gap measure, GNF, for variable X at time t as:

$$GNF_t^X = \sum_i |\Delta X_{it}| - \sum_i \Delta X_{it} \tag{10}$$

We use this measure below to examine the behaviour of both banks' reserve holdings and different types of deposits on their balance sheets. The advantage of this measure is that it captures the variability of banks' balance sheet positions, controlling for aggregate changes in the whole banking system. This is important when we examine variability of, for example, reserves so that we do not exaggerate the change in the churn with QE by not taking account of the fact that total reserves increased a great deal with the implementation of QE. The second term in our statistic captures the aggregate change in reserves across banks; if there are no changes in aggregate reserves, and reserves are simply moving between the banks, this second term is equal to zero. The first term sums the absolute changes in reserves across banks and measures the gross flows in reserves across banks' balance sheets. In the absence of changes in aggregate reserves, this is exactly a measure of the amount to churn in reserves in the banking system. When we subtract the aggregate change from this measure of churn, we get a strictly non-negative number that represents the extent to which banks changed their reserve positions during the reference period after some correction for the aggregate changes in reserves. An equivalent argument applies for deposit changes.

Figure 8 shows this statistic, calculated at a monthly frequency, for reserves (bars at the far left) and for various deposit series. The main point to note is that there is a marked pickup in churn of reserves during the QE periods, suggesting that there was indeed an increase in the variability of reserves during this period, and we find a similar pattern of increased variability for OFC deposits. In our framework, this increase in OFC deposit churn could be interpreted as a reduction in the persistence parameter (ρ) in our framework. The other point to notice is that during the pre-QE period the variability of OFC deposits was higher than that for

Figure 8: Gross/net flow gaps



Notes: Mean of gross-net flows gap (calculated monthly). Pre-QE defined as five years prior to first QE purchase in March 2009. Source: Bank of England.

households and PNFCs which could be interpreted as high variance of payment shocks (ϵ) in our framework. While there are likely to be other factors that affected reserves activity, this chart shows that OFC deposits are likely to have been an important factor. To check this we also run a regression of changes in reserves on different liability series. That regression returns a positive and significant coefficient for changes in OFC deposits. The increased level and variance of OFC deposits we have documented is consistent with the portfolio rebalancing channel of QE.

In our model, the fact that QE created reserves and boosted money and so provided banks with a cheap funding source, suggests that there is the potential for a bank lending channel. But we have also shown that while participation in APF gilt operations is correlated with changes in deposits and reserves, the coefficients are less than one. Moreover, there appears to have been an increase in the variance of banks' reserves and OFC deposit positions. The increased variance in OFC deposit and reserve positions is consistent with the portfolio rebalance channel of QE but, at least according to our model, may diminish any bank lending channel.[21] In the next section we draw together our theoretical framework and what we have uncovered from the data to test the hypothesis that increases in OFC deposits leads to increased lending.

[21] In fact, we examine this issue empirically using data between February 1989 and February 2009 (the pre-QE period). We find, consistent with our BLC framework, that banks who had more variable realised OFC deposit flows are less likely to increase lending for a given change in OFC deposits. This correlation is not causal and there are no obvious ways to address a number of endogeneity issues. We therefore do not report the full regression results here but rather note that the empirical evidence is not inconsistent with our BLC framework.

5 Analysis and results

We want to know whether variation in deposits *causes* variation in lending. The key challenge for empirical work on the BLC is isolating changes in supply from changes in demand. A simple regression of loan growth on total deposits cannot be interpreted causally because deposits do not, typically, vary exogenously. Instead, the regression will capture both the effect of deposits on loans (the BLC) as well as the effect of loans on deposits (as discussed by McLeay, Radia, and Thomas (2014)). There are two aspects to the reverse-causation concern that arise in a general regression of loan growth on deposit growth. First, extending loans (assets for the bank) is matched by the creation of deposits (a liability for the bank). Second, when a bank wants to extend loans, it might finance these by seeking new (sticky) deposits as funding; the deposit variation in this case is demand-induced.

Given the different concepts of the bank lending channel, there are also different approaches to identifying the bank lending channel empirically. Most are based on the idea that the BLC will have different effects on banks with different characteristics. This helps to identify the effects of shifts in the loan supply as opposed to changes in deposits due to demand from banks wishing to supply loans through a difference-in-differences approach. Kashyap and Stein (1995) rely on variation in the cost of external finance between banks. They argue that larger banks, with stronger capital positions and greater liquidity, have lower marginal costs of external finance.[22] Essentially, the identification relies on the relationship between loans and deposits in terms of the demand-induced effect being similar across the two groups of banks, so that any differential behaviour of large banks captures the BLC effect. Although Disyatat (2011) proposes a different model of bank lending channel, the identification is similar to KS. That is, he argues that 'bigger, more liquid and better capitalised banks may be less affected by monetary policy because these characteristics are associated with stronger balance sheets, a smaller degree of information asymmetries and hence less variability in their external finance premium'. Peek and Rosengren (1995) worry that the large-small identification strategy might pick up heterogeneous demand facing banks of different sizes and, given the predictions of their model, they focus on distinguishing the effects on different banks which are either capital constrained (identified by a formal regulatory action) or not.

[22]Specifically, they assume that a bank borrowing W_i pays $\frac{\alpha_s (W_i)^2}{2}$ such that the marginal cost increases linearly with W_i but at rate α_s. Large banks are assumed to have lower α_s than small banks such that they have cheaper external funding.

5.1 Specification and strategy

Ignoring dynamics which we introduce later,[23] we are interested in estimating a lending equation such as:

$$\Delta L_{i,t} = \gamma_1 \Delta L_{i,t-1} + \beta_1 \Delta D_{i,t} + \phi_1 X_{i,t} + \alpha_i + \tau_t + \epsilon_{i,t} \tag{12}$$

where the dependent variable $\Delta L_{i,t}$ is the change in lending to households and PNFCs (all units are £ millions); $\Delta D_{i,t}$ is the change in OFC deposits; $X_{i,t}$ are institution specific time-varying controls (described below); and α_i and τ_t are individual and time fixed effects, respectively. We include bank fixed effects, because while we can include balance sheet controls in our regressions, we think there are likely to be bank specific effects which we cannot directly control for. We run all of our regressions with and without time effects (τ_t).[24] In other specifications we include a more comprehensive lag structure including lagged dependent variables and lagged measures of deposits.

The $X_{i,t}$ controls we have used include the lagged value of the overall credit stock, the contemporaneous customer funding gap and holdings of liquid assets. We also follow Joyce and Spaltro (2014) and attempt to control for system wide, or demand driven, changes in lending on individual banks at time t. To do this, we create a variable that varies by bank and month called sector demand. The variable is calculated from the sectoral components of lending (secured (S), unsecured (U) and PNFC (P)), as follows:

$$\text{Sector demand}_{i,t} = \Delta L^S_{-i,t}\left(\frac{L^S_{i,t-1}}{L_{i,t-1}}\right) + \Delta L^U_{-i,t}\left(\frac{L^U_{i,t-1}}{L_{i,t-1}}\right) + \Delta L^P_{-i,t}\left(\frac{L^P_{i,t-1}}{L_{i,t-1}}\right) \tag{13}$$

where $\Delta L^x_{-i,t}$ is the total change in lending to sector x by all banks excluding bank i, $L^x_{i,t}$ is lending by bank i to sector x and $L_{i,t}$ is total lending by bank i. Therefore, the sectoral demand variable is a weighted-sum of total changes by all other banks to each sector, where the weights used are the importance of that sector to bank i measured by the lagged share of sector x loans in their total lending across sectors.

Our choice of dependent and independent variables deals with the first reverse causation concern we raised. Since we examine the effect on secured and unsecured lending to households and PNFCs (our dependent variable), it is unlikely that such lending creates (reverse causes) large OFC deposits contemporaneously as the independent variable.[25] While this helps to

[23]The dynamic version of this equation is:

$$\Delta L_{i,t} = \sum_{s=1}^{S} \gamma_s \Delta L_{i,t-s} + \sum_{s=0}^{S} \beta_s \Delta D_{i,t-s} + \phi_1 X_{i,t} + \alpha_i + \tau_t + \epsilon_{i,t} \tag{11}$$

[24]In some specifications we time de-mean all variables rather than include time dummies.

[25]For example, the creation of new household personal loan would, initially at least, create household deposits. These would likely to move to other households or corporate accounts after the money is used to purchase something or to pay bills.

alleviate the concern that higher lending creates more deposits, it does not deal with the concern that banks wishing to increase lending raise OFC deposits as a marginal funding source. This demand-induced reverse causation is harder to deal with.

We attempt to address this second endogeneity problem using an instrumental variable approach:[26] using our bank-level panel data, we instrument changes in OFC deposits at bank i using sales of gilts to the Asset Purchase Facility (APF) carried out by the bank on behalf of its customers. While the former may be endogenous to the lending plans of the bank, the latter are determined by customer decisions which are exogenous to lending but are correlated with changes in OFC funding. In the following sections, we discuss this identification strategy in more detail along with details of the estimated equations, results and robustness checks.

5.2 Instrumental Variable (IV) model: using APF Gilt sales as an instrument

As we showed in table 1, there is a positive and significant correlation between APF gilt sales and changes in OFC deposits with banks. Moreover, banks that carried out sales of gilts to the APF still had a portion of deposits at the end of that month. This offers a potential IV estimation strategy which addresses the concernt that banks wishing to extend loans might finance these by seeking new deposits as funding. The key to this identification is the fact that the decision to execute an APF transactions was made by a non-bank but executed through gilt-edged market makers, who are, on the whole, banks. Because such market makers are likely to be obliged to offer transactions on behalf of their clients (exisiting or new), it seems likely that APF gilt sales by banks are exogenous to banks' lending and funding decisions: the decision to sell gilts is taken by the OFC.

Nine of the 25 banks in our sample during the QE period are gilt participants and so we now proceed to instrument for the exogenous variation in OFC deposits using APF gilt operations at each bank in each period. This will purge the OFC deposits variable of those endogenous movements we have been concerned about until now. This provides our main BLC hypothesis:

Hypothesis 1 *Increases in OFC deposits, directly connected to APF gilt sales, lead to an increase in lending by the bank that carries out the sale via a bank lending channel.*

There are two concerns about instrument validity that may be apparent at this stage which we shall address before we turn to the results. The first concern is that APF transactions may be correlated with banks lending intentions. In particular, market makers wishing to extend loans may offer to conduct APF transactions at more favourable prices making APF

[26]Additionally, in the appendix, we use an alternative identification approach. In the spirit of the original identification approaches used in the literature, we exploit differences in banks' exposures to large changes in OFC deposits caused by QE. We argue that some banks have the expertise and technological infrastructure that make them natural magnets for newly-created OFC deposits and examine whether these banks increased lending more than other banks in the same month.

transactions as liable to endogeneity as uninstrumented OFC deposits. We think this is unlikely. The prices at which APF transactions were ultimately settled was determined by an auction process and so not subject to the control of the market maker.

Moreover anecdotal evidence from market participants revealed two primary ways in which such APF transactions were executed, niether of which is likely to be influential in terms of the decisions on the lending side of the banking operation. First the OFC would directly make an offer, via a bank, to the APF tender. Such transactions involved no balance sheet risk for the executing bank and therefore the bank typically carried out the transaction for no commission in order to build, or maintain, relationships with OFC clients. As such, there was no price competition to carry out such transactions. Second, market makers could agree to purchase gilts that OFCs wish to sell and sell them at a later date in an APF auction. As this approach involves balance sheet risk, which the market maker would expect to be compensated for, it may have given rise to a small trading profit. Nonetheless, it seems highly unlikely that such profit, and the decision to take on the balance sheet risk, was determined by a Treasury function of the bank trying to raise funding for new lending. Overall, we are unconcerned that the size of APF transactions is endogenously related to desired lending.

The second potential concern about instrument validity is that the instrument is not very strong. It is plausible that, shortly after the operations, OFCs deposited large amounts of deposits with banks that were not the sellers of their gilts, and this point is particularly relevant given the increase in the variance of OFC deposit positions seen during QE, but this will come down to the strength of instrument. Therefore, we begin by examining the validity of our instruments; specifically, good instruments should be correlated with the endogenous variable, not be correlated with the error term in (12), and should have sufficient strength. In order to illustrate the results clearly, we start with the most parsimonious representation before exploring the specifications such as (11). **Table 2** presents the first stage regressions for the specifications where there is only one endogenous regressor (i.e. no lags of OFC deposit flows).[27] The estimation covers the QE period from March 2009 to the end of asset purchases in October 2012, and includes the periods between when purchases were not made. Two different specifications are shown: the first includes contemporaneous correlation with gilt sales and some institution specific controls while the second specification includes lags of lending (the simplest specification with just contemporaneous correlations is shown in the preceding section). For each specification we present the results with and without time fixed effects. We test the data for serial correlation, using the test set out by Wooldridge (2007), and find evidence for serial correlation in the error terms. We therefore use heteroskedastic and serial autocorrelation robust standard errors.

Table 2 shows that the coefficients on APF gilt sales are both positive and significant in all specifications (at either the 1% or 5% level) which suggests that APF gilt flows may be appropriate instruments. In the simple case here with only one endogenous regressor,

[27] In all these regressions we omit the contemporaneous customer funding gap and holdings of liquid assets as X_{it} controls as they were insiginificant when included. Their inclusion, however, does not alter the results.

Table 2: First stage IV regressions

	$\Delta D_{i,t}$			
	(1)	(2)	(3)	(4)
APF gilt sales$_{i,t}$	0.338***	0.223***	0.326***	0.287**
	(0.062)	(0.066)	(0.070)	(0.093)
$\Delta L_{i,t-1}$			-0.478	-0.236
			(1.052)	(1.073)
$\Delta L_{i,t-2}$			1.467	1.709
			(1.094)	(0.990)
Sector demand$_{i,t}$	2.266**	-0.444	2.331*	0.711
	(0.979)	(1.433)	(1.187)	(1.288)
Credit stock$_{i,t-1}$	0.053	-0.005	0.031	-0.005
	(0.073)	(0.019)	(0.067)	(0.017)
Bank fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	No	Yes	No	Yes
Observations	424	419	423	414
Banks	12	12	12	12
F	22.4	4.1	15.7	6.9

Notes: Robust standard errors are reported in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Estimation period: March 2009 to October 2012.

the strength of the instrument can be assessed by the first stage regression F-statistic.[28] Specifications 1 and 2 suggest the instrument has sufficient strength when time fixed effects are not included (Columns (1) and (3)); the F-statistic is 28 or 23 and clearly above the suggested minimum value of 10. When time effects are also included (Column (2) and (4)), the F statistic falls to below 10. This suggests that the strength of the instrument is diminished in this case.[29] Instrument strength is therefore greater in the specifications without time effects but using variables to control for changes in system-wide credit provision. However, we shall nonetheless report the results including time-effects while noting that the strength of the instrument is weaker in this case. Columns (3) and (4) show the results for regressions with two lags of lending. Adding further lags has little impact on the joint significance of the estimation and leads to a less parsimonious model.

Table 3 presents the results of the second stage regressions. The main coefficient of interest is the contemporaneous change in OFC deposits. In both specifications, the coefficient for OFC deposits is close to, and insignificantly different from, zero. In fact, the point estimates are negative rather than positive as would be expected if there was a traditional BLC.

The above specifications only imply a possible contemporaneous relationship between OFC deposits and lending. But it might be reasonable to assume that changes in OFC deposits

[28] With one endogenous regressor and one instrument, the model is just identified which means that we cannot test the correlation of the instrument with the error term from the lending equation.

[29] The time fixed effects are also likely to cause problems with the calculation of robust standard errors (Wooldridge (2007)).

Table 3: Lending IV regressions (Second Stage)

	$\Delta L_{i,t}$			
	(1)	(2)	(3)	(4)
ΔOFC Deposit$_{i,t}$	-0.171	-0.335	-0.175	-0.254
	(0.153)	(0.425)	(0.158)	(0.260)
$\Delta L_{i,t-1}$			-0.071	-0.001
			(0.157)	(0.181)
$\Delta L_{i,t-2}$			0.336	0.489
			(0.256)	(0.476)
Sector demand$_{i,t}$	0.371	-1.247*	0.411	-0.840
	(0.395)	(0.669)	(0.418)	(0.526)
Credit stock$_{i,t-1}$	0.036*	-0.002	0.030	-0.002
	(0.019)	(0.006)	(0.021)	(0.005)
Bank fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	No	Yes	No	Yes
Observations	424	419	423	414
Banks	12	12	12	12
F	1.465	1.333	0.955	1.129

Notes: Standard errors are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Estimation period: March 2009 to October 2012.

affect changes in lending only with a lag. We proceed using a local projections approach, in the spirit of Jorda (2005). We maintain $\Delta D_{i,t}$ in the main regression **(11)** and instrument with $\Delta G_{i,t}$, but in each regression we use different leads of $\Delta L_{i,t}$. This allows us to test the effect of $\Delta D_{i,t}$ on lending at different horizons. We are therefore investigating the effects of an instrumented endogenous regressor on the leads of a second stage dependent variable. We estimate, for different values of h, the projection equation version of equation (12):

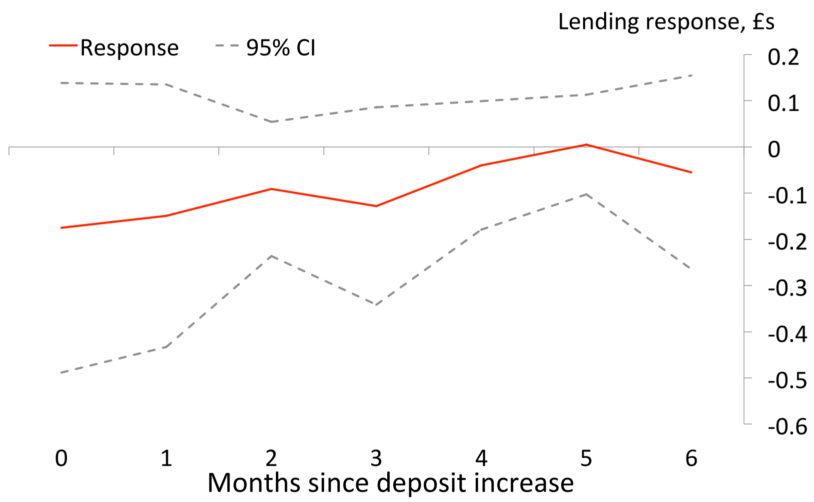
$$\Delta L_{i,t+h} = \gamma_1 \Delta L_{i,t-1} + \beta_1 \Delta D_{i,t} + \phi_1 X_{i,t} + \alpha_i + \tau_t + \epsilon_{i,t} \tag{14}$$

Figure 9 represents the results as a form of impulse response and show that the response is close to zero at all time-horizons and the 95% confidence interval covers zero at all points. **Table 4** presents the estimation results from these equations.[30]

The first stage regression results (presented in **Table 2**), and the baseline IV results (**Table 3**) are robust to various checks. The results are robust to inclusion of controls for other bank characteristics such as customer funding gaps, liquidity positions and capital. We estimate the equations with random and fixed effects. The baseline sample includes banks

[30] We also estimate a lending equation as in (11), which includes lags of OFC deposit flows. The results also return coefficients close to zero for all lags of OFC deposits, and none of the lags are significant. In this case, we should acknowledge that the instrument strength is somewhat reduced. With more than one endogenous regressor, we cannot use the F-statistic but rather we must use the Kleibergen-Paap statistic, compared to critical values computed by Stock and Yogo (2002), to test instrument strength. The problem is really driven by the fact that there is only statistically significant correlation between OFC deposits and gilt operations contemporaneously. This is consistent with the flightiness of the OFC deposits created by APF purchases.

Figure 9: 'Impulse response' for an instrumented 1 unit change in OFC deposits



Notes: This figure plots, for ease of visualisation, the estimated effect of an increase in OFC deposits at time 0 on lending to households and PNFCs at different horizons. The plot is based on the results reported in Table 4.

Table 4: Second stage estimation, with leads of the dependent variable

	$\Delta L_{i,t}$	$\Delta L_{i,t+1}$	$\Delta L_{i,t+2}$	$\Delta L_{i,t+3}$	$\Delta L_{i,t+4}$	$\Delta L_{i,t+5}$	$\Delta L_{i,t+6}$
ΔOFC Deposit$_{i,t}$	-0.175	-0.153	-0.100	-0.132	-0.045	-0.004	-0.059
	(0.158)	(0.147)	(0.078)	(0.109)	(0.071)	(0.054)	(0.107)
$\Delta L_{i,t-1}$	-0.071	0.032	0.170	0.058	0.029	-0.001	-0.063
	(0.157)	(0.222)	(0.150)	(0.111)	(0.073)	(0.075)	(0.123)
$\Delta L_{i,t-2}$	0.336	0.003	0.091	0.314*	0.106	0.104	0.113
	(0.256)	(0.165)	(0.158)	(0.179)	(0.086)	(0.082)	(0.112)
Sector demand$_{i,t}$	0.411	0.031	-0.065	0.288	-0.200	-0.149	0.181
	(0.418)	(0.328)	(0.250)	(0.321)	(0.190)	(0.169)	(0.231)
Credit stock$_{i,t-1}$	0.030	0.029	0.019	0.013	0.012	0.009	0.016
	(0.021)	(0.022)	(0.016)	(0.020)	(0.013)	(0.012)	(0.017)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	423	423	422	421	421	421	409
Banks	12	12	12	12	12	12	12
F	0.955	1.488	1.534	0.878	2.482	1.938	0.514

Notes: Robust standard errors are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Estimation period: March 2009 to October 2012. The headings for each column represent leads of the dependent variable, such that in the last column we are investigating the effect of OFC deposit flows on credit flows six months ahead.

who are eligible to take part in APF gilt operations but the results are robust to extending this to using all institutions. Similarly the results remain little changed when the very largest movements in lending and OFC deposits are removed.

As mentioned in footnote 26 above, in the appendix we also report a difference-in-differences approach to identify the 'treatment effect' of QE. We separate the banks into two groups based on pre-QE characteristics — those with a large share of funding from OFCs, and those without. This allowed us to test whether QE boosted OFC deposits in aggregate leading banks with capacity to absorb OFC deposits to increase lending via a bank lending channel. We find no evidence of this over the period between the start of QE in March 2009, and June 2013.

6 Conclusion

This paper has tested whether QE provided a boost to bank lending in the UK. Our instrumental variables approach exploited the exogeneity of gilt sales by a bank's customers to funding and lending decisions of that bank. Though these transactions appear to be a valid instrument for contemporaneous changes in OFC deposits, we find that instrumented changes in OFC deposits were not correlated with changes in lending. This finding is despite controlling for bank specific effects and system-wide changes in credit provision and holds across a variety of different specifications. We reject the hypothesis that QE gave rise to a traditional BLC.

The approaches used do not provide an explanation for why there may not have been a BLC. But we developed a simple framework to show that if QE gives rise to deposits that are likely to be short-lived in a given bank ('flighty' deposits), then the traditional BLC is diminished. We described how QE was intended to operate via a portfolio rebalancing channel that would give rise to such flighty deposits. And we documented that QE has been associated with an increase in the variance of banks' reserves and OFC deposit positions. This is consistent with the idea that there was no BLC from QE precisely because portfolio rebalancing was occurring.

There are other explanations for why there may have been no BLC. For example, as pointed out by Romer and Romer (1990), deposits may not have a special role and so banks receiving extra deposits may simply offset the movement by reducing other liabilities with no effect on lending. Or as highlighted by Peek and Rosengren (1995), how a bank responds to a monetary-policy-induced expansion of deposits might be sensitive to whether it holds sufficient capital to expand its lending. The MPC believed that any BLC might be limited for this reason, which is plausible. But this paper raises the possibility that because QE worked through portfolio rebalancing, a BLC would not have occurred even in the absence of such strains in the financial system. Either way, our results caution against relying on a BLC.

We hope to stimulate more research in this topic area. For example, it is possible that there could have been other BLC mechanisms that would not be identified using the two approaches in this paper. And it is possible that bank lending channels other than the traditional sort that we examine here result from the effect of QE on asset prices: for example QE may have boosted lending by aiding recapitalisation (as discussed in Bridges and Thomas (2012) and Butt, Domit, McLeay, Thomas, and Kirkham (2012)); or QE may have boosted lending by aiding banks to hit the new regulatory liquidity requirements introduced by the Financial Services Authority.[31] Moreover, our results are time and location specific and do not prove that there would not be a bank lending channel from QE in future or in other countries.

To conclude, while our evidence suggests that QE did not boost bank lending it remains consistent with other studies which show that QE boosted aggregate demand and inflation. UK policymakers did not rely on QE to boost bank lending and our evidence lends support to the use of other policies, rather than QE, to attempt to improve the supply of credit.

[31] See http://www.fsa.gov.uk/about/what/international/liquidity for details of the new regime which were published in April 2009.

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A Model Solution

Given the period 0 profit maximisation for the bank as:

$$\max_{\{L_0,B_0\}} rL_0 - S_0(B_0) - C(F_1) \tag{A.1}$$

The first order conditions for a maximum:

$$r - \frac{\partial C}{\partial L_0} = 0 \tag{A.2}$$

$$-\frac{\partial S_0(B_0)}{\partial B_0} - \frac{\partial C}{\partial B_0} = 0 \tag{A.3}$$

Using the chain rule,[1] and the expression for F_1, we can rewrite (A.2) and (A.3) as:

$$r = \frac{\partial C}{\partial F_1} \tag{A.4}$$

$$\frac{\partial S_0(B_0)}{\partial B_0} = \frac{\partial C}{\partial F_1} \tag{A.5}$$

which we can solve to give the equations in the main text:

$$r = \frac{\partial S_0(B_0)}{\partial B_0} \tag{7}$$

$$r = \frac{\partial C}{\partial F_1} \tag{8}$$

[1] $\frac{\partial C}{\partial X} = \frac{\partial C}{\partial F_1}\frac{\partial F_1}{\partial X}$.

B Robustness: Difference-in-Differences model

As a robustness exercise, we conduct another test of the BLC using an alternative approach to identification. We follow much of the existing literature and use bank level differences to uncover whether QE gave rise to a BLC. As we showed in the main text, QE represented a large positive shock to the aggregate quantity of OFC, as opposed to other, deposits and therefore we seek to exploit structural differences in banks' OFC funding which capture the degree to which they are likely to benefit from the increase in OFC deposits. Our alternative hypothesis to try to identify evidence of a traditional BLC as a result of QE is:

Hypothesis B.1 *QE boosted the aggregate level of OFC deposits which would lead banks with capacity to absorb OFC deposits to increase lending via a bank lending channel.*

We test this hypothesis using a diff-in-diff approach which exploits the fact that some banks have the knowledge and technical infrastructure in place to handle large deposits by financial market counterparties. These banks typically use OFC deposits as both a standard and a marginal funding source and they would be comfortable accepting large OFC deposits. Other banks would be less able to accept large OFC deposits. Accordingly we split our sample into two sets of banks - one group who are likely to be subject to large exogenous deposit shocks as a result of QE, and another group who are unlikely to be subject to such shocks. We call the former group 'OFC funders' and we call the latter group of banks, who may still use OFC deposits as a marginal funding source, 'non-OFC funders'. We can then look at the change in the behaviour of these banks when the QE-induced increase in OFC deposits occurs. The idea is that funders are exogenously affected by the generation of OFC deposits from APF activity and therefore a traditional BLC as a result of QE would, other things being equal, equate to higher relative lending for funders after the beginning of QE.

Specifically, we identify OFC funders and non-OFC funders by the peak share of OFC funding in the period leading up to March 2009, when QE1 started; those with a peak share of less than 12.5% are classified as 'non-OFC funders'. We use the peak in order to capture capacity to use OFC as a funding source. We choose the cut-off of 12.5% because it effectively divides the sample in half though we have checked that our results are robust to a number of other choices of cut-off. We therefore define:

$$D(Funder)_i = \begin{cases} 1 & OFC\ funder \\ 0 & otherwise \end{cases} \tag{B.1}$$

Table B.1 shows that whether a bank was a large OFC funder is not simply capturing the bank being a gilt participant (through which APF transactions could take place) as was important in the identification used in the main text. This means that the diff-in-diff analysis is picking up an alternative split of the banks.

Our diff-in-diff test is to check whether, controlling for a number of bank level determinants of lending growth, funders have higher lending growth than non-funders after the start of QE.

Table B.1: Cross-tabulation of OFC funders and gilt participants

	D(Gilt participant)		Total
D(OFC funder)	0	1	
0	8	3	11
1	8	6	14
Total	16	9	25

Notes: This table shows, for the 25 banks in our QE-period sample, how they breakdown between being banks that are participants in the APF gilt auctions (D(Gilt participant)=1) and being those banks identified as having capacity to adsorb OFC funds ((D(Funder)=1).

We estimate, in the most parsimonious case, a regression of:

$$\Delta L_{i,t} = \alpha_i + \tau_t + \delta D(QE)_t + \gamma_1 \Delta L_{i,t-1} + \phi_1 X_{i,t} + \beta_0 D(Funder)_i \times D(QE)_t \\ ... + \lambda_0 \Delta D_{i,t-1} + \epsilon_{i,t} \tag{B.2}$$

where $\Delta L_{i,t}$ is the change in lending to households and PNFCs, $D(QE)_t$ is a dummy variable equal to one after the policy of QE was introduced in March 2009, and $X_{i,t}$ contains a number of potentially important controls which we discuss below. The coefficient β_0 captures the extent whether OFC funders lending growth was, on average, larger or smaller after the introduction of QE. A BLC should give rise to a positive β_0.

All regressions include bank fixed effects (α_i) to capture the average lending of each bank. We will report some results that include time fixed-effects (τ_t), and some that do not. The $X_{i,t}$ controls include the lagged value of the overall credit stock, the contemporaneous customer funding gap, holdings of liquid assets and sector demand.

Since all types of banks might use OFC deposits as a marginal funding source, the coefficient λ_0 is included to pick up the correlation between deposits and lending that might be driven by banks that want to lend more increasing their marginal funding (including OFC deposits). To measure the extent to which funders actually used OFC deposits more (or less) in the QE period, we also estimate the extended equation:

$$\Delta L_{i,t} = \alpha_i + \tau_t + \delta D(QE)_t + \gamma_1 \Delta L_{i,t-1} + \phi_1 X_{i,t} + \beta_0 D(Funder)_i \times D(QE)_t + \lambda_0 \Delta D_{i,t} \\ ... + \lambda_1 D(QE)_t \times \Delta D_{i,t} + \lambda_2 D(Funder)_i \times D(QE)_t \times \Delta D_{i,t} + \epsilon_{i,t} \tag{B.3}$$

Here λ_1 captures the fact that the period of QE may have led to changes in the typical use of OFC as a marginal funding source. The λ_2 coefficient allows there to be a differential change in behaviour for our funder banks.

Since our identification, under both regression models, relies on the two groups being homogenous apart from their OFC funding share, we now examine whether this is the case. **Table B.2** provides an overview of the characteristics of the banks in the two splits. The main difference between the two groups is their size, both in terms of their real economy

Table B.2: Summary statistics for OFC funding split

	$\text{D(Funder)}_i = 0$	$\text{D(Funder)}_i = 1$
Capital buffer	5.8	4.7
Total liabilities	45587	56386
Real economy lending	2266	9099
Liquid assets	8.3	14.7

Notes: Medians by group.

Table B.3: Probit to predict D(Funder)

	$\text{D(Funder)}_i = 1$
Total liabilities	-0.000
	(0.000)
Real economy lending	0.000
	(0.000)
Liquid assets	-0.019
	(0.056)
Capital buffer	-0.088
	(0.183)
Observations	17
Chi-squared	12

Notes: Standard errors are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Estimation using bank means calculated over 2004-2009

lending and total liquid assets. Despite these differences, **Table B.3** shows the results of a probit estimation on the D(Funder) variable and shows that the membership of the OFC funder group is is not predictable based on these observable characteristics.

Given that we find evidence that OFC funders and non-funders are similar in other characteristics, there is no obvious reason to reject our identifying assumption. We therefore proceed to test our BLC hypothesis using this diff-in-diff approach: under a BLC, funders should increase loans to households and PNFCs by more than that of non-funders, which means that $\beta_0 > 0$ would be evidence in support of the traditional BLC under either (B.2) and (B.3). **Table B.4** shows the estimation results when we use monthly data over the period starting in February 1989 to January 2013. The set threshold that separates OFC funders from non-OFC funders is set to 12.5% as described above and we exclude banks for which we have less than ten observations. We use standard errors which are clustered at the bank level to compute significance levels to take account of heterogeneity across banks.

The first column of **Table B.4** presents the results from estimating equation (B.2) while column (2) presents the estimation of equation (B.3). Columns (3) and (4) replicate (1) and

Table B.4: Difference-in-differences estimation

	(1)	(2)	(3)	(4)	(5)
D(Funder)$_i$×D(QE)$_t$	-167.608**	-155.171*	-104.825*	-103.211	-66.026
	(80.853)	(78.840)	(61.032)	(62.239)	(46.998)
D(QE)$_t$	-	-	-	-	-0.860
					(14.485)
ΔL$_{i,t-1}$	0.378***	0.378***	0.287***	0.282***	0.265***
	(0.072)	(0.073)	(0.057)	(0.056)	(0.058)
ΔL$_{i,t-2}$			0.165***	0.173***	0.171***
			(0.033)	(0.029)	(0.028)
ΔL$_{i,t-3}$			0.108***	0.112***	0.108***
			(0.034)	(0.035)	(0.035)
Sector demand$_{i,t}$	-0.013	-0.013	-0.026	-0.027	0.057***
	(0.027)	(0.027)	(0.024)	(0.024)	(0.015)
Credit stock$_{i,t-1}$	0.002	0.002	0.001	0.001	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Customer funding gap$_{i,t}$	0.041	0.043	0.029	0.030	0.001
	(0.041)	(0.041)	(0.041)	(0.041)	(0.011)
Liquid assets$_{i,t}$	0.000	0.000	0.000	-0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ΔOFC deposits$_{i,t}$	0.010	0.032*	0.008	0.031*	0.031
	(0.007)	(0.016)	(0.008)	(0.019)	(0.018)
ΔOFC deposits$_{i,t-1}$			0.009***	0.008	0.007
			(0.002)	(0.008)	(0.009)
ΔOFC deposits$_{i,t-2}$			-0.005	-0.017	-0.018
			(0.005)	(0.013)	(0.013)
ΔOFC deposits$_{i,t-3}$			-0.007	-0.023**	-0.023**
			(0.005)	(0.011)	(0.011)
D(QE)$_t$ × ΔOFC deposits$_{i,t}$		-0.023		-0.035	-0.037**
		(0.020)		(0.022)	(0.018)
D(QE)$_t$ × ΔOFC deposits$_{i,t-1}$				-0.043***	-0.036***
				(0.007)	(0.010)
D(QE)$_t$ × ΔOFC deposits$_{i,t-2}$				-0.014	-0.009
				(0.016)	(0.017)
D(QE)$_t$ × ΔOFC deposits$_{i,t-3}$				0.003	0.008
				(0.020)	(0.020)
D(Funder)$_i$×D(QE)$_t$ × ΔOFC deposits$_{i,t}$		-0.011		-0.002	0.001
		(0.010)		(0.012)	(0.007)
D(Funder)$_i$×D(QE)$_t$ × ΔOFC deposits$_{i,t-1}$				0.044***	0.041***
				(0.010)	(0.008)
D(Funder)$_i$×D(QE)$_t$ × ΔOFC deposits$_{i,t-2}$				0.033***	0.029***
				(0.010)	(0.010)
D(Funder)$_i$×D(QE)$_t$ × ΔOFC deposits$_{i,t-3}$				0.021	0.015
				(0.017)	(0.018)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	No
Observations	6191	6191	5948	5948	6086
Banks	55	55	55	55	55
F	3	4	39	43	129

Notes: Standard errors clustered at the bank level are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Estimation period: February 1989 to January 2013. D(Funder) is equal to 1 for institutions with maximal OFC funding share > 12.5% in the five years prior to QE, and zero otherwise. The results are robust to varying the threshold for the dummy between 5-20%.

(2) respectively but with the addition of a variety of additional lags. As described above, a BLC should show up as a positive estimate of β_0, the coefficient on the $\mathrm{D(Funder)}_i \times \mathrm{D(QE)}_t$ variable. We find, consistent with the results of the most parsimonious model using the IV approach, that the coefficient on this interaction term is negative though not usually statistically significant. This, if anything, points to a negative BLC which could be driven be the fact that OFC deposits may have increased in aggregate, but they may have also become a less stable source of funding for banks.

In some of the specifications we find a positive coefficient on ΔOFC deposits$_t$ (λ_0), though the coefficient is economically small. Given that banks that want to lend may demand OFC deposits as a marginal funding source, we would expect this reverse causation to lead to such a finding; as such, we do not think that this positive coefficient reflects a BLC. When we estimate equation (B.3) in columns (2), (4) and (5), we allow this relationship to change after QE, and to allow this change in coefficient to change differentially for funder and non-funder banks as captured by the coefficients on $\mathrm{D(QE)}_t \times \Delta$OFC deposits$_t$ (λ_1) and $\mathrm{D(Funder)}_i \times \mathrm{D(QE)}_t \times \Delta$OFC deposits$_{i,t}$ (λ_2).[2] While these specifications do not alter our finding in terms of no evidence of a BLC, the relationship between OFC deposit flows and lending seems to have changed with QE. In the post QE period, the average relationship seems to have weakened across the non-funder banks (and especially at one lag) though the relationship does not seem to have changed for the funder banks (λ_1 and λ_2 offset each other).[3] This, like the earlier results, is consistent with OFC deposits becoming a less stable source of funding for non-funder banks, though the increase in the amount of OFC deposits may have offset the increase in the churn for the funder banks.

We have carried out a number of robustness tests on these regressions but in the interests of space we shall simply report what we found. We have carried out all of the analysis omitting time-effects (one of these specifications is reported in column (5) of **Table B.4**. The results are also robust to varying the threshold for being a funder to values between 5% (a very low threshold) and 20% (making funder a more exclusive classification). Finally, we use a less stark measure of the treatment. Instead of setting the treatment to one for funders after the beginning of QE, we recognise that the extent to which OFC deposits were created depends on the quantity of asset purchases made by the MPC. Therefore, we replace $D(QE)_t$ with APF_t, a variable which measures of the amount of assets purchased and therefore varies over the QE period. The results in terms of the BLC are unchanged.

Overall, our test of hypothesis B.1 suggests that QE, via an increase in the aggregate level of OFC deposits, did not lead banks with capacity to absorb OFC deposits to increase lending to households and PNFCs. That is, we find no evidence of a BLC.

[2]We have also run these regressions allowing the pre-QE relationship to differ between funder and non-funder banks. As we find no difference, we do not report the regressions in the paper.

[3]A specification that includes only $\mathrm{D(QE)}_t \times \Delta$OFC deposits$_t$ finds that on average the relationship has weakened slightly.