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Non-Conventional Monetary Policies: QE and the DSGE literature*

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Abstract

At the zero lower bound, the scale and scope of non-conventional monetary policies have become the key decision variables for monetary policy makers. In the UK, quantitative easing has involved the creation of a fund to purchase medium term dated government bonds with borrowed central bank reserves and so has increased the liquidity of the non-bank financial sector and temporarily eased the budget constraint of HMT. Some of these reserves have been used to increase the extent of capital held by banks and there have also been direct injections of capital into the banking system. We assess some of the issues arising from the three policies by using three separate DSGE models, which take seriously the role of financial frictions. We find that it is possible to correct the effects of a lower zero bound in DSGE models, by (i) offsetting the liquidity premium embedded in long term bonds and/or (ii) adopting countercyclical subsidies to bank capital able and/or (iii) the creation of central bank reserves that reduce the costs of loan supply. But the correct quantitative response and ongoing interaction with standard monetary policy remains an open question.

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1 Introduction

An almost intractable hand was dealt to central bankers in the aftermath of the financial storm of 2007-2008, which culminated with the collapse of Lehman Brothers. The scale of the negative demand shock meant that central bankers found themselves bumping up against the zero lower bound for short term policy rates, as nominal income growth went negative. A parallel debate ensued about the appropriate level of capital and liquidity for financial intermediaries, which has led to the Basel III agreement. Finally central banks had to deal with the frozen interbank markets and burgeoning levels of bad debt and poorly performing assets. Quantitative easing was the new instrument of monetary policy, which in some degree can be thought of finessing this triplet, and so in this note we are interested in the extent to which it can substitute for or, indeed, complement the usual instrument, which is the short term policy rate. This problem is considered in this short note by calibrating and simulating three recently developed DSGE models. These model constructs are used to consider how QE, or more generally balance sheet policies, might achieve their objectives.

Each of these recently developed DSGE models differ from the 'plain vanilla' New Keynesian case by having more than one interest rate. So as well as a New Keynesian core model with forward-looking households and firms, optimising profits and consumption streams, subject to sticky prices and central bank operations conducted with an active interest rate rule. In each model one or more interest rates also impact on aggregate demand and have some traction on stabilising the economy. The creation of models with more than one interest rate means that the short term interest rate performs as an approximate control device at all times and an especially problematic one when the zero lower bound acts to constrain the interest rate path.

In the first model, developed by Harrison (2010) in this volume, the consumption Euler equation is tilted by a linear combination of short (policy) and long term interest rates.[1] The long term interest rate deviates from the long term expectation of the policy rate by a preference term that increases in the relative supply of long to short bonds. The policy maker can offset this premium by buying long term bonds and reducing the relative supply. And so when policy rates can fall no more, the purchase of long term bonds will reduce the average economy wide interest rate and help stabilise output.

The second model, a variant of that developed by Gertler and Karadi (2009), endogenises the commercial bank (financial intermediary) decision on the appropriate level of leverage to match a given loans production objective. The commercial bank choice on leverage impacts directly on the external risk premium paid by firms for lending. A negative shock to aggregate demand can lead to a large increase in the external finance premium and a contraction of leverage so a considerable amplification of the initial shock unless the government steps in to provide a bank capital subsidy to allow the premium

[1] Our version of Harrison (2010) is not exactly the same but captures the key linear equations.

shock to be attenuated.

In the third model, a variant of Goodfriend and McCallum (2007) developed by Chadha and Corrado (2011), consumers are deposit constrained and banks choose a mix of lending and reserves holding to meet a given level of deposit demand. Banks produce loans using a combination of the value of collateral, monitoring workers and also have preference for liquid reserves. Reserves act as a cushion against hiring and firing of monitoring workers and thus can attenuate movements in the external finance premium, which is essentially the marginal costs of loans supply.

For each model we run a similar exercise and assess two key aspects of monetary policy. In each case, we generate a large negative shock to aggregate demand in the model. This acts to propel the economy into a deep recession. We then explore the stabilising properties of a QE-like policy by examining whether output can still return to its steady state, even in the absence of an interest rate response. Then we allow policy rates to fall and examine whether the new instrument complements the policy rate over a business cycle. For each model, we assess the extent to which the new instrument of monetary policy is able to generate in isolation and when used in conjunction with the policy instrument a stabilising response. We find that there non-conventional policies can offset a persistent and large negative demand shock but seem rather a blunt tool in comparison to policy rates.

Section 2 outlines the recent UK experience with QE over 2009-2010. We present in simple terms the impact of QE on asset prices and on the broad money numbers. These findings help us to calibrate the models in the following section in which we outline the impact of new monetary instruments in each model. In Section 3, we outline the impulse response analysis conducted on each model, naturally the results are highly sensitive to the choice of parameters but we have tried to present a reasonable result in each case. Section 4 concludes and offers some remarks on future work

2 QE and the UK

The announcement in March 2009 to develop a bond purchase facility and the eventual purchase of £200bn of mostly conventional medium term dated debt has been a far from uncontroversial policy. With arguments coming from both sides of the debate, as some commentators have argued for more comprehensive purchases of more distressed assets and some have been concerned about the inflation consequences of such a large expansion of the central bank balance sheet. Later in this section, we will simply state the monetary balance sheet pre- and post- the (first) round of QE. But before that we will assess the simple announcement effects on financial prices of QE. This simple analysis allows us to pick appropriate calibrations of the models. Let us first outline the policy carried out. For more details on its intentions read the Chadha and Holly (2010) in this volume.

2.1 Quantitative Easing

In the five months immediately following the collapse of Lehman Brothers the Bank of England's Monetary Policy Committee (MPC) cut Bank Rate aggressively from 5% to just 0.5% by March 2009. Even coupled with a large depreciation of sterling and a fiscal stimulus, conventional interest rate policy seemed to have hit the zero lower bound and faced the possibility of a liquidity trap as four quarter growth in nominal GDP fell to -2.4% in the first quarter of 2009. Even before this intensification of the crisis in late 2008, the Bank of England had enacted a number of special measures designed to improve market conditions and liquidity in response to the mortgage, banking and credit crises. The Special Liquidity Scheme was introduced in April 2008, which let banks and building societies exchange high quality mortgage backed securities (MBS) for more liquid UK Treasury bills. This was followed in October 2008 by more permanent liquidity insurance in the form of the Discount Window Facility.

Then, on the 5th March 2009, coinciding with the cut of the policy rate to 0.5%, the Bank announced that it would begin a large scale asset purchase programme to loosen monetary policy even further due to substantial downside risk to the inflation target. These purchases would be funded by issuing new central bank reserves via the Bank of England Asset Purchase Fund Facility and would initially total £75bn. There have subsequently been announcements of increased purchases after MPC meetings in May, August and November 2009 (Table 1) until February 2010 when the programme was held at £200bn.[2] This figure amounts to some 14% of nominal GDP and around 23% of net debt. A full breakdown of the Bank's purchases to date (Table 2) shows the assets bought from the private sector were predominantly government securities (gilts) and there have been relatively small purchases of corporate bonds and commercial paper.[3]

The initial purchase range for gilts was set at 5-25 years maturities but this was extended to a wider range following the August 2009 MPC meeting.[4] In creating its version of quantitative easing, the Bank of England seems to have mimicked the unsuccessful Japanese idea of the early part of this decade. But it acted quicker in response to reaching the zero lower bound by beginning asset purchases in the same month as it cut Bank Rate to 0.5%. In so doing it tried to send a strong signal to the economy that the central bank is prepared to take whatever action may be necessary to reach its policy objectives. This is in contrast to the Japanese case where a policy rate of 0.5% was set in September 1995 but QE was not introduced until March 2001.

In the Bank of Japan's QE framework up to 2002 the only assets bought were government debt. The Bank of England bought a small amount of corporate assets as well,

[2] The Bank of England are keen to communicate that that they are prepared to resume purchases should it be considered necessary to do so.

[3] Arguably, the purpose of these smaller purchases differed from that of the gilt purchases in that their objective was to ease frozen markets and provide liquidity to firms by bolstering confidence.

[4] Any gilts with a residual maturity greater than three years.

with the intention of some direct easing of credit conditions. But the most fundamental difference between the two policies is that the Bank of England has purchased assets from the non-banking private sector. The Japanese asset purchase programme bought government debt almost exclusively from banks which meant the transmission of this increase in the money base to an increase in broad money depended wholly on the banks' decision on their optimal reserves holdings. What actually happened was that banks held the money as reserves in order to increase their own capital and improve balance sheets.

By buying assets from the non-banking private sector, the Bank of England provides a boost to broad money regardless of whether or not the banks increase lending. This might be important as following the financial crisis, the banking system is going through a necessary period of deleverage and balance sheet adjustment, so it was likely that any extra reserves would have been used to recapitalise and not necessarily passed onto the wider economy. Of course, the non-banking sector may also decide to use increased money balances to pay off debt and mend balance sheets and banks may still decide to hold reserves holdings or recapitalise. But once broad money holdings have been increased there are a number of channels through which the Bank of England's QE can work, unlike the Japanese concept which relied on the impaired bank-lending channel.[5]

The Bank of England's asset purchase programme is somewhat removed from the quantitative easing of the Bank of Japan at the turn of the century. But as the policy involves the temporary swap of central bank money for high quality government assets, all forms of QE are really just traditional open market operations with a significantly longer maturity and it is the impact of these operations we will try to model.

2.2 The Event Study

The main problem we face when evaluating the impact of the quantitative easing programme is the difficulty of the counterfactual. How do we try to separate the change in variables caused by asset purchases and changes caused by the myriad of other factors which affect them, particularly in the midst of such a profound financial crisis? How do we know what the economy would have been like in the absence of QE, *ceteris paribus*? To help isolate just the movements attributable to QE in the UK case, we follow the lead of Bernanke, Reinhart and Sack (2004) and Joyce *et al* (2010) and try to understand the price movements in a range of variables over the course of policy announcements relating to QE. More specifically we observe the change over a two day window for six significant policy announcements made by the Bank of England's MPC. Assuming that much of quantitative easing's impact on prices and yields will not necessarily occur when purchases and auctions physically take place, but when the news appears, the key events

[5] A fuller explanation of the Japanese experience of QE and the problems it faced can be found in Ugai (2006).

we focus on therefore are when the monetary policy authority released new information concerning the asset purchase programme (Table 3).

As with Joyce *et al* (2010), a two day window is chosen and we measure the change in variables from the close of business the day before the announcement to close of business the day after. Summing across the six policy announcement days gives an estimate for the change that might be attributed to the QE policy. A weakness of this methodology is that is fails to capture any lagged or learning effects or may incorporate some misunderstandings about the ultimate magnitude and composition of government purchases. This may lead to some bias in understanding the full impact of QE.

2.2.1 The Gilt Market

We begin with analysis of the sterling gilt market as this is where the vast majority of the APF's direct intervention occurred and where the clearest impact of quantitative easing should be observed. Over the course of the six policy announcements, average gilt yields are estimated to be 104 basis points lower across the initial purchase range. This figure is in line with other studies. The majority of this fall in yields came about in the event window surrounding the 5th March announcement where QE was officially outlined for the first time suggesting that this is when investors' behaviour, expectations and decisions were most affected by QE. But another reason the March announcement was associated with a larger change is that the introduction of QE was also joint with a cut in Bank Rate of 50 basis points. The latter extensions of the asset purchase programme were widely anticipated so were already built into agents' expectations and decisions to a degree before the announcement, muting its effect.

The yield curve flattened and became less steep in response to asset purchases as the slope fell by 42 basis points and the curvature by 36. This can be viewed as an indicator that the QE announcements helped to reduce term premia across the yield curve and reduce market perceptions of medium and longer term risk in the UK economy. Again, the large proportion of this change occurred in response to the introductory March announcement. In the case of the slope variable, there was an initial steepening of the curve following the February Inflation Report, attributed by Joyce *et al* (2010) to investors erroneously expecting the Bank to buy shorter term gilts than it eventually did. The March announcement then saw a 41 basis point swing back the other way as investors readjusted their expectations to include the new information from the policy announcement. The movements of slope around the other events were minimal, except in the case of the August announcement which was accompanied by an extension of the purchase range of gilts the Bank was willing to buy. This caused a 24 basis point fall in the slope of the nominal yield curve.

2.2.2 Corporate Bonds

We next look at corporate bonds. Investment grade corporate bond yields fell by 69 basis points over the six QE policy announcements, whilst non-investment grade corporate bond yields fell by 146 basis points. In the case of investment grade bond yields, the change occurred predominantly over the first, second and fourth announcements, hinting, as with the gilt markets, that these were the announcements which contained new information compared to the others which were in general anticipated prior to their official announcement. For non-investment grade bonds more than three quarters of the change happened in a single event, but not, as with the other variables so far considered in the March announcement but following the May announcement. In fact these results suggest some small widening of the investment grade spread over benchmark Treasuries and a narrowing of the non-investment grade spreads over benchmark Treasuries.

2.2.3 Spreads

The LIBOR spread (3 month LIBOR rate less Bank Rate) increased over the course of the QE announcements by 40 basis points and the LIBOR-OIS spread (3 month LIBOR rate less the overnight index swap rate) widened by 27 basis points. We might expect these spreads to narrow if QE helped alleviate liquidity problems in the banking sector. And so this counter-intuitive result is explained by closer analysis of the contributions from each interest rate at each announcement date. It is the March policy announcement, that also cut Bank Rate by 50 basis points, that explains the rise in both spreads at 43 and 33 basis points, respectively. If we exclude this anomalous result our study finds the LIBOR spread narrowing by 4 basis points and the LIBOR-OIS spread by 6 basis points.

Quite simply, as the March announcement did not only contain information about QE but was coupled with a cutting of Bank Rate by 50 basis points and all other things being equal this would automatically widen the LIBOR spread by 50 basis points. It seems that the LIBOR rate does not respond immediately to changes in Bank Rate and that this delay in its response is what causes us to observe this rise in the spread. We can also assert that the OIS rate reacts quicker to changes in Bank Rate and almost exactly mirrors it.

2.2.4 Interest Rate Forwards

Interest rate forwards fell at longer horizons over the six day event study at over 100 basis points. Inflation forwards at the 5, 10 and 20 year horizons all fell significantly with the longer maturities responding to a greater extent but real forwards fell by somewhat more. This implies that the QE announcements impacted significantly on expected real rates as well as inflation forwards.[6]

[6] Work is in progress to estimate the direct impact of QE on a macro-finance yield curve of the nominal and real term structure.

2.2.5 Exchange Rate

Using the effective sterling exchange rate, sterling depreciated by some 326 basis points, implying that sterling is approximately 3-4% lower thanks to the QE announcements. This result corresponds to a monetary view of the exchange rate where increases in the money supply devalues sterling against other currencies. Of course, the Bank of England was not the only central bank implementing unconventional measures and these would mitigate changes in bilateral exchange rates over the entire time period of QE but this effect should be largely stripped out as in an events study. We also look at two bilateral exchange rates; sterling against the euro and sterling against the US dollar. The event study finds that sterling fell 3.2% against the euro and 4.7% against the dollar.

2.2.6 Equity Markets

The event study of all six events shows that equity prices, represented by the FTSE All Share Index, have fallen in response to QE. The index fell by 74.5 over the policy announcements which equates to a 3.4% decline. The same is true if we take data on the FTSE All Share Total Returns which fell by 93.5, a very similar 3.3% in percentage terms. However, if we do not include the final February 2010 policy announcement in the event study the picture changes dramatically. Both All Share measures rise marginally (0.28% and 0.36% respectively) showing it is just the extreme negative nature of the changes following the final policy announcement which cause the overall event study results to be so skewed. The equity markets do not show any great response in the events studies.

2.2.7 Six versus Five Day Announcements

There is a considerable difference in the impact when we add up across all six annoucements and when we exclude the pivotal March announcement. Figure 1 shows first the impact on the term structure of nominal forwards from all six annoucements and also when we exclude the March announcement, at which policy rates were cut by 50 basis points and the first tranche of QE was confirmed. For comparison we also plot the estimated impact on the term structure from a typical 50 basis point cut.[7] There is a 70-80 basis point impact from the March announcement alone that is clearly not well explained by the cut in rates. And implies that the announcement of the initial tranche of QE was substantially responsible for the event study results. But it is not clear whether the larger interest rate response from the March announcement results directly from planned purchases of government debt or simply a signal that the 50 basis point cut would be more persistent than normal, or both.

[7] We used a three factor term structure model esimated over 1993 to 2007 and evaluated the typical response to a 50bp cut in policy rates. The details of this estimation are available on request.

2.3 Bank Capital Injections

Alongside the Bank of England's asset purchase programme there have been a number of other measures utilised in the attempt to stabilise the UK economy. On 13 October 2008, the UK Government announced it would buy £37bn of shares in banks, which had been drastically affected by the financial crisis. The purchases were implemented through the Bank Recapitalisation Fund and comprised a mixture of ordinary and preference shares. The initial announcement was for a capital injection of £20bn to RBS and £17bn to the newly merged HBOS/Lloyds Banking Group. This meant that the UK taxpayer owned around 58% of RBS and approximately 40% of HBOS/LBG.[8]

In total, data published by the Bank of England shows that between 2007 and 2010 the British Government directly injected around £50bn of capital into UK banks and building societies,[9] the vast majority of which went to the biggest banks. It should be noted that this capital injection corresponds to some 17% of capital held by UK banks pre-crisis. From the public policy point of view this subsidy may have been necessary in the end to prevent the failure of these institutions. However, it highlights the now apparent problem of a risk transfer, which is beyond the scope of this paper. A fuller discussion of the problems of systematically important financial institutions and a series of policy recommendations can be found in the G20 Financial Stability Board report released in October 2010.

2.4 Monetary Analysis

We turn our attention to the impact of QE on the monetary sector and on the balance sheet of the UK banking sector as this will not only enable us to better understand the monetary transmission mechanism and understand the destination of the £200bn but also help calibrate and evaluate our models. Broad money (deposit) growth over the QE period was weak. Chart 2 shows the Bank of England's favoured measure of broad money, M4x (standard M4 less intermediate OFCs) and Chart 3 shows the year on year growth rate. Immediately following the introduction of QE the growth rate of M4x continued to fall reaching just under 1% at the end of 2009. So far over 2010 broad money growth has remained considerably lower than the Bank's 6-8% target range but there have been some recent positive signs as it began to rise, reaching 1.6% in August 2010.

This low rate of growth results from a number of factors. First, without QE there might easily have been even weaker growth, if not a significant contraction of broad money. Secondly, the level of new debt and equity issuance by the UK banking sector, as it aims to recapitalise, may have reduced broad money growth and arguably can be viewed as a destruction of money in much the same way that quantitative easing temporarily creates it. Investors buying newly created debt and equity from banks pay using existing

[8]HM Treasury: Financial Services.

[9]Financial Stability Report, June 2010.

deposits and thus remove them from the system. A measure of the downward pressure on the money supply caused by this recapitalisation of UK banks is captured by net non-deposit liabilities, Chart 4.[10] Over the QE period the cumulative total was approximately £240bn suggesting a substantial undermining of the impact the monetary boost might have had on the money supply. Note that the direct effect on the money stock is not the only channel through which QE is designed to work and that the UK banking sector would have had to recapitalise anyway, which without additional quantitative intervention may have lead us to a much bleaker counterfactual for money growth.

A sectoral breakdown of M4 money holdings, Chart 5, reveals that PNFCs' holdings of M4 have now returned to their pre-crisis levels and show positive year on year growth. M4 money holdings of OFCs have jumped, mainly due to a change in reporting practices as of January 2010.[11] So the year on year growth rate is perhaps a better example of how OFCs' broad money holdings are evolving, Chart 6, and whilst this remains positive, it has slowed considerably. The growth of households' money holdings slowed through 2008 and 2009 but appears to be stable around 3% so far in 2010.

On the other side of the balance sheet, claims held by commercial banks against the Bank of England (reserves) rose by £111.5bn over the course of the asset purchase programme. This is a direct consequence of the creation of new reserves to finance the unsterilised purchases which make up QE, Chart 7. Total M4 lending excluding securitisations and loan transfers (M4Lx) fell over the QE period by £197.5bn, reflecting commercial banks' unwillingness to expose themselves to further risk and lend in the uncertain economic climate post-crisis. A sectoral analysis of year on year growth rates of M4Lx (Chart 8) shows that there are some signs of improvement with a return to positive year on year growth in lending to households. It reached around 3% at the end of 2009 and continued into 2010, having been contracting in the 12 months following the collapse of Lehman Brothers. Importantly, lending to PNFCs also shows signs of recovery. After it hit a year on year contraction of 4.2% in May 2010, it managed a fragile but marginally positive growth rate of 0.1% in August.

To summarise, the period concerning the Bank of England's asset purchase programme can be characterised by low but positive growth in deposits counteracted by strong levels of debt and equity issuance by the banking sector. Reserves increased whilst lending continued to be weak though with some more recent signs of recovery. Whilst some effects can be seen to be instantaneous, such as that on reserves, our monetary analysis suggests some others may work with a considerable lag and may only just be beginning

[10] Non-deposit liabilities (net) consists of capital and other non-deposit liabilites of UK banks less their investments in UK banks and other non-financial assets. In the Bank of England series used (series code LPMVRHV) a negative value indicates an increase in non-deposit liabilities and downward pressure on broad money.

[11] This adjustment involved off balance sheet securitised assets being brought onto the balance sheet. The one-off effect was estimated at around £176bn. For more details see http://www.bankofengland.co.uk/statistics/ms/articles/art1feb10.pdf

to be seen. Table 5 summarises the composition and size of the consolidated UK banking sector balance sheet immediately before the Lehman bankruptcy, immediately preceding the introduction of QE by the Bank of England, and in March 2010, just after the asset purchases were held at £200bn and we can note that reserves-deposit ratio rose from 2.4% to 9.8%.

3 The DSGE models

The development of DSGE models with financial frictions represents (at least) two analytical hurdles. First, that the maintained hypothesis of Modigilani-Miller must be put to one side for the macroeconomic models, so that changes in net worth or collateral impact on the optimal split between private sector debt and equity issuance, rather than disappearing in aggregate. Secondly, that the resulting set of interest rates in various credit markets reflect some ongoing heterogeneity otherwise they would be arbitraged away by our representative agent.

The literature on financial frictions and DSGE models is burgeoning and we do not aim to survey that here.[12] But what we can do is to assess the impact of unconventional policy instruments in three recently developed models. In Harrison (2010), the representative agent lives in a standard optimising economy with price stickiness, a New Keynesian Phillips curve and a forward-looking spending equation, albeit one in which there are interest rates of both short and long run maturity that tilt expenditures. The long term rate differs from the expected stream of short term rates because of a preference for short term bonds, which drives the liquidity premium on long term bonds up. This implies that even at the zero lower bound the monetary policy maker has some ability to tilt expenditures by buying long term bonds and therefore reducing the liquidity premium. And so we consider the impact on long term bond rates, and hence on consumption, from a monetary authority purchase of some 25% of outstanding government bonds.

The Gertler-Karadi model is a model of unconventional monetary policy with capital and financial intermediation. The flow of funds from savers to borrowers are organised by financial intermediaries. The liability side comprises of deposits from households and bank capital, which is matched with loans to firms to finance their investment. The net return from lending minus monitoring costs must always be greater than the cost of funding deposits at the nominal interest rate. There is therefore an equilibrium level of leverage which reduces in monitoring costs and increases in the interest rate spread between lending and deposit rates. Policy rates will act to reduce leverage by reducing the spread and non-conventional policies can directly impact on bank capital by offering state contingent subsidies or levies to affect the quantity of loans offered by banks, which

[12] See Altug *et al* (2003) for a statement of the problem. We leave the technical description of each model to the Annex, as that is not the contribution of this paper.

are always the product of leverage and bank capital employed.

The Chadha-Corrado model, is an extension of the Goodfriend and McCallum model (2007), in which credit constrained consumers require loans from a commercial bank in order to effect their planned consumption paths. The bank employs a loans production technology with arguments in the value of collateral and the employment of workers who monitor loans and also has to respect a liquidity constraint in deciding on the optimal levels of the reserve-deposit ratio. The commercial bank's liabilities can thus be funded by a mix of interest rate paying reserves and external finance premium paying loans. Chadha and Corrado (2011) find that in this framework, banks can use reserves as a buffer against costly changes in monitoring costs and so can choose to alleviate some of the counter-cyclical variation in the external finance premium. So we examine the implications from increasing the reserve ratio by some 7% in this model.

3.1 Results

3.1.1 Simulation Scenarios

For each model, we use the unconventional policy tool in a manner consistent with the magnitude of unconventional policy measures undertaken in the UK and assess the impact on key economic state variables: output, inflation, finance premia, lending, asset prices and policy rates. Each simulation is undertaken with three scenarios, (i) with the active interest rate rule switched on; (ii) then in conjunction with unconventional policy and finally, (iii) with unconventional policy alone. We can therefore gauge the partial in each general equilibrium policy to the new instrument alone.

Portfolio Balance Model We simulate the model with a 10% downward shock to real output, which replicates the experience of the UK. We then show three impulse responses, Chart 9, to key state variables in the portfolio balance model when the monetary policy maker (i) uses a Taylor rule only, (ii) in conjunction with asset purchases and (iii) uses asset purchases only to stabilise the economy.[13] In what might be considered normal times. when the zero lower bound does not constrain, policy rates fall by around 75bp, and output is stabilised in a year or so. When we also allow for asset purchases, these appear to take some of the workload off the nominal interest rate in correcting for the AD shock as the policy rate then falls by a little less and allow us to return to equilibrium output at roughly the same time. This suggests a possible but limited role for asset purchases as interest rates become constrained in their movements or if central bankers want to limit the volatility of the policy rate over the business cycle. Asset purchases

[13] There is no investment or government spending in the baseline version of this model. An interesting extension would be to consider the impact of liquidity premium on the structure of the maturity of private and public sector debt, in which we might expect relative overissuance of short term compared to long term debt to reflect the different costs.

combined with standard interest rate policy cause the long rate and 5 year forward to fall by a little more than would have been the case without QE style purchases. But clearly asset purchases can bring about a similar fall in long term interest rates as that implied by a fall in the short rate alone. A long term interest rate fall of some 100bp would seemingly require a much larger purchase of assets than the 25% suggested here, perhaps more in the region of 50-75%. But in any case such purchases will not offset the fall in output as much as a reduction in policy rates because output responds to both the short and long term rate.

Bank Capital Model With a model of bank capital, the initial downward shock to output of around 2-3% is stabilised with a cut in policy rates of some 50bp and a return to base in about 4 years and in this scenario inflation falls to around 0.4-0.5% below target, Chart 10. If there is no ability to cut interest rates and an injection of bank capital of some 17% is employed as the stabilisation device,[14] then output falls by around 2-3 times further and there is a similarly larger downward shock to inflation. And whilst that can lead to some stabilisation in output, if interest rates do not rise once the economy emerges from recession, in around 4 quarters on this calibration, it seems that there is a significant possibility of an overshoot in both inflation and output. The bank capital model thus suggests that a larger injection of capital than 17% may be required to offset a large negative demand shock and also highlights the need to raise rates once the momentum for recovery is established.

Bank Reserves Model The fall in output following a negative demand shock is, in this case, shown to be some 15%, Chart 11. Inflation falls by around 6% with real wages and employment both falling by something more than 20% and in this case the increase in monitoring effort by commercial banks puts upward pressure on the external finance premium. The increased issuance of bonds by the government, which tries to stabilise output also pushed up liquidity premia on bonds. In the two cases where the reserve-deposit ratio is not fixed but chosen endogenously by commercial banks, the contractionary shock leads to an increase in demand for reserves, which are supplied perfectly elastically by the central bank. This increase in reserves acts to limit the increase in the costs of loans supply, because banks hold reserves *ex ante* against potential problems with loans. Liquid reserves offset some of the upward shock to interest rats spreads and can mitigate around 30-40% of the shock in this model. In fact, if the non-standard monetary policy increased the reserves-deposit ratio by around 12%, it seems possible to stabilise the economy even if interest rates do not fall at all.

It would appear that some combination of government purchases of bonds, capital and

[14] Representing the £50bn direct injection calculated by the Bank of England's Financial Stability Report (June 2010) as a percentage of the £300bn of sterling capital and other internal funds held by UK banks as of 1st January 2007 (Source: Bank of England)

reserves injection can stabilise these DSGE economies following a large contractionary shock. But a number of issues remain. First, the non-conventional policies require careful calibration against an uncertain set of deep parameters and more work is required to understand how to ensure robust results across a wide-range of possible parameterisations. Secondly, the rate of exchange between unconstrained interest rates paths and unconventional policies seems poor, so that not only are we employing policies with an uncertain impact we seem to have to use them in relatively large amounts to substitute for a standard monetary policy. Thirdly, there seems to be a significant possibility of overshooting when using these policies and there is a difficult choice on how to complement the withdrawal of these policies with appropriately set interest rates. Finally, we have not really, other than using standard forward-looking models, been able to understand the importance of signalling and credibility in these models and that may be the most important transmission mechanism for policies when the zero lower bound matters.

4 Concluding Remarks

The models briefly outlined in this paper are fully described by their original authors and only represent the tip of a largescale research agenda by recently re-embarked upon by macroeconomists to understand the importance and implications of financial frictions for monetary analysis. It is far too early to provide a clear summary of the results of this research agenda but a few points are emerging. It does seem possible to modify the canonical DSGE model to incorporate additional conditions for market clearing in credit markets. This modification will ensure that the constellation of interest rates are not strictly proportional to the policy rate. At a stroke this implies that traditional interest rate policy will, at the very least, have to be supplemented with an analysis of the contributions from other factors on the monetary policy transmission mechanism. The detachment of financial prices, to some degree, from the household and production economy because of the existence of financial intermediaries with incomplete information is likely to be an enduring progress.

This substantive progress may initially be masked by a need to understand the availability of tools when policy rates approach the zero lower bound. The models outlined here develop financial market liquidity premium, endogenous capital and reserve allocations for financial market intermediaries. Tentatively, they suggest that governments can substitute for the zero lower bound and help the theoretical policy maker avoid the liquidity trap. It seems that the scale of interventions required are large by historic standards, not only because the size of the shock that needs to be stabilised is large but also because these interventions operate in model-based financial markets where there is relatively close substitutability across most financial assets, and thus require large quantities of net government transactions to lead to a substantive impact on prices.

In reality though the main impact of financial intermediation seems to be heavily procyclical - as financial activity seems to heighten and elongate business cycle expansions and exacerbate downturns. The models developed so far allow us to understand somewhat better the mechanisms that drive this impact. But we have yet to turn these essentially qualitative stories outlined here into a full fledged view on the exact calibration of the macro-prudential tools that may well be required over the business cycle to help staunch the impact of financial intermediation. It seems reasonable clear to us that this research agenda will continue to occupy us.

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Appendix

This appendix lays out the systems of log-linearised equations which make up each of the three models.

A: Portfolio Balance Model

This is our version of Harrison (2010), x, π and m are respectively output, inflation and money. The Government issues short and long term bonds. Long term bonds (b^L) pay a return (R^L) whilst short term bonds pay a return equal to the policy rate (R). There are two further interest rates in this model; the ex post return (R^A) and the real or natural rate of interest (r^*). V is the value of a consol (infinitely lived with no redemption date) and q is the level of assets purchased by the central bank to facilitate quantitative easing.

The Output Gap

$$\hat{x}_t = E_t\hat{x}_{t+1} - \sigma\left[\hat{R}^A_t - E_t\hat{\pi}_{t+1} - \hat{r}^*_t\right] \tag{A1}$$

Money Demand

$$\hat{m}_t = \frac{\sigma_m}{\sigma}\hat{x}_t - \frac{\beta\sigma_m}{1-\beta}\hat{R}^A_t \tag{A3}$$

Ex Post Return

$$\hat{R}^A_t = \frac{1}{1+\delta}\hat{R}_t + \frac{\delta}{1+\delta}E_t\hat{R}_{L,t+1} \tag{A5}$$

Short Term Bond Return

$$\hat{R}_t = E_t\hat{R}_{L,t+1} + \nu\left(\hat{b}_t - \hat{b}_{L,t}\right) \tag{A7}$$

Inflation

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \kappa\hat{x}_t \tag{A9}$$

Short Term Nominal Rate (Taylor Rule)

$$\hat{R}_t = \rho_R\hat{R}_{t-1} + (1-\rho_R)\left(\alpha_\pi\hat{\pi}_t + \alpha_x\hat{x}_t\right) + \varepsilon^R_t \tag{A11}$$

CB Balance Sheet

$$q_t = \rho_q q_{t-1} + \varepsilon^q_t \tag{A13}$$

Government Budget Constraint

$$\hat{b}_t + \frac{m}{b}\left(\hat{m}_t - \hat{m}_{t-1}\right) = \delta q_t - \left[\frac{m}{b} + \frac{1+\delta}{\beta}\right]\hat{\pi}_t + \left(\frac{1}{\beta} - \theta\right)\hat{b}_{t-1} - \frac{\delta}{\beta}q_{t-1} \tag{A15}$$

Issuance of Long Term bonds

$$\hat{b}_{L,t} = -q_t + \hat{V}_t \tag{A17}$$

Return on Long Term Bonds

$$E_t \hat{R}_{L,t+1} = \beta E_t \hat{V}_{t+1} - \hat{V}_t \tag{A19}$$

Real Rate of Interest

$$\hat{r}_t^* = \rho \hat{r}_{t-1}^* + \varepsilon_t \tag{A21}$$

The following two equations are for the two additional impulse responses. The 5 year spot is the expected sequence of one-period consol returns $E_t \hat{R}_{t-i}^L$.

Five year spot rate

$$5ys = \frac{1}{20} \sum_{i=1}^{n} E_t \hat{R}_{t+1}^L \tag{A21}$$

$$R_{L,t} = V_t - V_{t-1} \tag{A23}$$

Table A: Descriptions and Parameter Values

Parameter name	Description	Value
σ	Elasticity of intertemporal substitution	6
β	Discount factor	0.9
κ	Slope of the Phillips curve	0.1
ρ	AutoCorr. of real interest rate	0.9
σ_m	Money demand elasticity	6
α_π	Policy response to inflation	1.5
α_x	Policy response to output	0.5
ρ_R	Interest rate smoothing	0.8
ρ_q	Persistence of asset purchases	0.95
$\frac{m}{b}$	Money to Bonds in ss	0.001
δ	Ratio of long to short bonds in ss	3
ν	Elasticity of long bonds to portfolio mix	0.1
θ	Feedback parameter in tax rule	0.025

B: Gertler-Karadi Model

In this model Y, C and I are respectively real output, consumption and investment. Output is a function of total factor productivity (Z), labour hours worked (h) and physical capital (K) which has a price (q). The marginal cost is denoted by X. Commercial banks hold deposits (D) and capital (B) and extend loans (L) to the wider economy. This faces a cost (λ). Policymakers can directly affect banks' capital with a subsidy/levy (τ). The model contains three interest rates; R is the short-term nominal or policy rate, R^n is the natural rate of interest and R^k is the return on physical capital.

The linearised model is;

The Resource Constraint

$$Y_t = \frac{C}{Y}C_t + \frac{I}{Y}I_t \tag{B1}$$

Production Function

$$Y_t = Z_t + \alpha K_{t-1} + (1-\alpha)h_t \tag{B2}$$

Labour Market Equilibrium

$$Y_t = (1+\chi)h_t - X_t + \sigma C_t \tag{B3}$$

Price of Physical Capital

$$q_t = \phi(I_t - K_{t-1}) \tag{B4}$$

Return on Physical Capital

$$R_t^k = (1-\epsilon)(Y_t - K_t + X_t) + \epsilon q_t - q_{t-1} \tag{B5}$$

Law of Motion for Physical Capital

$$K_t = \delta I_t + (1-\delta)K_{t-1} \tag{B6}$$

Consumption Euler Equation

$$\sigma C_t = EC_{t+1} + E\pi_{t+1} - R_t + R_t^n \tag{B7}$$

New Keynesian Philips Curve

$$\pi_t = \beta E\pi_{t+1} + \kappa X_t \tag{B8}$$

No Shirking Condition for Bankers

$$L_t - B_t = \theta_1 R_{t+1}^k - \theta_2 R_t - \lambda_t \tag{B9}$$

Bank Capital Equation

$$B_t = \gamma\left[\theta_2(R_{ss}^k - R_{ss})D_{t-1} + R_{ss}^k B_{t-1} + \theta_1 R_{ss} R_t^k - R_{ss}\theta_2 R_{t-1}\right] - \tau \tag{B10}$$

Natural Rate of Interest

$$R_t^n = \rho_{NR} R_{t-1}^n + \varepsilon_{ADt} \tag{B11}$$

Short Term Nominal Interest Rate (Taylor Rule)

$$R_t = \rho R_{t-1} + (1-\rho)(\alpha_\pi \pi_t + \alpha_Y Y_t) \tag{B12}$$

Loans

$$L_t = K_t + q_t \tag{B13}$$

Bank Capital Subsidy/Levy

$$\tau_t = \rho_\tau \tau_{t-1} + \varepsilon_{taut} \tag{B14}$$

Balance Sheet Constraint

$$L_t = \frac{Bss}{Lss} B_t + \frac{Dss}{Lss} D_t \tag{B15}$$

Expected Liquidity Premium

$$ER^k_{t+1} - R_t = D_t + \lambda_t \tag{B16}$$

Marginal Cost Equation

$$X_t = \gamma_L h_t + (\gamma_C - \frac{C}{Y})C_t - \frac{I}{Y} I_t \tag{B17}$$

As well as identities for the lags.

Table B: Parameter Descriptions and Values

Parameter	Description	Value
$\frac{C}{Y}$	Fraction of output used for consumption	0.7
$\frac{I}{Y}$	Fraction of output used for investment	0.3
α	Cobb-Douglas PF coefficient	0.35
σ	Intertemporal substitution coefficient of consumption	0.97
$1+\chi$	Elasticity of output to labour hours	4
ϕ	Price elasticity of investment demand	0.5
ϵ	Price-return pass through	0.95
δ	Depreciation rate of capital	0.025
κ	Slope of the NK Phillips curve	0.1
β	Discount factor	0.9
R^K_{ss}	Steady state return on capital	0.02
R_{ss}	Steady state policy/deposit rate	0.01
L_{ss}	Steady state level of loans	8
D_{ss}	Steady state level of deposits	7.9
B_{ss}	Steady state level of bank capital	5.7
θ_1	$\frac{Lss}{Bss}\frac{R^K_{ss}}{R_{ss}}$	5.33
θ_2	$\frac{D_{ss}}{B_{ss}}$	1.25
γ	Profit elasticity of bank capital	0.3
ρ	Interest rate coefficient of the Taylor Rule	0.8
α_π	Inflation coefficient of the Taylor Rule	1.5
α_Y	Output coefficient of the Taylor Rule	0.5
γ_L	Labour elasticity of marginal cost	1.33
γ_C	Consumption elasticity of marginal cost	$\frac{1}{\sigma}$
ρ_{NR}	Persistence of natural rate shock	0.9
ρ_τ	Persistence of capital injection shock	0.95

The coefficient parameters are all chosen using standard values in New Keynesian literature. The steady state values have required more attention. From Bean (2010), which also uses a version of Gertler-Karadi, we are told that the steady state leverage (L/B) must equal 10 and that the steady state spread between the return on capital and the policy/deposit rate must be 1%. Once we have assertained that our steady state values are the log level of each variable (and not a growth rate as we originally assumed) then we can use the Bean criteria to calibrate for the UK economy pre-crisis. For instance the log value of bank capital before the 2007 crisis was approximately 5.7, so with leverage (L/B) being equal to ten, our steady state log level of loans was 8. The log level of deposits pre-crisis was approximately 7.9 which gives us our steady state value. Assuming a quarterly policy rate of 1% is logical, thus in order to set our steady state spread to 1% our steady state return on capital is set to 2%. As long as the spread is kept at a constant 1% however, changes in where we set the levels of these rates seem to have little impact on the model. The shock to bank capital is set to 0.17, as the direct capital injection to UK owned banks over the crisis period (2007 to present) was approximately 17% of the pre-crisis level of UK-owned banks' capital.

C: Chadha-Corrado Reserves Model

In this model households provide labour to the goods production sector (n) or to the banking sector (m) and recieve a real wage (w). Agents hold bonds (b) and a price (q) is paid on assets. The aggregate price level in the economy is denoted by P and inflation by π. The model contains 5 interest rates; R^T is the riskless rate, R^B is the rate paid on bonds, R^L is the rate paid on loans, R^D is the rate paid on deposits and R^{IB} is the short term nominal/ inter-bank/ policy rate.

Labour Supply

$$\frac{n}{(1-n-m)}\widehat{n}_t + \frac{m}{(1-n-m)}\widehat{m}_t - \widehat{\lambda}_t - \widehat{w}_t = 0 \tag{C1}$$

Demand for Labour

$$\widehat{m}_t + \widehat{w}_t + \frac{(1-\alpha)c}{mw}\left(\widehat{c}_t + \frac{\phi}{\lambda}\widehat{\lambda}_t\right) = 0 \tag{C2}$$

Supply of Banking Services [15]:

$$\begin{aligned} \widehat{c}_t &= \widehat{v}_t c + \widehat{rr}_t c + (1-\alpha)(a2_t + \widehat{m}_t) + \\ & \alpha\left[\frac{bc}{bc+(1+\gamma)kK}(\widehat{c}_t + \widehat{b}_t) + \frac{kK(1+\gamma)}{bc+(1+\gamma)kK}(a3_t + \widehat{q}_t)\right] \end{aligned} \tag{C3}$$

CIA constraint

$$\widehat{c}_t + \widehat{P}_t = \widehat{H}_t + \widehat{v}_t - \widehat{rr}_t \tag{C4}$$

Aggregate Supply:

$$\widehat{c}_t = (1-\eta)(1+\frac{\delta K}{c})(a1_t + \widehat{n}_t) - \frac{\delta K}{c}\hat{q}_t \tag{C5}$$

Marginal cost:

$$\widehat{mc}_t = \widehat{n}_t + \widehat{w}_t - \widehat{c}_t \tag{C6}$$

Mark-up

$$\widehat{mc}_t = \widehat{\xi}_t - \widehat{\lambda}_t \tag{C7}$$

Inflation:

$$\widehat{\pi}_t = \widehat{p}_t - \widehat{p}_{t-1} \tag{C8}$$

Calvo pricing:

$$\widehat{\pi}_t = \kappa\widehat{mc}_t + \beta E_t\widehat{\pi}_{t+1} + a5_t \tag{C9}$$

Marginal Value of Collateralized Lending

$$\widehat{\Omega}_t = \frac{kK}{bc+kK}\left(\widehat{c}_t - \widehat{q}_t - a3_t\right) - \frac{bc}{bc+kK}\widehat{b}_t \tag{C10}$$

[15] The relationship is derived by setting $b = \frac{B}{P(1+R^B)c}$ and $b_{t+1} = b_t c_t$

Asset Pricing [16]:

$$\widehat{q}_t \left[1 - k\Omega(\frac{\phi}{c\lambda} - 1)\right] = [\frac{\beta(1-\delta)}{1+\gamma} + \frac{\beta\eta mc}{1+\gamma}(\frac{n}{K})^{1-\eta}] \left(E_t\widehat{\lambda}_{t+1} - \widehat{\lambda}_t\right) + \frac{\beta(1-\delta)}{1+\gamma} E_t\widehat{q}_{t+1} + \frac{k\Omega\phi}{c\lambda}\left(-\widehat{c}_t - \widehat{\lambda}_t\right) + k\Omega(\frac{\phi}{c\lambda} - 1)\left(\widehat{\Omega}_t + a3_t\right) + \left(\frac{\beta\eta mc}{1+\gamma}(\frac{n}{K})^{1-\eta}\right) E_t\left[\widehat{mc}_{t+1} + (1-\eta)\left(\widehat{n}_{t+1} + a1_{t+1}\right)\right] \tag{C11}$$

Government Budget Constraint[17]:

$$T\widehat{T}_t = \frac{rr\ c}{v(1+R^{IB})}\left(\widehat{re}_t + (1+R^{IB})(\widehat{\pi}_t - \widehat{re}_{t-1} - \widehat{R}^{IB}_{t-1})\right) + b\left(\widehat{b}_t + (1+R^B)(\widehat{\pi}_t - \widehat{b}_{t-1} - \widehat{R}^B_t)\right)$$

Bond Holding:

$$\widehat{b}_t = a6_t \tag{C12}$$

Riskless Interest Rate:

$$\widehat{R}^T_t = \widehat{\lambda}_t + E_t\widehat{\pi}_{t+1} - E_t\widehat{\lambda}_{t+1} \tag{C13}$$

Liquidity Service of Bonds[18]:

$$\frac{1+R^B}{1+R^T}\left(\widehat{R}^B_t - \widehat{R}^T_t\right) = \frac{\phi\Omega}{c\lambda}\left(\widehat{c}_t + \widehat{\lambda}_t\right) - \left(\frac{\phi}{c\lambda} - 1\right)\Omega\widehat{\Omega}_t \tag{C14}$$

External Finance Premium :

$$\widehat{EFP}_t = \widehat{v}_t + \widehat{w}_t + \widehat{m}_t - \widehat{c}_t + \widehat{rr}_t \tag{C15}$$

Other Interest Rates:

$$\widehat{R}^{IB}_t = \widehat{R}^T_t - \widehat{EFP}_t \tag{C17}$$

$$\widehat{R}^L_t = \widehat{R}^{IB}_t + \widehat{EFP}_t \tag{C18}$$

$$\widehat{R}^D_t = \widehat{R^{IB}}_t - \widehat{rr}_t\frac{rr}{(1-rr)} \tag{C19}$$

Policy Feedback Rule:

$$\widehat{R}^{IB}_t = (1-\rho)\left(\phi_\pi\widehat{\pi}_t + \phi_y\widehat{mc}_t\right) + \rho\widehat{R}^{IB}_{t-1} + a4_t \tag{C20}$$

[16] Note that in steady-state $\frac{\xi}{\lambda} = mc$ and $\frac{\lambda_{t+1}}{\lambda_t} = \frac{1}{1+\gamma}$.

[17] We define the percentage deviation from steady state of flow and stock variables by $\ln x_t - \ln x$, while for interest rates and ratio variables they are $R_t = R + \widehat{R}_t$ (rates) and $r_t = r + \widehat{r}_t$ (ratio, assuming $r_t = x_t/y_t$), respectively. It can be shown the approximation comes from first-order Taylor expansion: $e^x \approx 1 + x$, while for rate variable: $\widehat{R}_t \approx \ln(1+R_t) - \ln(1+R)$ and for ratio: $\widehat{r}_t = r_t - r = \ln(x_t/y_t) - \ln(x/y) = \widehat{x}_t - \widehat{y}_t$.

[18] Log-linearisation of interest rate is defined as difference from steady state: $R_t = R + \widehat{R}_t$.

Velocity:

$$\widehat{v}_t = a7_t \tag{C21}$$

Reserves:

$$\widehat{r}_t = \frac{1}{r\ R^T}\left[-\left(\tau + R^{IB} - R^L\right)\widehat{R}_t^T + R^{IB}\widehat{R}_t^{IB} - R^L\widehat{R}_t^L + \tau\widehat{\tau}_t\right] \tag{C22}$$

Liquidity:

$$\widehat{\tau}_t = a8_t \tag{C23}$$

Loans:

$$L_t = \frac{1}{1-rr}D_t - \frac{rr}{1-rr}r_t \tag{C24}$$

The benchmark model has 22 endogenous variables $\{c,\ n,\ m,\ w,\ q,\ P,\ \pi,\ mc,\ H,\ b,\ \Omega,\ EFP,\ R^T,\ R^B,\ R^{IB},\ R^L,\ R^D,\ \lambda,\ \xi,\ T,\ r,\ re\}$, 6 lagged variables $\{P_{t-1}, H_{t-1}, c_{t-1}, b_{t-1}, re_{t-1}, R^B_{t-1}\}$ and 8 exogenous shocks $\{a1, a2, a3, a4, a5, a6, a7, a8\}$

Table C1: Parameter Descriptions and Values

Parameter	Description	Value
β	Discount factor	0.9
κ	Coefficient in Phillips curve	0.1
α	Collateral share of loan production	0.65
ϕ	Consumption weight in utility	0.4
η	Capital share of firm production	0.36
δ	Depreciation rate of capital	0.025
γ	Trend growth rate	0.005
rr	Reserve ratio	0.1
ρ	Interest rate smoothing	0.8
ϕ_π	Coeffieicnt on Inflation in Policy	1.5
ϕ_y	Coefficient on Output in Policy	0.5
F	Production coefficient of loan	9.14
k	Inferiority coefficient of capital as collateral	0.2
θ	Elasticity of substitution of differentiated goods	11

Table C2: Steady-State Parameter Descriptions and Values

Steady State	Description	Value
m	Banking Employment	0.0063
n	Labour Input	0.3195
R^T	Risk Free Rate	0.015
R^{IB}	Interbank Rate	0.0021
R^L	Loan Rate	0.0066
R^B	Bond Rate	0.0052
b/c	Bond to Consumption Ratio	0.56
c	Consumption	0.8409
T/c	Transfers over consumption	0.126
w	Real Wage	1.9494
λ	Shadow Value of Consumption	0.457
ν	Velocity	0.31
Ω	Marginal Value of Collateral	0.237
K	Capital	9.19
r/c	Reserves to Consumption	0.58

Table 1: MPC announcements regarding the Asset Purchase Programme.

Date of MPC Meeting	Amount of new, unsterlised asset purchases announced (£Bn)	Cumulative total of unsterilised asset purchases (£Bn)	Unsterilised asset purchases as a percentage of net debt
5th March 2009	75	75	10.1
7th May 2009	50	125	16.1
6th August 2009	50	175	21.8
5th November 2009	25	200	23.7
4th February 2010	0	200	23.1

Source: Bank of England & ONS

Table 2: Types of asset bought with the creation of new reserves (on a settled basis).

Type of asset purchased	Quantity (£Mn)
Gilts	198,275
Commercial paper	80
Corporate bonds	1,384

Source: Bank of England

Table 3: Announcement dates included in event study

Event date	Relevent policy announcement
11th February 2009	Publication of the Inflation Report and press conference in which it is first suggested the bank of England is likely to embark on a large scale asset purchase programme.
5th March 2009	First announcement of £75bn of asset purchases by the MPC. Policy rate cut to 0.5%
7th May 2009	Extension of QE to £125bn.
6th August 2009	Extension of QE to £175bn. Extension of initial purchase range to any gilts with a residual maturity of greater than 3 years.
5th November 2009	Final extension of QE (Phase1) to £200bn.
4th February 2010	MPC announces APF will be maintained at £200bn but will be monitored in case future economic conditions require it to be adjusted

Source: Bank of England

Table 4: Total impact of QE over event study on key variables

	Change Over 6 Events	Change Over 5 Events
Gilt Yields		
Level	-104 bp	-29 bp
Slope	-42 bp	-0.7 bp
Curvature	-36 bp	+18 bp
Corporate Bond Yields		
Investment Grade	-69 bp	-39 bp
Non-Investment Grade	-146 bp	-206 bp
Inflation Forwards		
5 years	-40 bp	+23 bp
10 years	-42 bp	-5 bp
20 years	-71 bp	-53 bp
Real Forwards		
5 years	-67 bp	-31 bp
10 years	-69 bp	-12 bp
20 years	-59 bp	-3 bp
Nominal Forwards		
5 years	-105 bp	-9 bp
10 years	-109 bp	-15 bp
20 years	-136 bp	-54 bp
Spreads		
3 Month LIBOR	40 bp	-3.8 bp
3 Month LIBOR-OIS	27 bp	-5.7 bp
Exchange Rates		
Effective Sterling Exchange Rate	-4%	-3.9%
Eur/£	-3.2%	-2.6%
$/£	-4.7%	-4.1%
Equities		
All Share Index	-3.30% (-93.51 points)	-0.07% (-18.13 points)
Pharmaceuticals	-1.50% (-56.46 points)	-0.13% (-11.83 points)
Mining	-8.95% (-625.11 points)	-6.40% (-521.25 points)
Mobile Telecoms	-3.08% (-46.01 points)	0.15% (+11.43 points)
Banks	-7.20% (-58.33 points)	2.04% (+56.78 points)
Oil & Gas Producers	3.53% (+145.16 points)	3.76% (+154.53 points)
HSBC	1.89%	11.93%
Standard Chartered	-2.50%	-3.27%
RBOS	-28.60%	-15.82%
Barclays	-33.97%	-9.06%

Table 5: Balance Sheet Changes

	Pre-Lehman Bankruptcy	Introduction of QE	Post QE
Deposits (M4x) (£Bn)	1500	1539	1554
Non-Deposit Liabilities (£Bn)[19]	-	-4.06	-243.86
Lending (M4Lx) (£Bn)	2614	2810	2594
Reserves (£Bn)	36	41	152

[19] Due to a lack of data on the level of non-deposit liabilities we report the cumulative change using the Pre-Lehman event date as our point of reference.

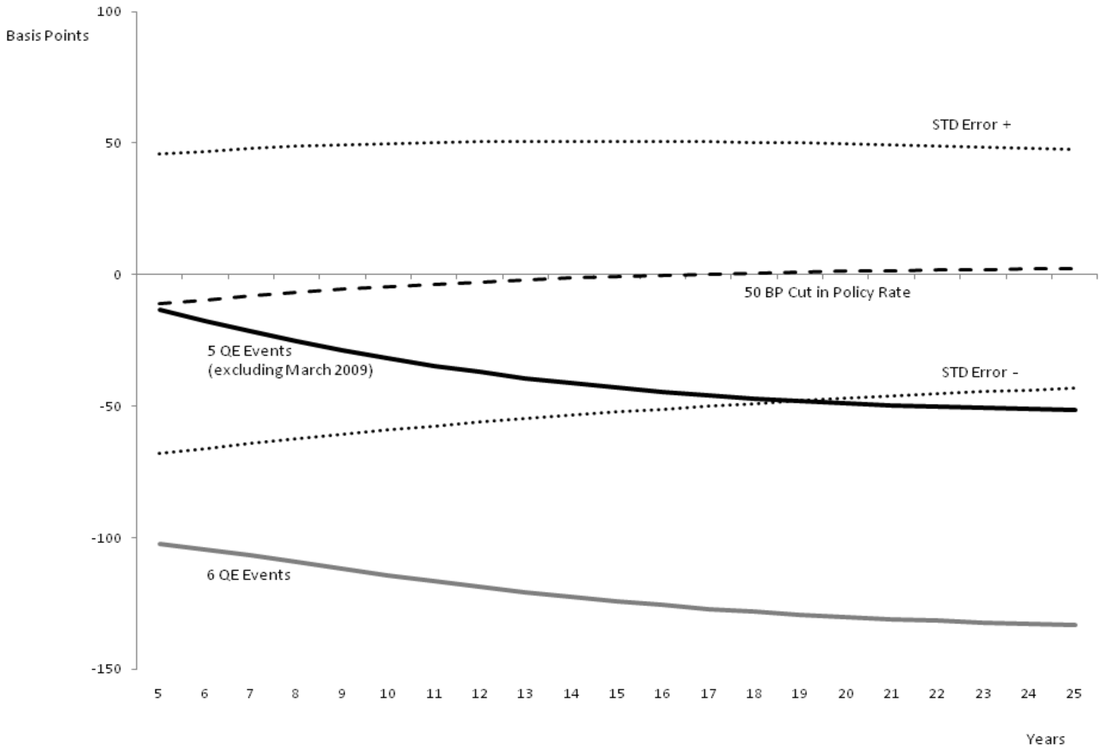

Chart 1: Announcement Effects

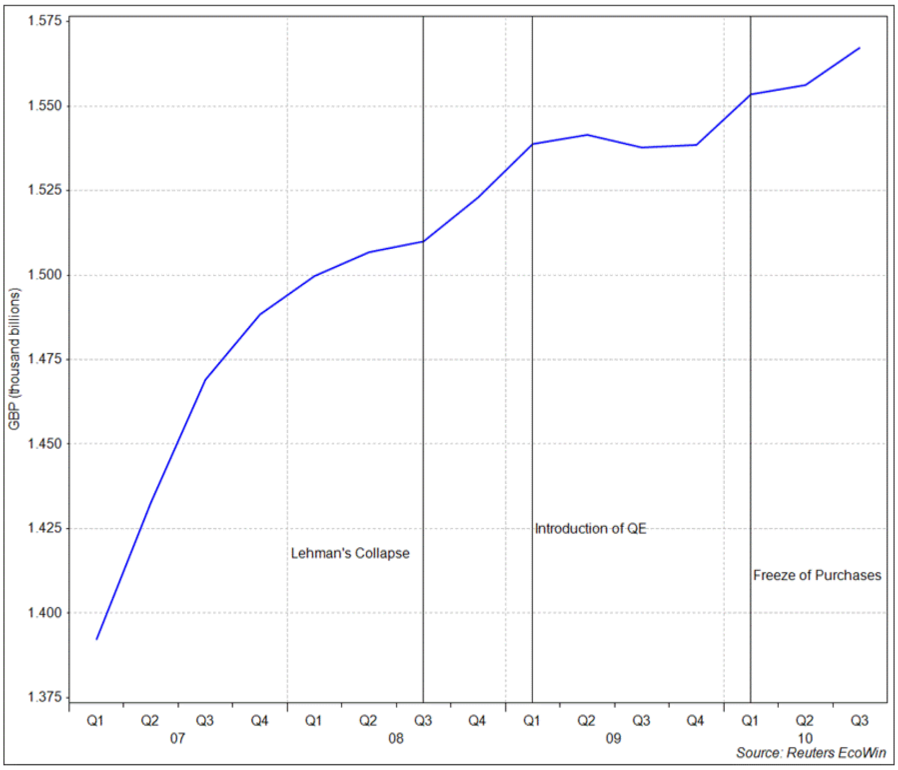
GBP (thousand billions)
1.575
1.550
1.525
1.500
1.475
1.450
1.425
1.400
1.375
Lehman's Collapse
Introduction of QE
Freeze of Purchases
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3
07
08
09
10
Source: Reuters EcoWin

Chart 2: M4x

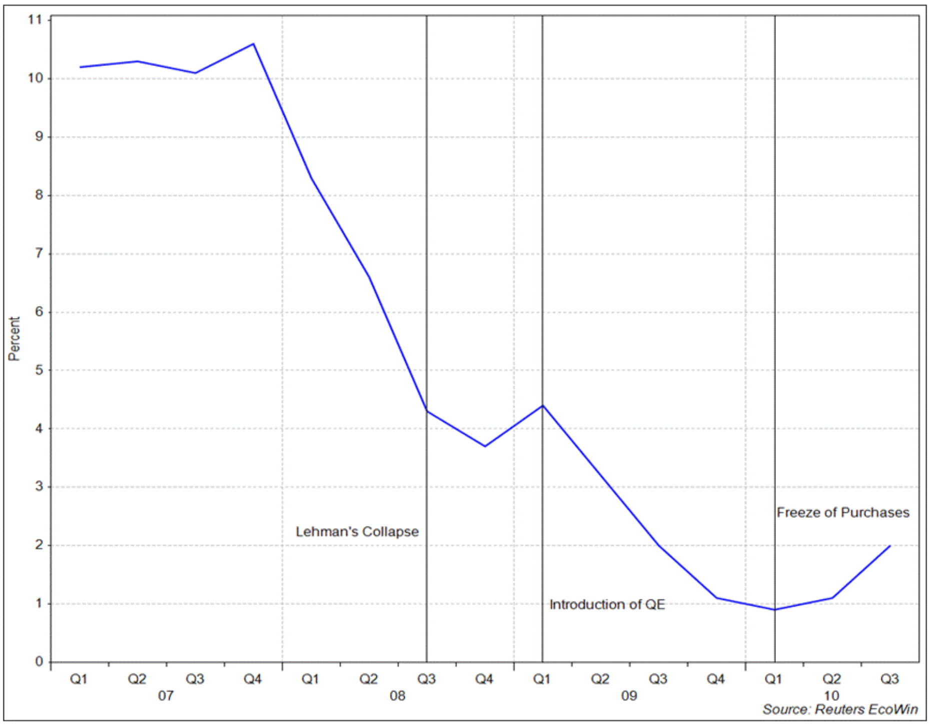

Chart 3: Year on year growth of M4x

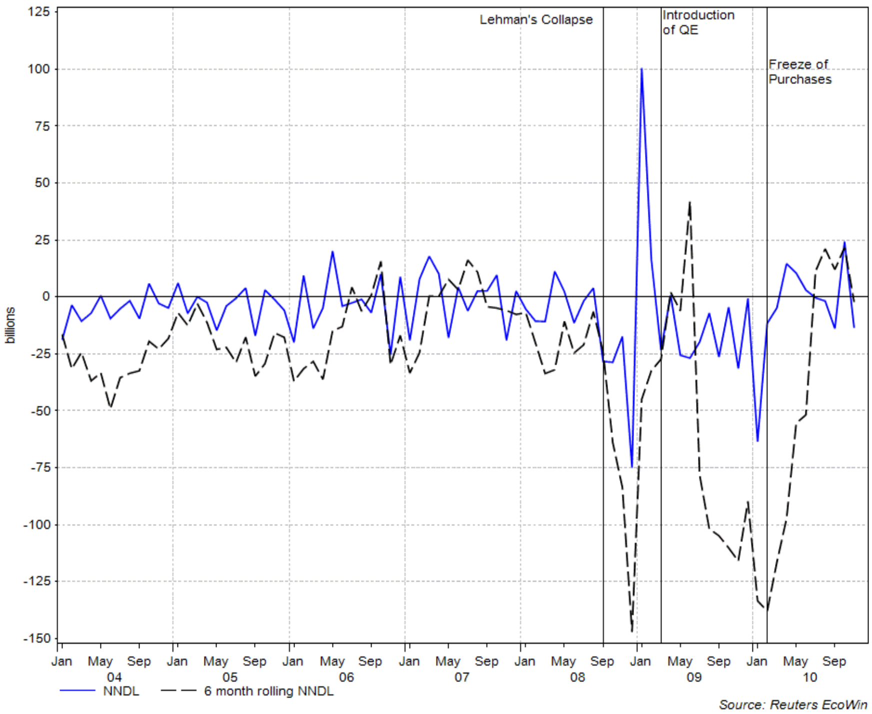

Chart 4: Net Non-Deposit Liabilities

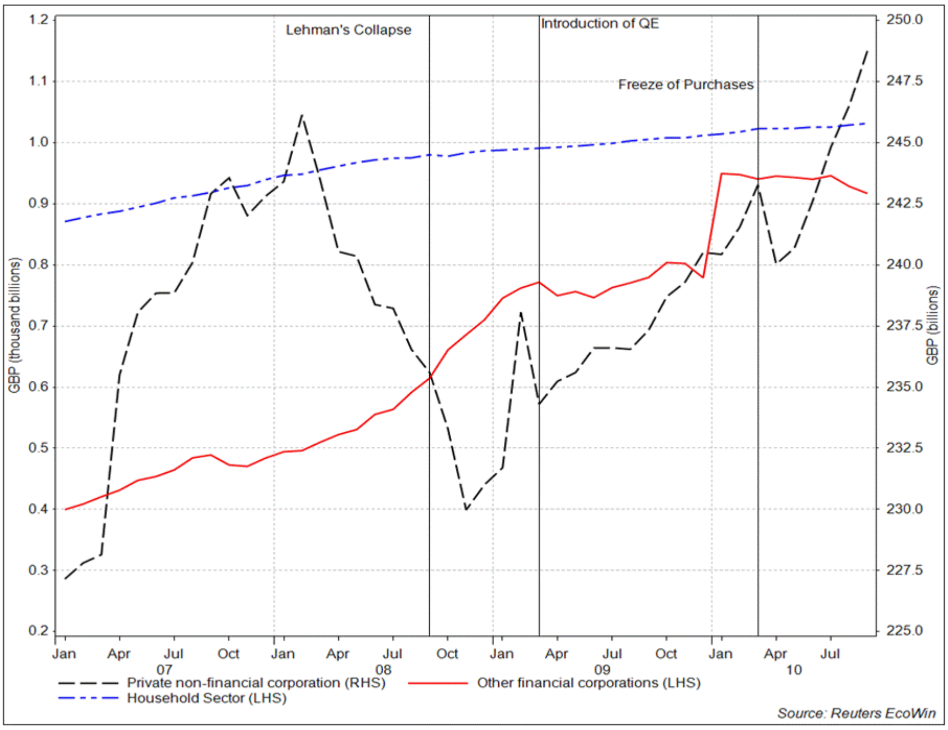

Chart 5: Sectoral M4 Money Holdings

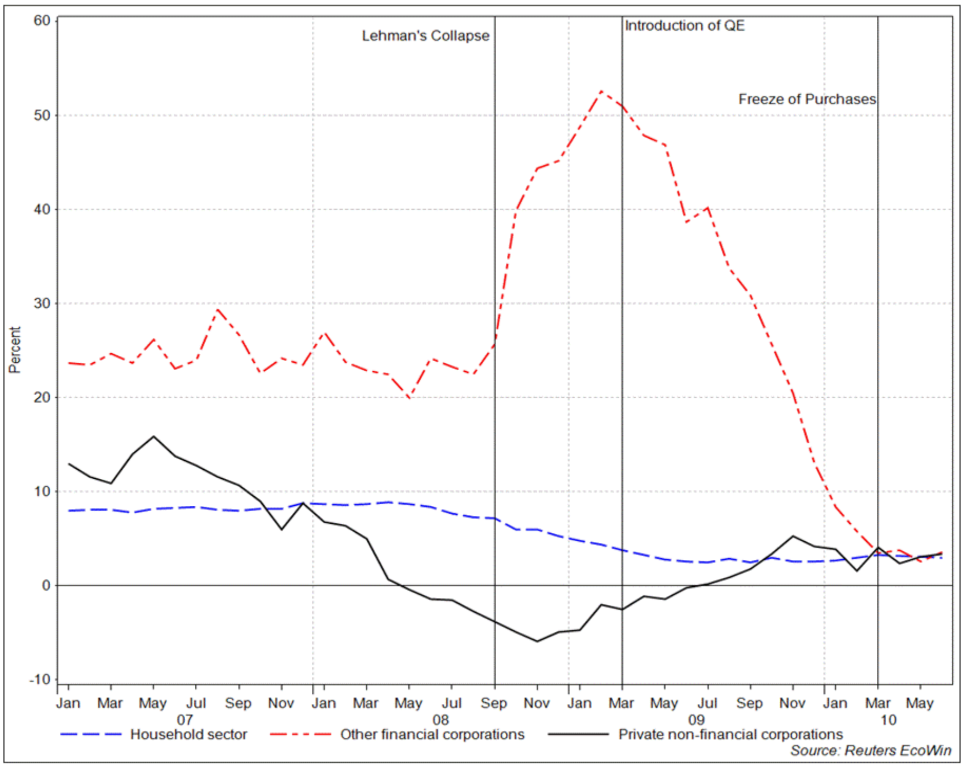

Chart 6: Year on year growth of money holdings

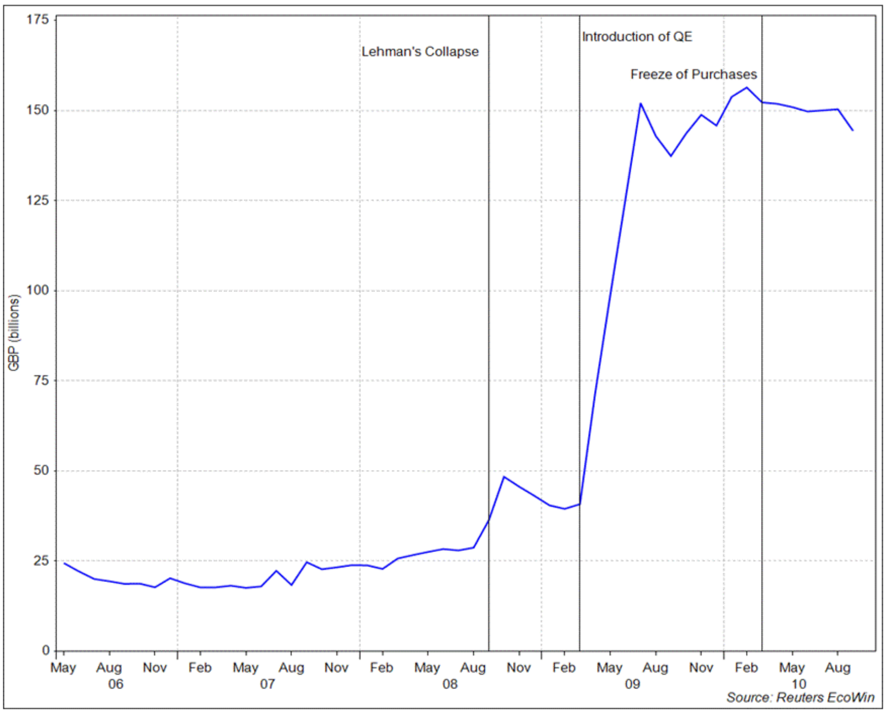

Chart 7: Reserves

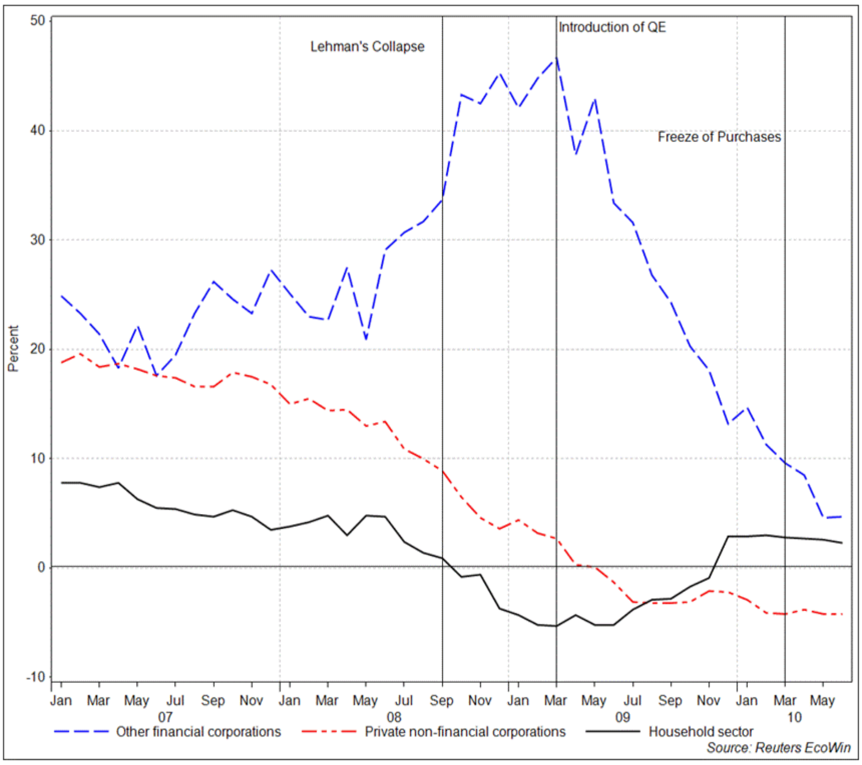

Chart 8: Sectoral Year on year growth of M4Lx

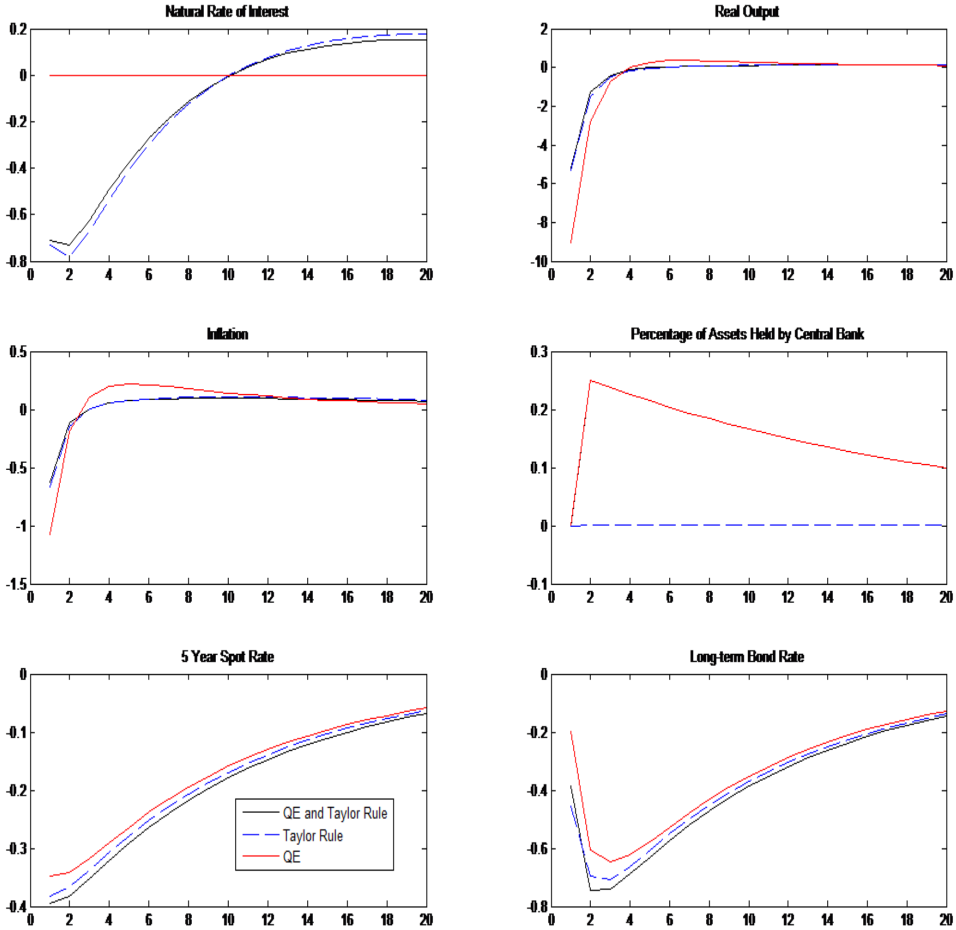

Chart 9: Impulse responses of Harrison model

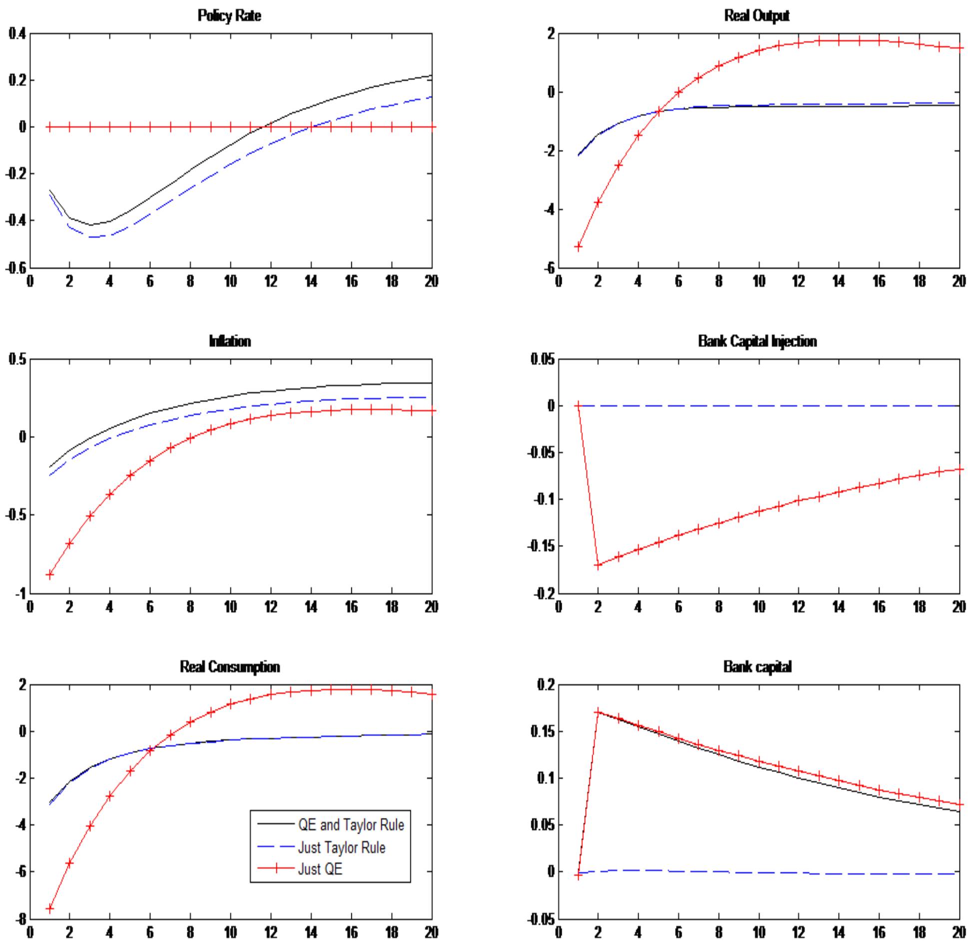

Chart 10: Impulse responses of Gertler-Karadi / Bean model

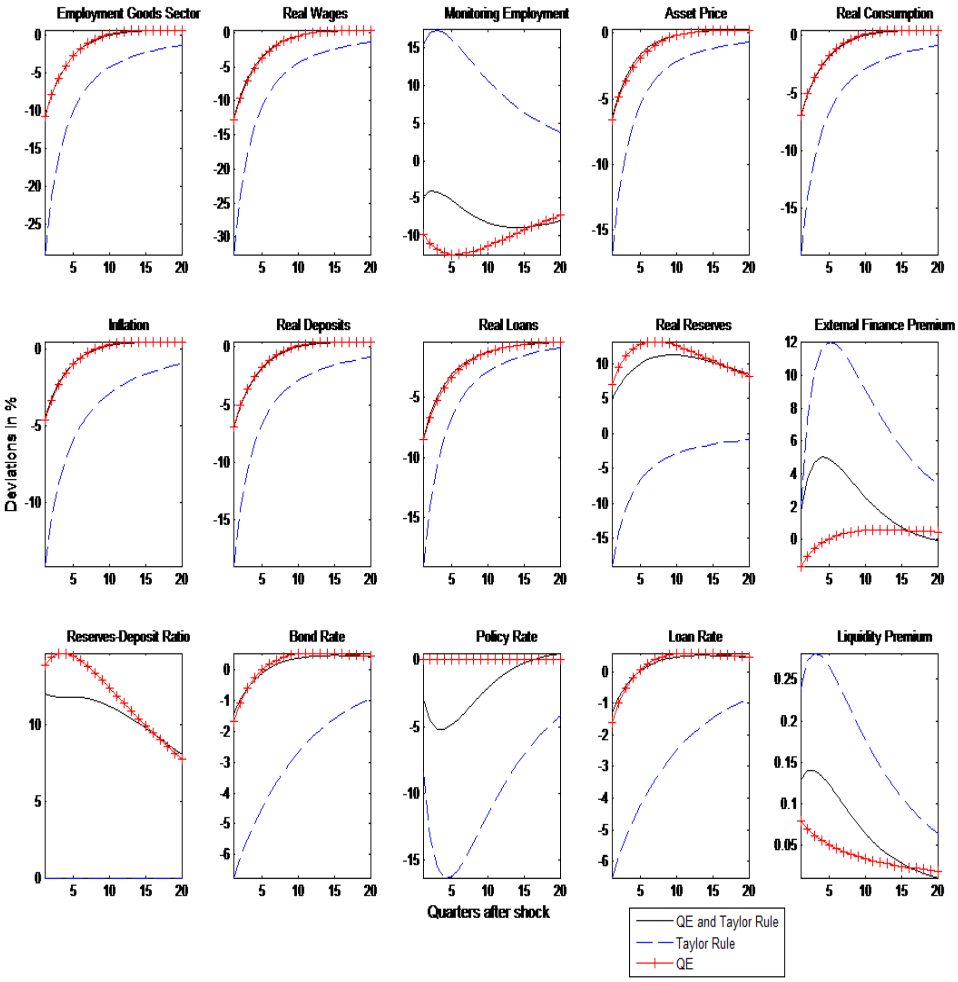

Chart 11: Impulse responses of Chadha-Corrado model