Unconventional Monetary Policies and the Macroeconomy: The Impact of the UK's QE2 and Funding for Lending Scheme*

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Abstract

In this paper we assess the macroeconomic effects of two of the flagship unconventional monetary policies used by the Bank of England during the later stages of the global economic crisis: additional Quantitative Easing (QE) and the introduction of the Funding for Lending Scheme (FLS). We argue that these policies can be seen as complements, as QE effectively bypasses the banks by attempting to reduce risk-free yields directly in order to have a wider effect on asset prices, while FLS operates directly through banks by reducing their funding costs and increasing incentives to lend. We attempt to quantify the effects of these policies by estimating their impact on long-term interest rates and bank funding costs, respectively, and then tracing out their wider effects on the macroeconomy using simulations from a large Bayesian vector autoregression (VAR), which are cross-checked with a simpler Auto-regressive distributed lag (ARDL) approach. We find that the second round of the Bank's QE purchases during 2011-12 and the initial phase of the FLS each boosted GDP in the UK by around 0.5%-0.8%. Their effect on inflation was also broadly positive reaching around 0.6 pp, at its peak.

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1 Introduction

The pronounced global financial crisis in late 2008 led to a severe economic downturn on a scale not seen since the Great Depression of the 1930s. The fiscal and monetary authorities of many countries responded with a variety of conventional and less conventional measures aimed at mitigating the effects on financial stability and the real economy. In the aftermath of the crisis, the Bank of England (BoE), like many other central banks, introduced a number of innovative policy measures to loosen monetary conditions, as the scope for conventional policy rate reductions became increasingly constrained by the fact that interest rates were already close to their lower bound. These measures included enhanced liquidity support, actions to deal with dysfunctional financial markets and large-scale asset purchases, as discussed in Bean (2011).

The aim of this paper is to assess the macroeconomic impact of two of these so-called unconventional monetary policy measures: Quantitative Easing (QE) and the Funding for Lending Scheme (FLS).

The first of these policies, QE, was initially announced in March 2009 at the height of the global crisis, with the first round of £200 billion of purchases, predominantly of UK government securities (gilts), concluding in January 2010. Our focus in this paper, however, is on the second round of purchases between October 2011 and June 2012, when the Bank of England purchased £175 billion of gilts, about 11% of nominal GDP, in response to concerns that the euro area sovereign crisis would lead to UK CPI inflation undershooting its 2% target.

The second policy measure, FLS, was first announced by the Chancellor of the Exchequer and the Governor of the Bank of England on 14 June 2012, with the aim of boosting lending to firms and households, which had been broadly flat for over three years, despite the large monetary loosening brought about by lower policy rates and QE. Under the scheme, banks and building societies were offered cheap funding linked to additional lending to the real economy. Outstanding drawings at the end of the first phase of the scheme, in January 2014, were £41.9bn. In total 46 groups participated (in the first phase of the scheme), of whom 41 made at least one drawing. With its focus on reducing bank funding costs in order to increase bank lending, the FLS can be viewed as complementary to the policy of QE, which aimed to bypass banks through boosting asset prices and reducing borrowing costs.

A large and growing literature has developed over recent years that tries to evaluate the impact of the unconventional monetary policies adopted by central banks during the global financial crisis.[1] Most of this literature has focused on the Fed's various policy measures, and particularly its large-scale asset purchase programmes, and their impact on financial markets (see eg Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), D'Amico et al. (2012) and D'Amico and King (2013)) and the macroeconomy (see eg Chen et al. (2012) and Baumeister and Benati (2013)). A large literature has also grown up around the ECB's non-standard measures (see eg Lenza et al. (2010), Giannone et al. (2012) and Eser and Schwaab (2013)). In relative terms, much less has been written on the BoE's unconventional monetary

[1]For a review of some of the early literature, see Joyce et al. (2012b).

policies, with most of the published studies to date focusing on the financial market impact of the first phase of QE during March 2009 to January 2010 (see eg Joyce et al. (2011a), Breedon et al. (2012), Joyce and Tong (2012)). Exceptions to this are Bridges and Thomas (2012) and Kapetanios et al. (2012) who look at the macroeconomic effects of QE1.[2] Of those papers covering the more recent period, McLaren et al. (2014) and Butt et al. (2012) both focus more narrowly on the effects on the gilt market and broad money respectively, and there are no studies of the macro effects of the FLS to our knowledge.

By examining the macroeconomic impact of the later round of purchases by the Bank during October 2011 to December 2012 (QE2), and the FLS, this paper makes an important contribution to the literature on unconventional policies, by filling an important gap in our knowledge of the effectiveness of unconventional policies in the United Kingdom.[3] Methodologically, the contribution of our paper is most closely related to Kapetanios et al. (2012), who examine the macro economic impact of QE1 during March 2009 to January 2010 using several time-varying VAR models of the economy to construct counterfactual simulations, assuming that the impact of QE came through a reduction in longer-term interest rates. We follow their broad approach by assessing the impact of QE through a large-scale Bayesian VAR but extend the model to include bank funding costs, in order to allow us to investigate the impact of the FLS.[4] To check for robustness, we also estimate a much simpler ARDL model in line with the conclusions of Pesaran and Smith (2014). Both methods rely on us being able to identify the shock to the yield curve and to bank funding costs arising through QE and FLS. Kapetanios et al. (2012) relied on event study evidence on QE announcements to estimate the latter but a problem of using this form of analysis in later rounds of QE is that the market was better able to predict the MPC's decisions (see eg Joyce et al. (2012a)). We therefore draw on a number of additional approaches, including regression-based methods, in order to generate a plausible estimate of the impact of QE2. Quantifying the impact of FLS faces similar challenges, as a range of other factors, and in particular, developments in the euro area will have impacted on the funding costs facing UK banks. In order to estimate the impact of FLS, we explicitly model the effects of euro area developments on UK bank funding costs using a regression approach that uses principal components to summarise the information in euro area bank and sovereign CDS and unsecured bank debt. Our estimates of the impact of FLS on bank funding costs are an additional contribution of the paper.

The rest of the paper is structured as follows. In Section 2 we provide a short summary of the Bank of England's use of unconventional monetary policy during the financial crisis and in

[2] Baumeister and Benati (2013) also look at the impact of QE in the UK, as well as the effects of unconventional measures in the United States, euro area and Japan.

[3] More recently, in August 2016 the Bank of England launched a further package of unconventional policy measures, following the decision of the United Kingdom to leave the European Union. These measures included a 25 basis point cut in Bank Rate, a new Term Funding Scheme to reinforce the pass-through of the cut in Bank Rate, purchases of up to £10 billion of UK corporate bonds and an additional £60 billion of purchases of UK government bonds. These measures were taken after work on this paper had been completed and are therefore not incorporated into the analysis we report below.

[4] The use of macro VAR model techniques to investigate the impact of unconventional policies has been used in other studies, such as Baumeister and Benati (2013) and Giannone et al. (2012).

particular how and why QE and the FLS were implemented. Section 3 turns to the modelling techniques we use in the paper to quantify the macro-effects of the two policies. Sections 4 and 5 describe how we estimate the impact of QE and FLS on financial market prices and macroeconomic variables. Section 6 sets out our conclusions.

2 The Bank of England's use of unconventional monetary policies

This paper focuses on the macroeconomic impact of the BoE's QE and FLS policies during the financial crisis and therefore does not attempt to assess the full raft of policies introduced, by the UK authorities, after 2007, including the recapitalisations of the banks, the Special Liquidity Scheme, the Credit Guarantee Scheme, and the Asset Protection Scheme and Forward Guidance. With the exception of Forward Guidance,[5] these other policies are less obviously described as monetary policy measures, though this boundary line is perhaps less clear when policy rates approach their lower bound. This section starts by explaining what we mean by term unconventional monetary policy and why we consider both QE and FLS to be unconventional monetary policies. We then turn to the use of QE and FLS during the crisis by setting out the context in which both policies have been used. The third section briefly discusses the transmission channels through which both policies may affect the real economy, which can be viewed as complementary.

2.1 Conventional and unconventional monetary policies

Conventional monetary policy typically involves setting the value of the current policy rate. Bernanke and Reinhart (2004) group alternative monetary policies into three classes: (1) using communications policies to shape public expectations about the future course of interest rates; (2) increasing the size of the central bank's balance sheet; and (3) changing the composition of the central bank's balance sheet. All such policies are considered unconventional, and naturally come into play when greater monetary stimulus is required than can be achieved by cutting the policy rate to its effective lower bound. Such policies are likely to be complementary. King (2009) distinguishes between 'conventional unconventional' and 'unconventional unconventional' measures. QE is in the former camp, involving the purchase of liquid assets with the intention of expanding the central bank balance sheet and boosting the supply of money. FLS is very much an unconventional unconventional measure. It was a direct response to the threat to the UK economy caused by elevated bank funding spreads. It works primarily by changing the composition of the central bank balance sheet, rather than through expansion.

[5] Forward Guidance is clearly a form of unconventional monetary policy using our definition below, but our modelling approach - focussing on movements in observed contemporaneous variables - is not well suited to analysing it.

We discuss the likely transmission mechanisms of these policies in more detail below, but for now can conclude that they are both types of unconventional monetary policy.

One possible question regarding our categorisation of FLS as an unconventional monetary policy measure is that the scheme is not voted on by the MPC and instead overseen by a joint Bank of England/HM Treasury Oversight Board, potentially implying that there is an element of fiscal policy. But the Scheme is fully operated by the Bank and is operationally similar to other monetary policy operations such as the ECB's Longer-Term Refinancing Operations (LTRO) and targeted LTROs (TLTROs).[6] The operation of the scheme could also potentially impact on the Financial Stability objectives of the FPC and therefore both the MPC and the FPC were involved ahead of the decision to modify the scheme in November 2013.[7]

2.2 Implementation

Table 1 provides a brief chronology of the main QE and FLS events. As discussed in the introduction, QE was originally introduced in March 2009. This was in response to fears that without further monetary easing measures the reduction of policy rates to 0.5% would be insufficient to avoid inflation substantially undershooting the 2% inflation target in the medium term. The first phase of the Bank's asset purchases ended in January 2010, by which time the Bank had made £200 billion of purchases, which were overwhelmingly of UK government bonds. A second phase of purchases, sometimes referred as QE2, was announced in October 2011, when a deterioration in the economic outlook associated with the euro sovereign debt crisis again led to an increase in the risk of undershooting the inflation target in the medium term. The MPC initially voted to increase its asset purchases by a further £75 billion, with further extensions to the programme of £50 and £25 billion subsequently announced following the February 2012 and July 2012 MPC meetings. After the conclusion of this phase of purchases, at the beginning of November 2012, the Bank had purchased an additional £175 billion of gilts.

In June 2012, the Chancellor and the Governor of the Bank of England announced that the Bank and Treasury had plans to launch a 'funding for lending' scheme to tackle the high level of bank funding costs and give banks incentives to sustain or expand their lending to the UK households and companies. The details of this scheme, the FLS, were subsequently announced the following month on 13 July. The Scheme was designed to reduce funding costs for banks and building societies, so that they can make loans cheaper and more easily available. Access to the Scheme was directly linked to how much each bank and building society lends to the real economy. Those that increased lending were able to borrow more under the Scheme, and do so at a much lower cost than those that scaled back their loans.

In particular, over the eighteen months to the end of January 2014 – the 'drawdown period' – the Bank of England offered to lend UK Treasury Bills to banks and building societies. These were lent for a period of up to four years, for a fee. As security against that lending, banks

[6]See FLS explanatory note http://www.bankofengland.co.uk/markets/Documents/explanatory_notefls120713.pdf.
[7]For more information see http://www.bankofengland.co.uk/publications/Pages/news/2013/177.aspx

provided collateral – in the form of loans to businesses and households and other assets – to the Bank of England. Each participating bank was able to borrow an amount up to 5% of its stock of existing loans to the UK non-financial sector – 'the real economy' – as at end-June 2012, plus any expansion of its lending during a 'reference period' from that date to the end of 2013.[8] The price of each bank's borrowing in the Scheme was dependent on its net lending between 30 June 2012 and the end of 2013. For banks maintaining or expanding their lending over that period, the fee was 0.25% per year on the amount borrowed. For banks whose lending declined, the fee schedule increased linearly, adding 0.25% for each 1% fall in lending, up to a maximum fee of 1.5% of the amount borrowed for banks that contracted their stock of lending by 5% or more.

2.3 Transmission channels

QE was primarily expected to affect GDP and inflation by reducing gilt yields and boosting other asset prices, thereby reducing the costs of borrowing, and boosting expenditure through wealth effects. This would occur mainly through a portfolio balance channel. Agents in the non-bank private sector would prefer to reinvest the newly created bank deposits into riskier assets such as corporate bonds and equities, absent a change in the price of those assets. This would lead to portfolio re-balancing and asset price changes, due to the imperfect substitutability of money and securities, as originally set out in Tobin (1963) and Brunner and Meltzer (1973).[9] Asset prices might also be boosted through a signalling channel that policy rates would remain lower for longer and also through improvements in market liquidity. Other secondary channels were conceived as possible, including a bank lending channel,[10] although the MPC always downplayed the likely importance of the latter given that banks were in the process of de-leveraging (see Joyce et al. (2011b) for further discussion).[11]

In contrast, the operation of the FLS was expected to affect GDP by reducing banks' funding costs, leading to easier credit conditions for real economy borrowers. The FLS offered banks a lump sum of funding, which they could use for any purpose but which had a fee that was increasing if they shrank their lending to the real economy. The FLS also offered banks a cheap source of further funding, which they could access directly only if they expanded their lending to the real economy. And the availability of FLS funding could bring about a fall in the cost of other sources of bank funding by reducing the need for participating banks to issue debt in

[8]Any expansion of lending was calculated on a 'net' basis – new lending into the real economy minus repayments. Eligible lending was in sterling to UK resident households or private non-financial corporations and in the form of drawn loans. Banks' holdings of securities did not count; neither did undrawn facilities. Purchases or sales of loans do not affect this measure, because they leave unchanged the total amount of credit to households and companies in the economy. Write-offs are also excluded from the measure of net lending used under the Scheme.

[9]For a discussion of the portfolio balance channel, see eg Andres et al. (2004).

[10]Butt et al. (2014) evaluate whether QE provided a boost to bank lending in the UK. They find no evidence that QE gave rise to a bank lending channel, possibly because QE operating through a portfolio rebalancing channel gave rise to flighty deposits, mitigating any bank lending channel.

[11]For more on the intended transmission mechanism of QE, see Benford et al. (2009).

Table 1: QE and FLS Chronology of Key Announcements

Date	QE	FLS
5 March 2009	MPC statement announces Bank will purchase £75 billion of assets,primarily conventional gilts, over 3 months financed by the issue of central bank money. Purchases are to be split between two maturity sectors for gilts with remaining maturities of: 5-10 years and 10-25 years. [Bank Rate also reduced to 0.5%.] Subsequent extensions to the programme announced in May 2009, August 2009 and November 2009. Overall £200 billion of purchases made between March 2009 and January 2010.	
6 October 2011	MPC statement announces that QE purchases will be extended by £75 billion to £275 billion. (The start of QE2)	
9 February 2012	MPC statement announces that QE purchases will be extended by £50 billion to £325 billion. Purchases to be split between three sectors for gilts with remaining maturities of: 3-7 years, 7-15 years and 15 years and greater.	
14 June 2012		Governor and Chancellor announce Bank and Treasury working on ”funding for lending” scheme.
5 July 2012	MPC statement announces QE purchases will be extended by £50 billion to £375 billion.	
13 July 2012		The Bank and Treasury launch the Funding for Lending Scheme (FLS).
1 August 2012		The Funding for Lending scheme drawdown window opens.

public markets or compete as hard for term deposits. Together, lower overall bank funding costs would allow banks to reduce the cost of loans or ease other, non-price terms. The increased supply of credit would then boost consumption and investment spending.[12]

In general, QE was intended to work by circumventing the banking sector. QE would in the first instance benefit the owners of assets, and businesses who could issue debt or equity in capital markets. In contrast, FLS aimed to reduce borrowing costs by going directly through the banking sector. For this reason the immediate beneficiaries were likely to be those who were reliant on banks as a source of finance. Because the transmission mechanisms of the two policies were different they can be regarded as complements. More importantly for this paper, it means that it is possible for us to identify them separately.

3 Models

3.1 Bayesian VAR (BVAR)

The seminal work by Sims (1980) introduced the use of vector autoregressions (VAR) into macroeconometric modelling and VAR models continue to play a central role. More recently, the studies of Lenza et al. (2010) and Koop (2011) illustrate how this modelling approach can be extended to large information sets with remarkable good forecasting properties. Bayesian estimation techniques turn out to be particularly useful in this large information setup to overcome parametrisation problems which would otherwise be encountered when a standard VAR is estimated in large dimensions.

3.1.1 Notation and preliminaries

The model we use belongs to the general class of BVAR models for large data sets.[13] Assuming that all the variables in the large data set are in the vector $\mathbf{Y_t}$, we can write the model as:

$$\boldsymbol{Y_t} = \boldsymbol{\Theta_0} + \boldsymbol{\Theta_1 Y_{t-1}} + \cdots + \boldsymbol{\Theta_p Y_{t-p}} + \boldsymbol{e_t} \tag{1}$$

where $\mathbf{e_t}$ is a vector white-noise error term, $\mathbf{\Theta_0}$ is a vector of constants and $\mathbf{\Theta_1}$ to $\mathbf{\Theta_p}$ are parameter matrices. In our study $\mathbf{Y_t}$ consists of 44 series meaning that $\mathbf{\Theta}_j$ (where $j = 1,...,p$) is a function of 1936 parameters, which leaves us no other choice but to restrict the number lag order of our empirical model to one

$$\boldsymbol{Y_t} = \boldsymbol{\Theta_0} + \boldsymbol{\Theta_1 Y_{t-1}} + \boldsymbol{e_t} \tag{2}$$

3.1.2 A Normal-inverted Wishart prior

As will be discussed later, our large data set comprises both macroeconomic and financial market variables. A good prior for BVAR models of the macroeconomy is a simple random

[12] For more on the intended transmission mechanism of FLS, see Churm et al. (2012).
[13] See, for example, Bandbura et al. (2010).

walk forecast; see, for example, Litterman (1986). Many macroeconomic and financial market variables are characterised by persistent processes. In general, simple autoregressive (AR) or random walk (RW) models are known to produce reasonable forecasts for macroeconomic and financial variables over short horizons. We therefore choose a univariate $AR(1)$ process as our prior for each of the stationary variables in the BVAR model, while our prior for each nonstationary series is a RW process. With these priors, the 'own' first lag is considered to be the most important in every equation in the BVAR and the first two moments of the VAR coefficient vector are given by:

$$E[\Theta_1^{(ij)}] = \begin{cases} \rho & \text{if } i = j \\ 0 & \text{otherwise} \end{cases}, \; Var[\Theta_1^{(ij)}] = \phi\sigma_i^2/\sigma_j^2, \tag{3}$$

where ρ is set equal to one for nonstationary variables and estimated for stationary series (Mumtaz and Zanetti (2012)), $\mathbf{\Theta_1}^{(ij)}$denotes the element in position (i, j) in the matrix $\mathbf{\Theta_1}$, and the covariances among the coefficients in $\mathbf{\Theta_1}$ are zero. The shrinkage parameter ϕ determines the tightness of the prior or the extent to which the data influences the estimates. With a tight prior the data has little or no influence on the estimates as $\phi \to 0$. For a loose prior, where $\phi \to \infty$ there is an increasing role for the data and the estimates then converge to the standard OLS estimates. In our exercise ϕ has been set equal to one implying loose priors. To complete the specification of our BVAR prior, we assume that the constant, $\mathbf{\Theta_0}$, has a diffuse zero mean normal prior and the matrix of disturbances have an inverted Wishart prior, $\mathbf{\Sigma} \sim iW(v_0, S_0)$, where v_0 and S_0 are the prior scale and shape parameters with the expectation of $\mathbf{\Sigma}$ equal to a fixed diagonal residual variance $E[\mathbf{\Sigma}]= diag(\sigma_1^2, ..., \sigma_N^2)$. This is a conjugate prior with a normal-inverted Wishart posterior distribution. The BVAR model is estimated using rolling windows to account for structural change. Additional technical information on model estimation and prior tightness is provided in Appendix A.

3.2 Autoregressive distributed lag model (ARDL)

Our approach to assess the real economy effects of unconventional policies relies on counterfactual analysis. Pesaran and Smith (2014) argue that if the policy intervention affects the reduced-form policy parameters in the empirical model then one would not be in a position to carry out counterfactual analysis correctly unless a full model of all endogenous variables is entertained and estimated. Our BVAR model is such a model so our work can be considered as immune to their critique. However, Pesaran and Smith (2014) also suggest an alternative approach. They argue that a general autoregressive distributed lag model is robust to the problem they pose, and can be used to assess policy effects. The model takes the form

$$y_t = \rho(L)\, y_t + \psi(L)\, x_t + \phi(L)\, u_t + \varepsilon_t \tag{4}$$

where y_t is the variable of interest (GDP and CPI Inflation in our case), x_t is the policy variable such as, e.g, spreads, in our case, and u_t denotes exogenous series that might affect y_t. $\rho(L)$,

$\psi(L)$ and $\phi(L)$ are lag polynomials needed to account for the dynamics of the overall data generation process. All other endogenous variables are bypassed by the use of sufficiently long lag structures enabling the use of this rather parsimonious ARDL model. In our case, we do not consider any exogenous variables and end up with a model of the form

$$y_t = \rho(L) y_t + \psi(L) x_t + \varepsilon_t \tag{5}$$

Although we argue that policy interventions did not change the reduced-form empirical parameters (as change would be consistent with the idea that unconventional policies had a permanent effect on the economy), we feel that applying Pesaran and Smith's suggested model provides a useful robustness check to our benchmark BVAR model.

3.3 Data

Our data set comprises 44 variables, with monthly observations covering January 1991 to February 2013. UK variables include those capturing real activity, prices, money, the yield curve and financial markets.[14] To incorporate potential international financial and economic linkages, we also include data for real activity, prices and the policy rates for the United States and the euro area. We use log-levels for the variables except those expressed in percentage terms. The list of variables are provided in Appendix B.

3.4 Counterfactual analysis

Similar to Kapetanios et al. (2012), the analysis is carried out in two steps. In the first step, we identify the effects of the unconventional policy on the variable of interest u_t, that is banks' funding costs for FLS and 5-year and 10-year maturity government bond yields for QE. By doing so we can identify what the path of u_t would be without the policy intervention. This path is denoted by $\tilde{u}_t$. We provide a detailed discussion below of how $\tilde{u}_t$ is obtained but here only offer a 'high-level' description of our methodology.

In the second step we use u_{T+H} and $\tilde{u}_{T+H}$ to derive two sets of conditional forecasts denoted by $E(\mathbf{Y}_{T+H}|u_{T+H})$ and $E(\mathbf{Y}_{T+H}|\tilde{u}_{T+H})$, respectively. Finally, the effect of unconventional policies is assessed by taking the difference between the two sets of forecasts

$$D\left(_{T+H}|u_{T+H}, \mathbf{Y}_{T+H}|\tilde{u}_{T+H}\right) = E(\mathbf{Y}_{T+H}|u_{T+H}) - E(\mathbf{Y}_{T+H}|\tilde{u}_{T+H}) \tag{6}$$

The conditional forecasts are produced using the methodology developed by Waggoner and Zha (1999, 'hard conditions').[15] In all counterfactual exercises we do not allow changes in the domestic economy to have an effect on the foreign economy (small open economy assumptions).

[14] We obtain monthly GDP estimates from the National Institute of Economic and Social Research. Mitchell et al. (2005) discuss the methodology in detail.

[15] The conditioning paths can be implemented into a linear state space model via the shocks of the system. Waggoner and Zha (1999) analysis illustrate how the solution to this problem can be used to derive the posterior distribution of the conditional forecasts.

Furthermore, when we measure the economic impact of FLS we control for QE effects and vice versa.

4 The effects of the Funding for Lending Scheme

This section explains how we assess the macroeconomic effects of FLS and also discusses our empirical results.

4.1 Estimating the impact of FLS on funding costs

In the spirit of Kapetanios et al. (2012), we need a way of estimating the impact of FLS on banks' marginal funding costs. But this is not simple, for at least three important reasons. First, even without FLS there is no single perfect measure of the marginal funding cost for a bank. Banks have a variety of different funding options, with different headline interest rates, but also different indirect costs such as fees, costs of collateral usage, and associated liquidity requirements. Assuming that banks arbitrage between different funding sources such that their ultimate cost is similar, it is common to look at the implied cost over time of issuing a new senior unsecured bond.[16] Because there are low indirect costs to such issuance the total funding cost can be proxied by the headline yield or spread over a benchmark reference rate. The two most common proxies are the spreads on debt trading in the secondary market and the Credit Default Swaps (CDS) referenced to such debt. Secondary market debt is attractive because it is closest to the instrument that would be issued. But CDS are attractive when a consistent constant horizon time series is available, as tends to be the case for larger banks. For this reason practitioners often prefer secondary market bonds, whereas academic papers often use CDS. We avoid taking a strong view by producing estimates based on both in what follows.

A second issue is the more familiar one of identification. The timing over which FLS should impact on market funding costs is not clear a priori, so while there was an immediate response following the announcement of FLS, it is not at all obvious that we will capture all of the impact through a one or two day event study window, particularly when the details of the scheme were not known. But when looking over a longer period moves in funding costs are likely to be contaminated by other influences. Most notably, UK bank funding spreads were highly correlated with those of euro area banks over this period, possibly because of concerns regarding the impact on their solvency of euro area breakup. Less than three months after the announcement of FLS in June 2012 - and less than a month after the FLS opened for drawings - Mario Draghi, the ECB president, gave his now famous 'whatever it takes' remarks, which led to a rally in European financial markets. For this reason we cannot rely on timing alone but need to identify and abstract from any improvement in UK bank funding costs stemming from an improvement in the outlook for the euro area. Our method for doing so is discussed below.

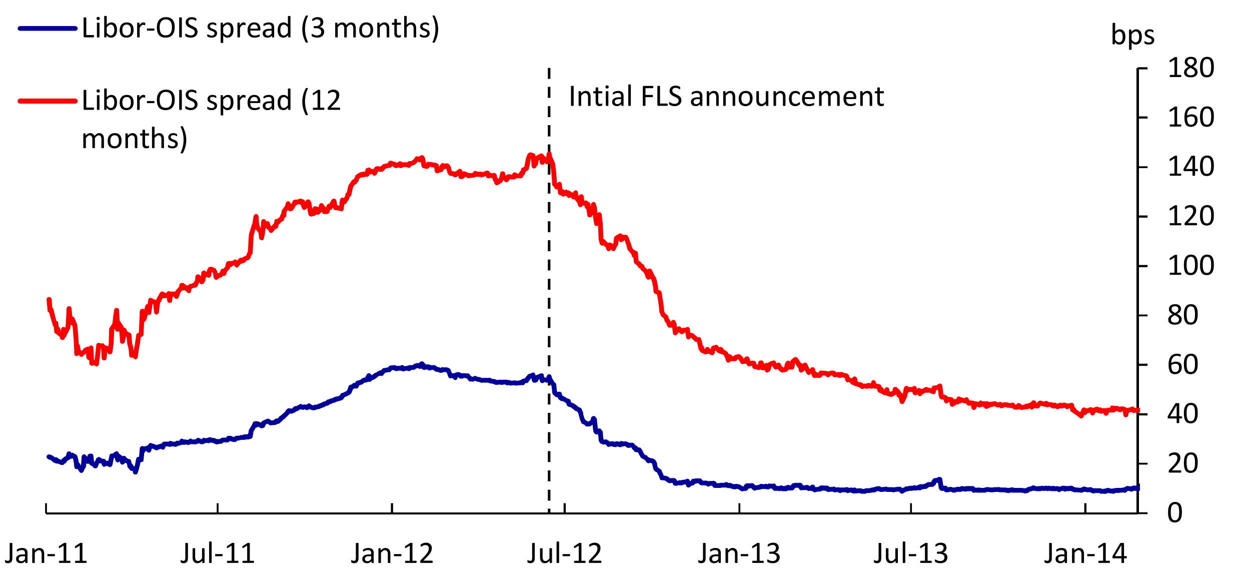
A third important issue is that, in addition to any impact on banks' funding costs in the market, the FLS delivers incentives to lend through the funding offered directly to participants.

[16]See also the discussion in Button et al. (2010).

An exposition of how the price and quantity incentives within FLS would affect a profit maximising bank is contained in Churm et al. (2012). But because banks change loan prices for numerous unobservable reasons, we have no good way to accurately identify these effects and test whether FLS participants changed their behaviour as a result. We therefore do not include any 'direct effects' of the FLS in this exercise. We do know that banks drew around £42bn from the first phase of FLS however, consistent with it lowering their funding costs. Further, we know from the Bank of England's market contacts, Credit Conditions Survey responses, and specific product announcements that access to FLS drawings played a role in reducing the cost of loans. So for this reason the estimates we produce are biased downwards and the beneficial impact of FLS overall is more likely to be larger.

Before explaining our method of identification it makes sense to summarise developments in UK bank funding costs and those for euro area banks and sovereigns, over this period. UK Libor-OIS spreads had risen in the second half of 2011 and remained elevated in 2012 (Figure 1). Libor rates and spreads fell sharply on 15 June 2012, the morning after the Mansion House speeches where the principle of the Funding for Lending Scheme was announced (see King (2012a)). In a speech Weale (2013) shows that the next day fall in Libor futures was statistically significant at the 1% level. But Libor-OIS spreads continued to fall during the rest of summer and autumn 2012, before flattening out. From close of business (cob) 14 June 2012, to 31 December 2012, the sterling 3-month Libor OIS spread fell from 55bps to 11bps (Table 2).

Figure 1: Libor-OIS spreads



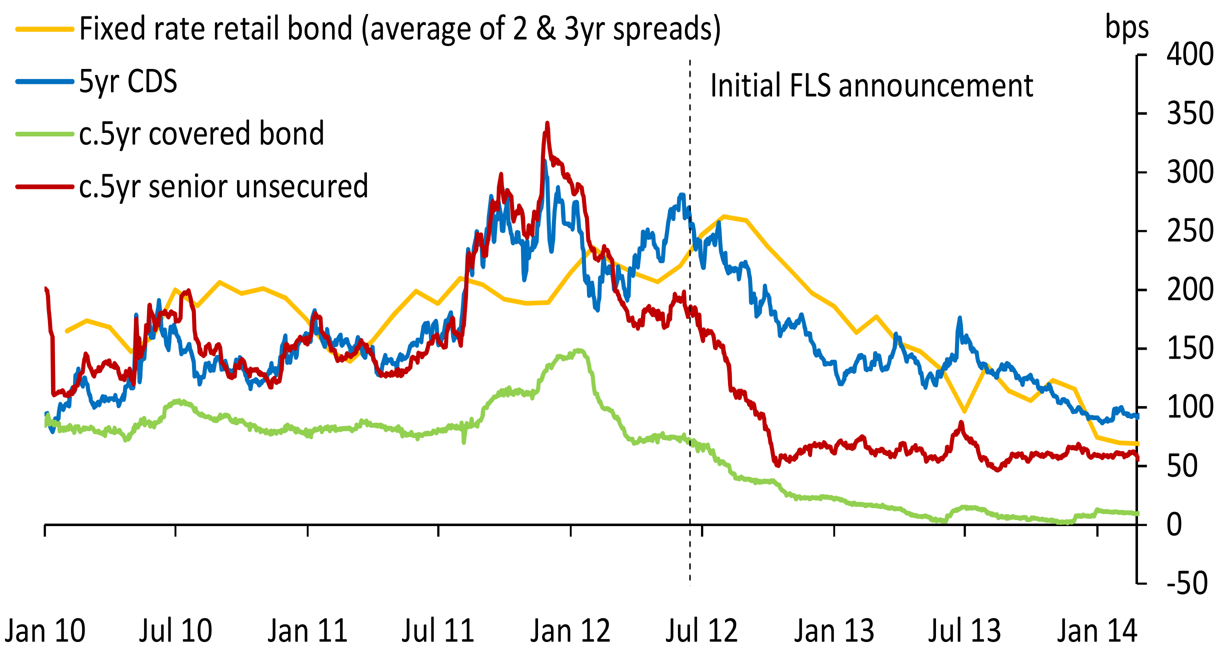
There were also significant falls in spreads on UK banks' senior unsecured debt - quoted over Libor swap rates, so as to avoid any double counting with the Libor spreads discussed above - and CDS premia (Figure 2). And following those with a lag, spreads on term retail deposits - an alternative source of stable uncollateralised term funding also fell. A simple average of CDS for the largest 6 UK banks fell from 263bps as of cob 14 June 2012, to 138bps at the end of

Table 2: Bank Spreads

		FLS announcement	Draghi 'whatever it takes' speech			
Instrument	31/12/11	14/06/12	25/07/12	30/09/12	31/12/12	24/02/2014
UK bank B6 average CDS	254.25	262.90	250.46	196.39	138.32	92.28
UK bank B6 average Senior Unsecured	296.17	183.52	156.55	88.17	65.51	59.28
CDS + 3m Libor	362.26	361.90	326.36	256.08	189.82	144.46
3m Libor-OIS spread	58.76	55.25	36.15	21.44	10.75	144.46

the year (Table 2). And over the same period senior unsecured bond spreads for the same six banks showed a fall from 184bps to 66bps.

Figure 2: Indicative long-term bank funding spreads. Covered and senior unsecured bond spreads taken over swap rates.



The full details of FLS were announced when it was subsequently launched on 13 July 2012, with the scheme opening for drawdowns on 1 August, and the first drawdowns actually occurring in September. For this reason it seems plausible that the impact of FLS on funding costs was not limited to the immediate aftermath of 14 June. And the data are suggestive of a positive dynamic starting at that point but continuing for a period. Importantly, there was a material fall in UK bank funding spreads before Draghi's 'whatever it takes' speech on 26 August 2012, during which time euro area bank spreads had on average changed little. But of course such a speech could have been anticipated and conversely FLS could have had further impacts after 25 August; for example, if market yields fell further in response to lower bank debt supply as specific issues matured and were not replaced.

One plausible method for identifying the impact of FLS was set out in a speech by King (2012b). In this speech he simply noted that funding spreads on bank unsecured debt in the UK had fallen by more than those in the US or in 'core' European economies. Such an approach makes relatively strict implicit assumptions, some of which we can relax. Notably, comparing levels of spreads implicitly assumes that UK banks' funding spreads should respond by an equal amount in basis points to euro area news. Such assumptions, when carrying out this type of exercise, cannot be varied according to the set of euro area countries considered 'core' and implicitly comparable to the UK, or according to the sample of banks chosen for each country. So while we find those early results plausible, we consider an alternative method that might be more robust.

The philosophy behind our method is to predict how much UK banks' funding costs 'should' have moved using regression analysis and the pre-FLS co-movement of UK bank spreads with developments in the euro area. We do this using data for as many related euro area funding costs as possible, without making an a priori judgement about which country or banks UK bank spreads should be most related to. More specifically, our method is as follows:

- Take daily observations of CDS data for as many euro area sovereigns and banks as we can.
- Calculate principal components of the euro area CDS observations. Assume that the first principal component is a quantitative metric of the primary shock driving euro area spreads.[17]
- Take daily observations of CDS data for the largest 6 UK lenders [18] and average them. Regress this on the metric of the euro area shock (first principal component) up to 14 June 2012.
- Produce an out-of-sample forecast of the UK banks' CDS using the regression above. The residuals are an estimate of the change in UK banks' CDS that is unexplained by the shock driving euro area spreads. We produce forecasts out as far as the end of 2012.

The final stage is to assume that, because FLS was the major UK specific development over this period, the change in funding spreads unexplained by the euro area shock is a reasonable estimate of its impact. If other UK specific developments were thought to have played an important role in increasing or decreasing UK bank's funding costs over the period then our estimate will be biased, but we feel that given the identification challenges ours is a reasonable starting point.

Our approach to constructing a counterfactual analysis is an alternative to the method of synthetic control recently promoted in Abadie and Gardeazabal (2003) and Abadie et al. (2010)

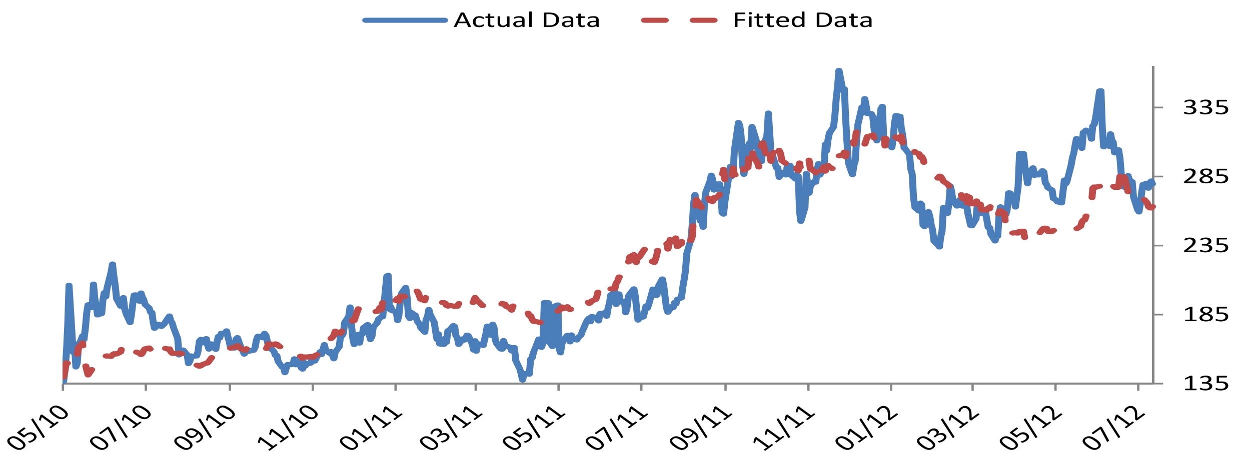
[17]Actually, the first principal component explains more than 80% of the euro area CDS series over that period.

[18]The major UK lenders are Banco Santander, Barclays, HSBC, Lloyds Banking Group, Nationwide and Royal Bank of Scotland and together they accounted for around 70% of the stock of lending to businesses, 45% of the stock of consumer credit, and 75% of the stock of mortgage lending at the end of December 2011. See Trends in Lending, July 2012 Bank of England (2012)

among others. The latter method is based on a comparative analysis between units that have experienced some form of intervention and others that have not. We feel that such a formal distinction between these two classes of units is difficult in our case and so we proceed with our own approach.

The results for the CDS-based measure are shown in Figures 3 and 4. The regression fits well over the May 2010 to June 2012 period, suggesting that UK bank funding costs were largely driven by the same shock driving euro area CDS during this period.[19] Following the introduction of the FLS, in July, a residual opens up, suggesting that something else reduced UK banks' funding costs over that period (blue line on Figure 4). We are aware that results based on a regression starting in May 2010, while justified by our priors, would not be convincing if choosing other start dates resulted in very different results. The swathe around our 'preferred estimate' on Figure 4 shows the resulting estimates derived by choosing different start dates for the regression ranging from 1 January 2009 right up to including only data in June 2012. The result that the euro area does not explain all of the falls in UK banks' CDS is, therefore, robust to different estimation periods.

Figure 3: B6 banks' CDS and fitted value (bps)



As we discussed earlier, senior unsecured bond spreads fell by more than CDS following the introduction of FLS. We can apply the same methodology as above but this time using senior unsecured spreads as the proxy of UK banks' funding costs. We might expect the impact on cash bonds to be larger if there is imperfect arbitrage and the scheme affects liquidity or other premia specific to them. The estimated effect on senior unsecured bonds is larger (75bps). However, the regression fit over the preceding period is less good (Figure 5), suggesting bond specific factors were playing an important role before the FLS, and these are not explained by movements in euro area CDS.

[19]The R-squared of the regression is 75% over this period. A natural interpretation is that this shock emanated in the euro area, and was related to the likelihood of very bad outcomes, but the method here simply demonstrates co-movement.

Figure 4: Estimate of the FLS effect on UK bank CDS

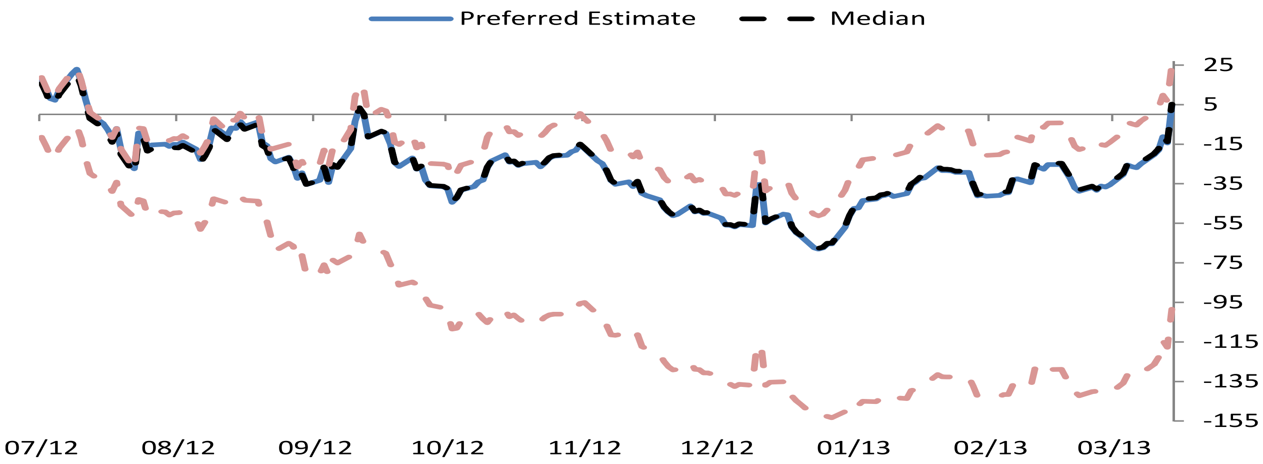
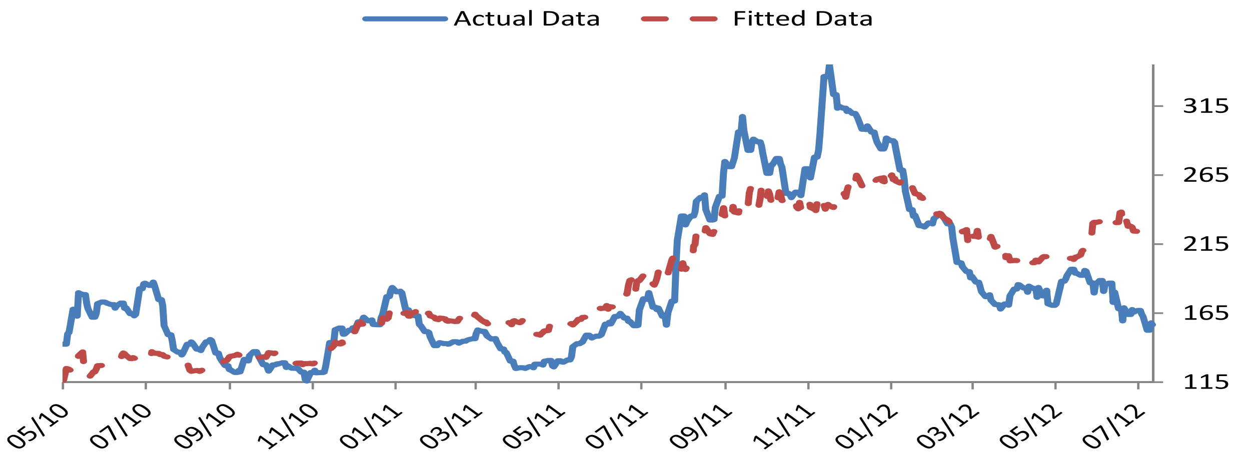


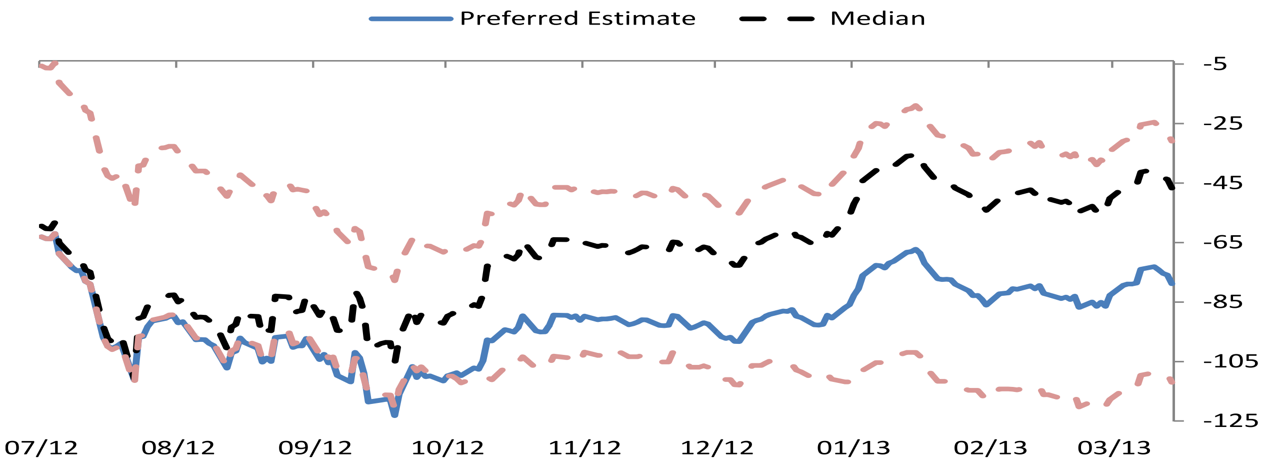
Figure 5: B6 banks' senior unsecured bond spreads and fitted value (bps)



4.2 The Impact of lower market funding costs on GDP and inflation

From the last exercise we have an estimate of the level of UK banks' wholesale funding spreads without the policy intervention and this is our counterfactual scenario. Our next step is to estimate the large BVAR model over the period between 01/2008 and 06/2012 (FLS announcement month). The estimated model is then used to forecast (from 07/2012 to 02/2013) how the state of the economy would have evolved without the policy stimulus (conditional on counterfactual spreads) and to derive agents' projections about the future evolution of the economy once they are informed about the policy actions (conditional on actual spreads). We then proceed to forecast further (03/2013-03/2014), without conditioning on spreads but letting the model dynamics fully determine the forecast of all variables in the model. The difference between the two forecasts offers a metric to assess the effectiveness of FLS. Figure 7 illustrates the FLS effect on GDP and annual CPI inflation, using the CDS+3-month Libor measure. The blue solid line denotes the pointwise posterior median while the 16%-84% posterior percentiles are captured by the red dashed-dotted lines.

Figure 6: Estimate of the FLS effect on UK bank senior unsecured bond spreads



Starting from Figure 7 we see the FLS impact on GDP is significant both in statistical and economic terms. The effect is persistent and it takes more than a year to reach a peak of 0.8%. As banks' funding costs fall, that lowers the effective interest rate for households and firms and boosts consumption and investment. The lower cost of capital also implies higher profits for firms and this increases asset prices, which further pushes up on GDP. These effects become even stronger if we believe that households and firms are subject to collateral credit constraints.

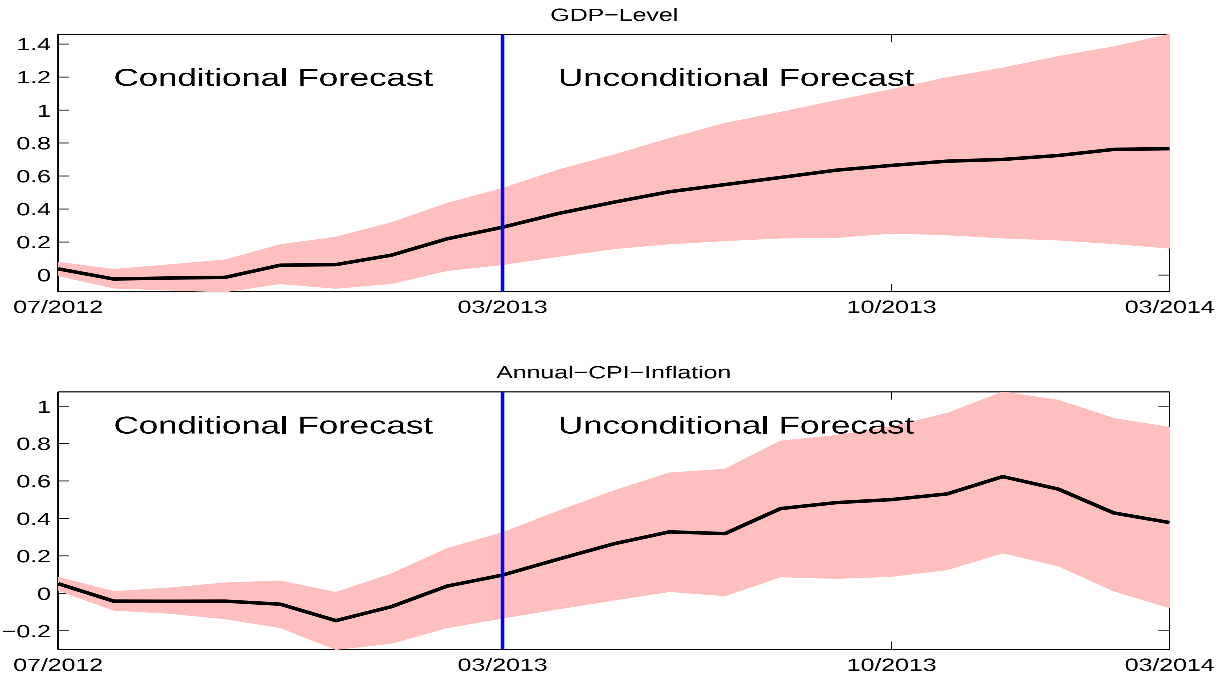
Inflation also increases as result of the FLS intervention. The increase reaches a peak of about 0.6 pp more than a year after the policy started. To understand what drives this results let us consider a New Keynesian Philips Curve (see Christiano et al. (2005) and Smets and Wouters (2007) among others) where inflation is function of the current and expected real marginal cost and the latter is a weighted average of real wages and the return on capital. The introduction of FLS lowers the cost of capital and puts downward pressure on marginal cost and inflation. However, as demand expands, the demand for labour rises too putting upward pressure on real wages and inflation. Since real wages are the largest component of marginal costs, the reduction of the cost of capital should eventually be offset by the increase in wages.

As expected and can be seen from Figure 8, the effects are larger when the secondary market bond spread proxy is used, given the larger estimate of the size of the shock. There is also a slight difference because the model estimate of the impact of funding costs is slightly different, but the results are not statistically different to scaling up the results from the CDS-based exercise for the larger estimated shock.

4.3 ARDL robustness exercise

As has been discussed earlier, Pesaran and Smith (2014) argue that if the reduced form policy parameters are different after the policy intervention then our counterfactual exercise is not valid. To check the robustness of our results, we apply their methodology, using the univariate model described by equation (4).

Figure 7: Estimate of the impact of FLS on the level of GDP and CPI inflation, based on its estimated impact on CDS



The first task is to decide about the dynamic order of the univariate model, for which we use the Hannan Quinn Information Criterion (HQIC, see Lutkepohl (2007)). For the GDP series, the information criterion selects the model with four endogenous and two exogenous variable lags as the best, while it chooses a significantly more parsimonious model for CPI (one lag for both endogenous and exogenous variables). Both models are estimated using OLS for the same estimation period and are used to produce conditional forecasts again for the same period.

From Figure 9, it appears that the ARDL analysis supports the BVAR results reported earlier. As predicted by the BVAR analysis, FLS has a positive effect on demand and prices. Although it can be argued that the effects obtained using the ARDL appear to be somewhat smaller they are equally persistent.

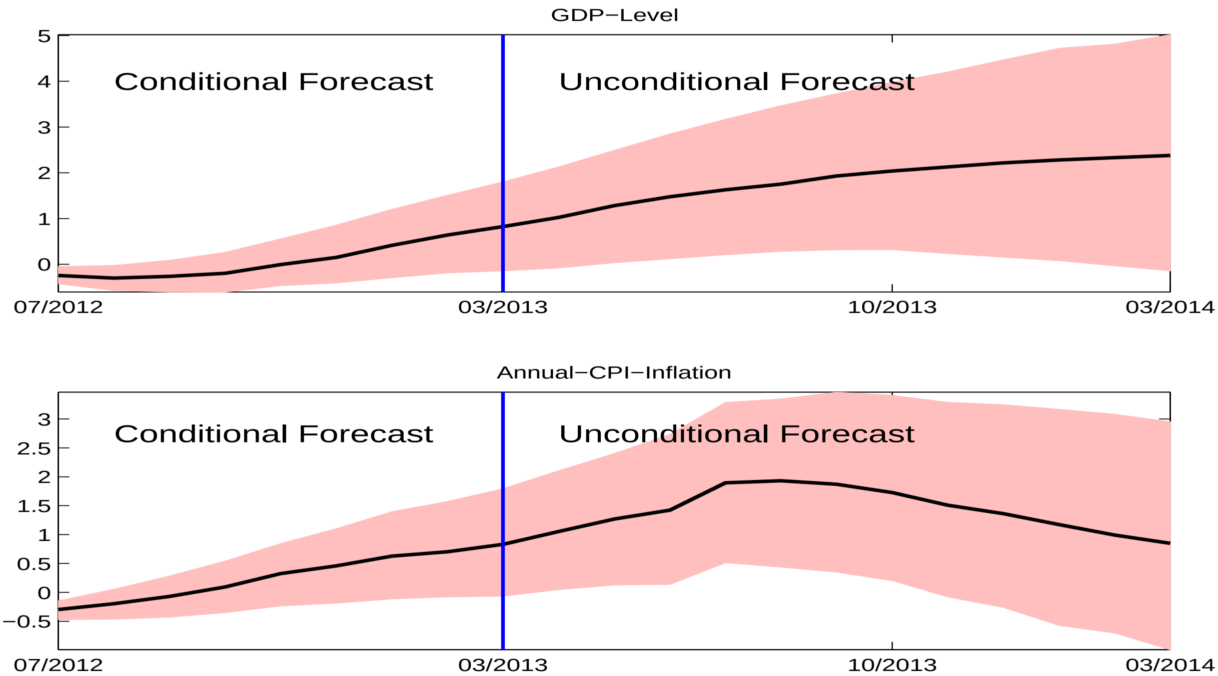
5 The effects of Quantitative Easing 2

5.1 The impact of QE2 on yield spreads

In order to estimate the impact of QE2 on the macroeconomy, our analysis again broadly follows the approach used by Kapetanios et al. (2012), where the counterfactual simulations presented are derived on the assumption that the main impact from QE comes from its effects on government bond spreads.[20] In order to quantify this initial yield impact, Kapetanios et al. (2012) use the event study evidence reported in Joyce et al. (2011a), which suggested the impact

[20]Given the reduced form nature of the models used, the study does not attempt to identify the precise transmission channels involved, though the main transmission channels were assumed to be through portfolio balancing and signalling.

Figure 8: Estimate of the impact of FLS on the level of GDP and CPI inflation, based on its estimated impact on senior unsecured bond spreads



on 5-25 year gilt yields from the Bank's first round of asset purchases summed to about 100 basis points during March 2009 to January 2010.

Table 3 repeats a similar exercise for 5 and 10-year gilt yields showing the announcement reactions over both 1 and 2 day windows and also extending the dataset to include the policy announcements associated with QE2. Summing over the QE1 events using the longer 2-day window preferred by Joyce et al. (2011a) suggests that overall 5-year yields fell by around 55 basis points and 10-year yields fell by 80 basis points. The reactions to the QE2 announcements are much smaller, however, particularly for longer maturities. In considering the impact of later purchases and particularly QE2, there are reasons for thinking that event study methods might be less useful, as financial markets may have become more familiar with the use of QE (i.e. the Bank's reaction function) and therefore been better able to anticipate its use (as discussed in Joyce et al. (2012a)). At the same time there are reasons why it may not be appropriate to quantify QE2 on the basis of QE1 event studies, as the importance of some of the channels through which QE works may have been weaker in QE2 relative to QE1 (eg any impact through signalling might plausibly have been greater when the new policy was first announced than when it was extended). We therefore examine several methods, in order to derive a plausible estimate for the yield curve impact.

Figures 10 and 11 illustrate the 2-day reactions of 5-year and 10-year gilt yields (estimated zero coupon spot rates) to the news about total QE purchases following various QE announcements and the 2009 Q3 GDP release, where news is calculated using the Reuters survey of economists.[21] For both 5 and 10-year yields, the responses to the QE1 announcements all

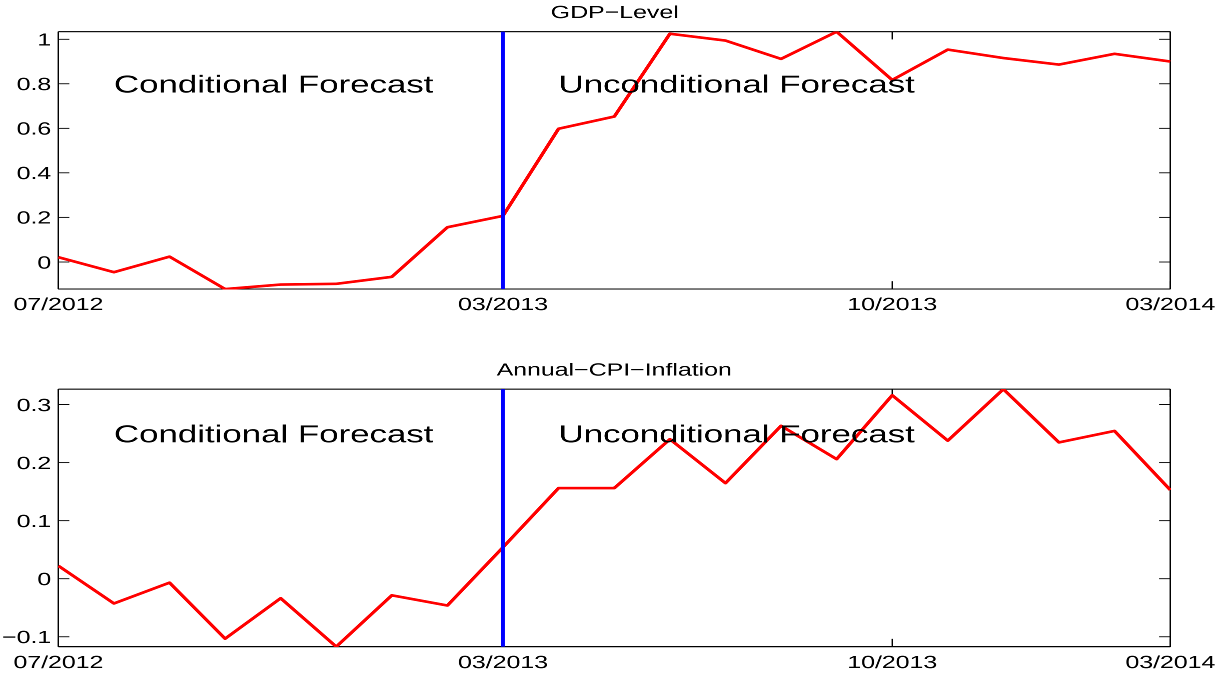
[21] The details on the construction of this chart are explained in Joyce et al. (2011a) and Joyce et al. (2012a).

Table 3: Reaction of gilt yields to QE1 and QE 2 announcements

Event	Date	5-year yield		10-year yield	
		1-day change	2-day change	1-day change	2-day change
1. February 2009 Inflation Report and associated press conference indicates QE likely	11.2.2009	-11	-26	-13	-27
2. MPC announces £75 billion of asset purchases	5.3.2009	-18	-34	-32	-68
3. MPC announces £50 billion extension of programme	7.5.2009	5	9	6	10
4. MPC announces further extension of £50 billion, as well as extension of buying range	6.8.2009	-11	-4	-7	-3
5. GDP release for 2009Q3 suggests more QE likely	23.10.2009	-5	-3	-4	-1
6. MPC announces further £25 billion of purchases	5.11.2009	4	4	7	10
7. MPC decision to resume purchases, with additional £75 billion	6.10.2011	3	7	4	12
8. MPC announces further £50 billion of purchases	9.2.2012	-1	-13	5	-5
9. MPC announces further £50 billion of purchases	5.7.2012	-10	-15	-6	-11
QE1 events (1)-(6)		-36	-54	-44	-80
QE2 events (7)-(9)		-8	-21	4	-4
Total all events		-43	-75	-40	-84

Notes: Part of the fall in yields following the February 2009 announcement may have reflected the market's greater certainty that there would be a Bank Rate cut in March 2009. The figures reported in parentheses are adjusted to take account of this effect: spot rates for 12 February were recalculated with 25 basis points subtracted from the underlying instantaneous forward rates between zero and five years on a sliding scale, as in Joyce et al. (2011a).

Figure 9: Effects of FLS on GDP and CPI inflation based on its estimated impact on CDS and using ARDL model



fall fairly close to the solid regression line which represents the line of best fit through them, although they are dominated by the initial impact of QE (which is represented by the dot in the bottom right of each chart, which combines the yield reaction of February and March 2009 (see Joyce et al. (2011a))). For two of the QE2 announcements, the size of the implied news is quite small, but the gilt yield reaction is slightly larger, particularly for 5-year yields. The first QE2 announcement in October 2011 stands out, however, in implying a fairly large change in QE news accompanied a rise rather than a fall in yields.[22] There are reasons for not taking this announcement reaction at face value, as there was a change to the survey question used to calculate QE news in this month and there was a significant amount of international news at the same time. Joyce et al. (2012a) report that gilt yields rose by less than international yields on the same day. Nevertheless, overall the yield reaction to news about QE2 does seem weaker for the later purchases.

To the extent that a weaker impact might be the consequence of additional QE being anticipated by the markets, it may be more relevant to examine the market reaction to macro news that might have signalled the likely use of the policy. Goodhart and Ashworth (2012) find that 5-25 year yields actually rose in aggregate over the seven MPC announcements they examine during the QE2 period, and even when they include the yield reaction following the Purchasing Manager's Index (PMI) manufacturing and services at the beginning of September

The difference from these papers is that we show the reaction of 5 year and 10-year gilt yields, rather than the 5-25 year yield. We use the 5 and 10-year yields, as these are the yields that feed into the spreads used in the BVAR model we report later.

[22] An article by Chris Giles in the Financial Times on the day following the announcement ('QE2: Old Lady delivers shock and awe', 7 October 2011) has the byline "Few anticipated the scale of the Bank of England's decisive move to tackle weak growth".

Figure 10: The 2-day reaction of 5-year gilt yields to QE news. Least squares regression line based on QE1 observations

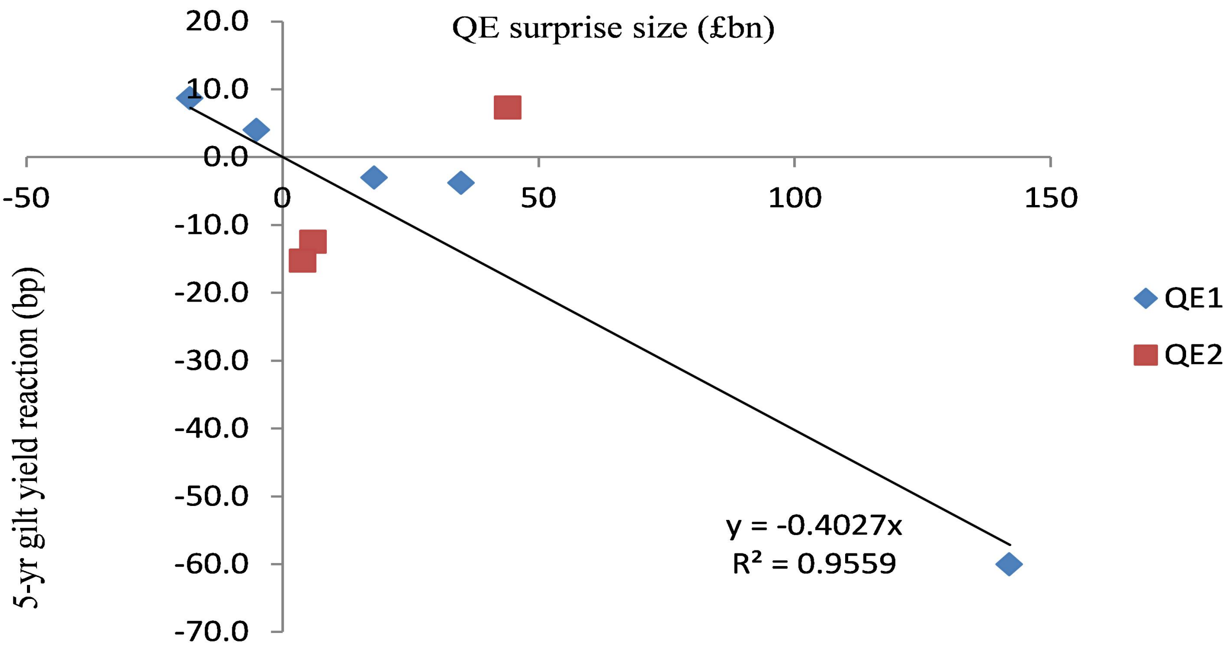


Figure 11: The 2-day reaction of 10-year gilt yields to QE news. Least squares regression line based on QE1 observations

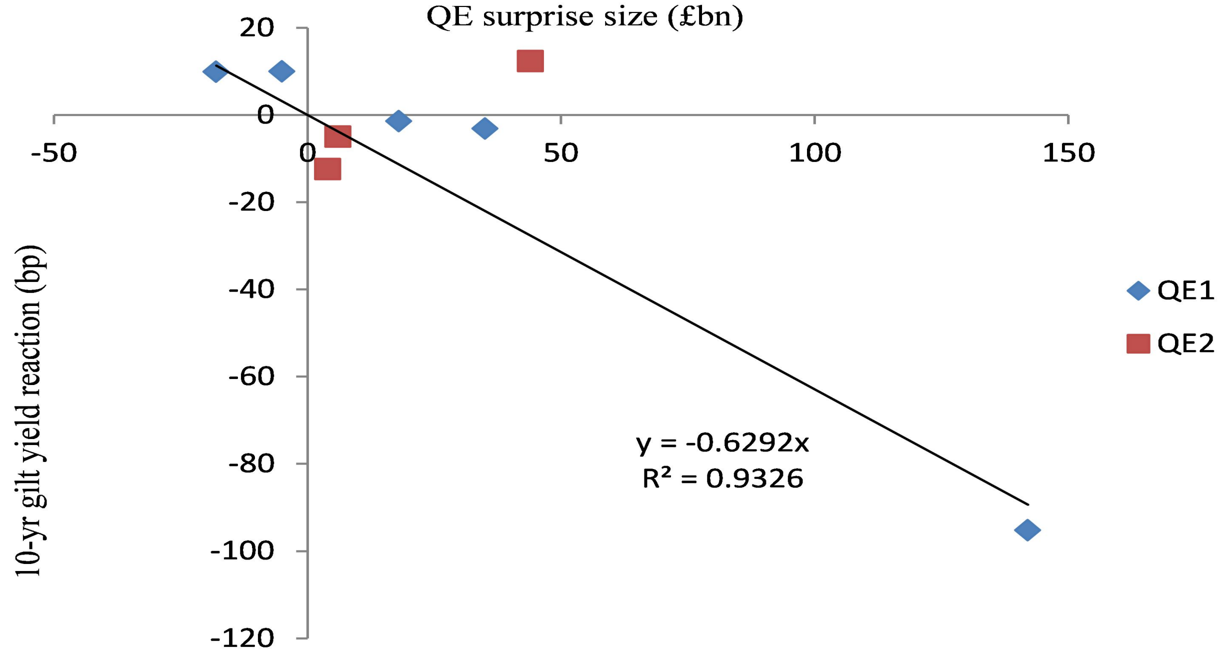


Table 4: Reaction of gilt yields to wider set of QE 2 policy and macro announcements

Event	Date	5-year yield		10-year yield	
		1-day change	2-day change	1-day change	2-day change
1. Aug 2011 Inflation Report	10.8.2011	-22	-20	-21	-21
2. PMI manufacturing survey for August 2011	1.9.2011	-8	-15	-8	-17
3. PMI services survey for August 2011	5.9.2011	-13	-11	-15	-16
4. MPC minutes	21.9.2011	1	0	2	-7
5. MPC decision, £75bn	6.10.2011	3	7	4	12
6. BoE inflation report	16.11.2011	2	10	2	9
7. MPC decision £50bn	9.2.2012	-1	-12	5	-5
8. MPC minutes	21.3.2012	-2	-5	-6	-11
9. MPC minutes	18.4.2012	6	9	4	6
10. MPC decision	10.5.2012	7	3	8	7
11. MPC decision, £50bn	5.7.2012	-10	-15	-6	-11
Total (4)-(10)		16	12	20	11
Total (2)-(10)		-4	-14	-3	-22
Total all QE2 events		-36	-49	-30	-54

Notes: The events (4)-(10) correspond to the 7 policy announcements reported in Table 10 of Goodhart and Ashworth (2012). The events (2)-(10) include the reactions to the PMI surveys they also cite, but exclude reaction to the August 2011 Inflation Report.

they find a modest negative impact of about 20 basis points. However, their analysis excludes the impact of the August 2011 Inflation Report, which they argue caused yields to fall for reasons unrelated to QE, and the £50 billion extension of QE that was announced in July 2012, which occurred after their paper was written. In Table 4, we tabulate the 1-day and 2-day reactions of 5-year and 10-year gilt yields to all these events. Like Goodhart and Ashworth (2012), we find that the seven monetary policy events they focus on accompanied a small rise in yields overall, but including the other events leads to a larger and negative impact up to 55 basis points. Even so, the estimated impact is still rather less than proportionate to the impact of QE1 and, of course, the choice of these events can be questioned. A couple of other studies have attempted to look at these issues in different ways. Butt et al. (2012) look at the comparative effects of QE2 and QE1 on broad money and find the effects have been broadly proportionate, although the precise transmission channels seem to have been different. McLaren et al. (2014) look instead at the reaction of gilt yields to shocks to the distribution of QE purchases across the term structure associated with various operational changes in the QE programme spanning across QE1 and QE2. They find the impact of local supply surprises had a similar impact across the events they examine, suggesting that the strength of this channel (part of the portfolio balance effect) has not changed significantly over time, but they also find it only accounts for only about half the estimated effect of QE on gilt yields.

As an alternative approach, and mirroring the earlier analysis of banks' CDS discussed in the section on the FLS, we can also compare the behaviour of UK yields over the QE2 period with what might have been expected given their normal relationship with international yields. In order to construct this counterfactual, we first carried out a principal component analysis using daily data on 5-year and 10-year benchmark yields for 11 and 13 different countries respectively over the period from April 1999 to March 2013.[23] The first two principal components explain over 90% of the variation in the 5 and 10 year yield data, with the first principal component alone accounting for more than 80% of the variance of yields in each case. We then regressed UK 5-year and 10-year spot yields on the first two principal components over a sample preceding the start of the global financial crisis (up to the end of March 2008). There is clearly a large amount of comovement between UK yields and international yields, with this simple regression having an adjusted R-squared of more than 75% for both 5 and 10 year maturities. Finally, we used this historical relationship between UK yields and international yields to forecast the behaviour of UK yields over the global crisis period. The results from this exercise are shown in Figures 12 and 13, where the shaded areas show the QE1 and QE2 periods, where the start of each period is defined by the first official MPC QE announcement and the end of each period coincides with the day of the last reverse gilt auction. Although the principal components regressions explain the past behaviour of UK yields well, they overpredict them during the crisis period. During the QE2 period, the underprediction of 5-year and 10-year yields increases by 10 basis points and more than 30 basis points respectively from the day before the first QE2 announcement to the day of the third announcement on 5 July 2012 (if it is assumed that QE2 was anticipated and we take a longer window back to the 1 September the increase is of the order of 12 basis points and 55 basis points respectively). Of course, there were other factors driving UK yields over this period, including safe-haven flows into gilts associated with the euro area sovereign debt crisis, but it is nonetheless striking that UK yields were depressed by a significant order of magnitude relative to the counterfactual based on the behaviour of international yields. Nevertheless, the estimated effects are still considerably smaller than the event study based ones for QE1.

These various approaches to calibrating the impact of QE2 are summarised in Table 5 alongside their caveats. Overall the balance of the estimates suggests that QE2 had a smaller impact than the previously estimated impact of QE1. Given the uncertainties surrounding the individual estimates, for the purposes of the simulations we assumed that the impact on 5 and 10 year yields of QE2 was 45 basis points. This figure is broadly in line with the reactions of gilt yields reported in Table 4.

5.2 Macroeconomic effects of QE2

The steps taken to infer the real economy effects of QE2 are similar to those discussed in Section 4.2. To be precise, the BVAR model is estimated over the period between 01/2008 and 01/2012 and used to forecast (from 02/2012 to 02/2013) how the state of the economy would have evolved with and without the stimulus. We model the stimulus by assuming that spreads were 45 basis points lower under QE during October 2011 to October 2012.

[23]The 13 countries included in the 10-year yield analysis were Australia, Belgium, Canada, Finland, France, Germany, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United States. Dropping the United States from the set of countries had little effect on the results. For the 5-year yield, we dropped Denmark and Finland because of lack of available data over parts of the sample period.

Figure 12: 5-year gilt yields vs predicted values based on international yield correlations (%)

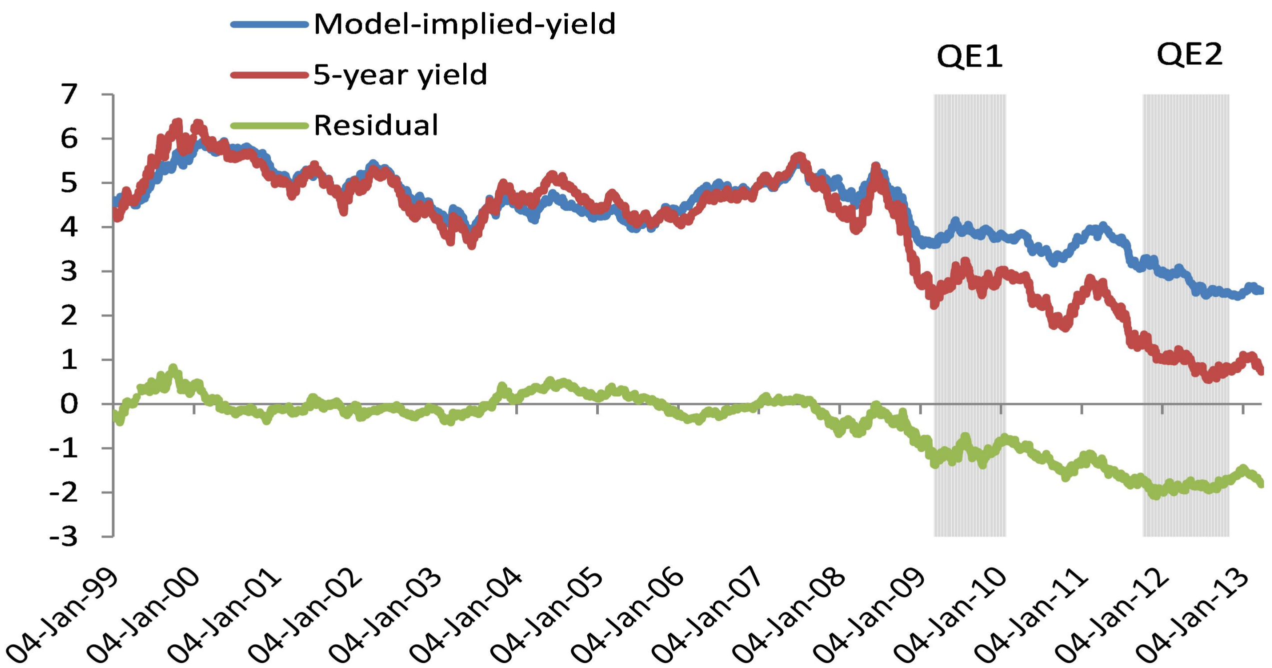


Figure 13: 10-year gilt yields vs predicted values based on international yield correlations (%)

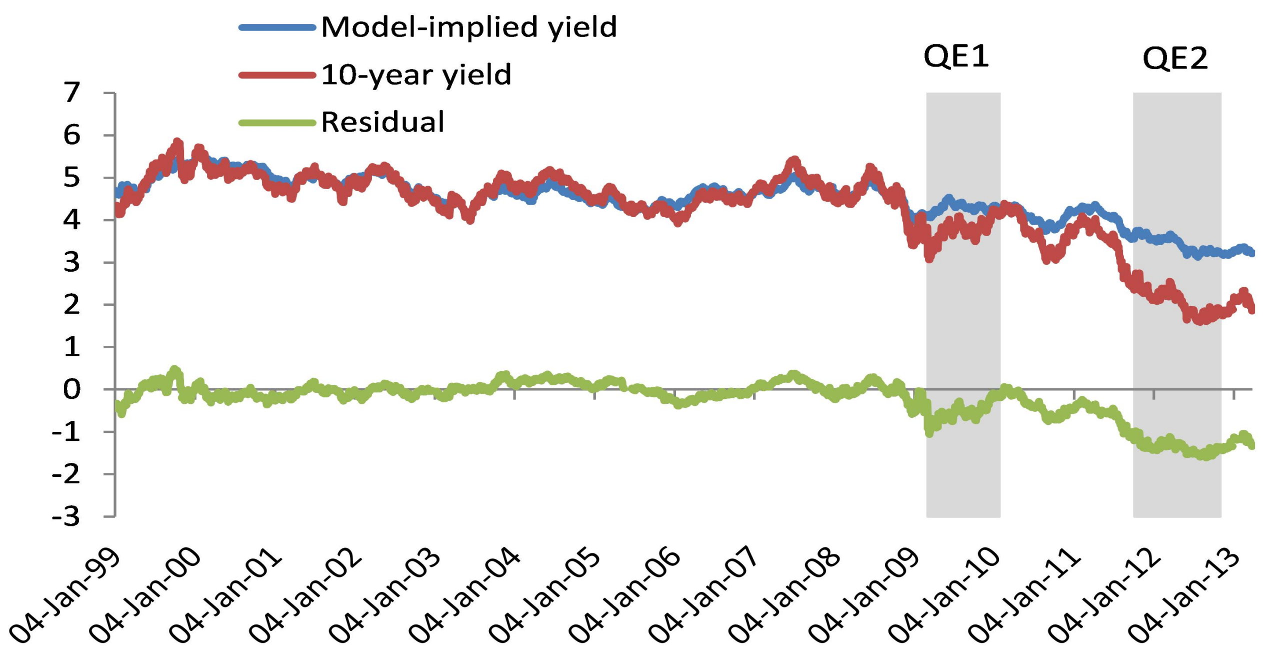
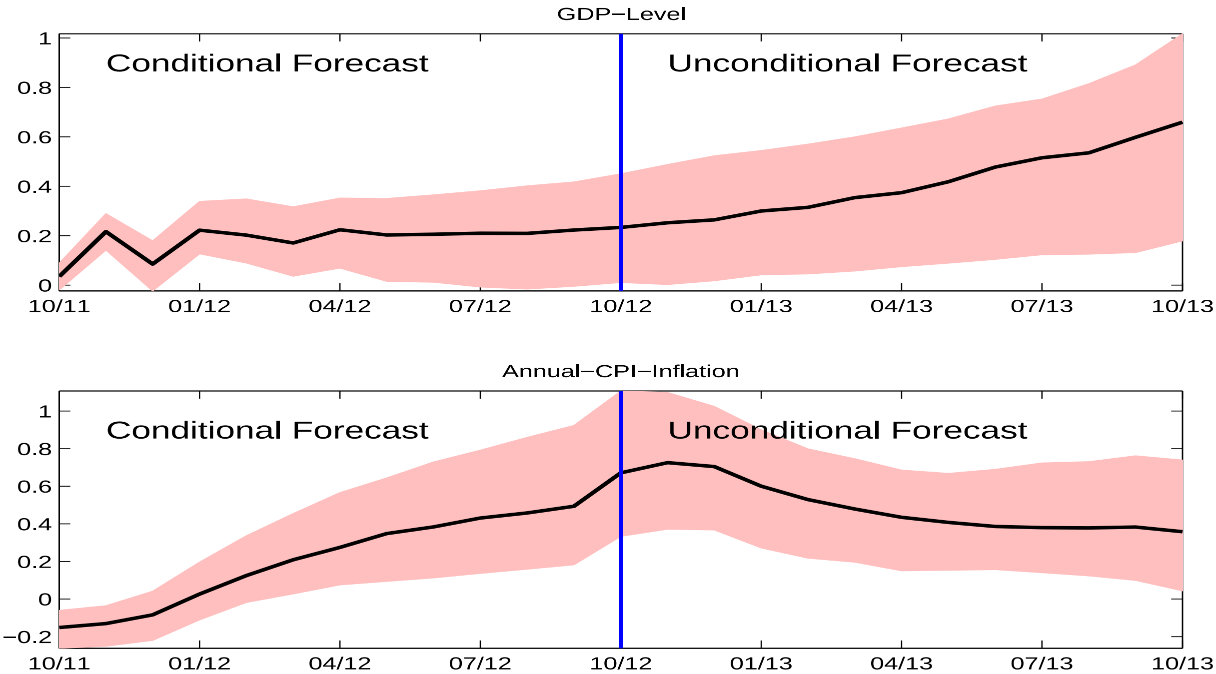


Figure 14 illustrates the effects of QE2 on GDP and annual inflation under the scenario that the yield spread was reduced by 45bps. The exercises suggest QE2 had a significant effect on demand. GDP rises 0.6 % by the end of the period under consideration. The inflation response has an inverted U shape, and is initially increasingly positive and significant, peaking at 0.6 pp. Then, it declines to about 0.25pp. These estimates can be contrasted with the findings of Kapetanios et al. (2012), where QE1 was found to have had a positive impact on GDP of about 1.5% and to inflation of about 1.25pp. Given our finding that QE2 had a smaller effect on spreads compared to QE1, these differences appear intuitive.

Figure 14: Effects of QE2 on GDP and CPI Inflation using BVAR model

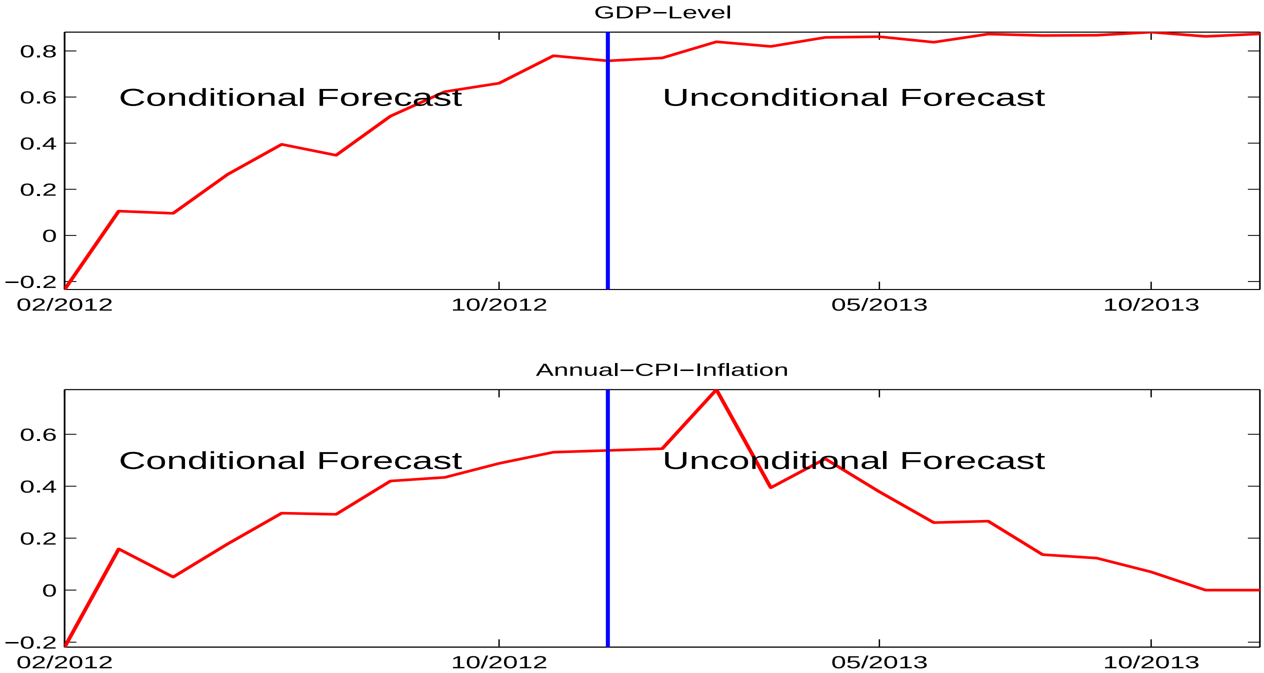


We also carry out an ARDL analysis whose results are reported in figure 15. This analysis delivers qualitatively similar estimates, thereby suggesting that the counterfactual analysis undertaken in this section is not subject to the problems discussed in Pesaran and Smith (2014).

6 Conclusion

In this paper we provide new results on the potential macroeconomic effects of two key unconventional monetary policies pursued by the Bank of England after the 2008 financial crisis. Our analysis is structured in two steps. Firstly, we use both existing and new approaches to determine the effect of the unconventional policies on relevant financial variables, such as spreads and bank funding costs. Secondly, we use two econometric models to map out the effect changes in these financial variables had on the macroeconomy. The use of BVAR and ARDL models provides a useful cross-check for our empirical analysis, especially since the two models have different characteristics and motivations and use different data.

Figure 15: Effects of QE2 on GDP and CPI Inflation using ARDL model



Starting with FLS we have documented the scheme's effect on bank wholesale funding spreads and considered the effect this drop in spreads had on GDP growth and inflation. In particular, we find a positive peak effect of 0.8 % on GDP and 0.6 pp on inflation more than a year after the start of the policy. For QE2 we find a significant positive effect for GDP growth of about 0.6 % and a significant positive effect on inflation that has an inverted U shape.

Finally, it is appropriate to qualify our analysis and results by noting several caveats. First, the relative uniqueness of the two policy interventions and the economic environment in which they took place means that our efforts to model their impact are obviously uncertain. This is compounded by the fact that we have estimated our models using relatively small samples, in order to account for potential parameter time-variation associated with structural change. Second, we have focused exclusively on what we consider the main channels from the unconventional policies to the macroeconomic variables of interest, ignoring other possible transmission channels that can be less well approximated through our models. Despite these caveats, we believe our modelling approach represents a reasonable compromise, given the inevitable constraints of any such counterfactual analysis, and that it provides a useful estimate of the overall macroeconomic impact of QE2 and the FLS.

Table 5: Impact of QE2 on 10-year gilt yields

Method	Source	Impact	Caveats
Extrapolation from QE1 event studies	Joyce et al. (2011a) Joyce and Tong (2012)	On 5-year yields: -50 bp On 10-year yields:-70 bp	Relies on QE1 evidence (2-day window) only
Event study analysis of QE2	Goodhart and Ashworth (2012) extended to other events	On 5-year yields: -29 to -49 bp On 10-year yields: -33 to -54 bp (lower estimate excludes impact of August 2011 IR)	Selection of events is slightly arbitrary
Impact on monetary aggregates	Butt et al. (2012)	Similar proportionately to QE1	Assumes a straightforward equivalence between the monetary and yield curve impacts
Analysis based on changes in purchases ranges during QE1 and QE2	McLaren et al. (2014)	Strength of local supply effects similar, 40-60% of total impact on yields	Focuses only on local supply channel so may underestimate the total effects
Evidence from principal component model of international yields	This paper	On 5-year yields: -10 to -12 bp On 10-year yields: -30 to -55 bp	Model ignores other factors than international yields

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A *Estimation of BVAR model*

In what follows we briefly discuss the estimation of the large BVAR described in Section 3. We can compactly rewrite the VAR as:

$$\boldsymbol{Y} = \boldsymbol{X_h}\boldsymbol{\Psi_h} + \boldsymbol{E}, \tag{7}$$

where $\mathbf{Y}= [y_{h+1}, .., y_T]'$ is a $T \times N$ matrix containing all the data points in y_t, $\mathbf{X_h}$=[1 $\mathbf{Y_{-h}}$] is a $T \times M$ matrix containing a vector of ones (1) in the first columns and the h-th lag of $\mathbf{Y}$ in the remaining columns, $\mathbf{\Psi_h}$=[$\Phi_{0,h}$ $\Phi_{1,h}$]$'$ is a $M\times$ N matrix, and $\mathbf{E}$=[$\varepsilon_{h+1}, .., \varepsilon_T$]$'$ is a $T \times N$ matrix of disturbances. As only one lag is considered we have $M = N + 1$. The prior distribution can then be written as:

$$\boldsymbol{\Psi_h}|\boldsymbol{\Sigma} \sim N(\boldsymbol{\Psi_0}, \boldsymbol{\Sigma} \otimes \boldsymbol{\Omega_0}),\ \boldsymbol{\Sigma} \sim IW(v_0, S_0). \tag{8}$$

Note that $\mathbf{\Psi_h}|\mathbf{\Sigma}$ is a matric-variate normal distribution where the prior expectation $E[\mathbf{\Psi_h}]$=$\mathbf{\Psi_0}$ and prior variance $Var[\mathbf{\Psi_h}]$=$\mathbf{\Sigma} \otimes \mathbf{\Omega_0}$ are set according to equation (3). The prior variance matrix has a Kronecker structure $Var[\mathbf{\Psi_h}] = \mathbf{\Sigma} \otimes \mathbf{\Omega_0}$ where $\mathbf{\Sigma}$ is the variance matrix of the disturbances and the elements of $\mathbf{\Omega_0}$ are given by $Var[\Phi_{1,h}^{(ij)}]$ in (3). Since the normal-inverted Wishart prior is conjugate, the conditional posterior distribution of this model is also normal-inverted Wishart

$$\boldsymbol{\Psi_h}|\boldsymbol{\Sigma}, \boldsymbol{Y} \sim N(\bar{\boldsymbol{\Psi}}, \boldsymbol{\Sigma} \otimes \bar{\boldsymbol{\Omega}}),\ \boldsymbol{\Sigma}|\boldsymbol{Y} \sim IW(\bar{\mathbf{v}}, \bar{\mathbf{S}}), \tag{9}$$

where the bar denotes that the parameters are those of the posterior distribution. Defining $\hat{\mathbf{\Psi}}$ and $\hat{\mathbf{E}}$ as the OLS estimates, we have that $\bar{\mathbf{\Psi}} = (\mathbf{\Omega_0^{-1}} + \mathbf{X'X})^{-1}(\mathbf{\Omega_0^{-1}\Psi_0} + \mathbf{X'Y})$, $\bar{\mathbf{\Omega}} = (\mathbf{\Omega_0^{-1}} + \mathbf{X'X})^{-1}$, $\bar{\mathbf{v}}$ = $\mathbf{v_0}$+T, and $\bar{\mathbf{S}} = \hat{\mathbf{\Psi}}'\mathbf{X'X}\hat{\mathbf{\Psi}} + \mathbf{\Psi_0'\Omega_0^{-1}\Psi_0} + \mathbf{\Psi_0} + \hat{\mathbf{E}}'\hat{\mathbf{E}} - \hat{\mathbf{\Psi}}'\bar{\mathbf{\Omega}}^{-1}\hat{\mathbf{\Psi}}$.

In order to perform inference and forecasting one needs the full joint posterior distribution and the marginal distributions of the parameters $\bar{\mathbf{\Psi}}$ and $\mathbf{\Sigma}$. One could use the conditional posteriors in (9) as a basis of a Gibbs sampling algorithm that drawing in turn from the conditionals $\mathbf{\Psi_h}|\mathbf{\Sigma}, \mathbf{Y}$ and $\mathbf{\Sigma}|\mathbf{Y}$ would eventually produce a sequence of draws from the joint posterior $\mathbf{\Psi_h\Sigma}|\mathbf{Y}$ and the marginal posteriors $\mathbf{\Psi_h}|\mathbf{Y}$, $\mathbf{\Sigma}|\mathbf{Y}$, as well as the posterior distribution of any function of these coefficients (for example, multi-step forecasts or impulse responses).

Still, if one is interested only in the posterior distribution of $\mathbf{\Psi_h}$ (rather than in any non-linear function of it) there is an alternative to simulation: by integrating out $\mathbf{\Sigma}$ from (9). It can be shown that the marginal posterior distribution of $\mathbf{\Psi_h}$ is a matric-variate t:

$$\boldsymbol{\Psi_h}|\boldsymbol{Y} \sim MT(\bar{\boldsymbol{\Psi}}, \bar{\boldsymbol{\Omega}}^{-1}, \bar{\boldsymbol{S}}, \bar{\boldsymbol{v}}). \tag{10}$$

The expected value for this distribution is given by:

$$\bar{\mathbf{\Psi}} = (\mathbf{\Omega_0^{-1}} + \mathbf{X'X})^{-1}(\mathbf{\Omega_0^{-1}\Psi_0} + \mathbf{X'Y}), \tag{11}$$

which is obviously extremely fast to compute. Recalling that $\hat{\mathbf{\Psi}}$ is the OLS estimator, and using the normal equations $(\mathbf{X'X})^{-1}\hat{\mathbf{\Psi}} = \mathbf{X'Y}$ we can rewrite this as:

$$\bar{\mathbf{\Psi}} = (\mathbf{\Omega_0^{-1}} + \mathbf{X'X})^{-1}(\mathbf{\Omega_0^{-1}}\mathbf{\Psi_0} + \mathbf{X'X}\hat{\mathbf{\Psi}}), \tag{12}$$

which shows that the posterior mean of $\mathbf{\Psi_h}$ is a weighted average of the OLS estimator and of the prior mean $\mathbf{\Psi_0}$, with weights proportional to the inverse of their respective variances. In the presence of a tight prior (ie, when $\theta \to 0$) the posterior estimate will collapse to $\bar{\mathbf{\Psi}} = \mathbf{\Psi_0}$, while with a diffuse prior (ie, when $\theta \to \infty$) the posterior estimate will collapse to the unrestricted OLS estimate.

Given the posterior mean $\bar{\mathbf{\Psi}} = [\bar{\mathbf{\Phi}}_{\mathbf{0,h}}\ \bar{\mathbf{\Phi}}_{\mathbf{1,h}}]'$, it is straightforward to produce forecasts up to h steps ahead simply by setting:

$$\hat{y}_{t+h} = \bar{\Phi}_{0,h} + \bar{\Phi}_{1,h} y_t, \tag{13}$$

As shown by Bandbura et al. (2010) it is also possible to implement the prior described above using a set of dummy observations. Consider adding T_d dummy observations $\mathbf{Y_d}$ and $\mathbf{X_d}$ such that their moments coincide with the prior moments: $\mathbf{\Psi_0} = (\mathbf{X_d'X_d})^{-1}\mathbf{X_d'Y_d}$, $\mathbf{\Omega_0} = (\mathbf{X_d'X_d})^{-1}$, $\mathbf{v_0} = T_d - M - N - 1$, $\mathbf{S_0} = (\mathbf{Y_d} - \mathbf{X_d\Psi_0})'(\mathbf{Y_d} - \mathbf{X_d\Psi_0})$. Augmenting the system in (7) with the dummy observations gives:

$$\boldsymbol{Y}^+ = \mathbf{X_h^+\Psi_h} + \mathbf{E}^+, \tag{14}$$

where $\mathbf{Y}^+ = (\mathbf{Y}'\ \mathbf{Y_d'})'$ and $\mathbf{E}^+ = (\mathbf{E}'\ \mathbf{E_d'})'$ are $(T + T_d) \times N$ matrices and $\mathbf{X}^+ = (\mathbf{X}'\ \mathbf{X_d'})'$ is a $(T+T_d)\times M$ matrix. Then it is possible to show that the OLS estimator of the augmented system (given by the usual formula $(\mathbf{X_h^{+\prime}X_h^+})^{-1}\mathbf{X_h^{+\prime}Y^+}$) is numerically equivalent to the posterior mean $\bar{\mathbf{\Psi}}$.

A.1 *Prior tightness*

To make the prior operational, one needs to choose the value of the hyperparameter ϕ. We discuss a number of methods for addressing this issue. The marginal data density of the model can be obtained by integrating out all the coefficients, ie, defining $\mathbf{\Theta}$ as the set of all the coefficients of the model, the marginal data density is:

$$p(\mathbf{Y}) = \int p(\mathbf{Y}|\mathbf{\Theta})p(\mathbf{\Theta})d\mathbf{\Theta}. \tag{15}$$

Under our normal-inverted Wishart prior the density $p(\mathbf{Y})$ can be computed in closed form (see Bauwens et al. (1999)). At each point in time ϕ could be chosen by maximising:

$$\phi_t^* = \arg\max_{\phi} \ln p(\mathbf{Y}) \tag{16}$$

This method has been used by Carriero et al. (2011). However, as discussed there, such a method may have a tendency to choose low values for the tightness parameter implying a large weight on the prior. It is important for our purposes to give considerable weight on the data. We therefore adopt an alternative approach whereby the tightness parameter is chosen by matching the fit of particular equations in the large VAR to those from smaller VAR models. Lenza et al. (2010) use a similar approach to set tightness. We find this approach produces a reasonable balance between the effects of priors and data that is appropriate for our analysis.

B *Data appendix for large BVAR model*

The data set for the large BVAR model is given in Table 6.

Table 6: *Data appendix for large BVAR model*

No.	Variable	Source	No.	Variable	Source
1	US industrial production	DS	23	20-year UK gilts	BofE
2	US CPI	DS	24	15-year UK gilts	BofE
3	Euro-area industrial production	DS	25	7-year UK gilts	BofE
4	Euro-area HICP	ECB	26	3-year UK gilts	BofE
5	UK GDP	NIESR	27	5-year 5-year implied inflation	BofE
6	UK industrial production	ONS	28	6-month Libor	BG
7	Brent dollar oil price	DS	29	12-month Libor	BG
8	UK CPI	ONS	30	FTSE All-Share index	DS
9	UK-PPI	ONS	31	FTSE All-Share dividend yield	DS
10	UK-UEMP	ONS	32	FTSE All-Share price-earnings ratio	DS
11	UK house price index	HF	33	UK exchange rate index	BofE
12	10-year gilt - T-bill spread	BofE	34	US dollar-sterling exchange rate	BofE
13	UK consumer confidence	EC	35	Euro-sterling exchange rate	BofE
14	M4	BofE	36	T-bill - Bank Rate spread	BofE
15	M3	BofE	37	3-month Libor - T-bill spread	BofE
16	Retail deposits and cash in M4	BofE	38	3-month Libor-Bank Rate spread	BofE/BG
17	Secured lending to individuals	BofE	39	2-year gilt - T-bill spread	BofE
18	M4 net lending to private sector	BofE	40	5-year gilt - T-bill spread	BofE
19	M4 lending	BofE	41	Bank Rate	BofE
20	Household M4	BofE	42	US federal funds rate	Fed
21	PNFC M4	BofE	43	Euro-MRO interest rate	BD/BG
22	OFC-M4	BofE			