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Quantitative easing and bank lending: a panel data approach

Michael A S Joyce and Marco Spaltro

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Michael A S Joyce[1] and Marco Spaltro[2]

Abstract

Studies of the Bank of England's quantitative easing (QE) policy have tended to focus on its impact on financial markets and the broader macroeconomy. Less attention has been given to the effect on banks' balance sheets and bank lending. In this paper we use a new non-publicly available panel data set of UK banks to address this question. Based on the historical bank-level relationship between deposits and bank lending, our analysis suggests that the first round of the Bank's QE purchases during 2009–10 may have led to a small but statistically significant increase in bank lending growth. These effects appear more important for small rather than large banks. Our evidence also suggests that QE had weaker effects on lending because of low levels of bank capital.

Key words: Banking, quantitative easing, panel data.

JEL classification: E52, G21.

(1) Bank of England. Email: mike.joyce@bankofengland.co.uk
(2) Morgan Stanley Investment Management. Email: marco.spaltro@morganstanley.com

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Publications Team, Bank of England, Threadneedle Street, London, EC2R 8AH
Telephone +44 (0)20 7601 4030 Fax +44 (0)20 7601 3298 email publications@bankofengland.co.uk

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Summary

In response to the sharp deterioration in the global financial crisis in Autumn 2008, the major central banks cut their policy rates dramatically and began looking for other unconventional measures to loosen monetary conditions further. In the United Kingdom and United States, a key element of these unconventional measures has been the policy of large-scale asset purchases financed by central bank money, sometimes referred to as quantitative easing (QE).

In the United Kingdom, the Bank of England's Monetary Policy Committee (MPC) announced the introduction of the QE policy in March 2009, at the same time as it reduced Bank Rate to 0.5%, a historical low. In announcing the new policy, the Committee noted that without further measures there was a serious risk inflation would undershoot the 2% consumer prices index inflation target in the medium-term. By the end of the first round of purchases that ended in January 2010 the Bank of England had purchased £200 billion of assets, consisting almost exclusively of government bonds – an amount equivalent to 14% of annual nominal GDP. In October 2011, the Bank resumed its QE purchases and by November 2012 the Bank had completed a further £175 billion of purchases.

There is now a large and growing literature that attempts to measure the impact of central bank asset purchases during the financial crisis in the United Kingdom and elsewhere. So far, the vast majority of research on QE has focused on its impact on economic growth and financial markets, while the effect of QE on bank lending has received much less attention. This relative neglect reflects the fact that policymakers in the United Kingdom and elsewhere expected QE to affect demand mainly through its impact on asset prices, while the effect on bank lending was expected to be small because of banks' incentives to deleverage and reduce the overall size of their balance sheets. This reasoning is consistent with the literature on the so-called bank capital channel, which suggests that capital can be an important driver of banks' lending decisions particularly in periods of market stress.

The MPC's caution about the strength of the bank lending channel was reflected in the design of the Bank of England's asset purchase programme, which was targeted towards the non-bank financial sector by skewing purchases towards medium and long-term maturity government securities (gilts), rather than the shorter-maturity gilts typically held by banks for their liquidity needs. However, to the extent that the Bank's QE asset purchases came from non-banks (directly or indirectly), the banking sector will have gained both additional reserves and a corresponding increase in its deposits. The additional reserves mean that banks' holdings of liquid assets will have increased, which might make banks more willing to extend illiquid loans. At the same time, by increasing their deposits, QE will have made banks less reliant on seeking other funding to manage their liquidity needs. Put another way, the extra deposits that banks consequently held will have helped relieve any funding constraints they may have faced. Since these constraints are more likely to bind in times of financial stress, it seems possible that this might have led to additional lending. While any effects on lending might have been expected to be weak during a period when the banks were also trying to deleverage, it seems unlikely that there will have been no effect at all. In other words, relative to the counterfactual of no QE, bank lending seems likely to have been larger.

The contribution of this paper is to test for the existence of this bank lending channel historically and thereby to quantify likely the size of the effects of the Bank of England's QE policy during 2009-10 on bank lending, using a new non-publicly available quarterly panel data set on UK banks. The use of this unique data set allows us to model the relationship between bank lending growth and its determinants over a 20-year period pre-dating the financial crisis and to explore whether the relationship between deposits and bank lending changed during the crisis. We are also able to explore heterogeneities between large and small banks and to control for balance sheet effects, by including information on bank capital ratios at the level of individual banks. Using the historical relationships between bank lending growth and deposit growth, macroeconomic indicators and individual controls, we can then simulate the potential effects of QE on the banking sector.

We find that historically movements in the deposit ratio have a small but statistically significant effect on bank lending growth, which suggests that QE may have led to an increase in bank lending through its effect on deposits. These effects, however, are likely to have been small, both because the estimated marginal effects through deposits are small and also because we assume as a benchmark that there was a full pass-through from QE to deposits, which seems likely to overstate the impact. We also find no evidence that the impact from deposits increased during the QE period. Our analysis suggests that the effects on bank lending were heterogeneous across banks, as we find lending by small banks to be more responsive to the level of deposits than the lending of large banks. We also find evidence that bank lending is positively related to how well capitalised banks are, suggesting that the impact of QE on bank lending may have been weaker because of the lower levels of capital during the crisis. In a sense, this is to be expected and justifies the emphasis policymakers gave to QE going round the banks. At the same time, it suggests that macroprudential policy may potentially influence the effectiveness of monetary policy.

"*A significant programme of asset purchases was likely to be necessary in order to make up this shortfall in nominal spending. 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...The Committee noted that ...asset purchases were likely to be most effective if they were purchased from the domestic non-bank financial sector rather than from banks.*"

Bank of England Monetary Policy Committee Minutes, 4 and 5 March 2009.

1 Introduction

In response to the sharp deterioration of the global financial crisis in Autumn 2008, the major central banks cut their policy rates dramatically and began looking for other unconventional measures to loosen monetary conditions further. In the United Kingdom and United States, a key element of these unconventional measures has been the policy of large-scale asset purchases financed by central bank money, sometimes referred to as quantitative easing (QE).

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There is now a large and growing literature that attempts to measure the impact of central bank asset purchases during the financial crisis in the United Kingdom and elsewhere. Most of this literature focuses on the impact of asset purchases on financial markets (for the UK, see for example, Joyce et al (2011) and Breedon, Chadha and Waters (2012); for the US, see Gagnon et al (2011) and D'Amico and King (2013)) and to a lesser extent the wider economy effects (for the UK, see Kapetanios et al (2012), Bridges and Thomas (2012) and Pesaran and Smith (2012); for the US, see Chung et al (2012) and Chen, Curdia and Ferrero (2012)), but there has been very little analysis of the effects of asset purchases on banks.[1] This relative neglect probably reflects the view among policymakers that the main effects of QE have come through increasing asset prices, through

[1] The Bridges and Thomas (2012) paper looks at the impact on money and bank lending, but at the aggregate level. The closest study to our own is probably Bowman et al (2011) who look at the effects of QE in Japan during the 2001-2009 period using bank-level data.

signalling and portfolio balance effects (see e.g. Joyce, Tong and Woods (2011)).

As the quote above from the Bank of England's MPC's March 2009 Minutes indicates, the MPC specifically downplayed the possibility of QE working through a bank lending channel because of the pressures on banks to deleverage in the crisis. This focus on the importance of bank's balance sheets is consistent with the literature on the so-called bank capital channel,[2] which suggests that capital can be an important driver of banks' lending decisions particularly in periods of market stress. Kashyap and Stein (1994), Van Den Heuvel (2002), Jimenez et al. (2010), Gambacorta and Marques-Ibanez (2011) show that the health of banks' balance sheets, and in particular the amount of capital they hold, is important in determining the effectiveness of the bank lending channel. The last paper is of particular relevance, as Gambacorta and Marques-Ibanez (2011) find that banks with weaker core capital positions and more dependence on market funding cut back their lending more than other banks during the global financial crisis.

The MPC's caution about the strength of the bank lending channel was reflected in the design of the Bank of England's asset purchase programme, which was targeted towards the non-bank financial sector by skewing purchases towards medium and long-term maturity government securities (gilts), rather than the shorter-maturity gilts typically held by banks for their liquidity needs. However, to the extent that the Bank's QE asset purchases came from non-banks (directly or indirectly), the banking sector will have gained both additional reserves and a corresponding increase in its deposits. The additional reserves mean that banks' holdings of liquid assets will have increased, which might make banks more willing to extend illiquid loans. At the same time, by increasing their deposits, QE will have made banks less reliant on seeking other funding to manage their liquidity needs. Put another way, the extra deposits that banks consequently held will have helped relieve any funding constraints they may have faced. Since these constraints are more likely to bind in times of financial stress, it seems possible that this might have led to additional lending.[3] While any effects on lending might have been expected to be weak during a period when the banks were also trying to deleverage, it seems unlikely that there will have been no effect at all. In other words, relative to the counterfactual of no QE, bank lending seems likely to have been larger.

The contribution of this paper is to test for the existence of this bank lending channel historically and thereby to quantify the likely size of the effects of the Bank of England's QE policy during 2009-10 on bank lending, using a new non-publicly available quarterly panel dataset on UK banks. The use of this unique dataset allows us to model the relationship between bank lending growth and its determinants over a twenty-year period pre-dating the financial crisis and to explore whether the

[2] The origins of this literature go back to Bernanke and Lown (1991), who analysed the impact of capital shocks on bank lending in the US recession of the early 1990s.

[3] This potential channel has been highlighted by David Miles, a member of the Bank of England's MPC, in various speeches. See 'Asset prices, saving and the wider effects of monetary policy', 1 March 2012.

relationship between deposits and bank lending changed during the crisis. We are also able to explore heterogeneities between large and small banks and to control for balance sheet effects, by including information on bank capital ratios at the level of individual banks. Using the historical relationships between bank lending growth and deposit growth, macroeconomic indicators and individual controls, we can then simulate the potential effects of QE on the banking sector.

The rest of this paper is structured as follows. The next section sets out a partial equilibrium model that brings out the potential relationship between QE and bank lending and provides a set of hypotheses that will be tested in our empirical work. Section 3 discusses the MPC's asset purchase programme during 2009 to 2010 and how these purchases may have affected bank balance sheets and bank lending. Section 4 describes the non-publicly available panel dataset on UK banks that we have used for our empirical analysis. Section 5 turns to the econometric strategy we adopt, while Sections 6 and 7 discuss the econometric results and some simulations of the likely effects of the first round of the Bank of England's QE purchases on bank lending. The final section concludes.

2 A model of the effect of QE on bank lending

To draw out the intuitions behind the potential relationship between QE and bank lending, in this section we set out a partial equilibrium two-period model of the bank lending channel that is a slightly adapted version of the well-known model proposed by Kashyap and Stein (1994).

The model assumes that banks have the following stylised balance sheet. On the asset side, there are illiquid loans (L) and liquid securities (S), e.g. UK gilts. On the liability side, banks have equity (E), non-deposit liabilities (ND) and deposits (D).

Loans yield a return of r and cannot be liquidated at time 2, capturing their illiquid nature. Banks can invest in S at time 1, yielding a return of zero and the security can be costlessly liquidated at time 2. So the return on loans, r, is effectively a spread and this spread provides a measure of the effectiveness of the bank lending channel, i.e. movements in r show how changes in monetary policy affects banks' returns.

In this model the level of deposits is determined by the monetary authority. In the original Kashyap and Stein model, the monetary authority was assumed to affect banks' balance sheets through changes in reserves, which lead to a change in deposits, on the assumption that banks maintain a fixed ratio between reserves and deposits. This of course is not how conventional monetary policy generally works in practice. In the United Kingdom the monetary authority sets the short-term interest rate and supplies reserves to meet demand from the banking system. Moreover, banks are not required to maintain a fixed ratio between reserves and deposits. But while the effects of monetary policy on deposits will be indirect, it still seems likely that monetary policy will have some

effect. We are concerned with analysing the effects on lending of unconventional policy in a period where short-term interest rates were constrained at their effective lower bound. In this case, asset purchases by the monetary authority have a direct effect on bank reserves and also on deposits, to the extent that gilts are bought from non-bank financial institutions rather than banks (as discussed further in the next section). In these circumstances, it seems plausible to think of monetary policy shocks in terms of shocks to deposits.[4]

In period 1, after the amount of deposits, D_1, is realised, the distribution of deposits at time 2, D_2, follows a uniform distribution, where

$$D_2 \text{ is uniform on } [\rho D_1 + (1-\rho)D - \gamma/2, \rho D_1 + (1-\rho)D + \gamma/2]. \quad (1)$$

In this equation the mean of D_2 is $\rho D_1 + (1-\rho)D$ and ρ is a measure of the persistence of the shock, while γ measures the variance of deposit shocks. Here D represents the marginal effect of the monetary policy shock on the initial stock of deposits in the system, D_1.

Following the shock to deposits in period 2 (i.e. D_2 is realised), the bank can fund itself by issuing non-deposit liabilities (ND), so at time 2 the amount of non-deposit liabilities is ND_1(issued before the shock to deposits) plus ND_2 (issued after the shock to deposits). The key assumption in the model is that there are increasing marginal costs of finance for non-deposit liabilities (ND) and that their costs are $\frac{\alpha_1 ND_1^2}{2}$ at time 1 and $\frac{\alpha_2 ND_2^2}{2}$ at time 2. This is because this type of liability is not covered by deposit insurance and large issuance of non-deposit liabilities may signal a bad state of the bank, the so-called 'adverse selection' problem. These costs are likely to be higher for small than for large banks (i.e. α_1, α_2 are larger for smaller banks) because large banks have better access to capital markets. Kashyap and Stein show empirically that this is true for a panel of US banks.

When at time 2 the value of deposits is realized there are two possible cases:

1) $ND_1 + D_2 + E_1 > L$, then there is no need to issue external finance (ND) at time 2 and the bank can draw down the liquid asset buffer (S).

2) $ND_1 + D_2 + E_1 < L$, then the bank is short of funds and issues external finance (ND) at time 2 to absorb the shortage of funds.

The amount of non-deposit liabilities issued following the deposit shock will therefore be:

$$ND_2 = \max(0, L - ND_1 - D_2 - E_1) \quad (2)$$

[4] The Kashap and Stein model is obviously highly stylised and used here as a way of illustrating the possible operation of the bank lending channel. The objective of this paper is to provide evidence on the likely empirical strength of this mechanism. For a broader discussion of how money is created in a modern economy, see the recent article by McLeay, Radia and Thomas (2014).

In order to write down the profit function, we need to know the expected cost of issuing non-deposit liabilities at time 2 for the case of a deposit shock. Taking expectations and substituting for ND_2 we have:

$$E(\alpha_2 ND_2^2/2) = \tfrac{\alpha_2}{2} E(ND_2^2)$$

$$= \tfrac{\alpha_2}{2} E(\max(0, L - ND_1 - D_2 - E_1))^2$$

The right hand side is uniformly distributed between 0 and the larger positive quantity plus $\gamma/2$. From the result that the second moment of a uniform distribution distributed over [a,b] is $E(X^2) = \frac{a^2+b^2+ab}{3}$, it is easy to see that the expected issuance cost at time 2 from the perspective of the bank at time 1 is:

$$E(\alpha_2 ND_2^2/2) = \alpha_2(L - ND_1 - \rho D_1 - (1-\rho)D - E_1 + \frac{\gamma}{2})^2/6 \tag{3}$$

In the bank's profit equation, income is generated from loans and costs arise from non-deposit liabilities issued at time 1 and the expected costs of non-deposit liability issuance in the case of a shock to deposits at time 2. Therefore, the bank's profit function will be the following:

$$\pi = rL - \alpha_1 \frac{ND_1^2}{2} - \alpha_2 \frac{E(ND_2^2)}{2}$$

$$\pi = rL - \alpha_1 \frac{ND_1^2}{2} - \alpha_2(L - ND_1 - \rho D_1 - (1-\rho)D - E_1 + \frac{\gamma}{2})^2/6 \tag{4}$$

By differentiating (4) with respect to L and then ND_1 we can find the expression for bank lending supply and non-deposit liabilities, which is the same maximisation problem as in Kashyap and Stein with the addition of the equity term E_1.[5] The resulting lending supply equation can be written as follows:

$$L = \frac{3}{\alpha_2} r + \frac{r}{\alpha_1} + \rho D_1 + (1-\rho)D + E_1 - \frac{\gamma}{2} \tag{5}$$

Equation (5) suggests that an increase in deposits leads to an increase in lending supply, so that an increase in bank deposits due to QE should have a positive effect on lending. It also shows that a higher level of equity (E) is related to higher bank lending,[6] in line with the 'bank capital channel' literature where shocks to capital affect bank lending (as discussed in Section 1).

[5] We do not show the derivation of equation (4) as it is identical to Kashyap and Stein (1994).

[6] These results are effectively the same as Kashyap and Stein's with the exception that the loan supply equation here also includes E_1.

As discussed before, we would expect large and small banks to react differently to a change in deposits given their different capacity to access capital markets. To analyse the effects on large and small banks, we differentiate equation (5) with respect to D_1. The first derivative can then be written as:

$$\frac{\partial L}{\partial D_1} = \left(\frac{1}{\alpha_1} + \frac{3}{\alpha_2}\right)\frac{\partial r}{\partial D_1} + \rho \tag{6}$$

To close the model, Kashyap and Stein then assume a simple linear loan demand function taking the form:

$$L_D = Y - kr \tag{7}$$

Equation (7) says that demand for loans is a positive function of economic growth, Y, and a negative function of the loan return, r.

Suppose there are n banks (our theory implicitly assumes banks are identical). Then the equilibrium condition is

$$L_D = nL$$

Solving the equilibrium condition, we get:

$$r = \frac{1}{nb+k}\left(Y - n\left(\rho D_1 + (1-\rho)D + E_1 - \frac{\gamma}{2}\right)\right)$$

where $b \equiv \frac{1}{\alpha_1} + \frac{3}{\alpha_2}$.

By differentiating with respect to D_1 we obtain:

$$\frac{\partial r}{\partial D_1} = \frac{1}{nb+k}\left(\frac{\partial Y}{\partial D_1} - n\rho\right) \tag{8}$$

If $\frac{\partial Y}{\partial D_1}$ is small (i.e. changes in deposits do not have a large impact on economic activity) then $\frac{\partial r}{\partial D_1} < 0$ and there is a bank lending channel. From equations (6) and (8) we can infer that, for a given change in deposits, banks that find it more costly to issue non-deposit liabilities (e.g. small banks with high α_1 and α_2) will react more to a change in deposits. Conversely, large banks will react less to a shock in deposits. At the same time, this also suggests that if the costs of non-deposit liabilities increases during a financial crisis, α_1 and α_2 will also increase, causing bank lending to be more sensitive to deposits and by implication increasing the potential potency of QE to increase bank lending.

Summing up, equations (5) and (6) provide us with four testable hypothesis. First, that bank lending supply is positively related to deposits, so that we should expect QE to increase bank lending. Second, that bank lending should be positively related to how well-capitalised banks are. Third,

that small banks will react more to a shock to their deposits than large banks because small banks with limited access to capital markets are more likely to be credit constrained. Finally, that the sensitivity of bank lending to deposits should increase in a financial crisis to the extent that it increases the cost of raising non-deposit liabilities. Our empirical analysis supports all but the last of these hypotheses.

3 QE and its impact on bank deposits

The Bank of England's MPC announced the beginning of its first round of QE asset purchases in March 2009. The initial decision was to purchase £75 billion of assets over a three-month period, but further extensions to the programme were subsequently announced at the May, August and November 2009 MPC meetings and by the time the programme was paused in early 2010 the Bank had bought £200 billion of assets. Though the Bank purchased some private assets, the overwhelming majority of its purchases consisted of UK government bonds. Initially the Bank bought gilts with a residual maturity of between 5 and 25 years, although this was later extended to gilts with maturities of 3 years or over. Part of the motivation for purchasing medium to long-term bonds was to skew purchases towards the non-bank financial sector (eg insurance companies and pension funds) rather than buying from banks (see Joyce, Tong and Woods (2011)).

From a balance sheet perspective, central bank asset purchases from *banks* constitute an exchange of gilts for reserves on the asset side of their balance sheets, as the central bank credits each bank's reserve account with central bank money in exchange for the amount of the asset purchased. Because reserves are higher, so-called narrow money increases (i.e. the monetary base or currency in circulation plus reserves held at the Bank of England) but broad money (i.e. currency in circulation plus deposits) remains unchanged. At the same time the central bank expands its balance sheet by the amount of the assets purchased (Figure 1 upper panel).

During 2009 - 10, the Bank of England attempted to purchase gilts mainly from non-bank financial institutions (e.g. pension funds and insurance companies) with the intention of increasing not only narrow money but also broad money (via an increase in deposits) (Benford et al. (2009)). When the Bank purchases assets from a non-bank financial institution, such as a pension fund, it credits the bank of the pension fund with central bank reserves, while the pension fund gains a deposit at its bank. In contrast to the previous case, the asset purchase has increased the bank's balance sheet (Figure 1, lower panel).[7] The bank finds itself with a more liquid balance sheet on the asset side (a higher reserves ratio) and more deposits on the liability side. Given that the bank now has a

[7] In Figure 1 we present a simplified version of the Bank of England's asset purchase scheme. In practice, asset purchases were undertaken through an off balance sheet vehicle - the Bank of England Asset Purchase Facility - rather than the Bank of England directly. However, this does not affect the basic economic mechanisms or our econometric strategy.

higher level of liquid assets, possibly above that required to meet payment demands from customers, it may be less costly for the bank to increase lending to the real economy (e.g. to households or non-financial corporations).

Initially the 'new' deposits will be held by non-bank financial institutions. However, if the non-bank financial institutions use the cash to buy higher yielding assets (e.g. corporate bonds), the deposits move to the private non-financial corporate sector. If the bank then lends, say, to a household to purchase a flat, it also creates new household deposits. This means that it is likely that the bank's deposit mix will change over time, but in practice it is difficult (if not impossible) to track these changes through the banking system. In this paper we will therefore use total rather than disaggregated measures of deposits.

As well as these direct effects, asset purchases by the central bank may also have *indirect* (flow) effects on banks' balance sheets. For example, if these purchases affect long-term interest rates and the slope of the yield curve this can have an effect on banks' net interest margins (NIM). This in turn may affect the ability of banks to accumulate capital and extend new lending to the real economy. For example, Alessandri and Nelson (2012) show empirically that interest rates and the slope of the yield curve affect NIM using data on UK banks. In this paper we will focus only on the *direct* balance sheet effects, i.e. the reaction of bank lending following changes in the *stock* of deposits. In order to do this, we use a new unpublished panel dataset on individual banks. Before turning to our econometric analysis, the next section describes this dataset.

4 Data

The new panel dataset we use includes non-publicly available quarterly balance sheet and income statement data on 30 financial institutions active in the UK lending market from Q2 1989 until Q4 2010. The sample includes UK-owned banks, foreign-owned banks (around 60% of the sample), building societies (around 10% of the sample) and non-bank financial institutions (just over 15% of the sample). The panel is unbalanced as the time series is discontinued after mergers and failures - banks are observed for a minimum of 9 periods and a maximum of 92 periods.[8] Because of the treatment of mergers and failures, the sample is larger than the number of banks, as new banking units are created whenever there is a merger.

We have included financial entities on a consolidated level, as we assume that lending decisions are taken on a group-level basis. Considering a lower level of consolidation (as for example in Kashyap and Stein (2000)) would instead assume that liquidity could not be transferred within groups and that

[8] An alternative approach sometimes adopted in the literature is to construct 'artificial' banks that are observed across the whole time series. Even though this approach is likely to reduce problems resulting from the use of unbalanced panel data, it may create estimation biases. For example, following a merger, unobservable characteristics of the bank (e.g. management ability) may change but this 'structural' change would not be picked up in the estimates.

subsidiaries act in isolation. This seems an unrealistic assumption and we think that a consolidated approach better reflects the relationship between liquidity and lending in a complex banking group. This is consistent with Houston, James and Marcus (1997) who found that shocks to one subsidiary in a holding company are partially transmitted to other subsidiaries in the same banking group.

Table 1 describes the main variables used in this paper. Total (non-financial) lending is obtained by adding the stock of lending to households to the stock of total lending to private non-financial corporates (PNFCs) and 'total lending growth' is then calculated as the quarter on quarter percentage change in the total lending stock. The 'change in capital ratio' is the quarter on quarter change in capital over risk-weighted assets, where capital includes all types of qualifying regulatory capital,[9] and the 'change in the provision ratio' is the similarly defined change in the provisions over assets ratio. The 'capital buffer change' is the quarter on quarter change in the difference between the observed capital ratio and the individual bank's capital requirement. 'Changes in deposit ratio' is the quarter on quarter change in the total deposits over total assets ratio.

In the table, we have summarised these variables for large and small banks, where large banks are defined as those banks that are in the top five according to the size of their total assets in each period. Large and small banks have similar averages for total lending growth, the provision ratio and changes in the deposit ratio. But small banks have higher capital ratios than large banks on average. Large (and systemic) banks are often reported to hold a smaller buffer of capital, perhaps because they have lower funding costs and easier access to capital markets and benefit from an implicit government guarantee (Ueda and Weder di Mauro (2012), Noss and Sowerbutts (2012)). The small bank variables also exhibit greater dispersion than those for the large banks. This is likely to reflect the fact that small banks are more heterogeneous, ranging from medium sized to very small institutions.

Figure 2 (left-hand side panel) shows the deposit over asset (DA) ratio separately for the large and small banks in our sample. The DA ratio has declined steadily since the early 1990s consistent with the fact that banks have increasingly financed their assets with non-deposit liabilities. Since the late 1990s large and small banks' DA ratios started to diverge, becoming lower for large banks. Better access to capital markets by large banks and the evolution of more complex funding instruments (e.g. securitisation) probably explains the different behaviour of large and small banks.

The DA ratio ticked up around the second half of 2009 (particularly for small banks), which may indicate an impact from QE on the banks included in our sample. However, we should not over interpret the evidence from this chart, as this increase is comparable to previous increases in the series. Moreover, the increase might also reflect other factors, including the need for banks to fund

[9] Bridges et al (2014) use this total capital measure in their analysis of the impact of changes in regulatory capital requirements on bank capital ratios and bank lending.

more of their assets through deposits given the problems of obtaining other sources of funding during the financial crisis.

Figure 2 (right-hand side panel) shows that both large and small banks' lending growth declined during the crisis compared to pre-crisis averages. Small banks' lending growth turned negative shortly after the QE programme started while large banks' lending growth remained in positive territory. Small banks' lending growth then recovered after 2010 Q1. Our dataset therefore suggests that there might be differences in the way large and small banks reacted to QE. We will return to this in Section 5.2.

5 Econometric strategy

As discussed in Section 2, QE may affect lending through changes in deposits. This channel is similar to the bank lending channel, with the difference that in this case the central bank directly affects the amount of bank deposits in the financial system through its asset purchases. Our strategy is to use the QE-induced change in deposits to quantify the effect of QE on bank lending.

In the period following QE both the level of deposits and the ratio of deposits over total assets (DA) increased. We will focus on the DA ratio, as by construction movements in this variable capture changes in deposits that are out of line with the growth of other non-deposit liabilities. Our contention is that by looking at this ratio we are therefore more likely to capture large changes in deposits that 'drive' the increase in assets and are therefore closer to a QE-induced expansion of banks' deposits, but of course this measure is only a proxy and will be affected by other factors as well as deposit shocks.

We shall focus on explaining the response of lending *growth* to changes in DA ratio. Using lending growth as endogenous variable is quite common in the literature. For example, Kashyap and Stein (2000) investigate the existence of the bank lending channel mechanism by regressing bank lending growth on individual bank variables and macroeconomic factors. Bernanke and Lown (1991) study the effects on lending growth of both the level of the capital ratio (i.e. capital over assets) and the change in the capital ratio. Another possible left hand side variable, the lending over asset ratio, would not be useful for our purposes because this ratio may remain unchanged even though banks decide to increase lending to the real economy.

We investigate the relationship between bank lending growth and changes in the DA ratio by estimating the following relationship:

$$\Delta l_{it} = \alpha + \beta(L)\Delta l_{it} + \gamma(L)\Delta D_{it} + \delta(L)\Delta C_{it} + \mu' I_{it} + \theta' A_t + u_{it} \tag{9}$$

where Δl_{it} is quarterly lending growth for bank i in period t, ΔD_{it} is changes in the deposits

over assets ratio, ΔC_{it} is changes in published regulatory capital (capital over risk-weighted assets), I_{it} is a vector of micro controls and A_t is a vector of macro controls. The error term u_{it} is assumed to be normally distributed with mean zero and variance σ^2 and we assume the error terms are independent both in the time and cross-section dimensions, i.e. $E(u_{it}, u_{js}) = 0$ for $i \neq j, s \neq t$. L is the lag operator and $\beta(L)$, $\gamma(L)$ and $\delta(L)$ are lag polynomials.

This dynamic (Auto Regressive Distributed Lag) model allows us to estimate both short and long-run effects of *changes* in the deposit ratio on lending growth. The short-run effects are identified by the coefficients of the individual time lags, while the long-run cumulative effect is identified by the sum of the lagged coefficients divided by one minus the sum of the lagged lending coefficients.[10] In the following section we will present both long-run and short-run estimates.

Equation (9) can be thought of as a reduced-form relationship intended to pick up the influence on lending of both demand and supply factors, proxied through macroeconomic and micro variables (i.e. individual bank characteristics). Among bank characteristics we include the size of the bank, changes in the ratio of provisions over assets and changes in the total capital ratio (regulatory capital over risk-weighted assets). The size of the bank is likely to be linked to the bank's business model and therefore to lending growth, while the provisions ratio is an indicator of asset quality which affects the bank's capacity to lend. Changes in the capital ratio affect lending because capital is a costly source of funding. A low *level* of the capital ratio (i.e. close to the regulatory minimum) also provides a limit to lending growth. We also include a control variable to account for differences in sectoral demand that may be driving lending growth, as in Aiyar (2011).[11] The macroeconomic controls include GDP growth, the unemployment rate, FTSE 100 growth and Bank Rate.

If QE had an effect on bank lending through its impact on deposits, we require $\gamma(L)$ to be positive and statistically significant, so that an increase in the DA ratio leads to higher lending growth. Similar literature on this issue is scant at the moment, and therefore it is difficult to have strong priors on the sign and magnitude of the effect, but the bank lending channel literature would point towards there being a positive relationship between deposit growth and bank lending.

As discussed in the introduction, the MPC thought that the effect of an increase in bank reserves on bank lending would be muted during the banking crisis given the incentives for banks to delever-

[10] Using this specification we are able to estimate the long-run effects of changes in the deposit ratio on bank lending growth. This effect is defined as the cumulative effect of a change in the deposit ratio on lending growth as time goes to infinity. However this effect should not be confused with the effect on long-run lending growth, which we constrain to be zero.

[11] Total lending is calculated by adding lending to households (secured and unsecured) and lending to private non-financial corporations (PNFC). If a bank is particularly exposed to lending to PNFCs and there is a negative demand shock specific to this sector we would observe a sharp fall in total lending for this particular bank. To reduce the impact of secoral demand shocks on our estimates we have included a variable calculated as follows as in Ayiar(2011):
$\Delta S_{i,t} = \Delta l(s)_t * (\frac{l(s)_{i,t}}{totlending_{i,t}}) + \Delta l(u_t) * (\frac{l(u)_{i,t}}{totlending_{i,t}}) + \Delta l(p_t) * (\frac{l(p)_{i,t}}{totlending_{i,t}})$
where the changes in sectoral lending are computed by excluding changes in sectoral lending by the bank we are considering.

age.[12] One of the advantages of this study is that our panel dataset allows us to control directly for this factor by including changes in bank-by-bank capital ratios in our baseline regression.

Throughout the paper we are going to treat this panel dataset as a *time-series* panel dataset, as we would expect that our results will be largely determined by the time-series dimension within individual banks. Indeed for changes in total lending and changes in the DA ratio (our key variables), within (individual bank) variance explains almost all total variance (results available on request). This indicates that the cross-section dimension is not likely to contribute much to our estimates.

The relevance of the time-series dimension in the panel dataset may add two potential problems to the estimation process. First, there is the potential problem of the variables being non-stationary, so that the estimated relationships are spurious. But most of the variables we include are specified in terms of first differences, so this is less likely to be a problem.

Second, including the lags of the dependent variable may generate biased estimates.[13] In this case the estimates are consistent as long as there is no autocorrelation of the error terms. The inclusion of lagged dependent and explanatory variables has the effect of reducing the autocorrelation problem, however. In our regressions we have included lagged dependent and lagged exogenous variables, so autocorrelation should not affect the consistency of our estimates.

6 Results

Table 2 shows the estimation results for equation (9) using Fixed Effects (FE) with data for the pre-crisis period up to 2007 Q2. We report our preferred specification which excludes the most statistically insignificant variables, but the main results are robust to including a larger number of lagged variables.[14] We initially excluded the financial crisis period from the sample, as the relationship between the DA ratio and bank lending may have changed during this period. We will investigate this issue later in the section.

The estimated lags of the DA ratio all have a positive sign and are statistically significant.[15] This may suggest that a bank lending channel exists and that QE may potentially have had an effect on bank lending growth. The long-run coefficient suggests that the effect of an increase in the DA ratio

[12] See Minutes of the Monetary Policy Committee Meeting on 4 and 5 March 2009 available at http://www.bankofengland.co.uk/publications/minutes/mpc/pdf/2009/mpc0903.pdf, p. 9 paragraphs 31 and 34.

[13] Some studies (see e.g. Bond (2002), Alessandri and Nelson (2012)) deal with this problem by using the GMM estimator. However, the asymptotic properties of GMM estimators are derived for large N and small T datasets and may not be applicable to our case. Also consistency of the Fixed Effect estimator is not an issue because of the large T. We have therefore used Fixed Effects throughout the paper.

[14] To arrive at the final specification we first estimated a more general specification (with 4 lags for each variable) and then excluded the highly insignificant variables sequentially to arrive at a more parsimonius specification. A fuller explanation of the testing down procedure is available on request.

[15] The DA ratio estimates are similar in magnitude with Pooled OLS (not presented here) and FE, but fixed effects are significant and highly correlated with the regressors, so POLS estimates are not consistent. Therefore, we present only the FE estimates.

has a positive and statistically significant effect on lending growth (Table 3). For a 1pp increase in the DA ratio, quarter on quarter lending growth increases cumulatively by around 0.24pp in the long run.

The first lag of total lending growth is statistically significant, which indicates a certain degree of 'stickiness' of lending growth. Changes in capital have a statistically significant, negative impact on lending growth in the first lag and in the long run. This may be because an increase in capital is costly for the bank (Mayers and Majluf (1984)), which has to adjust lending following the negative profit shock. This does not necessarily contradict there being a positive long-run equilibrium relationship with the level of capital consistent with the bank capital channel, as discussed in Section 2. As expected, the provision ratio is negative and statistically significant, as banks reduce their lending when future losses are likely to be higher, in order to build up their capital buffer and absorb eventual losses. Size has a positive and statistically significant effect on lending growth, so that *ceteris paribus* larger banks have higher lending growth rates than smaller banks. The sectoral demand variable is not statistically significant.

Turning to the estimated impact of the individual macro control variables (not reported in Table 2), real GDP growth and Bank Rate are statistically significant for some lags, but they are not statistically significant in the long run. This is in line with previous research using data on UK banks (for example Francis and Osborne (2009)). On the other hand, changes in equity prices (as measured by the FTSE100) have the expected positive and statistically significant coefficient. This suggests that stronger equity prices are associated with stronger lending growth as firms' market leverage declines and it is less costly for banks to lend.

6.1 Effect of changes in the deposit asset ratio on large and small banks

So far we have discussed results that assume homogeneity of the DA ratio coefficient across large and small banks, i.e. in equation (9) $\gamma_i(L) = \gamma_j(L)$ with $i \neq j$. In this section we discuss the results from relaxing this assumption by letting the coefficients vary between small and large banks.

Understanding heterogeneity in lending responses is very important for public policy purposes, as the major banks account for the dominant share of total lending in the UK banking system. We therefore estimated equation (9) for small and large banks separately using FE (see the second and third columns of Table 2). The large banks' DA ratio coefficients remain positive, but are no longer statistically significant. The long-run effect also remains positive but it not statistically significant (Table 3). In contrast, the DA ratio has a positive and statistically significant effect on small banks in both the short and long run.[16]

[16] However, if we estimate a regression where every explanatory variable is interacted with a dummy for large banks, we cannot reject the hypothesis that the coefficients of large and small banks are the same using an F-test.

Finding heterogeneity between large and small banks is common in the literature and is often used as evidence for the existence of the bank lending channel e.g. Kashyap and Stein (1994, 2000). This is because small banks have limited access to capital markets to raise non-deposit liabilities and therefore a given negative shock to their deposits leads to a sharper reduction in lending than is the case for large banks.

6.2 Has the relationship changed during the crisis?

One possible criticism of using these historical estimates to simulate the effects of QE is that the positive relationship we have found held during a period of relative financial stability. Indeed, other factors during the current financial crisis may have reduced the ability of banks to increase their lending, even as their balance sheets became more liquid. For example, large losses during the financial crisis have reduced banks' capital buffers (i.e. the amount of capital above the minimum capital requirements), constraining new lending even when deposits (and reserves) were increasing due to QE. However, one of the advantages of using panel data is that we can control for changes in capital ratios on a bank-by-bank basis, so that our estimates are less likely to be affected by the effects of the banking crisis. Moreover, our relatively long sample includes periods of financial instability in the early 1990s, which will be incorporated into our econometric estimates.

A simple way to investigate whether the relationship changed during the crisis is to run a FE regression over the full sample which runs to the end of 2010 and check if the positive relationship still holds. More formally, we can include a 'crisis' dummy taking the value of one from 2007 Q3, which marks the beginning of the financial crisis in the UK when Northern Rock received liquidity support from the Bank of England. We can then test whether the DA ratio had a different effect during the crisis by including interaction variables between the deposit ratio and the crisis dummy.

The first three columns of Table 4 compare our pre-crisis model estimates with estimates for the full sample and an additional specification (also estimated over the full sample) that includes the additional 'crisis' dummy and interaction variables (all the models estimated also included all the other variables used in the regressions in Table 2 but these coefficients are not reported for ease of exposition).

The DA ratio coefficients and their significance are little changed when we consider the full sample up to 2010 Q4. But this does not tell us anything specific about the effects of QE during the financial crisis. If the effect of shocks to the DA ratio changed during the financial crisis we would, however, expect the interaction coefficients to be jointly statistically significant (column 3). The interaction terms are negative, which may indicate smaller DA coefficients, but the test for joint significance does not reject that the relationship remained stable even during the financial crisis.

If instead we test for a structural break during the financial crisis using a Chow test, we find

the test does not reject the null of no structural break. However, a variance ratio test rejects the hypothesis that the variances are the same in the two sub-periods and so the Chow test is not strictly valid. So we cannot exclude the possibility that there was a structural break, even though the deposit ratio estimates do not reject the hypothesis that the effect through deposits did not change during the crisis period.

An alternative approach would be to investigate the relationship between the DA ratio and capital *levels* over the full sample up to 2010 Q4 and infer from this relationship what might have happened during the crisis given the large capital losses experienced by UK banks during the financial crisis. If the effect of the DA ratio on lending changes with capital we would expect the interaction terms to be statistically significant, meaning that the effect of DA ratio may have changed during the crisis. The 'capital channel' literature predicts that banks with a higher capital ratio may react more to a given monetary policy shock (Van den Heuvel (2002)).

We therefore reran our baseline regression with a dummy for banks with a capital ratio higher than the sample average (around 15%), which we interacted with the DA ratio (Table 4, last column). The interaction terms are positive and highly statistically significant, suggesting that our overall estimates are driven by the better capitalised institutions. This may be because banks with a higher level of capital ratio have more 'room' for increasing lending following an increase in the DA ratio than lower capitalised banks, in line with the existence of a 'bank capital' channel. Even though this finding does not give a definitive answer on the effect of the DA ratio during the crisis (because the relationship between capital and DA ratio may have changed), these results suggest that the impact of QE might have been somewhat smaller given the capital losses experienced by some major banks.

6.3 Endogeneity of the deposit asset ratio

Until now we have assumed exogeneity of the DA ratio, i.e. that it is not correlated with the error term in equation (9). In this case a change in the DA ratio can be interpreted as having a causal effect on lending growth. However, banks may collect deposits only after they have identified lending opportunities. In this case deposits will be positively correlated with lending, even though more deposits are not *causing* the increase in lending. If the DA ratio is endogenous, our estimated effect of QE on lending could be biased and inconsistent.

If we assume that stronger economic growth is associated with more investment opportunities and vice versa, we can test the investment opportunities hypothesis by running a regression of DA ratio changes on a set of bank specific and macroeconomic variables in line with specification (9). This can be justified by the fact that the DA ratio is both related to bank specific factors (e.g. certain banks will have a structurally higher DA ratio) and to macroeconomic factors (e.g. during a boom the DA ratio declines as banks use alternative forms of financing to expand their balance sheet). If better

investment opportunities lead banks to seek deposits to finance them, we would expect indicators of economic growth to be statistically significant in a regression explaining changes in the DA ratio.

Table 5 shows the coefficients from several variants of this deposit growth regression. Macroeconomic variables that might be correlated with investment opportunities (e.g. GDP growth, changes in stock market prices and Bank of England Bank Rate) are all statistically insignificant.[17] F-tests for joint significance shows that these variables can be removed altogether from the main specification without much loss of explanatory power. This would suggest that any endogeneity issues with our regressions are likely to be limited.

7 Estimating the impact of QE on bank lending

We now use our estimates of the effects of changes in the deposit ratio on lending growth to infer the impact of QE during 2009-10 on UK bank lending. To do so we first need to identify the likely change of bank deposits that resulted from QE. We shall assume as our benchmark that this increase was of the same magnitude as the £200bn of assets purchased during the first phase of the QE programme (i.e. there is a one for one relationship between assets purchased and new deposits created). This is best regarded as an upper bound, as it seems likely that there were a number of offsetting effects, though attempts to estimate these effects are inevitably uncertain.[18]

We base these simulations on the actual time path of gilt purchases by the Bank of England during 2009 and 2010 (assuming that the effects were not anticipated by banks) and estimate the impact on the DA ratio for the average bank using our dataset (Table 6).[19] For example, after the first £15bn of asset purchases, it is assumed that £15bn of new deposits were created in the banking

[17] In a different specification we included BCC (British Chambers of Commerce) weighted manufacturing and services business confidence balances to control for growth expectations. As with the other macroeconomic variables, growth expectations were also not jointly statistically significant.

[18] Bridges and Thomas (2012) consider several factors that may offset the increase in deposits due to QE, including substitution from bank debt to the capital markets by non-financial companies and increased debt and equity issuance by the banking system. Their central assumption is that the £200 billion of asset purchases boosted the stock of broad money by around £122 billion, which would scale down our estimates by 40%.

[19] Note that the impulse response functions were constructed using changes in the aggregate deposit asset ratio. This is not necessarily the same as estimating deposit asset ratio changes for individual banks and then using the averages of these changes to construct the impulse responses. We cannot proceed with the latter approach as we do not know the distribution of QE-created deposits across banks. We therefore assume that:

$$\frac{\sum D_{it}}{\sum A_{it}} - \frac{\sum D_{it-1}}{\sum A_{it-1}} = \frac{\sum(\frac{D_{it}}{A_{it}} - \frac{D_{it-1}}{A_{it-1}})}{n} \tag{10}$$

or, in other words, that the change of the aggregate deposit asset ratio is equal to the average of the changes of this ratio at the individual bank level. With a bit of algebra we can see that this implies:

$$\frac{\sum D_{it}}{\sum A_{it}} - \frac{1}{n}(\sum \frac{D_{it}}{A_{it}}) = \frac{\sum D_{it-1}}{\sum A_{it-1}} - \frac{1}{n}(\sum \frac{D_{it-1}}{A_{it-1}}). \tag{11}$$

This expression is the restriction that we are applying to individual bank changes in the deposit asset ratio. The way to interpret this is that the deviation of the aggregate change from the bank average changes needs to be constant across time.

system and that total assets changed by the same amount. This would imply that the DA ratio increased by around 0.1pp.

We then use these estimated changes in the DA ratio as the 'shock' in our simulation, using our regression estimated over the pre-crisis period reported in Table 2. It is worth noting here the obvious point that we are assuming that the impact of QE on bank lending only comes through deposits. To the extent that QE improved macro and financial conditions and these fed into higher lending this will not be taken into account.

Figure 3 shows the simulation for total lending, where the first asset purchase is assumed to occur in period 5. The effect of QE peaks after around four quarters (median effect around 0.1pp on quarter on quarter lending or 0.4pp quarter on quarter annualised) after the first purchases and the effect fades away around seven quarters after the first asset purchase. In the long run, the cumulative effect on the level of bank lending (derived by cumulating the growth rate effects under the red line) is around 0.3%.

As shown by the confidence bands, these effects are statistically significant, but small. As discussed in Section 5, the size and statistical significance of the DA ratio on bank lending differs for large and small banks. Figure 4 shows the simulations for large and small banks using the estimates in Table 2. Despite being positive and significant, the change in lending of large banks is economically small (confirming our earlier estimates). On the other hand, the lending impulse response for small banks is similar in shape and magnitude to the pooled regression in Figure 3.

Figure 3 suggests that the impact of the QE programme on bank lending is quite limited; the effect at the peak is just above 0.1pp on quarterly growth and 0.3% on the level. But we also suggested in Section 6.2 that the effect of changes in deposits may be stronger for banks with above average capital ratios. This is brought out in Figure 5, which shows that the impact of QE is much larger for better capitalised banks, around 0.5pp at its peak. Put another way, the effects of QE on bank lending would have been substantially larger if banks had been better capitalised.

8 Conclusions

In this paper we investigate the potential effects of QE on bank lending growth using a new and non-publicly available panel dataset on UK banks. So far, the vast majority of research on QE has focused on the impact on economic growth and financial markets using analysis based on aggregate data, while the effect of QE on bank lending has received less attention. This is because policymakers expected QE to affect demand mainly through financial markets, while the effect on bank lending was expected to be small because of banks' incentives to deleverage during the financial crisis. To

our knowledge, this is the first paper to try to quantify the effect of QE on bank lending in the UK using a bank-level panel dataset. Our approach allows us to control for bank specific factors (e.g. shocks to capital) and to test for heterogeneity in the effects of QE on bank lending.

We found that the deposit ratio has a small but statistically significant effect on bank lending growth, which suggests that QE may have led to an increase in bank lending through this channel. These effects, however, are likely to have been limited, both because the estimated marginal effects through deposits are small and also because we assumed there was a full pass-through from QE to deposits, which seems likely to overstate the impact. We also found no evidence that the impact from deposits increased during the QE period. Our analysis suggested that the effects on bank lending were heterogeneous across banks, as we found lending by small banks to be more responsive to changes in the level of deposits. We also found evidence that bank lending is positively related to how well capitalised banks are, suggesting that the impact of QE on bank lending may have been weaker because of the lower levels of capital during the crisis. In a sense, this is to be expected and justifies the emphasis policymakers gave to QE going round the banks. At the same time, it suggests that macroprudential policy may potentially influence the effectiveness of monetary policy.

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Table 1. Description of the main variables (1989Q2-2010Q4)

	Obs	Mean	Std. Dev.	Min	Max
All banks					
Total lending growth (%)	3336	1.8	8.5	-23.1	34.8
Capital ratio (%)	2777	15.1	5.4	10.2	42.0
Provision ratio (%)	3945	0.3	1.0	-2.5	15.5
Capital buffer change (pp)	2361	0.0	1.3	-16.0	17.2
Change in deposit ratio (pp)	3578	-0.2	4.3	-36.9	43.9
Large banks					
Total lending growth (%)	473	1.8	3.3	-15.5	28.3
Capital ratio (%)	527	11.9	1.3	10.2	17.1
Provision ratio (%)	725	0.3	0.3	0.0	3.1
Capital buffer change (pp)	470	0.0	0.4	-2.8	1.6
Change in deposit ratio (pp)	476	-0.2	2.5	-8.5	11.8
Small banks					
Total lending growth (%)	2863	1.8	9.0	-23.1	34.8
Capital ratio (%)	2250	15.8	5.7	10.2	42.0
Provision ratio (%)	3220	0.3	1.1	-2.5	15.5
Capital buffer change (pp)	1891	0.0	1.4	-16.0	17.2
Change in deposit ratio (pp)	3102	-0.2	4.6	-36.9	43.9

Notes: The table shows descriptive statistics from our panel dataset, which is unbalanced as each time series is discontinued after mergers and failures. As a result the sample is much larger than the number of institutions.

Table 2. Total lending growth regressions

	All banks	Small banks	Large banks
Lending growth (-1)	-0.114***	-0.120***	-0.0935
	(0.0290)	(0.0324)	(0.0667)
Lending growth (-2)	-0.0176	-0.0224	-0.00506
	(0.0281)	(0.0310)	(0.0780)
Lending growth (-3)	0.0383	0.0346	0.0625
	(0.0285)	(0.0315)	(0.0774)
Lending growth (-4)	-0.0350	-0.0417	0.146*
	(0.0291)	(0.0322)	(0.0768)
ΔCap. ratio (-1)	-0.677***	-0.696***	-0.629
	(0.209)	(0.235)	(0.429)
ΔCap. ratio (-2)	-0.275	-0.346	0.695
	(0.204)	(0.228)	(0.481)
ΔDA ratio (-2)	0.138**	0.161*	0.0655
	(0.0685)	(0.0826)	(0.0843)
ΔDA ratio (-3)	0.132*	0.144*	0.131
	(0.0689)	(0.0825)	(0.0879)
Sectoral demand	2.810	5.969**	-0.137
	(1.844)	(2.879)	(1.311)
Provision ratio (-2)	-1.567**	-1.485*	-2.238*
	(0.720)	(0.822)	(1.348)
Bank size	1.339**	1.599**	0.150
	(0.541)	(0.640)	(0.728)
Macro controls	Yes	Yes	Yes
Constant	-11.20*	-13.29*	2.296
	(6.038)	(6.827)	(9.523)
Observations	1,394	1,128	266
R-squared	0.049	0.057	0.093
Number of banks	50	39	11

Notes: This table reports fixed effects regression estimates of equation (9) over sample period 1990Q2-2007Q2. The equations shown were tested down from more general specifications that included four lags of each regressor. The macro control variables included were GDP growth, equity returns (FTSE 100), the unemployment rate and Bank Rate. Standard errors are shown in parentheses and ***, ** and * denote significance at the 1%, 5% and 10% levels respectively.

Table 3. Long-run coefficients from total lending regressions

	Coefficient	Standard error	T value	P>t	95% Confidence interval	
All banks						
ΔDA ratio	0.24	0.10	2.43	0.02	0.05	0.43
ΔCapital ratio	-0.84	0.23	-3.66	0.00	-1.30	-0.39
GDP growth	1.04	0.73	1.42	0.16	-0.40	2.47
Bank Rate	0.04	0.13	0.31	0.76	-0.21	0.30
Equity returns	0.03	0.02	1.75	0.08	-0.004	0.07
Small banks						
ΔDA ratio	0.27	0.11	2.33	0.02	0.04	0.49
ΔCapital ratio	-0.91	0.25	-3.59	0.00	-1.40	-0.41
GDP growth	1.59	0.87	1.82	0.07	-0.12	3.30
Bank Rate	0.04	0.15	0.29	0.77	-0.26	0.35
Equity returns	0.04	0.02	1.56	0.12	-0.009	0.081
Large banks						
ΔDA ratio	0.22	0.17	1.28	0.20	-0.12	0.56
ΔCapital ratio	0.07	0.65	0.11	0.91	-1.20	1.35
GDP growth	-1.27	1.14	-1.12	0.27	-3.52	0.97
Bank Rate	-0.18	0.20	-0.90	0.37	-0.58	0.22
Equity returns	0.005	0.029	0.17	0.86	-0.05	0.06

Notes: This table shows the long-run coefficients derived from the estimates in Table 2.

Table 4. Relationship between total lending growth and changes in the deposit asset ratio during the crisis period

	Sample: 1990Q2-2007Q2	**Sample: 1990Q2-2010Q4**	**Sample: 1990Q2-2010Q4**	**Sample: 1990Q2-2010Q4**
ΔDA ratio (-2)	0.138**	0.123**	0.157**	-0.120
	(0.0685)	(0.0617)	(0.0667)	(0.0790)
ΔDA ratio (-3)	0.132*	0.127**	0.145**	-0.137*
	(0.0689)	(0.0625)	(0.0671)	(0.0785)
Crisis			-0.280	
			(0.729)	
Crisis*ΔDA ratio (-2)			-0.254	
			(0.176)	
Crisis*ΔDA ratio (-3)			-0.179	
			(0.177)	
High capital				-0.360
				(0.595)
High cap*ΔDA ratio (-2)				0.595***
				(0.128)
High cap*ΔDA ratio (-3)				0.676***
				(0.129)

Notes: The estimated equations shown also included all the other regressors reported in Table 2. Standard errors are shown in parentheses and ***, ** and * denote significance at the 1%, 5% and 10% levels respectively.

Table 5. Deposit asset ratio regressions

	1.	2.	3.	4.
ΔDA ratio (-1)	-0.282***	-0.285***	-0.281***	-0.280***
ΔDA ratio (-2)	-0.0482*	-0.0446*	-0.0413	-0.0410
ΔDA ratio (-3)	-0.0858***	-0.0874***	-0.0862***	-0.0853***
ΔDA ratio (-4)	0.121***	0.123***	0.123***	0.123***
ΔCap. ratio (-1)	0.381***	0.381***	0.379***	0.374***
ΔCap. ratio (-2)	0.209**	0.207**	0.203**	0.208**
ΔCap. ratio (-3)	-0.0473	-0.0466	-0.0445	-0.0465
ΔCap. ratio (-4)	0.216**	0.223***	0.223***	0.223***
Crisis	0.905**	0.958***	0.970***	1.033***
Provision ratio (-2)	0.183	0.182	0.234	0.244
Bank size	-0.0683	-0.0349	-0.261	-0.275
Equity returns (-1)	-0.0173*			
Equity returns (-2)	0.0116			
Equity returns (-3)	-0.000581			
Equity returns (-4)	0.0118			
Unemployment	-0.152*	-0.148*	-0.134*	-0.139*
GDP growth (-1)	-0.114	-0.0981	-0.126	
GDP growth (-2)	-0.0215	-0.00904	-0.0711	
GDP growth (-3)	0.0161	0.155	0.195	
GDP growth (-4)	-0.0371	-0.108	-0.0585	
Bank Rate (-1)	0.0829	0.0788		
Bank Rate (-2)	0.129	0.199		
Bank Rate (-3)	-0.177	-0.273		
Bank Rate (-4)	0.0958	0.137		
Constant	0.652	0.192	3.029	3.150
Observations	1,729	1,729	1,729	1,729
R-squared	0.127	0.124	0.120	0.120
Number of banks	52	52	52	52

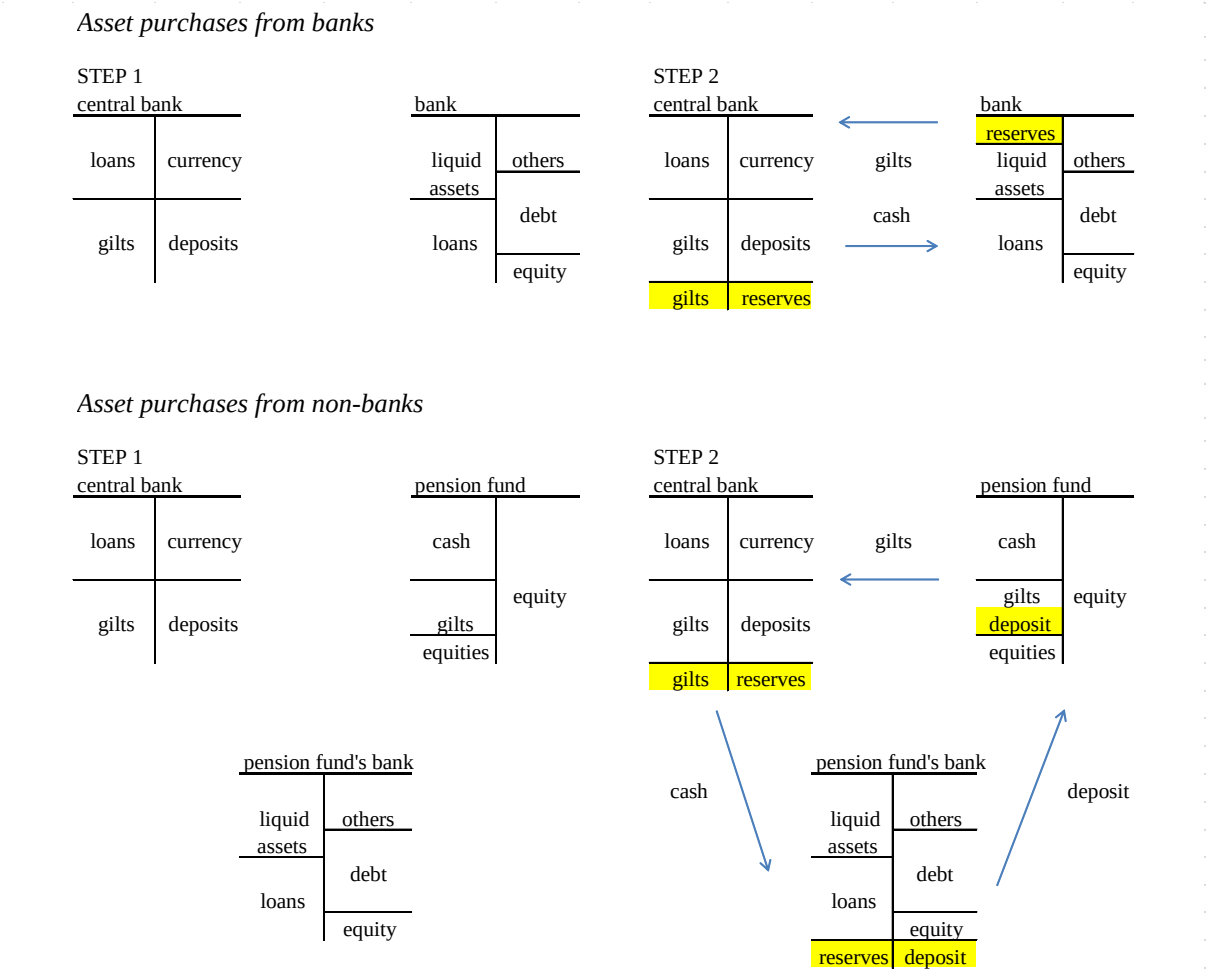
Notes: This table reports fixed effects regression estimates from equations explaining the deposit asset ratio over the sample period 1990Q2-2010Q4. Standard errors are shown in parentheses and ***, ** and * denote significance at the 1%, 5% and 10% levels respectively.

Table 6 Asset purchases and their impact on the deposit asset ratio

Date	Total purchases (£bn)	Total deposits (£bn)	Total assets (£bn)	Ratio (per cent)	Change (pp)
Q4 2008	0.0	3300.9	5455.3	60.5	
Q1 2009	15.5	3316.3	5470.8	60.6	0.1
Q2 2009	84.4	3400.7	5555.2	61.2	0.6
Q3 2009	56.1	3456.8	5611.3	61.6	0.4
Q4 2009	32.1	3488.9	5643.4	61.8	0.2
Q1 2010	9.6	3498.5	5653.0	61.9	0.1

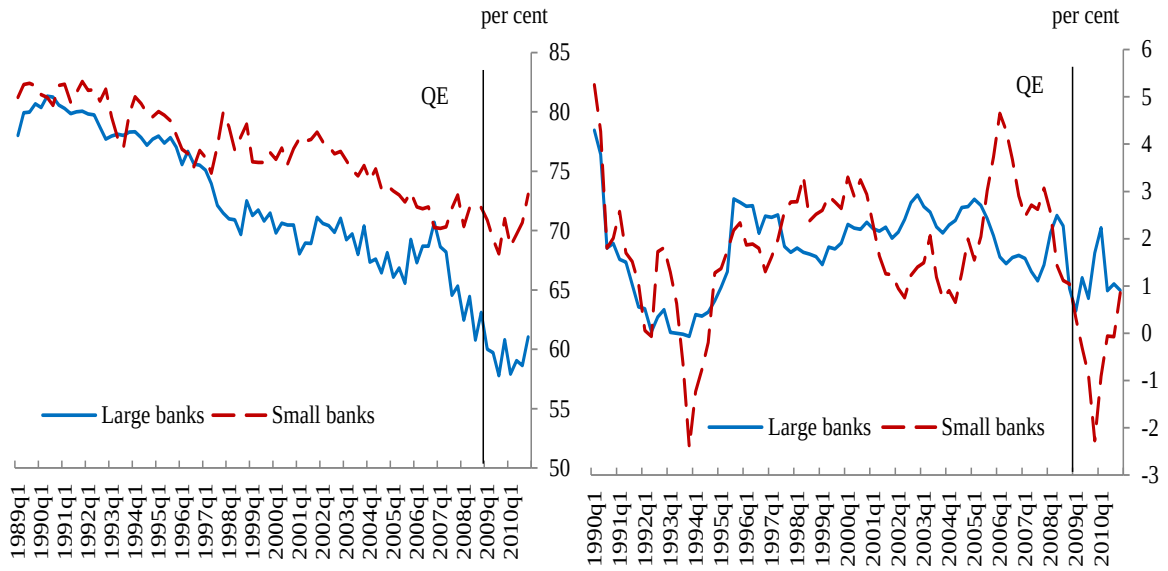
Notes: This table illustrates how the impact of QE purchases on the deposit asset ratio is quantified in each period.

Figure 1. Effects of QE on banks' balance sheets



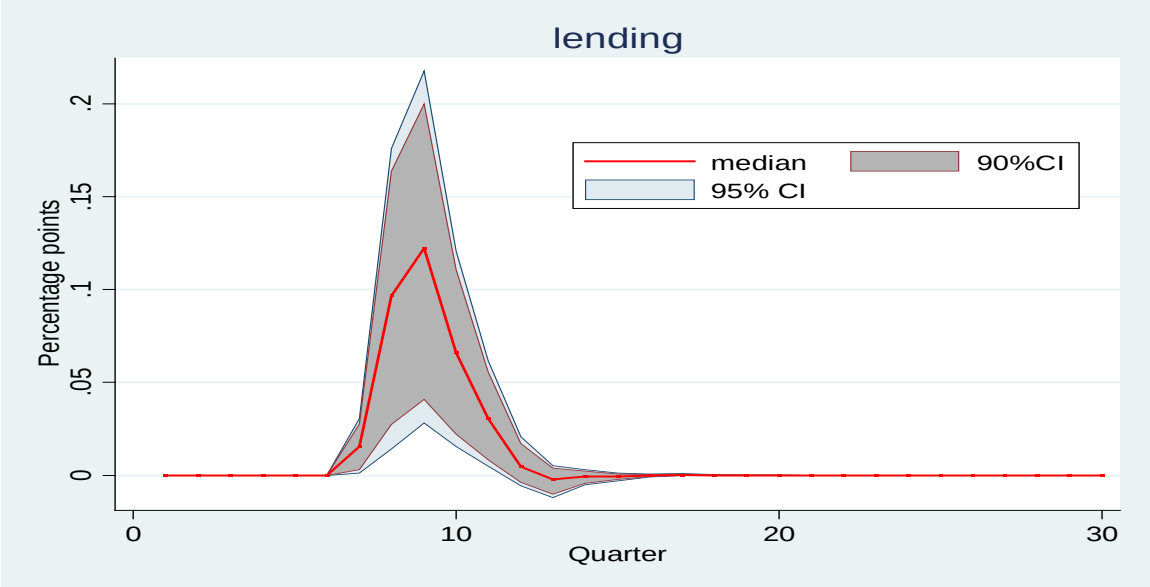
Notes: The upper panel of this figure shows the initial impact on the balance sheets of the central bank and the commercial bank when the central bank purchases gilts from the commercial bank. The lower panel shows the initial impact on the balance sheets of the central bank, the pension fund and the pension fund's bank when the central bank purchases gilts from the pension fund. The figure abstracts from the fact that the Bank of England's asset purchases were made through a separate legal entity, the Bank of England Asset Purchase Facility.

Figure 2. Deposit over assets ratio and total lending growth for large and small banks



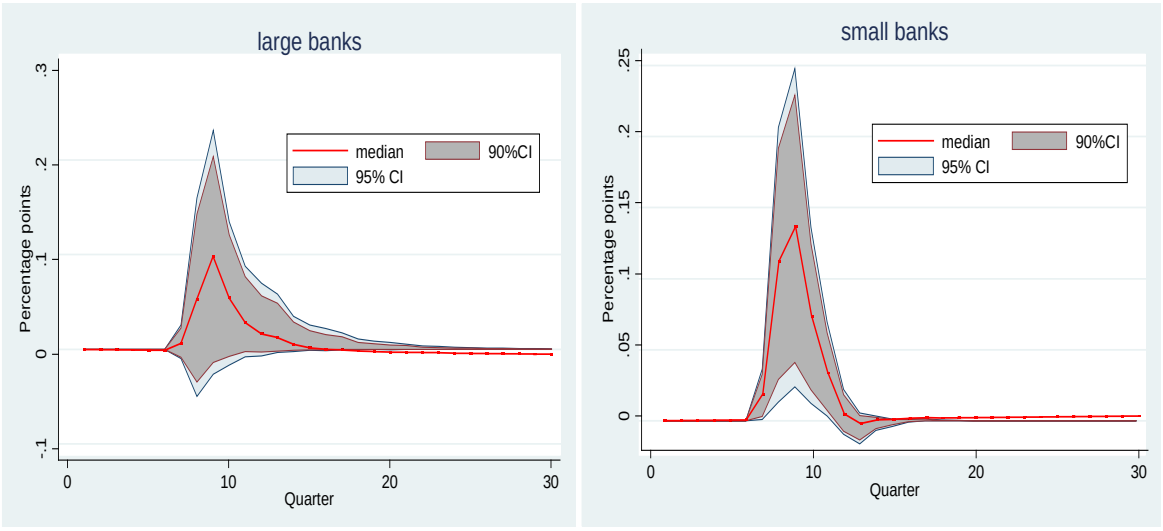
Notes: The left-hand panel of the figure shows the deposits over assets ratio separately for large and small banks. The right-hand panel of the figure shows quarterly total lending growth separately for large and small banks. Large banks are defined as those banks that are in the top 5 according to the size of their total assets in each quarter.

Figure 3. Bank lending following a £200bn increase in deposits



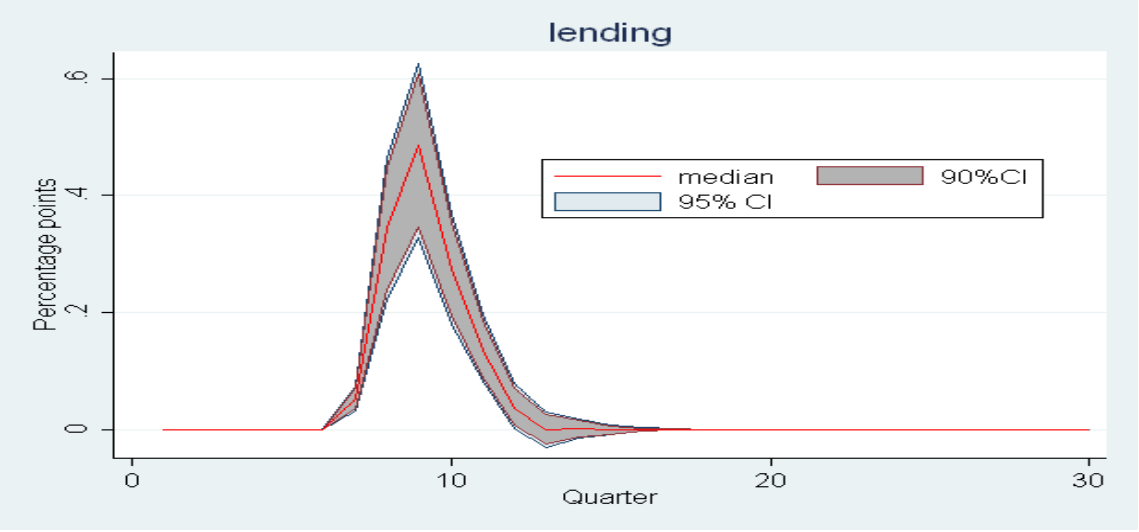
Notes: The figure shows a simulation of the impact of QE1 on total bank lending using the regression estimates in Table 2, assuming QE translates one for one into higher deposits. The first asset purchase is assumed to occur in period 5. The confidence intervals around the simulation were derived by Monte Carlo methods.

Figure 4. Bank lending for large and small banks following a £200bn increase in deposits



Notes: The figure shows simulations of the impact of QE1 on the total lending of large and small banks using the regression estimates in Table 2. The simulations assume that QE translates one for one into higher deposits, which affect large and small banks' deposits equi-proportionately. The first asset purchase is assumed to occur in period 5. The confidence intervals around the simulation were derived by Monte Carlo methods.

Figure 5. Bank lending for highly capitalised banks following a £200bn increase in deposits



Notes: The figure shows a simulation of the impact of QE1 on the total lending of better capitalised banks (defined as those with capital ratios above the sample average), using the regression estimates reported in the final column of Table 4, assuming QE translates one for one into higher deposits. The first asset purchase is assumed to occur in period 5. The confidence intervals around the simulation were derived by Monte Carlo methods.