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The impact of QE on the UK economy — some supportive monetarist arithmetic

Jonathan Bridges and Ryland Thomas

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Abstract

This paper uses a simple money demand and supply framework to estimate the impact of quantitative easing (QE) on asset prices and nominal spending. We use standard money accounting to try to establish the impact of asset purchases on broad money holdings. We show that the initial impact of £200 billion of asset purchases on the money supply was partially offset by other 'shocks' to the money supply. Some of these offsets may have been the indirect result of QE. Our central case estimate is that QE boosted the broad money supply by £122 billion or 8%. We apply our estimates of the impact of QE on the money supply to a set of 'monetarist' econometric models that articulate the extent to which asset prices and spending need to adjust to make the demand for money consistent with the increased broad money supply associated with QE. Our preferred, central case estimate is that an 8% increase in money holdings may have pushed down on yields by an average of around 150 basis points in 2010 and increased asset values by approximately 20%. This in turn would have had a peak impact on output of 2% by the start of 2011, with an impact on inflation of 1 percentage point around a year later. These estimates are necessarily uncertain and we show the sensitivity of our results to different assumptions about the size of the shock to the money supply and the nature of the transmission mechanism.

Key words: Quantitative easing, money demand, monetary policy.

JEL classification: C11, C32, E52, E58.

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Summary

In response to the intensification of the financial crisis and the onset of recession in 2008, the Monetary Policy Committee (MPC) loosened policy significantly. By March 2009 Bank Rate had been cut to just 0.5%, but the MPC judged that further stimulus was required. It was decided that the best way to loosen monetary policy further was to undertake a programme of asset purchases, financed by central bank money, known as quantitative easing (QE). Around £200 billion of assets, mainly government securities, were bought between March 2009 and February 2010. The ultimate aim of QE was to stimulate demand via a lower cost of external finance and stronger asset prices, and thus to bring about higher output growth and offset deflationary pressures. This was an exceptional policy response, in the face of a severe recession and it was therefore uncertain what the precise effects would be. The Bank of England has explored the impact of QE in a number of different ways. This particular paper does so by adopting an explicitly monetarist perspective.

In order to do this, a simple money demand and supply framework is used to estimate the impact of QE. Many papers have looked at the impact of QE by undertaking event studies of asset price movements, either on impact or over the QE period. Other studies have taken these financial market impacts and then looked at the effect of these on the macroeconomy. The role of asset quantities and the money supply in the QE transmission mechanism is often implicit or left in the background in these studies. But the hypothesised transmission mechanism of QE, at least as implemented in the United Kingdom, can be viewed within a monetarist framework, provided that money is broadly defined and that sectoral differences in money demand behaviour are taken into account.

First, standard money accounting is used to try to establish the impact of asset purchases on broad money holdings. In other words we ask: how big was the money supply shock resulting from QE? We show that the initial impact of £200 billion of asset purchases on the money supply was offset by other 'shocks' to the money supply, most notably the substitution from bank debt to the capital markets by non-financial companies and increased debt and equity issuance by the banking system. Some of these offsetting shocks may have been, at least partially, a by-product of QE. We estimate that QE boosted the broad money supply by at least 5% and potentially by as much as 13%, depending on the extent to which the offsetting shocks would have occurred in its absence. By making a comparison with reasonable counterfactuals for these offsetting factors, our central case assumption is that the £200 billion of purchases boosted the stock of broad money by around £122 billion or 8%.

Next, our estimates of the impact of QE on the money supply are applied to a set of 'monetarist' econometric models that articulate the extent to which asset prices and spending need to adjust to make the demand for money consistent with the boost to the broad money supply. We first look at an aggregate model. The long-run ('co-integrated') relationships in this model are pinned down by the theoretical determinants of the demand for money. In order to explore the dynamics of the model, we use an approach known as a structural vector autoregression (SVAR) to estimate a system of equations, where each equation includes lagged values of all the variables examined. 'Structural' here means that we attempt to identify the economic causes, or

'shocks', that have buffeted the system, which is done using restrictions implied by economic theory. We introduce a QE-like shock into this system and observe how the aggregate variables in the system might have to evolve to restore monetary equilibrium.

Alongside our aggregate model, we also perform a similar experiment on a set of sectoral money demand systems. In these systems the money holdings of a particular sector are modelled jointly with other relevant sectoral variables, such as asset prices in the case of the financial company sector and consumption and investment in the case of the household and corporate sectors. The sectoral approach is particularly informative given that previous research has suggested that the linkages between money, asset prices and spending have tended to be clearer at a sectoral level in the UK data. Moreover, focusing on each sector in turn allows for a richer investigation of the transmission mechanism of asset purchases, given that QE is likely to have impacted the money holdings of different sectors differently and with different lags. In order to establish an economy-wide impact from this sectoral approach, we glue our sectoral models together with a number of aggregate assumptions. This offers a useful insight into how QE works, by allowing us to trace out the QE transmission mechanism from the initial increase in financial sector money holdings all the way through to the ultimate impact on GDP and inflation.

Using our preferred sectoral approach, we obtain a central case estimate that an 8% increase in money holdings may have pushed down on yields by an average of around 150 basis points over the QE period and increased asset values by approximately 20%, relative to what would otherwise have been the case. In turn, these effects may have had a peak impact on the level of real GDP of 2% by the middle of 2011, with an impact on inflation of 1 percentage point around a year later. These estimates are necessarily uncertain and we show the sensitivity of our results to different assumptions about the size of the shock to the money supply and the nature of the transmission mechanism. But taking a mean response across all of our aggregate and sectoral specifications, we obtain similar macroeconomic effects to those derived from our preferred specification.

We do not wish to claim too much from the empirical results, given the models we use are estimated over periods that have not, for the large part, been subject to money supply shocks of a similar nature to QE. And, given the way we work out the size of the money supply shock and apply it to our models, it would probably be best to describe our results as a set of illustrative 'arithmetic' calculations rather than precise statistical estimates. Nevertheless, we can use the results to get some idea of what the counterfactual path of the economy would have looked like in the absence of QE. We show that once the QE 'footprint' is removed from the data, the counterfactual path of money growth and velocity looks more similar to the experience in the 1990s recession than would otherwise seem the case. We also show that, in the absence of QE, the growth rates of asset prices and GDP would have been notably weaker in 2009 and 2010.

1 Introduction

In March 2009, the Bank of England's Monetary Policy Committee embarked on quantitative easing (QE) – a policy of purchasing assets, financed by central bank reserves, in an attempt to boost nominal spending in the UK economy. By the time the Committee decided on a pause in the policy in February 2010, around £200 billion of assets had been purchased, predominantly gilt-edged securities (gilts). The aim of the policy was to induce a rebalancing of portfolios by the private sector. In short, asset purchases should lead to an increase in the prices of government bonds and other close substitutes and a fall in their yields. In turn, the implied rise in the value of portfolios and the lower cost of external finance should lead to a boost in consumption and investment spending in the economy.

This paper examines the evidence on the impact of QE from a monetarist perspective. By this we mean that the portfolio rebalancing induced by QE, and its subsequent impact on the broader economy, is examined through the prism of money supply and demand analysis. Many papers have looked at the impact of QE by undertaking event studies of asset price movements either on impact or over the QE period (see, for example, Gagnon *et al* (2010) and Joyce *et al* (2010)). Other studies have taken these financial market impacts and looked at the effect of these on the macroeconomy (see Baumeister and Benati (2010) and Kapetanios *et al* (2012)). In most of these papers, the role of asset quantities and the money supply in the QE transmission mechanism is in the background. But the hypothesised transmission mechanism of QE, at least as implemented in the United Kingdom, leads to several monetarist predictions that should be testable in the data. Indeed, the historically unique nature of asset purchases means that if ever the role of the money supply is likely to be relevant and a visible influence on the transmission mechanism, it is now.

In this paper we focus on the implications of QE for the supply and demand of *broad* rather than narrow money. A textbook analysis of QE in terms of its impact on the money supply might suggest analysing the reserves created on the asset side of banks' balance sheets and on the implication that this might have for banks' lending decisions and/or the public sector intertemporal budget constraint. But a stated aim of asset purchases in the United Kingdom was to purchase gilts from the non-bank private sector, so that the initial counterpart to increased reserves on the asset side of banks' balance sheets would be an increase in banks' deposit liabilities, rather than an offsetting fall in banks' liquid asset holdings. The deposit liabilities created would, in the first instance, be held by asset managers and other financial companies – the most likely sellers of gilts. So the portfolio substitution channel can be viewed in monetarist terms as the response of financial companies to an increase in their broad money holdings. Barring any leakages, for money demand to be consistent with a higher broad money supply, the prices and yields of non-monetary assets would need to change, so that financial companies were willing, in aggregate, to hold a higher stock of deposits.

An additional dimension to our approach is that we also consider how the *sectoral* pattern of money holdings and spending might evolve as the transmission mechanism of asset purchases unfolds. As households and companies respond to lower yields and higher asset prices by increasing their spending, that should raise the demand for money by these sectors. In the

absence of additional money creation through an increase in the provision of credit, that must imply a transfer of money holdings away from financial companies to households and corporates. In the case of corporates, this money transfer must be facilitated by capital market issuance purchased by the financial company sector; whilst money transfer to the household sector must occur through their liquidation of investments with financial companies. Given this sectoral dimension, it is important to consider the distribution of money holdings over time and not just the total quantity, when analysing the impact of QE in the United Kingdom.

Finally, we would describe our approach as more of a monetarist arithmetic exercise rather than an econometric one. Other papers apply a far more rigorous econometric approach to estimating the impact of QE than we attempt in this paper (see for example, Kapetanios *et al* (2012)). In particular, we first use money accounting techniques to estimate the size of the money supply shock induced by QE. We then use econometric estimates of money demand systems (both aggregate and sectoral) to work out what would need to happen to asset prices and nominal spending to make money demand consistent with the QE shock, and over what horizon. We then use these impacts to shed light on three testable monetarist predictions of QE:

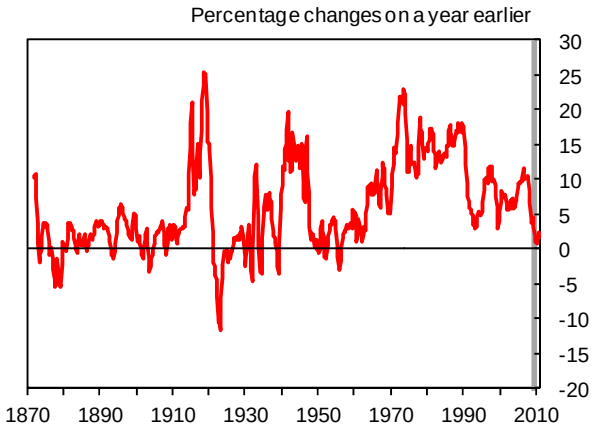
(i) Broad money growth should be stronger relative to some reasonable counterfactual, given the scale of asset purchases in the 2009 and 2010 period. In other words, there should have been a sizable shock to the money supply.

(ii) Broad money and real asset prices should rise relative to nominal spending in the short-run, but then fall back over time as QE impacts on nominal spending. So the velocity of circulation should exhibit a 'V' shape and real asset prices may appear to overshoot simple metrics of their fundamental value. The exchange rate might be one of those asset prices should financial companies try to buy foreign currency denominated assets.

(iii) The share of money holdings attributable to financial companies should initially rise relative to the household and non-financial corporate sectors. But over time this share should fall back as companies and households respond to higher asset prices by increasing their spending.

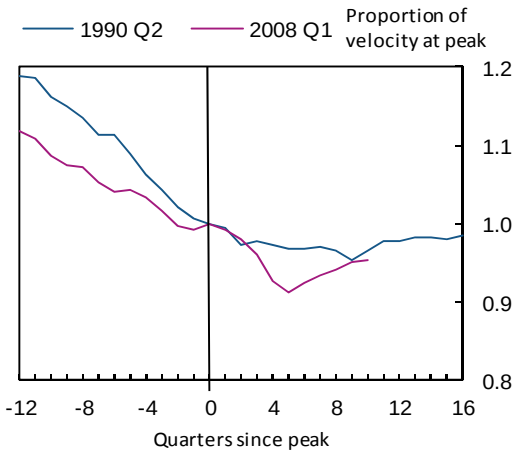
Charts 1 to 4 offer a cursory glance at these three predictions. Broad money growth during 2009 and 2010 was the weakest for some 50 years. That might suggest that QE was unable to prevent a large slowdown in the growth of the broad money supply. On the other hand, Charts 2 and 3 appear to show signs of a QE footprint. Broad money velocity did indeed show a V-shape in 2009 and 2010, a feature absent in the previous recession. And there was a noticeable sectoral shift in money holdings that was subsequently reversed, as suggested by the theory. Chart 4 shows that real asset prices also picked up noticeably relative to GDP in the immediate period following QE, although an overshoot story is not apparent. And, although the exchange rate depreciated substantially prior to QE, it was relatively stable during the QE period and has remained broadly flat since.

Chart 1: Broad money growth since 1870[(a)]



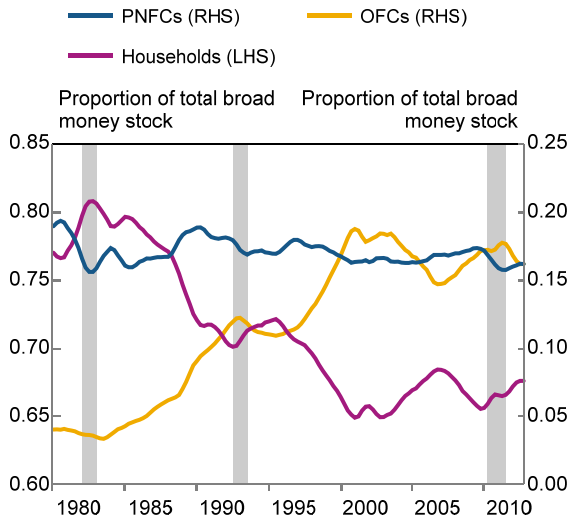
Sources: Capie and Webber (1985) and Bank of England, see Hills *et al* (2010). In this and subsequent charts the shaded area covers the QE period 2009 Q1 to 2010 Q1 unless otherwise stated.
(a) M3 up to 1963, M4 1963-98, M4 excluding intermediate 'other financial corporations' (OFCs) 1998-2010.

Chart 2: Broad money velocity compared to the 1990s[(a)]



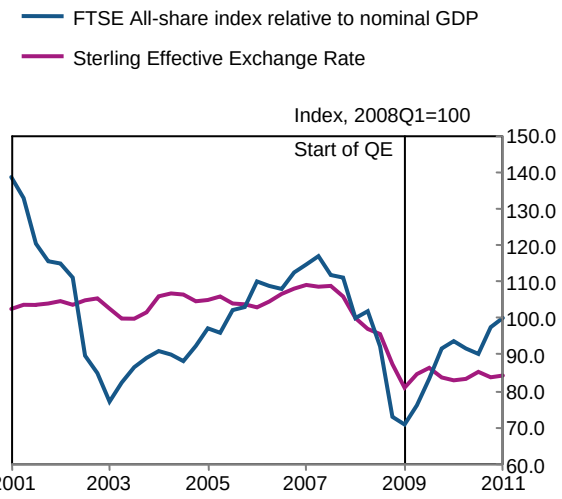
Source: Bank of England.
(a) Broad money velocity scaled to unit value in the quarter before the start of recession – that is 1990 Q2 and 2008 Q1 respectively.

Chart 3: Sectoral shares of the broad money stock[(a)(b)(c)]



(a) Recession periods are shown in grey. (b) Shares based on four-quarter moving average of the break-adjusted stocks. (c) Money shares calculated excluding the holdings of intermediate OFCs where available.

Chart 4: Equity prices and the exchange rate



Sources: ONS and Bank of England.

The fact that some but not all of our monetarist predictions are apparent from a superficial look at the data warrants a deeper counterfactual analysis of the economy. This is what we attempt in this paper.

The paper is divided into five sections. Section 2 provides a brief overview of the monetarist framework within which we analyse the impact of QE. In Section 3, we estimate a range for the impact of QE on broad money holdings or – put in crude monetarist terms – the size of the 'money supply shock.' We also discuss the reasons why, in absolute terms, money was weak

over the QE period. In Section 4, we apply the estimated money shock to a set of macroeconometric models developed at the Bank of England, both aggregate and sectoral. In these models, money plays an important empirical role and the equilibration of money demand and supply is explicitly built into the structure. We use these models to construct estimates of the impact of QE on asset prices and nominal spending. In Section 5, we summarise our findings and compare our results to estimates of the impact of QE based on financial market data alone. We then show the counterfactual path that the economy may have followed in the absence of QE.

2 Fitting QE into a monetarist framework

There are a number of frameworks which could be used to analyse the impact of QE. Some of the key papers in the various strands of the literature are summarised in Table 1. First, there is the original literature that examined the role of money and portfolio effects in a general framework, where all assets are assumed to be imperfect substitutes, see for example Tobin (1969) and Brunner and Meltzer (1987). The adjustment of financial yields to a discrepancy between actual money holdings and the long-run demand for money also featured extensively in the subsequent buffer stock money literature (see Laidler (1984) and Laidler and Robson (1995)), as well as in the applied economics of many UK economists, most notably Congdon (1992) and (2005). The post-Keynesian literature also heavily debated the role of money (see Kaldor and Trevithick (1981), Moore (1988) and Howells (1995)).

This older literature did not however use explicitly micro-founded models to examine the role of money and monetary policy. The recent New Keynesian literature, which has strongly advocated a micro-founded or DSGE (dynamic stochastic general equilibrium) approach, has generally taken a sceptical view about the efficacy of unconventional monetary policies such as QE. This applies even when assets are assumed to be imperfect substitutes (see, for example, Eggertsson and Woodford (2003), Curdia and Woodford (2010)). But it is fair to say that there is not yet a generally accepted way of integrating money (and especially broad money) into a current generation DSGE macroeconomic model and the research frontier continues to progress. For example, Andrés *et al* (2004) and Harrison (2012) have developed microfoundations for preferred-habitats and portfolio balance effects in an otherwise standard New Keynesian framework, and find a role for QE as an effective tool of monetary policy. Other approaches have also been advocated for introducing money and credit into DSGE models (such as Goodfriend (2004), De Santis *et al* (2008), Brunnermeier and Sannikov (2010), Khan and Thomas (2010)),[1] which may also provide channels through which QE might be effective.

Given the current state of flux in monetary economics, an empirical analysis of the impact of QE necessarily implies an eclectic approach, drawing on the various strands of literature outlined above where possible. The next section provides an overview of the simple analytical framework we use in this paper for investigating the impact of QE. Our framework is, to all intents and purposes, explicitly monetarist in its nature. It emphasises the role of asset prices

[1] There is certainly not an accepted way of introducing the idea of buffer stock money into a standard DSGE model given that the theory would suggest having to model different classes of heterogeneous agents who carry out transactions in a set of sequential markets.

and nominal spending in bridging a discrepancy, possibly incipient, between the supply of money and the demand for money. We outline the different factors affecting money supply and demand and consider the mechanisms through which the literature suggests that money supply and demand are made equal. We then use this framework to articulate the channels through which central bank asset purchases are likely to work.

Table 1: Key papers on the role of money in the transmission mechanism

- **Recent literature**
  - New Keynesian perspective: Eggertsson and Woodford (2003), Curdia and Woodford (2010)
  - New approaches: Goodfriend (2004), De Santis *et al* (2008), Brunnermeier and Sannikov (2010), Khan and Thomas (2010), Andrés *et al* (2004), Harrison (2012)

- **Older literature**
  - Aftermath of the general theory, loanable funds and the finance constraint: Ohlin (1937), Robertson (1940), Tsiang (1956,1980), Clower (1967)
  - Asset imperfect substitutability: Tobin (1969), Brunner and Meltzer (1987)
  - Buffer-stock money: Laidler (1984)

- **Alternative academic literature**
  - Micro-founded models of money: Kiyotaki and Moore (2002)
  - Post-Keynesian endogenous money: Kaldor and Trevithick (1981), Moore (1988), Howells (1995)
  - Circuitist theory: Rochon and Rossi (2003)
  - UK broad monetarism: for example, Congdon (1992)
  - Flow of funds modelling: Godley and Lavoie (2006)

2.1 An overview of the monetarist framework used

A textbook treatment of the impact of QE might focus on the narrow money created by asset purchases – either cash or (non interest bearing) commercial bank reserves. One argument against the efficacy of asset purchases in this simple case is that as the zero lower bound on interest rates is reached, such non interest bearing money becomes a perfect substitute for other interest-bearing assets such as one-period bonds. This is the initial leg of the 'irrelevance proposition' of Eggertsson and Woodford (2003). But a stated aim of asset purchases in the United Kingdom was to purchase gilts from the non-bank private sector, financed by interest-bearing central bank reserves. So QE, as practised in the United Kingdom, involved an expansion of commercial banks' balance sheets, with an increase in interest-bearing reserves on the asset side and an increase in interest-bearing bank deposits (or broad money) on the liabilities side. The implication is that a monetarist analysis of QE should also be viewed in terms of the supply and demand functions for broad money, which are likely to have very different determinants to their narrow money counterparts. This may imply a different impact

than the simple transaction of cash in exchange for one-period bonds that is often analysed in a simple New Keynesian model. It is useful to consider the determinants of broad money supply and demand in more detail.

The *supply* of broad money in a financially developed economy such as the United Kingdom is determined by transactions between the banking sector (including the central bank) and the non-bank private sector. The most important of these transactions historically has been the provision of credit by the banking sector to the non-bank private sector. When a bank or building society makes a loan to a household or company, it automatically creates a deposit – either for the borrower, or for the recipient of the borrowers' expenditure if the loan is spent immediately (as in the case of purchasing a house, spending on a credit card or drawing on an overdraft facility). More generally, any transaction between the banking sector and the non-bank private sector will involve the creation or destruction of banking sector deposits and will thus affect the supply of broad money. For example, paying out dividends will create money when a bank credits shareholders' accounts with a deposit. And issuance of bank long-term debt or equity will destroy money as asset managers purchase the instruments using their deposits.

The *demand* for broad money can be understood in terms of its two uses in the economy: first, it is used as a means of carrying out and settling transactions – its 'medium of exchange' role; second, it is also held as a financial asset in household and company portfolios – its 'store of value' role. So the demand for money is likely to depend on:

> (a) the value of transactions in the economy – nominal spending on goods and services and the value of asset transactions.
>
> (b) the overall value of asset portfolios – households and companies would be expected, other things equal, to hold a certain share of their portfolio in money;
>
> (c) the relative rate of return on money – the yield on money (deposits) compared to other assets will determine the share of the portfolio that households and companies choose to hold in money. These alternative assets include longer-term financial assets such as gilts and equities but also potentially real assets such as consumer durables. The responsiveness of the demand for money to the relative rate of return on money will depend on the substitutability between money and other assets. Money might be a highly imperfect substitute for other assets because of various frictions, costs and degrees of market segmentation as discussed for example in Goodfriend (2004) and Andrés *et al* (2004).

Given these influences on the supply of and demand for money, it is useful to consider the mechanism through which supply and demand are made consistent. If a set of transactions between the banking sector and non-bank private sector leads to a net increase in the supply of money, then one of the determinants of the demand for money – nominal spending, the value of portfolios or relative rates of return – must also move in order for households and companies to be willing to hold more money; or another of the determinants of supply must fall to offset these transactions. Similarly, if there is a rise in the demand for money by households or companies

then something must change to induce the banking sector to increase the money supply by lending more to those households and companies; or alternatively one of the other determinants of money demand must change to offset the original increase in demand.

Different schools of thought emphasise different adjustment mechanisms. Some would argue nothing needs to change. The second leg of the Eggertsson and Woodford (2003) irrelevance proposition is that even if there is imperfect asset-substitutability, there are Modigliani-Miller type arguments to suggest that a central bank purchase of riskier assets (such as long-term gilts) in exchange for less risky assets (such as reserves or deposits) should not require a change in asset prices or consumption. The private sector will simply attempt to undo the effects of the central bank's purchase of risky assets – the demand for risky assets by the private sector falls by exactly the same amount as supply. This is because such a trade simply transfers risk from the private to the public sector and the private sector hedges against the increased riskiness of future taxes and transfers by holding safer assets. Such arguments are similar to those made by Fama (1980) and Wallace (1981) about the irrelevance of open market operations.
Post-Keynesians and circuitists would argue the irrelevance from a different angle. Any incipient disequilibrium between money supply and demand is quickly removed by repayment or extension of bank credit, with little need for a change in asset prices or spending.

A (broad) monetarist would argue that these irrelevance propositions are all special cases and that once one allows for (collectively) market segmentation, preferred habitats, costs of adjusting portfolios, heterogeneity among different agents and the transactions motive for holding bank deposits, there are likely to be significant effects on asset prices and nominal spending as different agents rebalance their portfolios. We appeal to these sorts of arguments to justify the empirical models we consider in Section 4.

An additional monetarist angle to consider is that the adjustment in the determinants of the demand for money may not happen immediately. According to the buffer-stock theory of money demand (see Laidler (1984)), the demand for money by households and companies is a target level of money balances that they wish to hold on average over a given period. But at a particular moment in time they will often accept holding more or less than that amount, as a (possibly very temporary) means of bridging the gap between payments and receipts. Over time they will attempt to return to their target level following a change in their money holdings. This theory suggests that, in the short run, the aggregate stock of money is largely determined by supply factors and is only made consistent with the underlying demand for money over a longer horizon. But this time horizon may differ hugely between different sectors in the economy. For example, financial institutions are likely to want to eliminate any discrepancy between actual and desired money holdings relatively quickly; whilst households and non-financial companies may take longer due to inattention and portfolio adjustment costs.

A further key distinction is the difference between the individual agent's or sector's attempt to reduce its money holdings and the adjustment of the economy in the aggregate. An individual can only reduce his surplus liquidity by passing that liquidity on to someone else. This is the genesis of 'hot potato' effects where money gets passed on among agents until ultimately the transactions underlying the transfers of deposits lead to sufficient changes in asset prices and/or

nominal spending that the demand for money is made equal to supply.

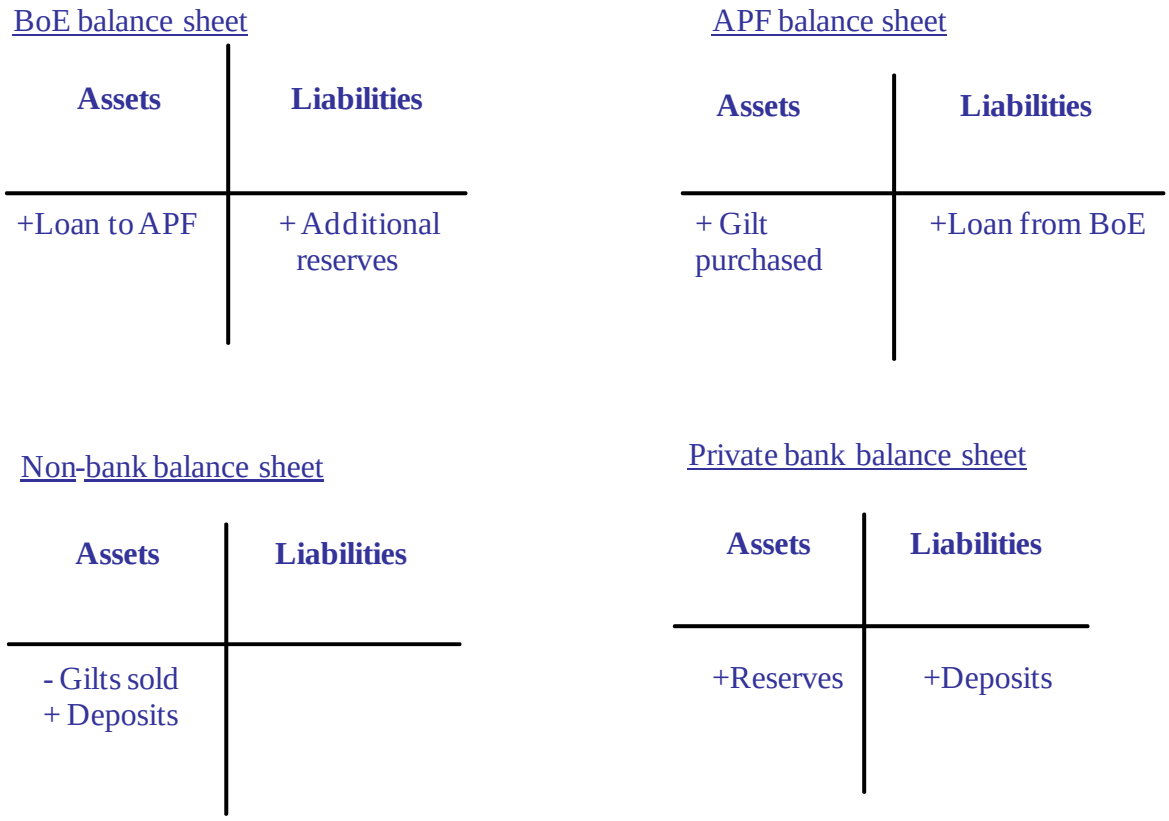
2.2 The impact of QE in a monetarist framework

In Figures 1 and 2, we show how the impact of QE (as implemented in the United Kingdom) fits into the simple monetarist framework outlined above. There are three steps:

Step 1: From asset purchases to an increase in the broad money supply

The aim of the programme of asset purchases in the United Kingdom was to purchase gilts and other assets from the non-bank private sector. These purchases were implemented through the creation of the Asset Purchase Facility or APF (see Benford *et al* (2009)) which obtained a loan from the Bank of England with which to purchase the assets. These purchases were settled in terms of bank deposits. As such, the initial first-round impact of APF asset purchases was an increase in reserves on the asset side of private banks' balance sheets and, as a counterpart, an increase in their deposit liabilities to the non-bank private sector – that is an increase in broad money. These balance sheet impacts are summarised in Figure 1.

Figure 1: The impact of QE purchases on different sectors' balance sheets



There might be additional *indirect* effects on the broad money supply to the extent that the reserves created by QE may encourage banks to lend more than they would otherwise, through a

money multiplier or portfolio balancing channel on the asset side of banks' balance sheets.[2] That would require banks to lower credit spreads or quantitatively increase their lending to constrained borrowers. There may also be potential leakages, to the extent that gilts were purchased from the banking system or from the overseas sector.

Step 2: From money to asset prices

In the first instance, the bank deposits created by QE would be held by the sellers of gilts – predominantly asset managers and other financial companies. Barring any leakages from this sector, the prices and yields of non-monetary assets (the determinants of financial companies' demand for money) would need to change to make financial companies willing, in aggregate, to hold the higher stock of deposits. Some of this change would happen instantaneously with the initial purchases of gilts. But some sellers of gilts may not have wanted to simply swap gilts for money, but rather exchange money for gilts as an intermediate step to purchasing other assets such as equities and corporate bonds. Given that these asset purchases would in turn transfer money to other financial companies, the initial purchases would set in motion a whole set of transactions that may spill over into many asset markets until yields and prices move sufficiently to make the financial sector willing to hold the extra deposits. If markets were efficient and frictionless, prices should adjust immediately in anticipation of this process and stop anyone wanting to do any transactions. But given some frictions in the system this 'hot potato' effect may take some time to filter through the asset markets.

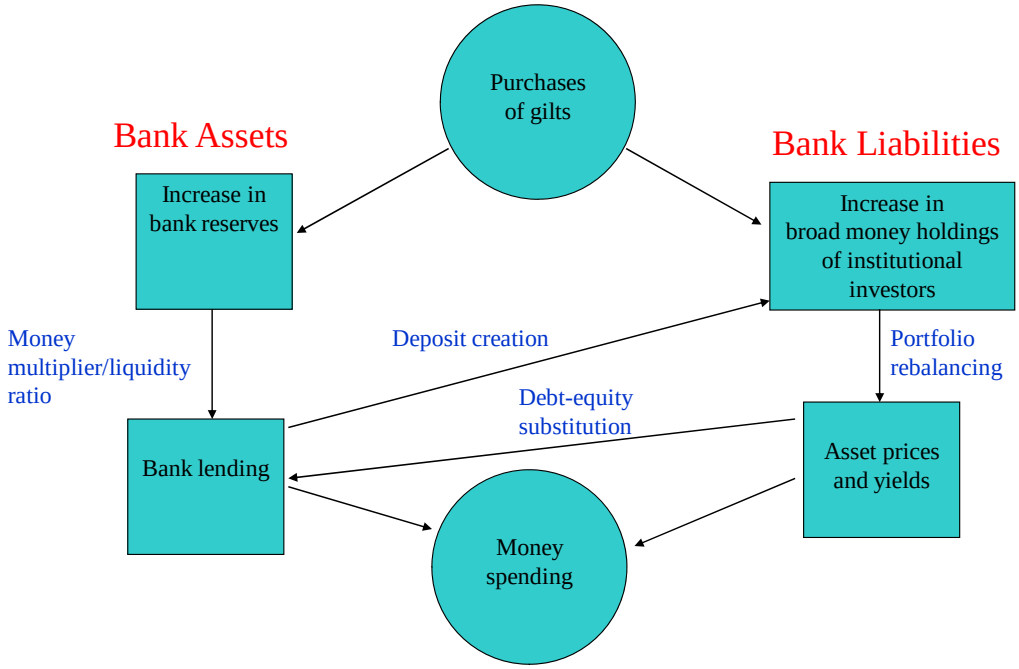
The exchange rate could form part of this adjustment mechanism. To the extent that financial institutions want to diversify into foreign currency assets, they may wish to exchange sterling deposits for foreign currency deposits as an intermediate step to purchasing foreign currency assets. That could bear down on the exchange rate. Of course, the net effect would depend on whether other countries were also carrying out similar QE-like policies. If they were, then the impact on international yield differentials and the exchange rate may be smaller, but the domestic economy might benefit from the higher overseas demand generated by the QE undertaken worldwide.

Step 3: From asset prices to spending (and possibly back to money)

Households and companies may respond to higher asset prices and lower yields by increasing their spending. That should raise the demand for money by these sectors. In the absence of additional money creation through an increase in the provision of credit, that must imply a transfer of money holdings away from financial companies to households and corporates. In the case of corporates, this money transfer must be facilitated by capital market issuance to the financial company sector; whilst money transfer to the household sector must occur through their liquidation of investments with financial companies. In the face of a fixed money supply, this issuance and/or sale of assets by companies and households would imply a fall back in asset prices over time. So asset prices may appear to overshoot.

[2] This channel was not expected to be material during the financial crisis, given the pressure on banks to reduce the size of their balance sheets (see for example, the Monetary Policy Committee Minutes, March 2009).

Figure 2: QE and the transmission mechanism via banks



Alongside a rise in spending, rising asset prices could also lead to a change in the demand for credit and a feedback on to the supply of money (see Figure 2). On the one hand, households experiencing an increase in nominal financial wealth may attempt to borrow money on the back of their good fortune rather than liquidate their investments. That would lead to an increase in the demand for credit and the money supply. On the other hand, the lower cost of bond and equity finance may induce companies to substitute towards these forms of financing and away from bank debt, leading to a fall in bank credit and the money supply.

Higher asset prices and lower yields may also lead to banks themselves increasing their bond and equity issuance. That too would, in aggregate, affect the money supply. The domestic purchasers of bank bonds and equities would ultimately have to pay for this issuance by lowering their deposits with the UK banking system. This effect may in part be offset in the longer term, to the extent that bank issuance may improve the capital and funding position of banks, which may influence their willingness to lend.

In summary, there are likely to be direct as well as indirect effects on the money supply from QE. Although QE increases the aggregate demand for bonds and equities, the resulting increase in asset prices may induce an increase in the issuance of these assets. To some extent, that might offset the original boost to the money supply and reduce the asset price adjustment required. In order to assess the evidence for a monetary transmission mechanism of QE to the UK economy as outlined above, it is first necessary to establish the size of the direct and indirect money supply effects induced by QE. That is the topic of the next section.

3 QE and the money supply – how big was the shock in 2009 and 2010?

This section outlines a central case for the likely impact of QE on the aggregate money supply. This accounts for the possible leakages and indirect effects identified in Section 2. These leakages and indirect effects need to be excluded from the money shock that we identify, since the focus of this paper is the impact of the net increase in money balances on the wider economy, transmitted via the portfolio rebalancing channel. The possible leakages from the QE money shock are identified and quantified below, allowing us to articulate the uncertainties around our central case.

3.1 Possible indirect effects and leakages from the QE money shock

As identified earlier, there are several potential indirect effects to consider that mean the money supply shock induced by QE may have been different to £200 billion. First, some gilt sales to the asset purchase facility may have come from outside of the UK non-bank private sector which may have reduced the initial effect on broad money. Second, the repair of banking sector balance sheets through the issuance of non-deposit liabilities may have drained money balances. Third, there may have been indirect effects on bank lending, both on the demand and supply side. These three indirect effects are examined in turn.

3.1.1 Gilt sales to the asset purchase facility from outside of the UK non-bank private sector

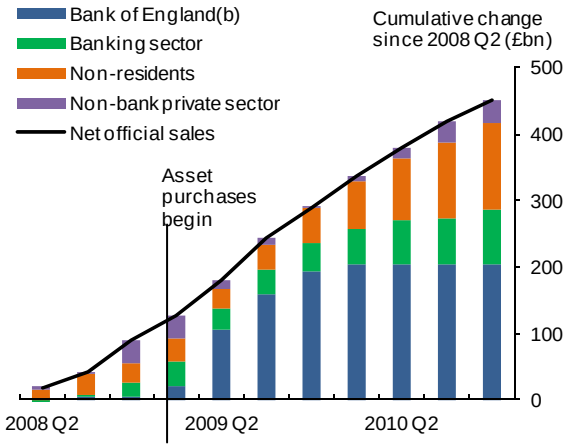
It cannot be certain that the ultimate sellers of all the gilts purchased during QE were members of the UK non-bank private sector. The intention of QE was to purchase assets largely from UK non-bank financial companies, such as insurance companies, pension funds and other asset managers. But the banking sector or non-resident sector may have sold some of their gilt holdings to the Bank of England. In this case, the money balances of the non-bank private sector would not have risen, so the initial increase in M4 money holdings may have been less than the programme of asset purchases.

The size of this potential leakage can be estimated from the data. By examining the movement in net gilt holdings over the QE period, we conclude that there was probably minimal direct leakage of asset purchases outside of the non-bank private sector. For this leakage to have been substantial, either the banking sector or the non-resident sector must have sold a significant amount of gilts to the Bank of England. But the banking sector held relatively few gilts at the start of the asset purchase programme.[3] Moreover, Chart 5 shows that both the banking sector and the non-resident sector actually increased their holdings of gilts during the period over which asset purchases took place. Indeed, looking over the period 2008-10 as a whole, the proportion of total government debt issuance purchased by the banking and non-resident sectors was broadly in line with the proportions purchased between 1991 and 1993, when the fiscal deficit last rose sharply following a recession (Chart 6). This counterfactual suggests that the key impact of Bank of England gilt purchases in this recession was to reduce the gilt holdings of the UK non-bank private sector, relative to where they would have been in the absence of QE.

[3] The UK banking sector's net holdings of UK government bonds at the end of 2008, prior to the onset of asset purchases, was £26 billion.

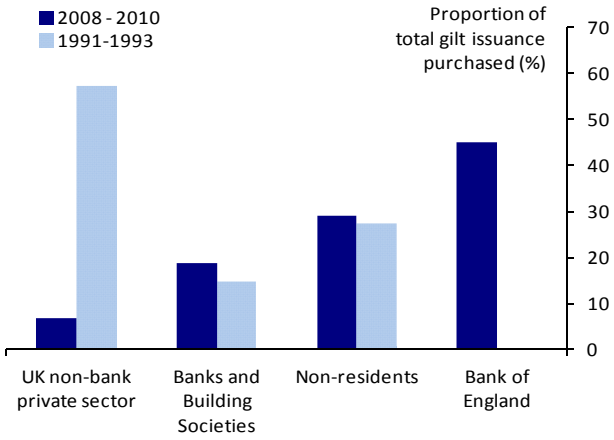
It therefore seems unlikely that a significant proportion of QE asset purchases leaked outside of the non-bank private sector. In all of our cases, we assume that the first-round impact of QE on broad money was the full £200 billion.

Chart 5: Change in gilt holdings by sector since the recession began [(a)]



Source: Bank of England.
(a) Purchases by the non-bank private sector exclude repos.
(b) Gilts acquired through asset purchases are held by the Asset Purchase Facility, a subsidiary of the Bank of England.

Chart 6: Comparison of gilt holdings between this recession and the 1990s

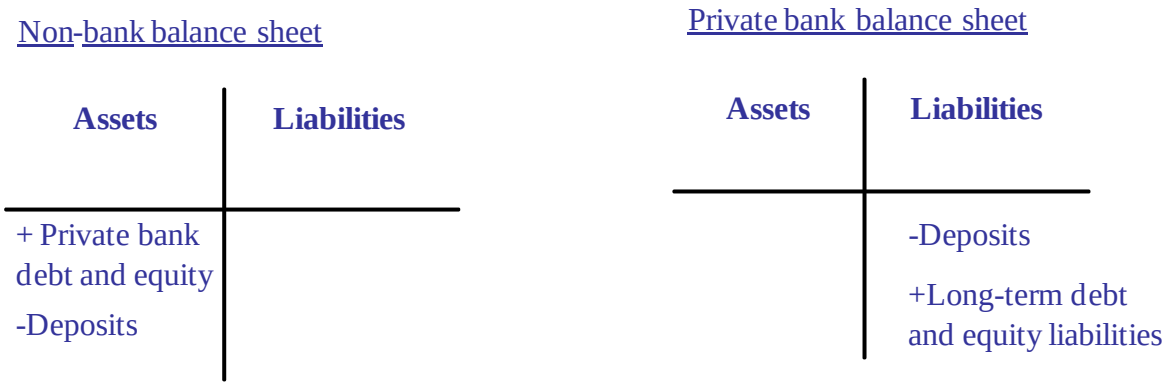


Source: Bank of England.

3.1.2 Repair of banking sector balance sheets through the issuance of non-deposit liabilities

Even if all gilts were purchased from UK non-bank financial companies, some of the resulting excess money balances may have been absorbed back into the banking sector directly. For instance, if QE resulted in higher asset prices and lower yields, that may have encouraged banks to issue more long-term debt and equity instruments, given the need to repair their balance sheets in the wake of the financial crisis. If UK non-bank financial companies purchased this increased issuance using their deposits, that would have partially offset the boost to the money supply. In this scenario, the money balances created by QE would be transformed into non-deposit liabilities of the banking sector as shown in Figure 3.

Figure 3: The impact of bank debt and equity issuance on balance sheets



In order to quantify the potential size of this leakage, it is helpful to look at the counterparts to money growth over the QE period and to compare the movements in those counterparts with the 1990s recession (Chart 7).[4] The large contribution of net sterling lending to the public sector, representing both central bank and private bank purchases of gilts, has already been discussed in Section 3.1.1. But it is also notable that a large accumulation of sterling non-deposit liabilities in the banking sector has acted as a significant drag on money growth.

The large accumulation of sterling non-deposit liabilities is consistent with the significant banking sector recapitalisation and long-term debt issuance observed following the crisis, as banks began to repair their balance sheets. Indeed, data on the net issuance of sterling equity, long-term debt and the retention of profits suggests that a reasonable estimate for the total drain on broad money from these factors was around £240 billion between 2008 Q2 and 2010 Q4 (Bridges *et al* (2011)). The challenge is to form a central case as to how much of this leakage can be attributed to QE – that is, how much of the bank balance sheet repair was facilitated by the positive impact of QE on asset prices, yields and market functioning?

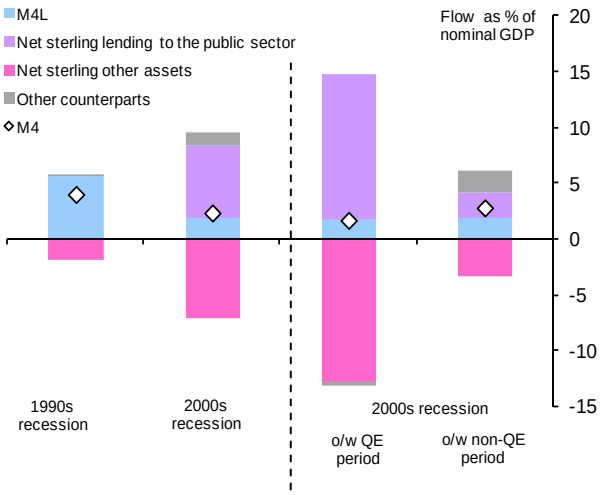
We make a number of assumptions in order to estimate the extent to which bank balance sheet repair facilitated by QE acted to offset the initial boost to the money supply. First, it is assumed that only bank balance sheet repair occurring during the QE implementation period (2009 Q1-2010 Q1) can be linked to QE. That identifies a potential leakage to the £200 billion QE money supply shock of about £120 billion through this channel. But second, we also assume that government injections of capital into the banking sector would have been the same over this period in the absence of QE. That leaves a potential maximum leakage to the money supply of around £80 billion from this channel.

But we also need to take into account that an increase in banking sector non-deposit liabilities was observed in the 1990s recession. This might provide a reasonable counterfactual for what monetary leakage would have occurred through this channel even in the absence of QE. This counterfactual suggests that we might have expected to see a leakage from money of around £20 billion through bank balance sheet repair during the QE period, even in the absence of QE. So our central case is that QE facilitated the additional repair of banking sector balance sheets that was observed over the period. This channel can therefore explain a leakage from money of about £60 billion, partially offsetting the initial £200 billion money supply shock associated with QE.[5]

[4] For a more detailed analysis, see Bridges *et al* (2011).

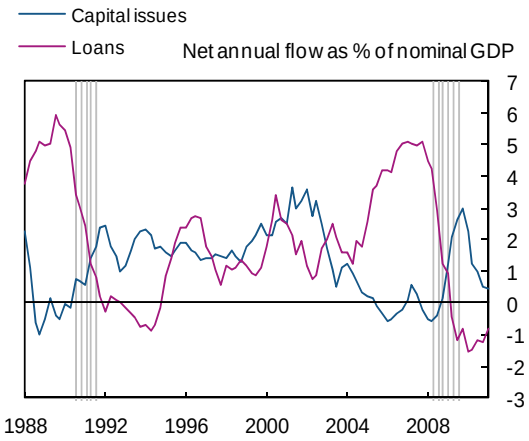
[5] This is an uncertain estimate. One cross-check is to examine the amount of non-deposit liability accumulation that occurred since the onset of this recession and split this into accumulation that occurred during the QE implementation quarters and accumulation that occurred in the other quarters (Chart 7). The fact that non-deposit liability accumulation was considerably stronger during the QE implementation period supports the conclusion that a significant amount of the associated money leakage was attributable to QE. Indeed, basing the counterfactual exercise of what would have happened in the absence of QE on this divergence (rather than relative to the 1990s recession), would lead to a broadly similar estimate of the leakage attributable to QE.

Chart 7: Counterparts to broad money



Source: Bank of England.
(a) For a full description, see Chart 4 of Bridges *et al* (2011). The recession periods cover the 12 quarters since the onset of recession in 1990 Q3 and 2008 Q2 respectively.

Chart 8: PNFC substitution of bank debt to capital market issuance[(a)]



Source: Bank of England. Grey bars indicate recession periods.
(a) The capital issuance series shows the net amount raised from sterling issuance of equity, bonds and commercial paper by UK PNFCs.

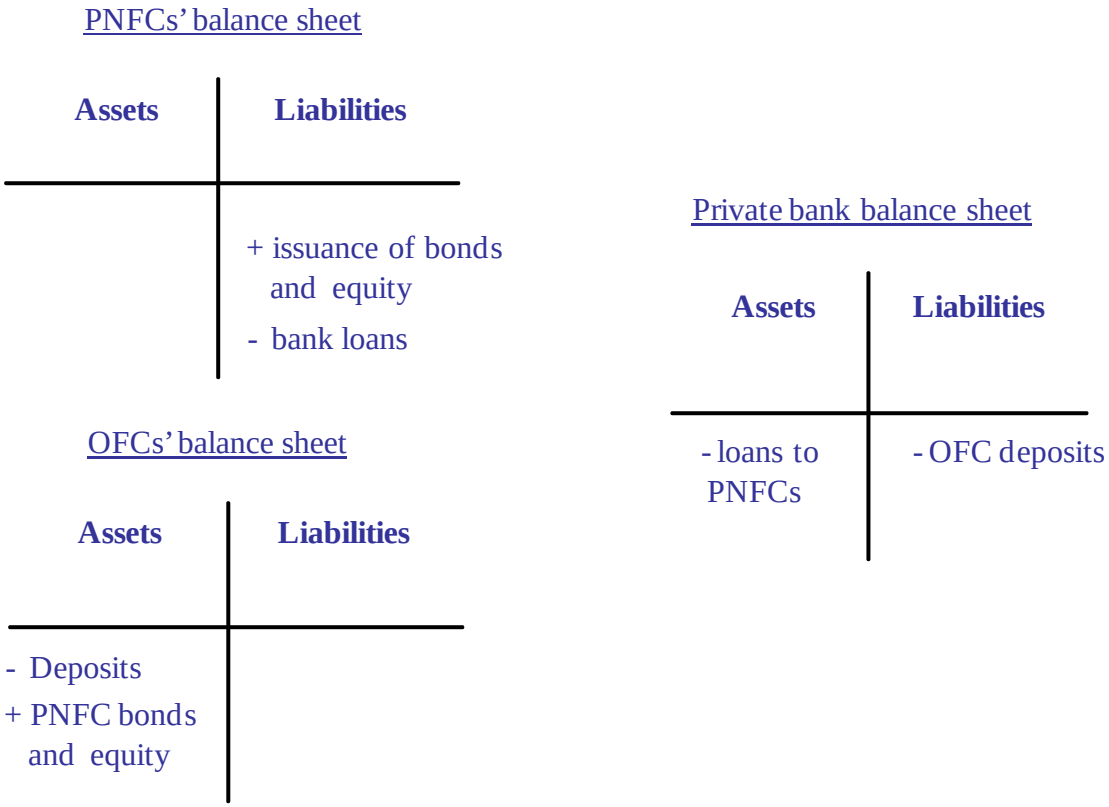
3.1.3 Indirect effects on bank lending

The weakness in credit creation has been a key counterpart to the weakness in money growth since the recent recession began (Chart 7). As a result it seems implausible to believe that QE significantly increased the *supply* of credit by the banking sector because of a 'money multiplier' effect or because of portfolio rebalancing on the asset side of banks' balance sheets. It is true that over the longer term, if QE helped to facilitate a better capitalised banking sector, with a more robust funding structure, then credit creation is likely to be stronger than it might otherwise have been. But given the ongoing repair of banking sector balance sheets and the adjustment to new regulation, such effects are likely to lie outside the horizon of our analysis.

It is more likely that QE may have had indirect effects on the *demand* for credit. For instance, the excess money balances created by QE may have been partially absorbed back into the banking sector, via the repayment of bank debt. During the credit supply shock and subsequent recession, private non-financial corporations (PNFCs) may have wanted to deleverage or disintermediate from the banking sector, by issuing equity or bonds and using the proceeds to pay down bank debt. QE may have facilitated this process by pushing down on yields in the capital markets. Non-bank or 'other' financial companies (OFCs) could have used the additional money balances generated by QE to purchase PNFCs' issuance. In this case, the aggregate money supply shock initially induced by QE is temporary, because it subsequently leads to a transfer of money to a sector that wishes to repay bank debt.[6] Figure 4 summarises how bank lending and deposits are reduced by debt-equity substitution.

[6] This is sometimes known as the Kaldor 'reflux' principle, see Kaldor and Trevithick (1981).

Figure 4: Debt-equity substitution by PNFCs



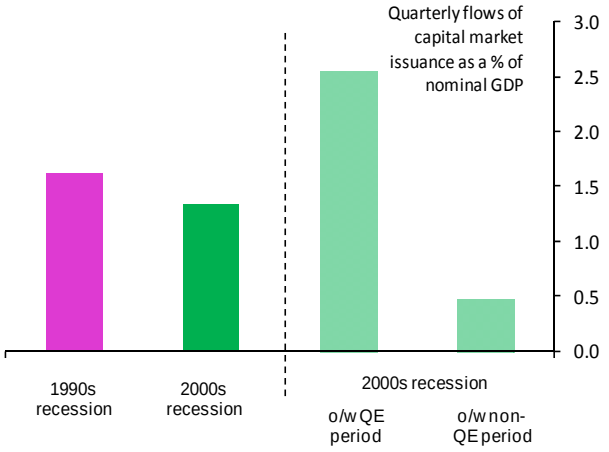
During the period over which QE was implemented, growth in bank lending to PNFCs fell sharply and corporates made net loan repayments to the banking sector of about £20 billion. At the same time, net sterling issuance of equity, bonds and commercial paper by PNFCs picked up sharply – totalling about £40 billion over the QE period. This suggests a significant substitution from bank finance to the capital markets. To the extent that this substitution was facilitated by QE, it represents another leakage to the aggregate money supply shock associated with QE. In our lower bound case for the size of the money shock, we assume that all of the PNFC net capital market issuance observed over the QE period can be attributed to QE. But again, the challenge is to estimate a reasonable central case, by considering what proportion of the observed data might be attributable to QE.

A significant substitution of PNFC finance to the capital markets also occurred during the 1990s recession, providing a useful counterfactual (Chart 8). Our central case is to assume that, in the absence of QE, PNFC capital market issuance would have been the same share of nominal GDP as was observed in the three years following the onset of the 1990s recession.[7] During the QE period, PNFC capital market issuance was about 40% stronger than during the 1990s recession (Chart 9). It is assumed that this additional strength was attributable to QE and that all of the proceeds of this extra issuance were used to repay bank loans. That gives a central case of a

[7] This assumes that the relative attractiveness of capital market finance relative to bank finance would have evolved in the same way during the recent recession, in the absence of QE, as it did in the 1990s recession. The severity of the financial crisis leading to this recession likely means that the bank credit supply shock was larger in this recession than in the 1990s. But the disruption to the functioning of capital markets was likely to have been larger as well. The shock to the relative attractiveness of different forms of finance might therefore have been comparable to the 1990s.

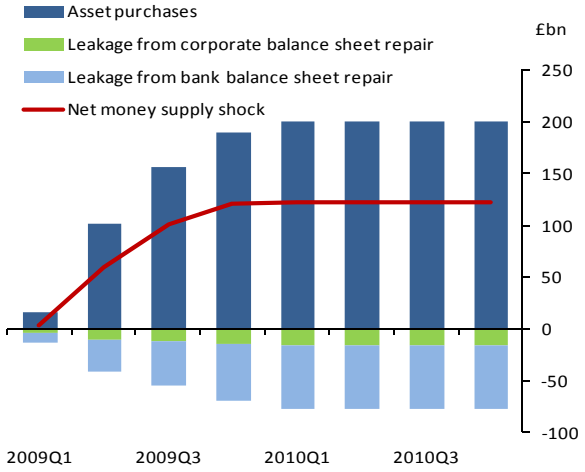
leakage of £16 billion from the total QE money supply shock attributable to corporate sector balance sheet repair.[8]

Chart 9: PNFC capital market issuance



Source: Bank of England.
Note that the recession periods cover the 12 quarters since the onset of recession in 1990 Q3 and 2008 Q2 respectively.

Chart 10: Central case for the money shock attributable to QE



Source: Bank of England.

3.2 Summary of the size of the money shock from QE

Drawing together the evidence on the potential leakages, our central case is that the total boost to the aggregate money supply imparted by QE was £122 billion. The evolution of this shock is shown in Chart 10 and is summarised in Table 2, which also gives our upper and lower bounds for the size of the money shock associated with QE.

Table 2: Contributions to the aggregate QE money shock over 2009 Q1-2010 Q1:

£bn	Lower Bound	Central Case	Upper Bound
+ Contribution of asset purchases initially	200	200	200
- Leakage to bank balance sheet repair	79	62	0
- Leakage to corporate balance sheet repair	44	16	0
Total	**77**	**122**	**200**

Our central case for the money shock profile attributable to QE will be used as an input into our monetarist models, in order to investigate the impact of QE on the UK economy. The lower and upper bounds for this shock will be used as part of our sensitivity analysis. But first, the appropriate multipliers from the monetary shock identified onto the wider economy must be established. Section 4 therefore begins by considering the empirical models used to analyse the effects of a money supply shock, in order to calibrate these multipliers.

[8] Again, a useful cross-check is to consider the capital market issuance since the recent recession in the quarters where no QE purchases took place. Issuance in these quarters was notably weaker than during the QE period, supporting the conclusion that QE was influential. Indeed, using these non-QE quarters as an alternative counterfactual would suggest a larger leakage of about £35 billion.

4 Empirical models of money – what do they suggest the impact of QE was?

In Section 3, we discussed the size of the money supply shock associated with QE. In this section, we use a set of empirical models, both aggregate and sectoral, to examine the wider impact of the identified money supply shock on the economy. We use models in which money has been found to play a key role in influencing asset prices and spending, to gauge how big an explicitly monetarist model would suggest the effects of QE on the economy might have been.

It is worth emphasising up front the challenges associated with empirical modelling of QE. As noted earlier, there is not a generally accepted way of integrating money into a current generation DSGE model, such that any quantitative analysis of the impact of QE requires the use of empirical models. But a challenge to the use of empirical models is that the sample periods over which these systems have been estimated have arguably not been subject to money supply shocks similar in type and/or scale to those implied by QE. In particular, as we will discuss, it is a challenge to identify or introduce QE-like shocks into these systems in a wholly satisfactory way. For this reason, we do not use these models to try to infer the size of the QE shock through the use of historical decompositions of the data, especially as we know that there were other large shocks going on at the time of QE, that any identification scheme will find hard to disentangle. Instead, we use our independent accounting estimates of the impact of QE on the money supply in Section 3 to calibrate the size of the shock and then introduce them into the different models in the most 'QE-like' way. Even though we do not attempt to gauge the size of the shock from the models, our approach still relies on the strong assumption that the underlying structural demands for money by different sectors have remained broadly stable over the QE period; or at the very least, it relies on the lags between money, asset prices and spending being broadly invariant, even though the money supply shocks hitting the economy may be different from the past.

First, we discuss the common core properties of the monetarist models that are available to us. We then address the aggregate and sectoral models used in turn. In each case, we discuss how the QE shock was introduced into the systems. We then present the range of empirical estimates for the impact of QE that the models suggest, using the money supply impacts estimated in Section 3. We bring our results together and summarise the impact of QE on the UK economy in Section 5.

4.1 Estimated 'monetarist' models for the United Kingdom

For the best part of two decades, a significant body of research work, largely undertaken by central banks, has gone into estimating systems of equations that explore the linkages between money and credit aggregates on the one hand, and asset prices and spending on the other.[9] Although the approach is largely empirical, these estimated systems do capture some of the linkages discussed in Section 2 and some theoretical restrictions can be placed on them. In particular, efforts to develop systems based around estimated equations for the long-run demand for money – the 'M-M*' approach – are the most directly related to the buffer stock monetarist

[9] See Thomas (1997a,b), Brigden and Mizen (2004), Dhar *et al* (2000), De Santis *et al* (2008), Papademos and Stark (2010).

idea. This approach attempts to map out the restoration of monetary equilibrium, at either an aggregate or sectoral level, following an increase in money holdings.
These buffer-stock or M-M* models have several core properties:

- *Money demand is estimated as a function of activity, value of assets ('wealth') and rates of return*. By assumption bank deposits are assumed to be an imperfect substitute for other assets so that the spread between bank deposit rates and other yields is the key relative rate of return.

- *Money is modelled jointly with asset prices and activity* in a VAR framework. So money can in principle have feedback effects on asset prices and activity as well as *vice versa*.

- *Theory is used to pin down the long run*. A cointegrated VAR approach is used, as advocated by Pesaran *et al* (2002). The idea is that theory pins down the form of certain long-run (cointegrating) relationships, the most important of which is the money demand relationship. But the dynamics of each variable around those long-run relationships are then freely estimated (though, as we discuss later, additional theoretical restrictions are required to produce impulse responses to QE-like shocks).

The typical approach in this type of model is relatively straightforward. First, a long-run demand for money equation – M* – is estimated. This equation attempts to capture the transactions and asset demands for money either for aggregate money or for a particular sector.

$$M^* = f(\text{nominal demand, deposit rate, other rates of return, wealth})$$

From this one can construct the gap between the actual stock of money and equilibrium money holdings – 'M-M*'.

Second, a cointegrated VAR or vector error correction mechanism (VECM) can then be estimated. In this system, nominal spending, rates of return and money itself are a (lagged) function *g(L)* of M-M* and other disequilibria terms (such as the output gap).

$$\text{Nominal demand, rates of return, wealth, money} = g(L)(M\text{-}M^*, \text{other disequilibria})$$

In this approach, it is therefore possible to investigate which variables, including money itself, are affected by the money disequilibria generated by particular shocks. For example, if M-M* negatively affects the aggregate money stock and nothing else, this would give more weight to the Kaldor-Tobin view that surplus money is easily extinguished via repayment of bank debt.[10] In contrast, if M-M* is found to affect asset prices and nominal spending, that would give more weight to the monetarist hypothesis. The key feature of these systems is that the estimated money equilibrium condition must hold in the long run through some mechanism. The system then identifies how equilibrium has typically been restored over the particular sample period

[10] See for example Kaldor and Trevithick (1981).

examined. The aggregate and sectoral models we use in this paper are now addressed in more detail.

4.2 An aggregate co-integrated SVAR model

The advantage of an aggregate model is that we can obtain a general equilibrium response of all the variables in the system to a particular shock. The model we use here is based on that of Dhar *et al* (2000) which includes all the key variables of interest for analysing QE and explicitly builds in a long-run money demand relationship. It involves estimating a VAR in eight non-stationary I(1) variables that includes the log of real broad money[11] ($m - p$), deposit rates (*id*), short rates (*is*), gilt yields (*il*), the log of real equity prices (*pk*) and the log of the real exchange rate (*e*), as well as logged real GDP (y) and annualised CPI inflation (π). The model estimates four long-run or 'cointegrating' relationships over a fairly long sample period from 1964 Q1 to the start of the crisis in 2007 Q3: a long-run money demand function; a term structure relationship; a real interest rate or Fisher relationship and an asset price relationship linking equity prices to GDP. This implies the following long-run relationships (where constant terms reflecting sample means are defined as k_1 to k_4):

$$m - p = 1.49*y + 12.19*(id - il) + k_1$$

$$is = il + k_2$$

$$is = \pi + k_3$$

$$pk = y + k_4$$

In summary, there is a long-run demand for real money balances that depends on the spread between deposit rates and long rates and also on output. The short-long rate spread and the real interest rate are stationary around their sample means as is the asset price to GDP ratio.

The challenge is to introduce a QE shock into this system. The first issue is that the spread between short and long-term interest rates is stationary over the sample period estimated. This means that by definition any QE-like shock will only have a temporary effect on gilt yields relative to (the expected path of) policy rates. Second we have to place restrictions to identify QE from other shocks hitting the economy. The model was originally identified using a mixture of short-run zero restrictions and long-run restrictions to identify eight structural shocks. Using the methodology of King *et al* (1991) and Mellander *et al* (1992) the eight shocks were split into four permanent shocks and four temporary shocks. The permanent shocks were identified as shocks to aggregate supply, financial liberalisation, the monetary policy objective (or inflation target) and overseas demand/preferences. The temporary shocks were identified as those to monetary policy, aggregate demand and two less well-defined shocks provisionally labelled foreign risk premium and term premium shocks.

[11] Defined as M4 excluding the holding of intermediate OFCs deflated by the GDP deflator.

Of the eight shocks identified in this system none are really likely to mimic the impact of QE. In response, we modify the identification scheme of Dhar *et al* (2000) and attempt to identify a QE-like shock over the past. We do this by assuming that this shock has the same timing assumptions as the monetary policy shock (so GDP and inflation are only affected with a lag) but a zero restriction is also placed on the short rate, so that the shock has to work initially through its impact on money, long rates and potentially the exchange rate. This is similar to the restriction adopted in the SVAR model in Kapetanios *et al* (2012). When identified in this way, the long-run zero restrictions for the permanent shocks and the short-run restrictions for the temporary shocks are as follows:

Permanent shocks: Long-run restrictions

$$\begin{bmatrix} m-p \\ y \\ is \\ il \\ pk \\ \pi \\ id \\ e \end{bmatrix} = \begin{bmatrix} * & * & * & * \\ * & * & 0 & 0 \\ * & * & * & * \\ * & * & * & * \\ * & * & * & * \\ 0 & * & * & 0 \\ * & * & * & 0 \\ * & * & 0 & * \end{bmatrix} \begin{bmatrix} \eta_{AS} \\ \eta_{Fin} \\ \eta_{Nom} \\ \eta_{For} \end{bmatrix}$$

Temporary shocks: Impact restrictions

$$\begin{bmatrix} m-p \\ y \\ is \\ il \\ pk \\ \pi \\ id \\ e \end{bmatrix} = \begin{bmatrix} * & * & * & * \\ * & 0 & 0 & * \\ * & * & 0 & * \\ * & * & * & * \\ * & * & * & * \\ 0 & 0 & 0 & * \\ * & * & * & * \\ * & * & * & * \end{bmatrix} \begin{bmatrix} \eta_{AD} \\ \eta_{Pol} \\ \eta_{QE} \\ \eta_{UR} \end{bmatrix}$$

Permanent shocks:

η_{AS} = aggregate supply shock

η_{Fin}= financial liberalisation shock

η_{Nom}= monetary policy objective shock

η_{For} = overseas demand / preference shock

Temporary shocks:

η_{AD}= aggregate demand shock

η_{Pol} = monetary policy shock

η_{QE} = QE shock

η_{UR} = unrestricted

An impulse response analysis under these identifying restrictions suggests that the predicted impact of the QE-like shock looks very similar to the predicted transmission mechanism of QE. In Chart 11 we show the impact of introducing a sequence of these QE-like shocks that deliver an impact on the money stock in line with the central case impact identified in Section 3 – namely £122 billion or 8% of the money stock.

Chart 11a: Money and asset prices

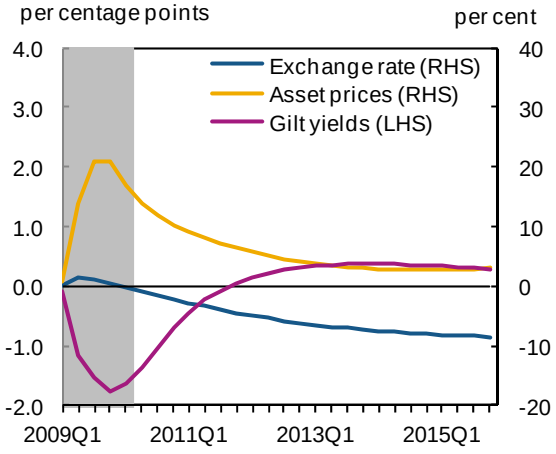
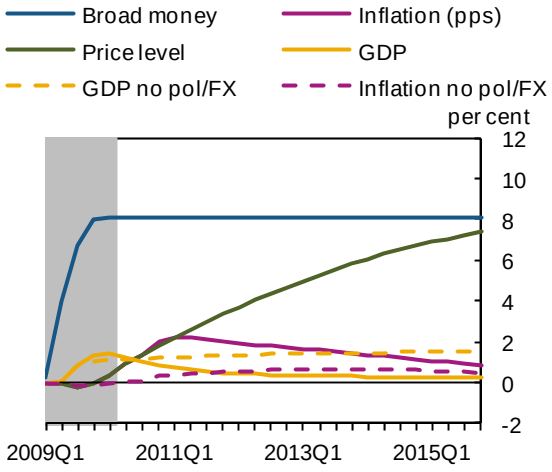


Chart 11b: Inflation and GDP



The simulations suggest that QE has a positive initial impact on nominal asset prices of just over 20% in the central case and lowers the spread of gilt yields over Bank Rate by around 175 basis points on impact. The nominal exchange rate response shows a slight initial appreciation followed by larger depreciation. The depreciation is commensurate with the overall price level impact in Chart 11b reflecting the long-run neutrality of money in the model. As a result, the long-run impact on the real exchange rate is zero. These financial market responses lead to a peak positive impact on the level of real GDP of around 1.5% at the start of 2010. The peak impact on inflation is a little larger than that on GDP at around 2 percentage points and occurs in 2011. The inflation response is likely to reflect both an impact of higher spending on the output gap and higher import prices arising from the depreciation of sterling.

The estimated impact of QE on asset prices and yields in this aggregate model look plausible and are in line with the expected transmission of a 'QE-like' shock. The magnitude of the boost to equity prices is also broadly in line with the event study findings of Joyce *et al* (2010). The only responses that we would treat with caution are the exchange rate response (and the implied impact on CPI inflation) and the relatively temporary effect on the level of GDP. As noted earlier, a substantial depreciation in response to QE was not evident in the data, with little movement in sterling since the onset of QE (Chart 4). But it is hard to know the counterfactual of how the exchange rate would have behaved in the absence of QE. The event study analysis of Joyce *et al* (2010), suggests that the exchange rate impact from QE was at most about half the size of the depreciation predicted in this model. That would lead us to aim off our exchange rate impact and, as a result, would suggest that the estimated impact on inflation is likely to be overstated in this simulation. The lack of persistence in the GDP response is probably due to the fact that there is a stabilising reaction of the short rate of interest after the initial period of the shock, reflecting the average policy response to these QE-like shocks in the past. In contrast over the QE period Bank Rate was held at 0.5%.

So as a sensitivity check we run the same shock through the SVAR but shut off the equations for the policy rate and the real exchange rate. The inflation and GDP impacts are shown as the dotted lines in Chart 11b. They show that the impact on GDP would initially be a little lower but would be considerably more persistent in the medium term when interest rates do not work against the QE impulse. And the lagged impact on inflation would be around only ½ the size of the GDP impact once the role of the exchange rate is removed. In the longer term the GDP response does not return to the baseline because we have switched off the stabilising role of policy and the exchange rate. But overall this simulation does given an idea of the potential persistence of the medium-term impact of QE on GDP when short-term interest rates are held fixed.

Overall it is encouraging that the responses of this aggregate model to a 'QE-like' shock are qualitatively in line with what we might have expected. But we are wary of attempting to squeeze much more from these simulations. We largely view them as offering an initial guide to the overall empirical plausibility of our hypothesised transmission mechanism of QE. The channels of that mechanism can be explored in more detail and with more precision using our sectoral models, where there is more scope to trace out the impact of QE in detail.

4.3 Sectoral models of money and spending

Although aggregate models are useful, as they allow us to look at the complete macroeconomic response to a QE shock, the linkages between money, asset prices and spending have tended to be clearer at the sectoral level in the UK data (see Congdon and Ward (1993), Fisher and Vega (1993), Thomas (1997a,b), Thomas (1997b), Brigden and Mizen (2004), Chrystal and Mizen (2005a,b),). Moreover, the fact that asset purchases initially affect the money holdings of the financial company sector means that tracing the impact of the QE shock at a sectoral level is likely to be revealing. We therefore also attempt to calibrate the impact of QE using a preferred set of sectoral money models.

The key challenge with these sectoral models is that they need to be augmented with assumptions that allow us to link the sectors together to produce an aggregate impact. The identification method is also different to that used in the aggregate model. The models start off as small co-integrated VARs estimated at the sectoral level. These systems are conditioned on certain variables that are treated as exogenous to the sector for estimation purposes. Some structural restrictions are then placed on the short-term contemporaneous relationships between the variables. Unlike the structural VAR approach adopted in the aggregate model, it is more difficult to identify independent 'shocks' at the sectoral level using theoretical restrictions. Instead, the models are identified by placing restrictions on the short-run interactions between the variables or on how the long-run cointegrating relationships enter particular equations. In this sense, the aim is to identify structural 'equations' that have some plausible theoretical interpretation, rather than to identify specific 'shocks'. In the econometric literature these models are known as structural econometric models or 'SECMs'. This framework raises an issue of how to introduce a QE-like shock into the system. This depends on the exogeneity/endogeneity of money holdings in the sectoral models as is discussed below.

We use three sectoral models, one for the household sector, one for the PNFC (private non-financial company sector) and one for the financial company sector. The key properties of each model are briefly articulated in turn, and the model equations are listed in the appendix.[12] We then discuss how the three models can be combined to produce an estimate of the aggregate impact of QE.

The financial company sector model

The financial company sector model consists of a four-equation VAR of financial company real sterling money holdings, real sterling asset values, the real deposit rate and a composite yield that weights together the dividend yield of the FTSE All-Share (plus a constant 3% as a proxy for real dividend growth) and the ten-year real zero coupon government bond yield. The weights reflect the shares of gilts and equities in financial companies' portfolios.

The appropriate definition of the financial company sector is a difficult one. Our preferred measure would be to include the range of institutions that would typically hold the assets purchased by the APF. This would include insurance companies and pension funds, asset

[12] More details on the econometric approach and identification procedure can be found in Thomas (1997a,b) and Brigden and Mizen (2004).

managers and other fund managers. In the UK monetary statistics, these institutions are termed non-intermediate OFCs or (NIOFCs).[13] Unfortunately the data for this sector are only available back to 1998 and are confined to their money holdings. Longer runs of data on both money and total asset holdings are available back further for the narrower insurance company and pension fund (ICPF) sector. We therefore use VAR estimates based on the ICPF sector as a proxy for the broader NIOFC sector.

The model, estimated over the period 1987 Q1 to 2008 Q3, suggests that there is one long-run relationship in the data. This is identified as a money demand relationship of the form:

$$m = w + \theta * (rd - rg)/100$$

where m is the log of money holdings, w is the log of 'wealth' or total financial assets, rd is the own rate on money (the deposit rate) in percentage points and rg is the weighted rate of return on non-monetary assets (gilts and equities) in percentage points. θ is the semi-elasticity of money holdings with respect to a change in the opportunity cost of holding money.

The dynamics of the VAR system suggest that asset values and yields both respond to an increase in money holdings in the financial company sector. In particular the gap between actual and equilibrium money holdings has a significant positive effect on asset prices and a negative effect on yields. But the feedback of this gap onto money itself is not significant (see Appendix for details). It may seem odd that excess money does not feed back onto actual money holdings, but in fact it is supportive of a monetarist transmission mechanism. It suggests that when money holdings increase in the financial company sector, asset managers do not repay bank debt or purchase many assets directly from overseas residents. Rather they purchase assets from each other in a financial merry-go-round. In this way, financial companies respond to monetary disequilibria by buying assets from one another, causing money to circulate like a 'hot potato' within the sector. The results suggest that this process would continue until asset prices are bid up sufficiently and financial yields fall sufficiently to make financial companies willing to hold additional money, restoring equilibrium.

The long-run impact on asset prices depends on the size of the percentage increase in money and on the semi-elasticity of money with respect to non-monetary yields. To see this we can 'invert' the long-run money demand function (legitimately, given that causality appears to go from money to asset prices) to give:

$$\%\ change\ in\ w \approx \%\ change\ in\ m + \theta * pp\ change\ in\ rg$$

where deposit rates are held constant. If we assume yields are inversely related in the long-run to their price with a coefficient of γ we get:

[13] This classification excludes financial companies that either intermediate between banks, such as the London Clearing House (LCH) or are bank holding companies or subsidiaries. For a more detailed discussion of the United Kingdom's monetary aggregates, see Burgess and Janssen (2007).

$$pp\ change\ in\ rg = -\gamma * \%\ change\ in\ w$$

$$\%\ change\ in\ w \approx (\%\ change\ in\ m) / (1 + \theta\gamma)$$

This suggests that in general the change in financial asset prices will be less than proportionate to the change in NIOFCs' money holdings if θ is non-zero[14]. As a result, money holdings will rise as a share of total financial assets. This reflects the fact that money demand is made consistent with a higher supply in part by a wealth or scale effect (the '1' in '1 + θ γ') and in part by a substitution effect (given by the 'θ γ' component). In the extreme case where θ is infinite, money is a perfect substitute for other assets and higher money holdings can be accommodated with little or no change in financial yields and prices. When θ is zero, money and other assets are perfect complements and will increase proportionately together. In our estimated system, θ is estimated to be around 10 and γ is around 0.04 in the long-run. This implies that a 10% increase in NIOFCs' money will lead to around a 7% increase in asset prices and a 0.4 percentage point fall in yields. Translating this into £ billion: £50 billion amounted to around 16%-18% of NIOFCs' money holdings in 2009, such that an increase in NIOFCs' money holdings of £50 billion would be consistent with an asset price increase of 11%-12%.

To show how long this impact takes to come through we introduce a £50 billion permanent increase in money (which given our test results is assumed to be strongly exogenous) and dynamically solve the system. The results are shown in Chart 12.[15]

The impact of a money shock on asset prices is not immediate – it builds slowly over time. This reflects the coefficient on the money disequilibrium term in the asset valuation equation. This might seem an implausibly slow response in the case of QE for several reasons. First, the policy of asset purchases was transparently announced such that market participants knew the scale of the purchases. In contrast, the average lagged relationship that is picked up in the VAR is likely to reflect the impact of a wide range of unanticipated increases in ICPF money holdings occurring in the past, which may have taken more time to filter through the system as a whole. In the case of QE, one might therefore expect asset prices to jump or move more quickly to eliminate any incipient monetary disequilibrium in the financial company sector. Second, the ICPF sector is used as a proxy for the non-intermediate OFC sector as a whole and it is likely that ICPFs adjust their holdings of assets over a longer period than other financial companies, such as securities dealers. A further issue is that the estimated response of yields (the γ coefficient) looks a little small at 0.04. For example, we might expect the γ for a ten-year zero coupon bond yield to be closer to 0.1 and for the dividend yield to be around 0.05 (given the dividend yield was around 5% in 2009).

For these reasons, when analysing the impact of QE, we also consider an alternative, preferred case, imposing two assumptions rather than relying on estimated coefficients. First, we assume that the asset price response is immediate and moves quickly to eliminate any money

[14] Throughout we make the simplifying arithmetic assumption that the change in asset values is approximately equal to the overall change in the asset prices of the securities held in NIOFCs' portfolios.
[15] Note that £50 billion is chosen arbitrarily, in order to provide an indicative guide to the multipliers resulting from the model.

disequilibria. Second, we also assume that the response of yields is given by a weighted average of the expected γ's for the ten-year bond yield and the equity yield. We determine the appropriate weights based on the proportion of ICPFs' portfolios held in gilts and equities (60% and 40% respectively), which gives a weighted γ of around 0.07. Together, these two assumptions imply an immediate asset price increase of around 10% in response to a £50 billion shock to NIOFCs' money holdings (see Chart 13).

Chart 12: The impact of a shock to financial company money on asset prices

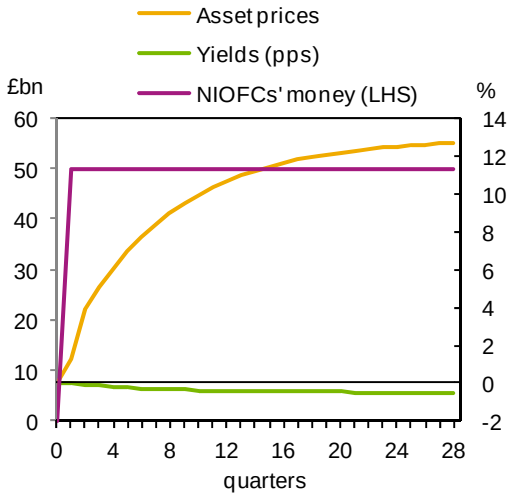
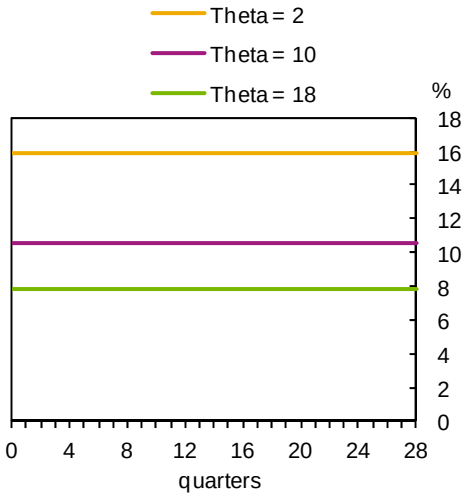


Chart 13: Sensitivity of the asset price increase to θ (theta)



Naturally, the long-run impact of a money shock on asset prices is also sensitive to the degree of substitutability between money and other assets. In Chart 13 we show the sensitivity of the asset price impact to two standard deviations around our central estimate of θ. This gives a range of 2-18 for θ and leads to a range for the asset price response of 8%-16%.

The household sector

The household sector model used is a simple two-equation system of household M4 and consumption spending based on Thomas (1997a). As discussed in that paper, for estimation purposes, income, financial and housing wealth and rates of return are treated as weakly exogenous. In this system, personal sector money holdings depend on consumption according to the transactions demand for money, and both consumption and long-run money demand depend on total net financial and housing wealth (asset values). But there is also a direct effect of money holdings on consumption spending, suggesting some form of liquidity effect on consumption.

In the household sector system, the link between money and spending depends heavily on the shock introduced. Unlike the financial company sector, a money shock is likely to be less relevant for the overall QE impact, as asset purchases are unlikely to affect household deposits directly. Instead, the expected channel from QE to the household sector is through a rise in asset prices, induced by portfolio rebalancing amongst financial companies. Chart 14 therefore shows the predicted impact of an increase in financial wealth on household deposits and consumption.

In particular, a 10%[16] increase in financial wealth leads to a 4% rise in total wealth (as equity and bond wealth is 40% of the total net financial and tangible wealth of households) and a 1%-1.5% increase in consumption. That would be broadly consistent with spending out of the increase in wealth at an annuity rate of 4%-5% per annum. The household demand for money rises by £20 billion over four years and £30 billion by the end of seven years.

The private non-financial corporation (PNFC) sector

The PNFC sector model uses a three-equation system of PNFC money holdings, borrowing and investment based on Brigden and Mizen (2004). Money is required for investment spending and investment itself depends on output, the cost of capital and capacity utilisation. But, like the financial company and household sectors, there is two-way feedback between money and investment. In particular, the gap between actual money holdings and equilibrium money demand has a positive effect on investment. This introduces some direct effects of money holdings on investment. But the key channel that is likely to be relevant for QE is the impact of a lower cost of capital and higher asset prices on investment and the demand for money. Chart 15 shows the predicted impact of a fall in the cost of capital of around 2.5%, which is consistent with a 10% change in equity and bond prices. The result is a 1.3% rise in investment. This increases the demand for money by PNFCs by around 0.5%, or just over £1 billion after three years. These look to be small effects but as these are only partial simulations they do not take into account second-round effects of higher GDP on investment and money demand. We will look at these when we combine the sectoral models together to produce an aggregate impact.

Chart 14: The impact of higher asset prices on household consumption

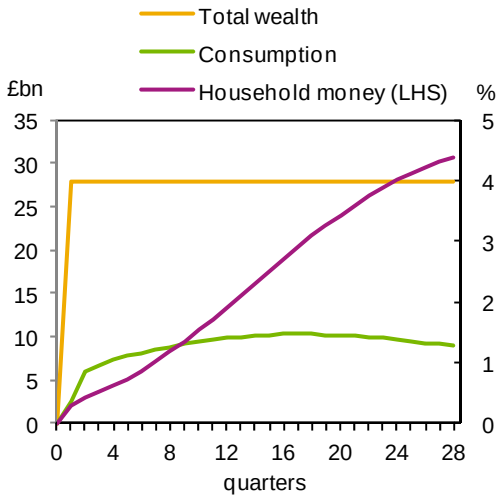
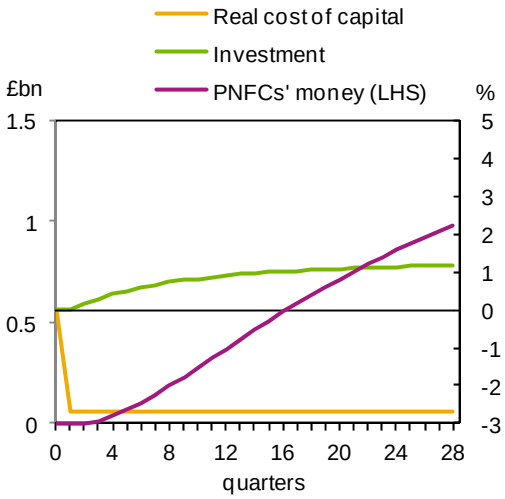


Chart 15: The impact of higher asset prices on investment



4.4 Linking the sectoral models together to produce an estimate of the impact on GDP and inflation

In order to produce an estimate of the impact of QE on the economy, the three sectoral systems outlined above need to be connected by various linking equations between asset prices,

[16] Note that a 10% increase in financial wealth is again chosen simply to give an idea of the multipliers resulting from the model. It is approximately the size of the asset price effect induced by a £50 billion money shock to the financial company sector, as shown in Chart 13.

household wealth and the cost of capital. Assumptions are also needed about how the aggregate money stock evolves and how sectoral money holdings are interlinked. Finally, assumptions are required about how real GDP responds for a given increase in real consumption and investment and how that in turn affects inflation. We make the following assumptions in our preferred baseline specification:

(i) We assume that the aggregate money supply impact is equal to the calibrated impact of asset purchases in Section 3. Based on the evidence in Section 3, this means that there is no additional credit expansion resulting from higher reserves in the banking system. In the PNFC system, we are therefore holding lending fixed (over and above the fall in bank lending arising from substitution to the capital markets). This assumption implies that any increase in the demand for deposits by households and corporates has to be obtained from the financial sector by selling assets to them or cashing in investments with them. That in turn means that asset prices will fall back, as a transfer of money holdings takes place. This is because asset prices are pinned down by the amount of money in the financial sector, according to the money demand equation for financial companies.

(ii) As discussed in the previous section, our preferred specification assumes an immediate asset price adjustment in response to QE. It also assumes that the impact on yields is a weighted average of the expected impact on ten-year bond yields and equity yields. The real cost of capital is assumed to fall according to the impact of higher equity and bond prices on the dividend and corporate bond yield. Household equity and bond wealth is assumed to move in line with the value of financial company assets. We assume that house prices and housing wealth are unchanged.

(iii) To produce an impact on GDP we combine the consumption and investment impacts according to their expenditure shares but also assume that imports increase in proportion to GDP. Dwellings investment is assumed to rise in proportion to business investment. Exports are held fixed as we assume that the exchange rate is unchanged in our baseline case. Note that consumption depends on income so there will be feedback or multiplier effects of higher GDP back on to household spending. Similarly, investment depends on capacity utilisation which we model as a function of GDP growth and the level of output de-trended by a linear time trend. So there are also investment accelerator effects embodied in the system. This means the system response of consumption and investment will be stronger than the partial effects of higher asset prices shown in the previous section.

(iv) We close the model with a simple Phillips curve equation linking the output gap to inflation, which we base on the specification of the Bank of England quarterly model (see Harrison *et al* (2005)).

(v) We also assume that nominal deposit rates and Bank Rate are unchanged. So there are no monetary policy feedbacks incorporated in these simulations. That is consistent with QE operating under the lower bound constraint for interest rates. We

also implicitly assume that inflation expectations are unchanged, given that they are not explicitly identified in the sectoral models. So *ex ante* real policy and deposit and loan rates are implicitly fixed in these simulations.

Chart 16a: Money holdings and asset prices in the preferred central case scenario

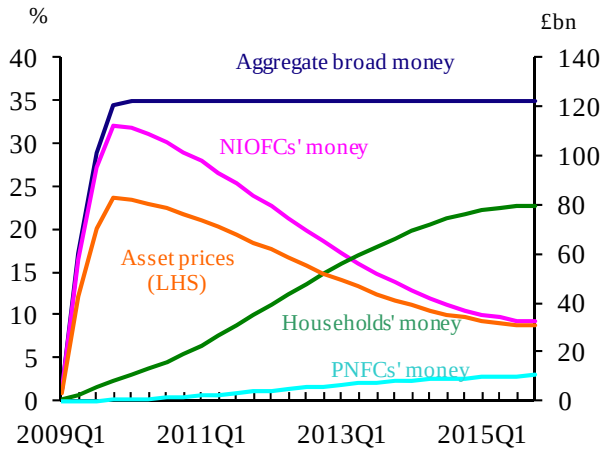


Chart 16b: GDP, inflation and velocity in the preferred central case scenario

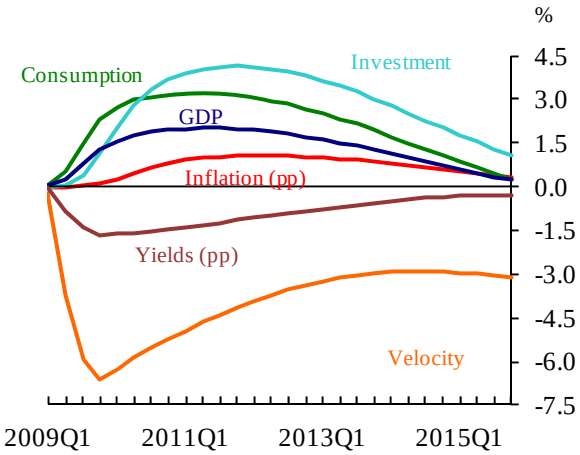


Chart 16 shows the impact of our central case QE money supply shock of £122 billion on the complete sectoral system, under our preferred assumptions. We introduce the shock into the NIOFC sector in the same way as the partial simulation earlier, but now allow the asset price impacts to spill over into the household and corporate sectors. So the money supply increase is treated as an exogenous shock to the ICPF sector, but this generates an endogenous demand for money from the other sectors.

Initially, the higher level of money holdings in the NIOFC sector leads to a rise in financial asset prices and a fall in yields, according to the portfolio adjustment implied by the estimated equations for this sector. Asset prices are predicted to rise by a little over 20% by the end of 2010 Q1. This translates into about a 150 basis point fall in the composite yield and a 6% fall in the real cost of capital.

The rise in asset prices in turn raises desired consumption and investment spending plans by households and PNFCs (by increasing wealth and lowering the cost of capital). The peak impact on consumption is around 3% and occurs by the middle of 2011, while the impact on investment spending peaks by the end of 2011 at around 4%. The peak impact on GDP from the increase in consumption and investment is around 2% and occurs around the middle of 2011. This leads to a peak impact on inflation of around 1 percentage point around a year later.

To finance higher spending plans, households and firms ultimately need more money balances. As discussed earlier, given the assumption that there is no additional money creation by the banking system, households and PNFCs can only obtain the additional money balances they need from the non-bank financial sector. It is therefore assumed that households would tap their higher wealth by cashing in investments that they have with an investment fund, and PNFCs respond to the lower cost of capital by issuing on the capital markets to the non-bank financial

sector directly. As a result, in this scenario, around two-thirds of the aggregate increase in money holdings gradually leaks out of the financial sector and into the other sectors. This nips some of the hot potato effect in the financial sector in the bud and asset prices decline somewhat from their peak. This leakage is largely to the household sector, given its larger share of total deposits. PNFC deposits only increase by a small amount, as the 4% pickup in investment only requires a similar proportional pickup in their money holdings – amounting to only around £10 billion.

As Chart 16 indicates the combined sectoral models do not produce a completely neutral impact from money. Even though real output broadly returns to its initial level after 7 years, the price level is only around 5% higher as a result of an 8% increase in broad money. As a result the velocity of broad money falls by around 3%. Unlike the aggregate SVAR model there are not a complete set of long-run relationships that pin down the aggregate response of the economy in real terms. And we have not closed our sectoral system with the sort of fiscal and monetary policy rules that are typically required in standard macroeconomic models to bring the economy back to a steady state. Nor have we included a full set of stock-flow relationships such as between investment and the capital stock. So it may be that an outcome closer to neutrality might be achieved in the very long run were these sorts of conditions to be included. As a result the long-run predictions of the sectoral system should be treated with caution. But we should also be aware that there are theoretical arguments that the impact of an increase in money might not be completely neutral on all real variables. For example, some models suggest money should only be neutral for 'helicopter drops' of money distributed in exact proportion to existing holdings of money (see Gale (1982) for a discussion). QE on the other hand represents an exchange of money for bonds with just the financial sector of the economy. Given the lag between higher asset prices and spending one should probably expect a persistent effect on the velocity of circulation at the very least, as money gradually gets transferred from the financial sector to companies and households.

4.5 Sensitivity to baseline assumptions

The estimated impact of QE outlined in the section above represents our preferred central case. It uses the sectoral approach to provide a coherent narrative of the transmission of QE from money balances onto asset prices and then through to different parts of the real economy. As discussed, the specification embodies reasonable assumptions given the nature of QE and observed features of the data over the QE period. For instance, asset prices are assumed to respond quickly, the exchange rate channel is excluded and there are no second-round effects via the bank lending channel.

But our central case and the assumptions that it embodies are necessarily uncertain. In this section, we therefore show the sensitivity of our results to different assumptions about the size of the shock to the money supply and the nature of the transmission mechanism. That provides a guide to the uncertainty around our central case. First, we show the range of responses in our preferred specification to the upper and lower bounds for the size of the money supply shock associated with QE that were discussed in Section 3. Second, we remove the imposition of immediate asset price adjustment in response to QE. Third, we allow for an increase in bank

lending in association with QE, consistent with a role for the bank lending channel. Finally, we investigate the sensitivity of our results to the specification of the consumption and investment functions. In Section 5, we then draw these estimates together, alongside those from our aggregate model, in order to present a full swathe of results. We show that our preferred central case gives an economic impact broadly in line with the mean of all the specifications.

4.5.1 Sensitivity to the size of the money shock

As discussed in Section 3, we are uncertain about the size of the money supply shock induced by QE. Our central case is that money was boosted by £122 billion as a result of asset purchases, but our upper and lower bounds for this impact are £200 billion and £77 billion respectively. Chart 17 below shows how the aggregate impacts from our preferred specification of the sectoral models vary with the size of the money shock. The charts show that the 5%-13% range for the money supply impact leads to a peak impact on asset prices of between 15% and 40%, a 1.3% to 3.2% peak impact on GDP and a 0.7 to 1.7 percentage point peak impact on annual CPI inflation.

4.5.2 Sensitivity to a gradual adjustment of asset prices

As discussed earlier, our preferred specification assumes that asset prices respond immediately to QE and that yields and asset prices are linked by simple asset pricing rules of thumb. An alternative approach is to allow both asset prices and yields to respond based on the estimated VAR coefficients which captures their average response to previous money shocks. That scenario would suggest a more gradual asset price adjustment and a smaller reaction of yields, given the change in asset prices than in our baseline specification.

Chart 18 shows the impact of our central £122 billion money supply shock on the sectoral models in the case where it takes time for money to ripple through the financial sector. In this delayed adjustment case, the peak impact on asset prices does not occur until the middle of 2012. The magnitude of the peak asset price effect is very similar to our central, immediate adjustment case. But the associated impact on yields is smaller. The peak impact on the level of real GDP remains broadly unchanged at 2%, but is delayed until the beginning of 2013. As with our preferred model, the peak impact on inflation is around 1 percentage point and follows around a year later.

Chart 17: Economic responses in the preferred specification of the sectoral models with central, upper and lower bounds for the size of the money shock

Chart 17a: Broad money

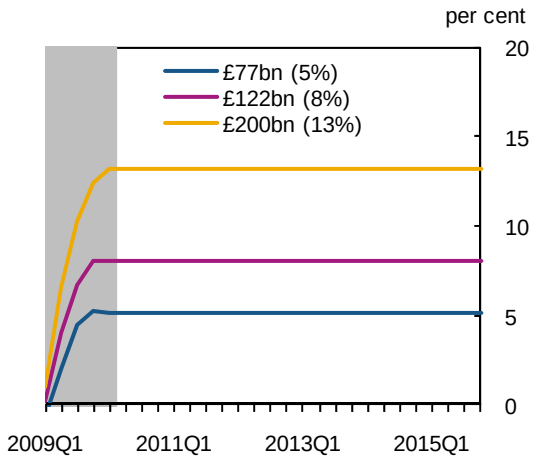


Chart 17b: Asset prices

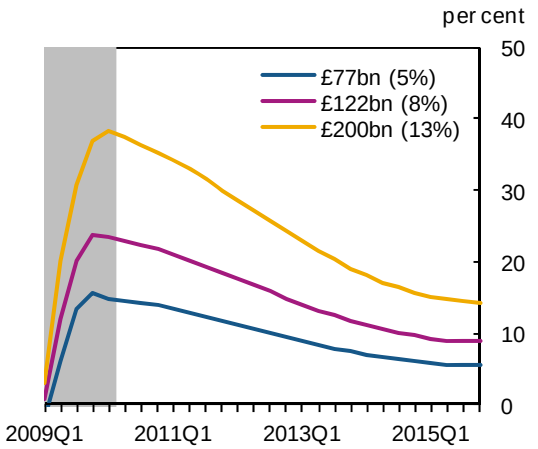


Chart 17c: Composite yield

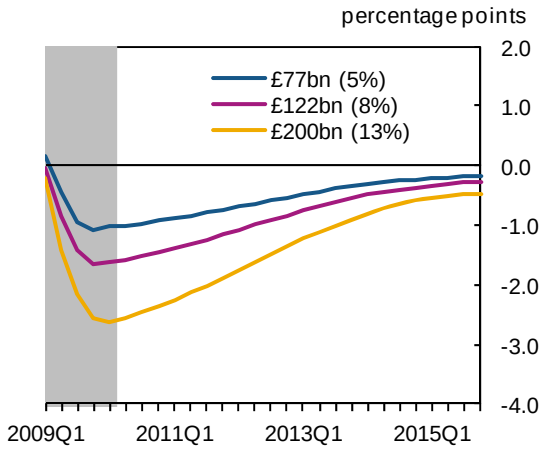


Chart 17d: Broad money velocity

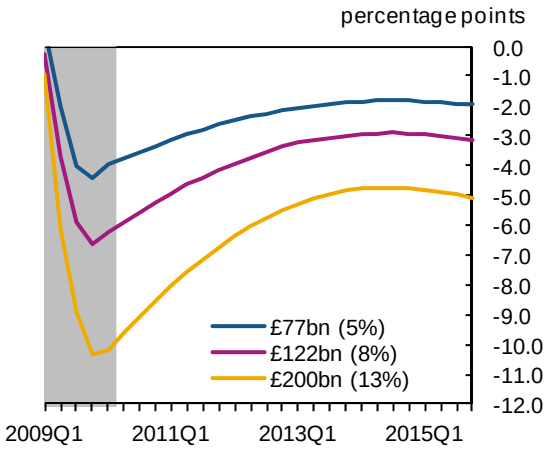


Chart 17e: Level of GDP

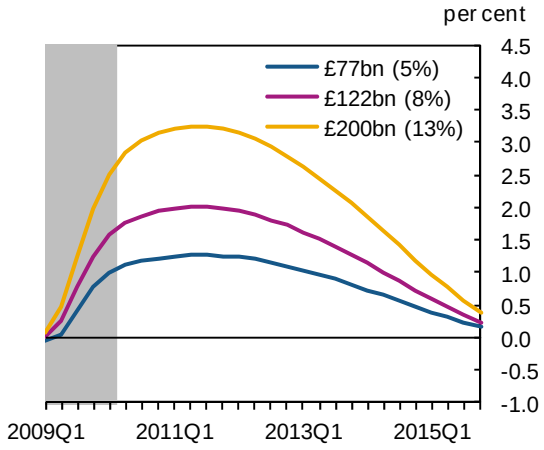


Chart 17f: Annual CPI inflation

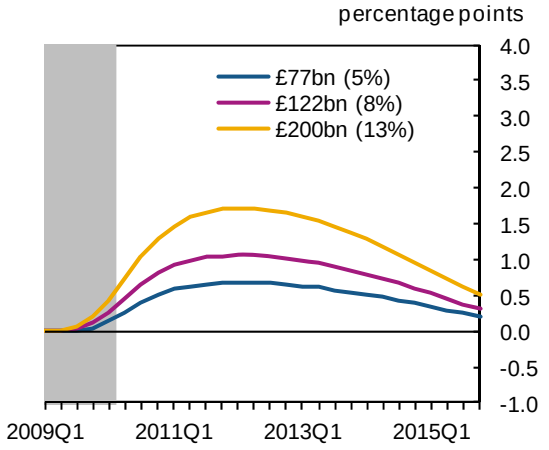


Chart 18a: Money holdings and asset prices in the delayed adjustment case

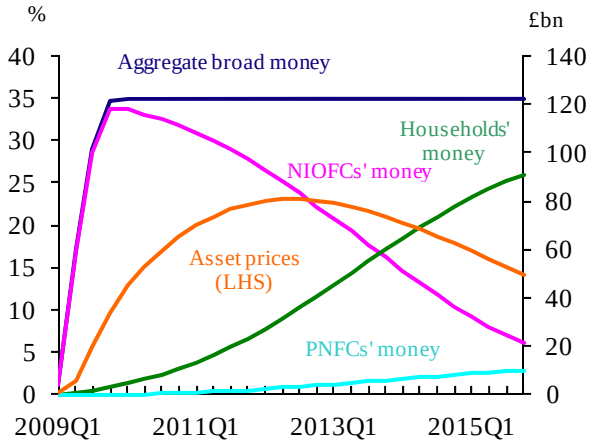
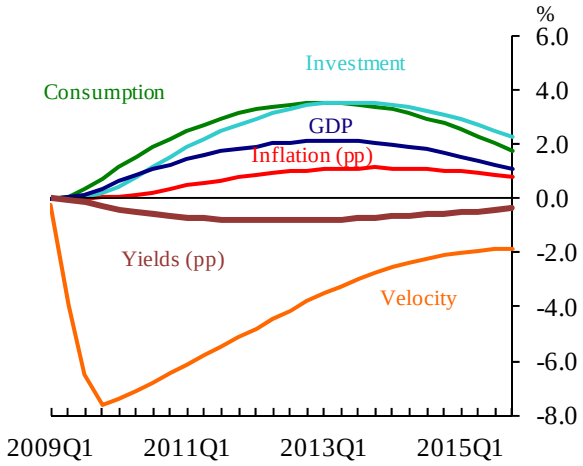


Chart 18b: GDP, inflation and velocity in the delayed adjustment case



4.5.3 Sensitivity to the response of bank lending

In our central case, it is assumed that households and companies obtain the extra deposits that they wish to hold in response to increased asset prices and spending from non-bank financial companies (see Section 4.4). This implies that as the impact of asset purchases filters through the economy, the aggregate money supply impact remains fixed at £122 billion. In turn, that means that there is no additional credit expansion from the banking sector as a result of asset purchases. This assumption is consistent with the sustained weakness in bank lending observed through the QE period (see Section 3).

An alternative approach would be to assume that households and companies are able to obtain the extra deposits they desire by borrowing from banks. In this scenario, the aggregate money supply is allowed to rise, as banks accommodate the higher demand for money from households and firms by providing more credit. This may be justified in the central and lower bound cases where the size of the money shock associated with QE is less than £200 billion. In these cases, part of the offset to the initial £200 billion of asset purchases was bank recapitalisation and balance sheet repair. Other things equal, that balance sheet repair should ultimately facilitate greater lending by the banking system. Similarly, the remaining money leakage in these scenarios occurs as PNFCs issue debt and equity on the capital markets in order to pay down bank debt. That deleveraging of the corporate sector might also encourage banks to conduct more new lending than they might otherwise have done.

Chart 19 shows the economic impact of our £122 billion QE money supply shock under this alternative assumption. Aggregate broad money now rises beyond the initial £122 billion boost from QE, as the household and PNFC sectors obtain additional money from the banking sector. No money is now drained from the OFC sector, such that the hot potato effect on asset prices is more persistent. As a result, the peak impacts on both GDP and inflation are higher, at 2.7% and 1.4 percentage points respectively. These impacts are also more persistent.

Chart 19a: Money holdings and asset prices with a variable bank lending

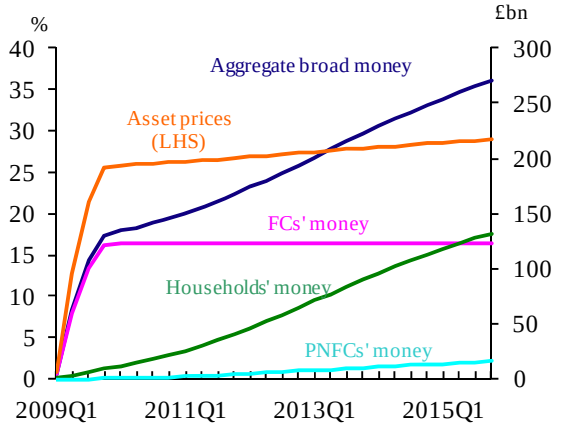
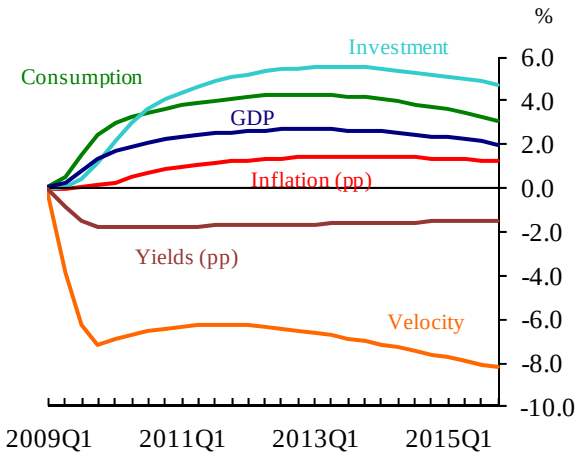


Chart 19b: GDP, inflation and velocity with variable bank lending



4.5.4 Sensitivity to the consumption and investment functions

The responses of consumption and investment to QE in our central case are fairly similar in percentage terms. This suggests that QE had a relatively balanced impact on the spending of households and companies.

One might expect that the effects of higher asset prices on household spending might be relatively smaller than those on corporate sector spending. That is because the corporate sector is more directly exposed to financial markets and a lot of household equity and bond wealth is indirectly held in the form of pensions and other long-term investments. Only around a quarter of household equity and bond holdings are held directly or in mutual funds that can be liquidated easily. The estimated coefficient on wealth in our central case consumption equation should pick this factor up on average and, as noted earlier, it is consistent with a reasonable annuity rate of 4%-5%. But it seems sensible to explore a variant where the impact on households' financial wealth is only a quarter of that of the central case, as a lower bound. This assumes that households only perceive and respond to their directly held wealth. The impact of this on consumption and GDP is shown in Chart 20. The peak impact on GDP would be just under half of the central case peak impact and would not occur until the middle of 2012.

Another key sensitivity is that investment spending effects are highly sensitive to how 'accelerator effects' are specified. The accelerator effect means higher output leads to further second-round effects on investment, as firms try to maintain the investment-output ratio. As noted earlier, in our central case, capacity utilisation was modelled as a function of GDP growth and the level of output de-trended with a linear time trend. We experimented with an alternative specification where output is de-trended with an HP-filter (which allows for more variability in trend output). This alternative specification shows significantly stronger accelerator effects. It is not abundantly clear which model we should prefer but we treat the stronger accelerator effect as an upper bound on the investment response. Chart 21 shows that stronger accelerator effects would imply a doubling of the investment response and would lead to a larger and more delayed peak impact on GDP of closer to 2.5%.

Chart 20: GDP response with lower wealth effect on consumption

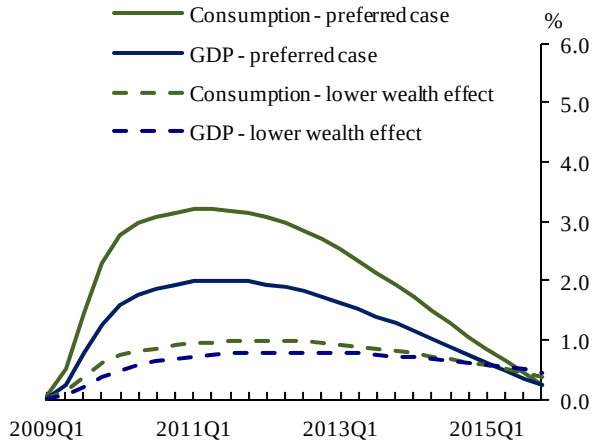
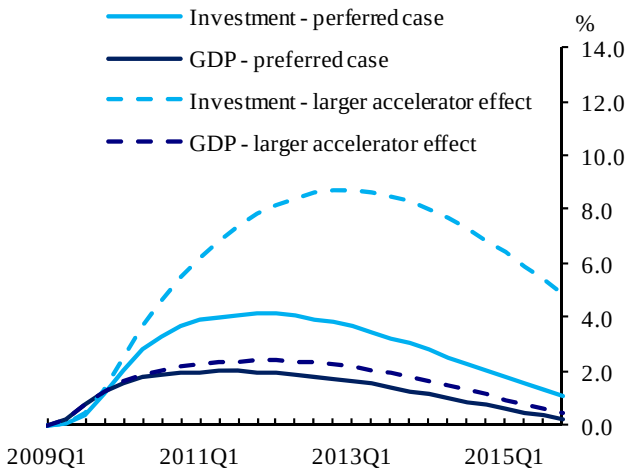


Chart 21: GDP response with larger accelerator effect on investment



5 What was the impact of QE on the UK economy?

5.1 Summary of our range of estimates

This paper has estimated the size of the money shock associated with QE and examined the impact of this shock on the wider economy using a set of empirical models. The exact multipliers vary according to the model used and the assumptions made. That is unsurprising given that each specification has its own set of issues with regard to introducing QE. But the estimated impacts on asset prices, yields, GDP and inflation are broadly within the same quantitative range across all of the specifications. Moreover, these responses are in line with the predictions of the monetarist transmission mechanism outlined in Section 2.

The range of responses estimated in this paper are summarised in Table 3 and Chart 22. The ranges given in the table and the swathes shown on the chart give an indicator of multiplier uncertainty across the different model specifications that we have analysed. As discussed earlier, our central case for the impact of QE in our preferred model specification is a boost to asset prices of just over 20% by 2010 Q1, followed by a peak impact on the level of real GDP of around 2% and on inflation of about 1 percentage point. Clearly these numbers are uncertain. But it is encouraging that our preferred responses are very similar to the mean response across the nine different model specifications included in the swathes on Chart 22. That provides broad support for the orders of magnitude depicted in our preferred model. And we can use our preferred specification as a 'representative model' to articulate a full story for the transmission of QE from a shock to money holdings through to an ultimate impact on GDP and inflation. Our alternative specifications are useful in highlighting uncertainties around the nature of that transmission.

Table 3: Summary of responses to QE across model and shock specifications

Impact on:	Asset Prices - 2010 Q1 (approx %)	GDP level - Peak (%)	Annual CPI Inflation - Peak (pps)
Preferred model estimate	**23½**	**2**	**1**
Sensitivity of preferred model to money supply shock uncertainty	15 – 38¼	1¼ – 3¼	¾ – 1¾
Sectoral model asset price impact uncertainty	12¾ – 33¾	1½ – 2¾	¾ – 1½
Sectoral model multiplier uncertainty	23½ – 25¾	¾ – 2¾	½ – 1½
Aggregate model estimate	17 – 19¾	1½	¾ – 2¼
Mean estimate across all model specifications	**22¼**	**1¾**	**1**

Note: The 'preferred model' responses are as described in Section 4.4 and Chart 16. The ranges showing the sensitivity of those responses to the size of the money shock are as described in Chart 17. The ranges capturing 'asset price impact uncertainty' include the uncertainty about the substitutability between money and non-monetary assets described in Chart 13 and the gradual adjustment case outlined in Chart 18. The 'sectoral model multiplier uncertainty' ranges include the variable lending channel, weaker consumption wealth effect and stronger investment accelerator cases described in Charts 19 to 21. The aggregate model estimates are as discussed in Chart 11. The mean response is a simple average of the response of all the specifications under the £122 billion money shock.

The range of responses in this paper also encompasses the estimates of other studies which investigate the impact of QE in the United Kingdom. Our estimates of the impact of QE on financial market asset prices are comparable with those of Joyce *et al* (2010). The swathe of estimates in this paper for the impact of asset purchases on GDP and inflation is also similar to that found in Kapetanios *et al* (2012). These comparisons are discussed in more detail in Joyce *et al* (2011). Overall, the arithmetic of various monetarist models is therefore supportive of the results of models that largely focus on financial market prices.

5.2 What would the world have looked like in the absence of QE?

Using our preferred estimates of the QE multipliers outlined above, we can show the impact of QE on the monetary and macroeconomic data in the United Kingdom. Our approach is simply to remove the impact of QE predicted in our central case, in order to demonstrate what the world might have looked like in the absence of QE. We can then examine whether the resulting counterfactual looks sensible. Once the shock associated with QE is removed, what should remain is the impact of other macroeconomic shocks on money, asset prices and spending.

Chart 22: Summary of responses to QE across model specifications

Chart 22a: Asset prices

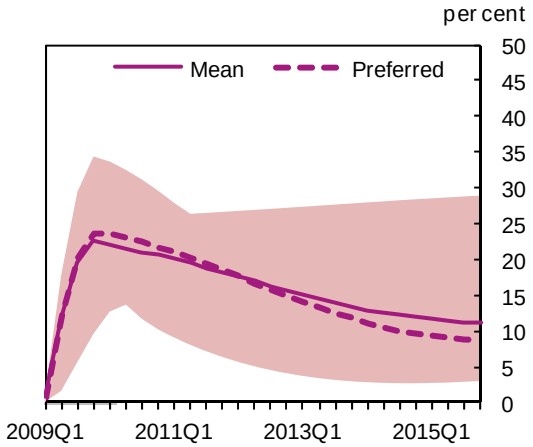


Chart 22b: Yields

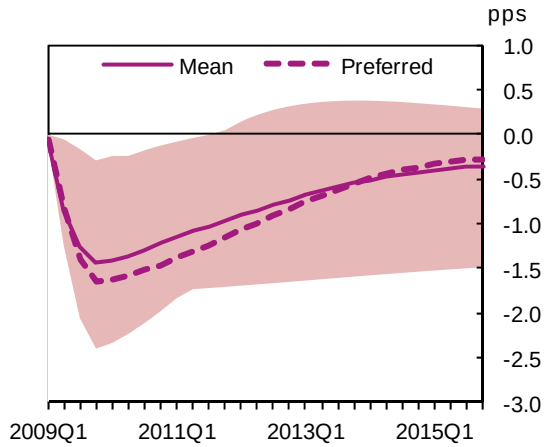


Chart 22c: Level of GDP

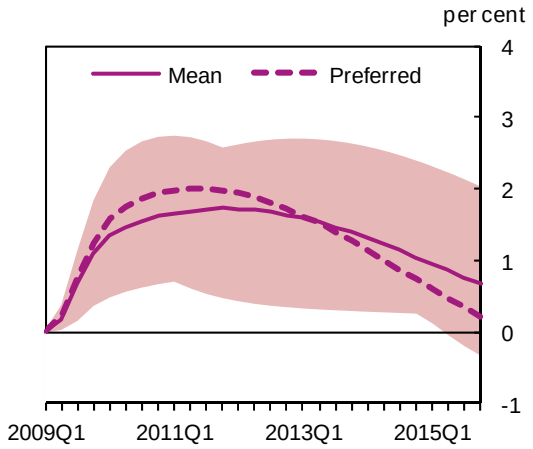
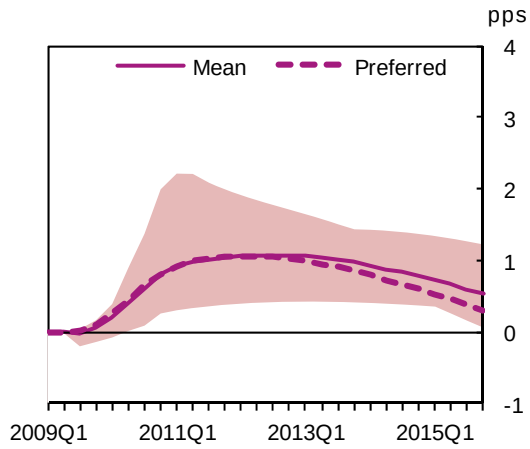


Chart 22d: Annual CPI inflation



Note: All responses shown are to the central case QE money supply shock of £122 billion. The 'preferred model' paths show the response of our preferred sectoral specification, as described in Section 4.4 and Chart 16. Each swathe contains a total of nine responses: alongside the preferred sectoral specifcation, each variant discussed in Section 4.5 is included: the delayed asset price adjustment case, the variable bank lending case, the weaker consumption response case and the stronger investment response case. We also account for uncertainty over the initial asset price impact in the sectoral model by including both the greater and lesser responsiveness cases discussed in Section 4.3 and Chart 13. Finally, the responses from the aggregate model (with and without a policy and exchange rate response), discussed in Section 4.2 and Chart 11 are included. The mean response is a simple average of the eight respones in each swathe.

Chart 23 shows what broad money and nominal GDP growth would have looked like if we remove the impact of QE suggested by our preferred model. Money growth would have been significantly weaker and would have exhibited a highly correlated but lagged relationship with nominal spending growth, similar to that observed in the 1990s recession. Chart 24 shows the same counterfactual in velocity space. This demonstrates that the observed V-shape in velocity would have appeared much shorter and sharper in the absence of QE. Indeed, following this temporary dip, velocity would have changed little relative to the start of the recession, similar to the stable path observed in the 1990s.

Chart 23 also demonstrates that nominal GDP growth would have been weaker in the absence of QE. That reflects the successful transmission mechanism of asset purchases onto real GDP and

inflation. As discussed, the first stage of that transmission occurs as QE boosts money holdings and hence requires an asset price adjustment to restore equilibrium. Chart 25 demonstrates that asset prices would have been notably weaker in the absence of QE, consistent with our preferred central case that QE boosted asset prices by around 20%. In turn, by generating higher asset prices and lower yields, QE stimulated consumption and investment and hence pushed up GDP. Chart 26 shows that the recovery in real GDP growth would have been notably weaker in the absence of QE, consistent with our central case that QE had a peak level impact on GDP of 2%.

Chart 23: Money and nominal GDP growth counterfactual

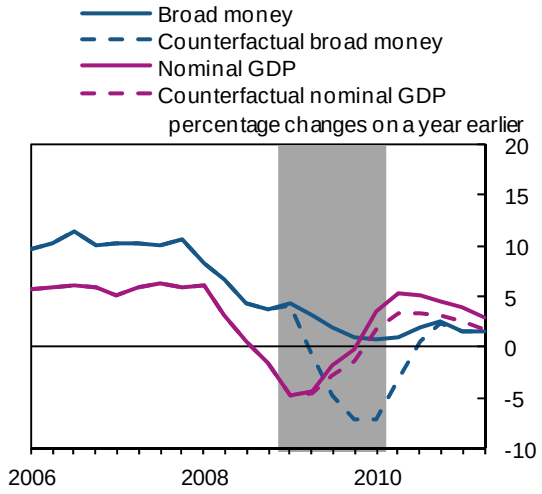


Chart 24: Velocity counterfactual

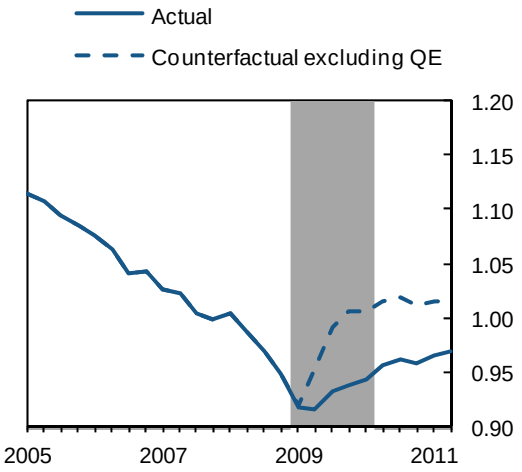


Chart 25: Asset price (FTSE All-Share index) counterfactual

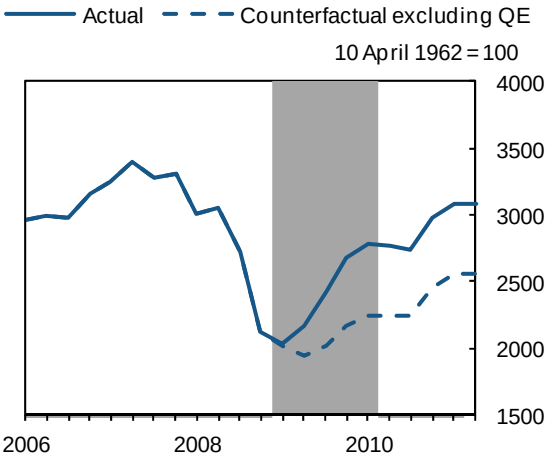
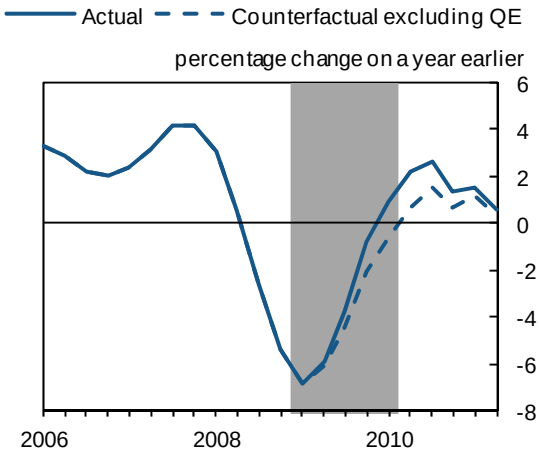


Chart 26: Real GDP growth counterfactual



6 Conclusion

This paper has estimated the impact of QE in the United Kingdom using a money demand and supply framework. We find, across a number of different models, that the increase in the broad money supply induced by QE is likely to have had a positive effect on GDP and inflation, by stimulating demand through lower yields and higher asset prices. Our results are supportive of those of other papers that have looked at the effects largely through the prism of financial market prices. Overall, the results suggest that money demand and supply arithmetic can provide a useful cross-check on other analyses for a shock that can be characterised as a money supply shock.

Appendix: Sectoral models

ICPF (Insurance company and pension funds) system of equations

Variables:
rm4icpf = log of real M4 holdings of ICPFs
rwicpf = log of real total sterling asset values of ICPFs
rdicpf = real rate of return on deposits
ryield = real rate of return on ICPFs domestic assets proxied by a portfolio share-weighted average of: (a) the real return on ten-year gilts; and (b) the FTSE All-Share dividend yield + the average growth rate of private sector output over the sample period (3% pa).

Cointegration and weak exogeneity test: 4 lags; sample 1988(1) to 2008(3)

Long-run money demand cointegrating vector (β), standard errors in brackets

rm4icpf	1.0000	
rwicpf	- 1.0000	
rdicpf	- 0.10403	
ryield	0.10403	(0.041642)

Loading vector (α), standard errors in brackets

rm4icpf		0.00000	
rwicpf		0.10431	(0.034)
rdicpf		0.00000	
ryield	-	0.45922	(0.172)

LR test of weak exogeneity restrictions: $\chi^2(4) = 4.9826$ [0.2891]
$\beta_1=1;\beta_2=-1;\beta_3=-\beta_4;$
$\alpha_1=0;\alpha_3=0;$

ICPF (Insurance company and pension funds) system of equations

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System estimated by FIML over sample: 1988(1) to 2008(3)

Δrwicpf = + 0.06692*Δrm4icpf(-1) + 0.06692*Δrm4icpf(-2)
(SE) (0.03003) (-----)

+ 0.0882*ECMicpf(-1) + 0.0163*Δrdicpf(-2)
(0.02946) (0.007181)

+ 0.2633
(0.0854)

Standard error of the equation = 0.0457

Δryield = - 0.2344*Δrm4icpf - 0.0975*Δrdicpf(-2) - 0.3892*ECMicpf(-1) - 1.1449
(SE) (0.235) (0.0358) (0.1463) (0.424)

Standard error of the equation = 0.226

ECMicpf = rm4icpf – rwicpf – 0.104*(rdicpf - ryield)

Single-equation diagnostics:

Δrwicpf	: AR 1-5 test:	F(5,73) = 0.38956 [0.8545]
Δrwicpf	: ARCH 1-4 test:	F(4,75) = 1.1406 [0.3440]
Δrwicpf	: Normality test:	$\chi^2(2)$ = 10.633 [0.0049]
Δrwicpf	: Hetero test:	F(8,74) = 0.33920 [0.9479]
Δrwicpf	: Hetero-X test:	F(14,68) = 0.42145 [0.9627]
Δryield	: AR 1-5 test:	F(5,74) = 0.47924 [0.7907]
Δryield	: ARCH 1-4 test:	F(4,75) = 1.1184 [0.3543]
Δryield	: Normality test:	$\chi^2(2)$ = 23.091 [0.0000]
Δryield	: Hetero test:	F(6,76) = 0.46871 [0.8295]
Δryield	: Hetero-X test:	F(9,73) = 0.50520 [0.8662]

Household sector model equations

Variables:
rm4hh = log of real M4 holdings of households
rwhh = log of real household total financial and tangible wealth
c = log of real consumption
y = log of real household disposable income
rdhh = own rate on household deposits
rb = Bank Rate
pc = log of consumption deflator

System estimated by FIML over sample: 1977(4) to 2008(4)

$\Delta rm4hh = + 0.7947*\Delta rm4hh(-1) - 0.04283*ECMrm4hh(-1) + 0.00837 + 0.1174*\Delta rwhh$
(SE) (0.152) (0.0166) (0.00258) (0.0377)

$+ 0.06627*\Delta rwhh(-1) + 0.1568*\Delta y + 0.1568*\Delta y(-1) + 0.002506*(\Delta rdhh-\Delta rb)$
(0.0413) (0.072) (0.072) (0.0019)

$+ 0.002219*(\Delta rdhh(-1)-\Delta rb(-1)) - 1.259*\Delta\Delta pc - 0.8127*\Delta c$
(0.00172) (0.248) (0.314)

Standard error of the equation = 0.00987802

$\Delta lc = + 0.3145*\Delta rm4hh(-1) - 0.2814*ECMc(-1) + 0.2963 + 0.05385*\Delta rwhh$
(SE) (0.126) (0.0446) (0.0474) (0.0279)

$+ 0.04429*\Delta rwhh(-1) + 0.1421*\Delta y + 0.07056*\Delta y(-1) - 0.003302*\Delta rb$
(0.0279) (0.0655) (0.0634) (0.000902)

$+ 0.003119*\Delta rdhh(-1) + 0.6778*\Delta rm4hh$
(0.00115) (0.138)

Standard error of the equation = 0.00835391

$ECMrm4hh = rm4hh - 0.55*c - 0.45*rwhh - 0.075*(rdhh-rb)$

$ECMc = c - 0.6*y - 0.25*rwhh + 0.00975*rdhh - 2.2854*\Delta pc$

Single-equation diagnostics:

$\Delta rm4hh$	: AR 1-5 test:	$F(5,107) = 1.7436$ [0.1309]
$\Delta rm4hh$	: ARCH 1-4 test:	$F(4,117) = 0.17307$ [0.9518]
$\Delta rm4hh$	: Normality test:	$\chi^2(2) = 7.7934$ [0.0203]
$\Delta rm4hh$	: Hetero test:	$F(24,100) = 1.3419$ [0.1579]
$\Delta rm4hh$	: Hetero-X test:	$F(90,34) = 1.7484$ [0.0341]
Δlc	: AR 1-5 test:	$F(5,107) = 2.4407$ [0.0389]
Δlc	: ARCH 1-4 test:	$F(4,117) = 0.79791$ [0.5289]
Δlc	: Normality test:	$\chi^2(2) = 49.029$ [0.0000]
Δlc	: Hetero test:	$F(24,100) = 1.0974$ [0.3608]
Δlc	: Hetero-X test:	$F(90,34) = 6.8719$ [0.0000]

PNFC sector model equations (with lending variables and terms removed)

Variables:
rm4pnfc = log of real M4 holdings of PNFCs
ibus = log of real business investment
y = log of real output
profits = log of real PNFC profits
rdpnfc = own rate on PNFC deposits
rl = effective PNFC loan rate
rb = Bank Rate
pgdp =log of GDP deflator
rcc = log of real user cost of capital
util = CBI capacity utilisation
D85 = dummy variable for 1985 Q1

System estimated by FIML over sample: 1978(3) to 2008(3)

$\Delta ibus = -0.1172*ECMpnfci(-1) + 0.0721*ECMpnfcm(-1)$
(SE) (0.0226) (0.025)

$- 0.02279*\Delta\Delta rl + 0.02252*\Delta\Delta rb$
(0.00585) (0.00544)

$+ 0.1169*\Delta D85 + 0.03665*util(-1) - 0.4706$
(0.0198) (0.00828) (0.114)

Standard error of the equation = 0.0227437

$\Delta rm4pnfc = - 0.06761*ECMpnfcm(-1) + 0.0264*(\Delta rdpnfc-\Delta rb) + 0.0170*(\Delta rdpnfc(-1)-\Delta rb(-1))$
(SE) (0.0179) (0.00775) (0.00803)

$+ 0.03414*\Delta prof - 1*\Delta pgdp$
(0.0152) (-----)

$+ 0.02628*\Delta D85 + 0.05605$
(0.0173) (0.0111)

Standard error of the equation = 0.0241983

ECMpnfci = ibus – y + 0.5*rcc + 0.082*(rl-rb)

ECMpnfcm = m4pnfc – 0.5*ibus – 0.5*y – 0.068*(rdpnfc-rb)

Single equation diagnostics:

Δibus	: AR 1-5 test:	F(5,95) = 2.5822 [0.0310]
Δrm4pnfc	: AR 1-5 test:	F(5,95) = 3.4099 [0.0071]
Δibus	: Normality test:	χ^2 (2) = 0.089551 [0.9562]
Δrm4pnfc	: Normality test:	χ^2 (2) = 5.0217 [0.0812]
Δibus	: ARCH 1-4 test:	F(4,106) = 1.5685 [0.1881]
Δrm4pnfc	: ARCH 1-4 test:	F(4,106) = 3.2204 [0.0155]
Δibus	: hetero test:	F(40,73) = 0.59760 [0.9609]
Δrm4pnfc	: hetero test:	F(40,73) = 3.0754 [0.0000]

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