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AN EMPIRICAL SECTORAL MODEL OF UNCONVENTIONAL MONETARY POLICY: THE IMPACT OF QE*

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This paper describes a sectoral empirical model of money and credit in the UK that can be used for analysing unconventional monetary policies that affect banks' balance sheets. The paper uses the model to assess the impact of QE on the UK economy focussing on the endogenous portfolio response of banks, financial companies and non-financial companies. The baseline results support the quantitative estimates found by other studies, but suggest the impact of QE is sensitive to the assumption about whether and to what extent QE affects bank lending.

1 Introduction

This paper constructs a structural empirical model to understand the monetary transmission mechanism of unconventional policy at a sectoral level. Following the onset of the financial crisis in late 2007 and the subsequent recession, the United Kingdom's policy rate was cut dramatically. By March 2009 the policy rate had reached a low of 0.5%. In response to the zero lower bound central banks around the world responded with unconventional policies involving large expansions in central bank balance sheets through the purchase of assets with newly created money. As implemented in the United Kingdom, quantitative easing (QE) involved the purchase of government bonds and targeted at buying them from the non-bank private sector. The purpose of this policy was to stimulate demand through a variety of channels, notably by lowering long-term interest rates, encouraging portfolio rebalancing towards riskier assets and boosting asset prices and household wealth.

Our sectoral approach is well suited to examining the transmission of unconventional policy such as QE. Most unconventional policy interventions have an important sectoral dimension. For example, the aim of QE was to purchase assets from counterparties in the non-bank financial sector (such as insurance companies and pension funds). These assets are purchased with new

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central bank money, leading to an increase in the reserve holdings of the counterparties' bank and the counterparties' own bank deposits. Agents will start to rebalance their portfolios and, as a result, the effect of the policy intervention feeds through to other sectors. Consequently, we are particularly interested in this sectoral transmission mechanism. Furthermore, as QE involves the purchasing of assets and the creation of money, we are also interested in the relationship between money, credit and real variables more generally and these linkages have tended to be clearer at a sectoral level in the United Kingdom.[1] Our objective is therefore to provide both a richer understanding of the monetary transmission mechanism and new estimates of the effect of QE on different sectors and in the aggregate.[2]

We organise our model around the consolidated banking sector's balance sheet. We then model the behaviour of households, private corporations (financial and non-financial) and banks separately as a series of interrelated vector error correction models. This allows us to look at the long-run relationships between monetary and real variables at a sectoral level, as well as the short-term dynamics. The sectors are weaved together through a series of identities and aggregate relationships. In this sense the model is part empirical, part theoretical. In principle, one might like to estimate all sectors and the aggregate relationships jointly. But, given the relatively short span of data available and the large number of variables of interest, this becomes practically challenging. Instead, we employ the encompassing VAR methodology of Hendry and Mizon (1993), which makes a number of simplifying identification assumptions that makes separate sectoral estimation attractive.

On the theoretical side, the wider academic research in recent decades has tended to focus on DSGE models. Typically, New Keynesian models have a limited explicit role for money. However, an active area of research has developed on the role of financial and credit frictions. Following Bernanke *et al.* (1999), a large number of models have sought to incorporate 'financial accelerators' and a credit channel for monetary policy. More recently, a new generation of these models has been used to examine the effects of QE (e.g. Eggertsson and Woodford, 2003; Cúrdia and Woodford, 2011; Gertler and Karadi, 2011; Chen *et al.*, 2012).

The DSGE approach has, however, a number of potential drawbacks. First, there is a range of financial and credit frictions now employed in the literature and a work horse model is yet to emerge. Second, many of these frictions tend to produce relatively small additional real effects following changes in interest rates. Third, in the standard New Keynesian model, central bank balance sheet operations have no effect due to a Modigliani–

[1]See Thomas (1997a, 1997b) for example.

[2]Our model can also be used to examine a range of policy interventions such as changes in macroprudential tools and other unconventional monetary interventions such as the Bank of England's recent funding for lending scheme.

Miller result discussed in Cúrdia and Woodford (2011). However, even the additional mechanisms in Cúrdia and Woodford (2011) that create a role for targeted asset purchases still leave no effect from the purchase of government securities, the form of QE implemented in the United Kingdom. One would have to include features that allow for market segmentation, preferred habitats, costs of adjusting portfolios or heterogeneity among different agents. These effects have only recently been incorporated into DSGE models (see, e.g. Andrés *et al.*, 2004; Harrison, 2012).

There is also a related empirical literature. On the one hand, there is a developing literature on the macroeconomic effects of QE using structural VARs and event study methods (see Joyce *et al.*, 2011 for a survey of some of the methods used to estimate the impact in the United Kingdom). On the other hand, there is an older literature on the relationship between money, credit and real activity at a sectoral level. For example, Thomas (1997a, 1997b) presents models of the household and private non-financial corporate sectors that examine the joint dynamics of money and real variables, such as consumption and investment. Chrystal and Mizen (2005a) study the joint behaviour of money, unsecured credit and consumption for households. Bridges and Thomas (2012), the closest framework to ours, bring together money and real variables across sectors and also employ a consolidated balance sheet approach to deliver aggregate results. Our model therefore speaks to all of these strands of the literature. In particular, we will be able to compare our aggregate results with the SVAR and event study findings. Our model can also be seen as an attempt to incorporate credit into the Bridges and Thomas (2012) framework, allowing us to explore the effect of monetary policy on lending at a sectoral level.

Our sectoral, disaggregated approach is therefore a hybrid of the more theory-free structural VAR methods (as our VECM structure is, after all, a reformulation of a standard VAR that we apply at a sectoral level) and a more structural approach. For all the reasons above we do not go anywhere near as far as the DSGE literature. Instead, our overall model can be thought of as an estimated disaggregated version IS-LM-CC model in the spirit of Brunner and Meltzer (1972) and Bernanke and Blinder (1988). As such, while we gain tractability and richness, we will be partially subject to the Lucas critique.

The remainder of this paper is structured as follows. Section 2 outlines the modelling approach used, focusing on the overall approach, the different sectors we consider and how they are brought together into an aggregate model.[3] Section 3 then uses the model to study the effects of QE. Section 4 concludes.

[3]More details on the econometric results of our models are available from the authors on request.

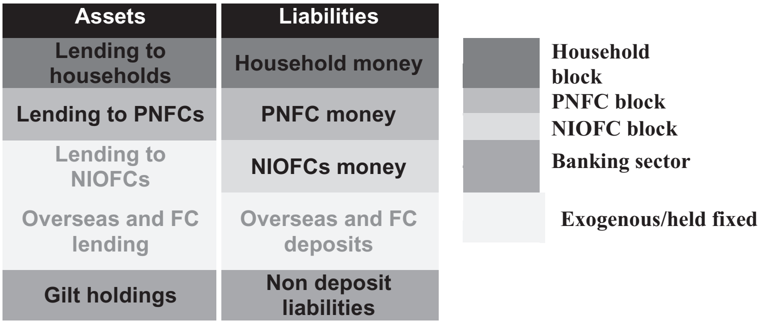

FIG. 1. A Stylized Consolidated Banking Sector Balance Sheet

2 Modelling Money, Credit and Real Activity

2.1 A Consolidated Balance Sheet Approach

Our modelling approach involves constructing separate empirical models for different sectors of the UK economy and linking these together using some aggregate assumptions and identities. To organize and motivate our framework, we consider the consolidated balance sheet of the banking system.[4] Specifically, we model sectoral credit and gilt holdings on the asset side of the balance sheet and sectoral money and non-deposit liabilities on the liability side. This setup is illustrated in Fig. 1 and is analogous to modelling the broad money counterparts that feature widely in many central banks' analysis of the money supply.

First, we estimate separate sectoral vector error correction models for money, credit and real activity in the household and private non-financial company (PNFC) sectors. These variables are shown in Fig. 1. Estimates of these sectors are based on previous research that has used estimated sectoral structural VECMs to examine the linkages between money and credit, on the one hand, and asset prices and spending, on the other.[5] Relative to this wider literature, our goal—as in Bridges and Thomas (2012)—is to embed these estimated systems into a wider macroeconomic model to examine the sectoral and aggregate effects of macroeconomic policy changes. In addition to estimated systems for households and PNFCs, we also estimate a sectoral VECM for the banking sector and for non-bank non-intermediate financial

[4]So interbank loans and deposits are netted out on the balance sheet. The central bank balance sheet is also consolidated with that of the commercial banking system, so central bank reserves do not appear on the asset side of the balance sheet. Instead holdings of government debt by both the Bank of England and the commercial banking system appear. But we discuss the unconsolidated balance sheets of the central bank and the commercial banking system in Section 3 when we look at the impact of QE.

[5]See, e.g. Thomas (1997a, 1997b), Brigden and Mizen (2004), Chrystal and Mizen (2005a, 2005b) and Bridges and Thomas (2012).

institutions (known as NIOFCs). NIOFCs collectively contain asset managers and institutional investors such as insurance companies and pension funds.[6] These institutions will be important in our analysis of the impact of QE in Section 3. The banking sector and NIOFC sectors provide dynamic equations describing the money demand of NIOFCs and the evolution of banks' holdings of gilts and their net non-deposit liabilities (shown in Fig. 1).

Having estimated these sectoral systems, we used the consolidated banking system's balance sheet identity to determine NIOFCs' holdings of money as a residual. Essentially in our model loans and other transactions by the banking system (including QE) lead to the creation of deposits (as discussed in more detail in McLeay *et al.*, 2014). Our estimated equations for household and PNFC deposits pin down how much of the money created flows to these sectors. What remains must be held by NIOFCs and asset prices and yields in the economy must adjust to make that happen, as we discuss below. This is the key link in our model between money and credit quantities, on the one hand, and financial yields and asset prices, on the other. We assume that NIOFCs' borrowing and net foreign currency assets are fixed and are not affected in our simulations, although in future work we intend to model these factors.

2.2 The Empirical Sectoral Modelling Methodology

The different sectors of the economy are modelled *separately* as vector error correction models. Although in principle we could estimate a conventional VAR, the VECM methodology is closest to the approach taken in the existing sectoral modelling literature. Furthermore, this methodology allows us to explicitly examine long-run relationships versus short-term dynamics. As noted in Thomas (1997a, 1997b), the modelling of sectoral money naturally fits into this framework. Money may be held for short-term reasons, such as temporarily accepting higher money balances as a buffer stock, and this may differ from the desired money holdings in equilibrium.

For each of the sectors, we will consider the joint behaviour of money, credit and real activity as a function of prices and other aggregate variables, estimated using quarterly data from 1977 to 2013. Our systems will contain a number of variables relevant for the monetary transmission mechanism. However, the system rapidly becomes cumbersome without some further assumptions. Following Thomas (1997a, 1997b) and Chrystal and Mizen (2005a, 2005b) we employ the encompassing VAR approach of Hendry and

[6]There are also a collection of institutions known as intermediate OFCs or IOFCs that represent institutions that are offshoots of the banking system such as securitization vehicles or that intermediate between banks such as central clearing counterparties like London Clearing House. These institutions are also consolidated out of our banking system balance sheet. As a result of this our measure of loans includes any household or corporate debt that is subsequently securitized, and non-deposit liabilities include the mortgage backed securities issued on the back of those securitizations.

Mizon (1993), where the emphasis is on making simplifying exogeneity and identification assumptions that make estimation more tractable. A more recent presentation of this methodology can be found in Garratt *et al.* (2006). Specifically, we start from the following unrestricted vector autoregression:

$$\boldsymbol{B}(L)z_t = \varepsilon_t \tag{1}$$

where $\boldsymbol{B}(L)$ is a lag polynomial of order p, z is a vector containing all the variables on interest and ε is a vector of serially uncorrelated reduced form errors. This forms the basis for the Johansen (1992) maximum likelihood approach to co-integration, which we employ. Equation (1) can be rewritten in vector error correction form as follows.

$$\Delta \boldsymbol{z}_t = \alpha\beta' z_{t-1} + \boldsymbol{C}(L)\Delta z_{t-1} + \varepsilon_t \tag{2}$$

where the Johansen (1992) procedure can be used to estimate the number of co-integrating vectors and the long-run matrix $\Pi = \alpha\beta'$. The matrix of co-integrating vectors is then $\beta' z_t$ and these are interpretable as the deviation of variables from their long-run equilibrium levels.

The rank of the Π matrix is used to determine the number of co-integrating vectors. A reformulation of the above system can then be estimated under the assumption of a particular number of co-integrating vectors. For practical purposes, it is then useful to have the same number of endogenous variables as co-integrating relationships and it is common in the literature to partition the z_t matrix into a set of endogenous variables and a set of variables assumed to be weakly exogenous. We therefore partition the reduced form in each sector in the following way:

$$\Delta y_t = \alpha\beta' \mathrm{z}_{t-1} + \Gamma_1(L)\Delta \mathrm{y}_{t-1} + \Psi_1(L)\Delta x_t + \xi_t \tag{3}$$

where y is the endogenous variable and x is the variable that is assumed to be weakly exogenous. These conditioning variables are described by the following system:

$$\Delta x_t = \Gamma_2(L)\Delta \mathrm{y}_{t-1} + \Psi_2(L)\Delta x_{t-1} + u_t \tag{4}$$

The computational advantage of this partitioning is that the maximum likelihood estimate of β is independent of whether we estimate equation (3) or whether we estimate equations (3) and (4) jointly. The disadvantage is that we need to make some implicit assumptions to justify this split, notably that the x_t variables are contemporaneously exogenous and that the exogenous variables are not affected by the error-correction terms (see Urbain, 1995; Chrystal and Mizen, 2005a, 2005b). In our framework, we make the prior choice of the x_t variables based on the assumption that certain aggregate variables are likely to be treated as given by a particular sector. Having estimated the co-integrating vectors, full information maximum likelihood methods can then be used to estimate the dynamics from the VECM (3).

This procedure alone still does not identify the structural form. For example, there could be contemporaneous correlation among the endogenous variables. We therefore need some further identifying assumptions. Let matrix $\boldsymbol{A}$ contains coefficients governing the contemporaneous relationships. Multiplying equation (3) by $\boldsymbol{A}$ produces the structural VECM representation. This implies a relationship between the structural and reduced form residuals $\grave{o}_{\mathrm{t}} = \boldsymbol{A}^{-1}\xi_t$. We then provide the required restrictions on the variance–covariance matrix of ξ_t by restricting how the long-run relationships enter the dynamics and by directly imposing restrictions on the contemporaneous relationships—setting elements of A to zero. For more on this approach to identification in the context of co-integration, see Thomas (1997a).

2.3 The Household Sector

Ideally we would like our household sector to include secured and unsecured credit, money holdings, household consumption, dwelling investment, household housing and financial wealth and a range of aggregate variables together with the lending and deposit rates facing households. This system is potentially large so, following Chrystal and Mizen (2005a, 2005b), we first consider a sub-block for unsecured credit, money and consumption. We then consider a second block for secured credit, dwelling investment and housing wealth. To our knowledge, and despite its importance for household behaviour, we are the first to estimate a system that includes secured lending.

2.3.1 Households: A Model of Unsecured Credit. Our unsecured household system is very similar to that of Chrystal and Mizen (2005a, 2005b). Unfortunately using a range of lag lengths, our tests suggested a range of estimates for the number of co-integrating vectors. This uncertainty is not unusual in the literature. In theory we would like to identify a money demand, consumption function and lending relationship. Without a clear steer from the rank tests, we follow Chrystal and Mizen (2005a, 2005b) in imposing three vectors and allow money, consumption and lending to be endogenous variables. The system is then conditioned on a lag polynomial of real household income (y), Bank Rate (i), real housing wealth and real non-monetary financial wealth, aggregate consumer price inflation (π), and a credit condition index (derived by Fernandez-Corugedo and Muellbauer, 2006), which picks up the stochastic trend in credit and three spread terms for mortgage lending, unsecured lending and deposits (s). We consider these spreads as proxies for changes in credit conditions and, in related work, we use these as proxies for credit shocks.[7]

Mortgage interest rates are a weighted average of two-year fixed rate interest rates at 75% and 90% loan to value ratios and the rates charged on bank rate tracker products. Including the two-year products allows us to capture longer maturity products. Unsecured interest rates are a weighted average of personal loan, credit card and overdraft interest rates. These data are quoted rates data collected by the Bank of England. However, due to data limitations, the deposit rate series is the effective household deposit rate. Our credit spread series are then mortgage rates, deposit rates and unsecured rates relative to bank rate.

To identify the co-integrating vectors β, we need to impose at least r^2 restrictions, where r is the number of endogenous variables. The implied over-identifying restrictions are tested using a χ^2 likelihood ratio test and are not rejected. The resulting estimated co-integrating vectors are as follows:

$$c_t = 0.030m_t + 0.023l_t^u + 0.54y_t - 0.0076i_t - 0.0044s_t^m - 0.0056s_t^u + 0.18w_t$$

$$m_t = 0.50c_t - 0.027\pi_t + 0.064s_t^d - 0.022s_t^u + 0.21w_t$$

$$l_t^u = 1.66y_t + 0.11s_t^d - 0.069s_t^u + 0.054w_t + 2.27CCI_t$$

This implies a long-run consumption to labour income elasticity of around 0.5 and that increases in Bank Rate and lending spreads lower long-run consumption. Consumption, money and unsecured lending are all positively related to wealth (w, which is defined as net total wealth excluding money holdings). The annual propensity to consume out of wealth is around 0.03, which is close to an estimate of the real interest rate in steady state and is if anything a touch lower than microestimates for the United Kingdom. Money holdings also increase with higher deposit rate spreads as one would expect.

Having estimated these long-run relationships, we then estimate the dynamics in equation (3) by full information maximum likelihood. In order to identify the structural form, we assume that a disequilibrium in consumption does not feed back onto money or lending and a money disequilibrium does not feed back to unsecured lending. These assumptions are then sufficient to identify the structural coefficients matrix $\boldsymbol{A}$. This means we also assume that consumption is allowed to contemporaneously affect unsecured lending and money holdings but not vice versa.

In the dynamics we also allow the separate components of net total wealth to enter the equations. This means that gross housing wealth and

[7]We are implicitly assuming that money, consumption and lending do not affect these conditioning variables within the same quarter. This is consistent with a view that, for example, lending rates are adjusted in a sticky manner.

other financial wealth can have different wealth effects on the dynamics of consumption, unsecured credit and money. We also allow money, unsecured lending and secured lending to enter the dynamics for consumption, creating a role for liquidity, debt and collateral channel effects on household spending.

2.3.2 Households: A Model of Secured Credit. For a range of lags, the Johansen procedure finds between two and seven co-integrating vectors for the secured system. Again, from theory we would like to identify long-run dwelling investment, house price and lending relationships. We therefore impose three vectors and choose secured credit (real household secured lending), dwelling investment and gross housing wealth as the endogenous variables. The conditioning variables are real household income (y), the composite mortgage interest rate (r^m), the associated mortgage spread (s^m) (relative to Bank Rate) and the same credit conditions index as above.

Once again, we impose some restrictions on the long-run relationships to identify the β vector for the secured lending system. The resulting long-run relationships are as follows where, again, the over-identifying restrictions were not rejected by a χ^2 likelihood ratio test.

$$ghw_t = 0.8y_t - 0.13r_t^m$$

$$h_t = -0.013ghw_t - 0.017s_t^m$$

$$l_t^s = h_t + 0.68ghw_t - 0.011r_t^m + 3.85CCI_t$$

Gross housing wealth (ghw) depends positively on income but negatively on mortgage rates. Dwelling investment (h) depends negatively on gross housing wealth and mortgage spreads. Secured lending (l^s) depends positively on housing wealth and dwelling investment and negatively on mortgage rates. Once again, the credit condition index captures a stochastic trend in secured lending.

2.4 PNFCs

The PNFC system uses a three equation setup based on Brigden and Mizen (2004). For the PNFC sector we again detect a wide range of estimates for the number of co-integrating vectors depending on the lag structure, but following Brigden and Mizen (2004) we impose a rank of three and choose real PNFC money holdings (*m4p*), real private investment (*inv*) and real lending to PNFCs (*m4lp*) as the endogenous variables. We then condition the system on a lag polynominal of real gross domestic product (GDP), the effective rate paid on firm deposits (*rdp*), the effective rate charged on firm lending (*rlp*), the price of commercial property (*pcp*), the cost of capital (*rcc*), the degree of utilization (*util*) and the rate on corporate bonds (*rcb*). The estimated co-integrating vectors are as follows:

$$m4p = gdp + 0.23\,(rdp - rlp) + 1.0632\,(pcp)$$

$$inv = gdp - 0.5\,rcc + 0.45269\,util$$

$$m4lp = 2.287\,gdp + 0.20737\,rdp - 0.18951\,rlp + 0.058219\,rcb$$

Money holdings are therefore positively related to the spread between deposit and lending rates and commercial property prices (which create wealth effects). Investment is related to GDP, negatively to the real cost of capital and positively to utilization. Lending to PNFCs depends on GDP and negatively on the lending rate. The positive effect of corporate bond yields on lending allows for a capital market substitution effect on borrowing which will be important in discussing the impact of QE in Section 3.

Conditional on these vectors, we then estimate the dynamics. To identify the structural form we exclude the investment error correction term from the money equation, the money and lending error correction terms from the investment equation and the investment and lending error correction terms from the lending equation. This implies money and lending can affect investment contemporaneously and investment also affects lending within the same period.

2.5 The Banking Sector

One key set of inputs into the household and PNFC sectoral systems are the loan and deposit rate spreads. To model loan pricing, we assume that banks are price setters in the loan and deposit markets. In order to calibrate how banks price loans and deposits we follow a loan price framework set out in Button *et al*. (2010). Lending and deposit rates are related to the relevant underlying funding costs. In principle, this is the sum of, for example, a swap rate (for fixed term products) or libor (for variable rate products) and a further credit risk component such as senior unsecured funding spreads or credit default swap premia. Due to data limitations associated with the latter two series, we estimate pass-through equations using Bank Rate (for variable rate products) and the two-year Libor swap rate (for fixed products).

Our composite mortgage rate is partly a variable rate product and partly two-year fixed rate products. We first estimate the long-run relationship between our mortgage rate and Bank Rate and the two-year swap rate, imposing full pass through in the long run. We assume that unsecured lending rates are priced off Bank Rate, with full pass through in the long run. The deposit rate series is based on effective rate data. We therefore estimate the co-integrating vector because pass through may not be complete in the long run. We then estimate the dynamic relationship between deposit rates and Bank Rate.

We also estimate a pass-through equation for the PNFC loan rate, assuming that it is related to Bank Rate and the corporate bond spread (relative to gilt yields). For simplicity, and due to a lack of good data, we tie the PNFC and NIOFC deposit rates mechanically to Bank Rate. The estimated equations are given in an appendix.[8]

We now need a description of how banks' non-deposit liabilities (capital and long-term debt) and gilt holdings evolve (see Fig. 1). In keeping with the previous sectors, we estimate a VAR for the banking sector. To motivate this, we assume that banks are price takers in asset and gilt markets. The banks' non-deposit liabilities (capital and long-term debt) and gilt holdings are therefore modelled as two endogenous variables and the system is then conditioned on five-year gilt yields (*r5*), and the non-intermediate financial corporations' deposit rate (*rdi*). The VECM is estimated with gilts (*bgilts*) and (net) non-deposit liabilities (*nndls*) expressed as a ratio of sterling liabilities (*sterliabs*). In other words, the endogenous and exogenous variables y and x are:

$$y_{B,t} = [nndls, bgilts]'$$

$$x_{B,t} = [r5, rdi, sterliabs]'$$

Our estimates suggest that a fall in gilt yields or a higher NIOFC deposit rate lowers banks' gilt holdings. Consequently, there may be an offsetting fall in bank deposits (money) following QE. Although QE injects money into the economy, lower gilt yields may lead to banks selling gilts to the Bank of England. In addition, higher asset prices and lower bond yields may lead banks to favour long-term debt and equity issuance over deposit funding that will act to reduce the money stock. This will also be important in assessing the impact of QE in Section 3.

2.6 Non-Bank Financial Corporations

The NIOFC sector is modelled as a four-variable VECM that includes NIOFC real money holdings ($m4i - p$), real asset values ($wi - p$), a weighted average of the real rate of return on NIOFC assets (*rg* including the dividend yield of the FTSE all share and the 10-year zero coupon government bond yield) and the real interest rate on NIOFC deposits (*rdi*). We take this estimated system from Bridges and Thomas (2012).

As described earlier, in simulating our model, and having pinned down the other components of the banking sector's consolidated balance sheet, NIOFC money holdings are determined by residual. NIOFC money holdings

[8]For reasons of space the full equation listing is not included in the paper but is available from the authors on request.

are determined by the log-linearized consolidated banking sector's balance sheet identity as follows:

$$\omega_i m4i = \theta_h m4lh + \theta_p m4lp + \theta_i m4li + \theta_q qe + \theta_b bgilts \\ - \omega_h m4h - \omega_p m4p - \omega_n nndls - \omega_h nosd$$

where *qe* is the central bank's holding of gilts (used to simulate QE), *bgilts* are private banks' holdings of gilts, *nndls* are net non-deposit liabilities and *nosd* are net overseas deposits (which we hold fixed in our simulations).

Furthermore, we want to allow equilibrium in asset markets to be ensured by letting the price of financial assets adjust to clear the NIOFC money demand equation (which would relate real asset prices to real money holdings and the deposit rate relative to the real rate of return on other domestic assets such as equity and gilts). We therefore treat real total sterling asset values and the real rate of return as endogenous but condition the system on real money holdings and the (banking sector determined) NIOFC deposit rate. Bridges and Thomas (2012) report the supporting weak exogeneity tests for this split. In the next section we consider two versions of the model: one using the full dynamic system and one where we consider only static relationships to simulate the case where asset prices adjust immediately to a change in NIOFC money holdings.

In the static case real asset values are determined by inverting the long-run money demand equation:

$$wi - p = m4i - p - 0.104(rdi - rg)$$

where the component yields of *rg* are also related (negatively) to *wi* according to standard asset pricing relationships between the prices and yields of the relevant assets.

In the dynamic case real asset values and yields jointly respond to the gap between the actual money holdings of NIOFCs and their long-run demand for money so that (and ignoring nuisance terms such as constants):

$$\Delta(wi - p)_t = 0.067\Delta(m4i - p)_t + 0.067\Delta(m4i - p)_{t-1} + 0.088 ecmm4i_{t-1}$$

$$\Delta rg_t = -0.0023\Delta(m4i - p)_t - 0.00389 ecmm4i_{t-1}$$

$$ecmm4i_t = (m4i - p)_t - (wi - p)_t - 0.104 * (rdi - rg)_t$$

2.7 The Aggregate Model: Linking the Sectors

A number of sectoral conditioning variables have already been linked together. For example, the interest rates charged and paid to households and PNFCs have been linked to pricing behaviour in the banking sector.

However, some of the remaining aggregate variables still need to be defined, notably GDP, inflation and Bank Rate. Our aggregate system closely follows Bridges and Thomas (2012). GDP is pinned down by the aggregate resource constraint, which implies that GDP is demand determined in the short term, in keeping with older Keynesian forecasting models:

$$gdp = \gamma_c hc + \gamma_d idkp + \gamma_i inv + \gamma_g g + \gamma_x nx$$

We assume that exports do not move in response to the simulations we consider and link imports to the components of GDP. This implies the current account itself (nx) moves with GDP. To fully tie this up with the balance sheet approach, we should tie overseas and foreign currency deposits to the current account as well, although in this version of the model we hold them fixed in the simulations.

To capture price dynamics we assume that inflation follows a simple Phillips curve relationship, which is estimated on a HP filter-based measure of the output gap as follows:

$$\pi_t = 0.25\pi_{t-1} + 0.1\hat{y}_{t-1}$$

where $\hat{y}_{t-1}$ is the output gap. These two equations make the aggregate structure of the model (an assumption that planned expenditure equals aggregate demand combined with a traditional neoclassical synthesis Phillips curve) closer to a Keynesian model than a modern DSGE model. Although some forward-looking behaviour will be captured in the estimated coefficients of the sectoral VECMs, the aggregate block currently does not include forward-looking terms.

Although a statistically filtered estimate of the output gap is used in estimation, we attempt to allow for a feedback of investment on to the output gap by introducing a crude log-linearised production function-based estimate of potential output (*gdpstar*). Given we cannot easily construct a New Keynesian style flex price measure of output, we evaluate potential output at the steady-state level of employment (*lstar*) and the predetermined level of the capital stock (k). A capital stock identity that feeds off the flow of investment is also added. In log-linear form the two equations are given by:

$$gdpstar_t = 0.2k_{t-1} + 0.8lstar_t$$

$$k_t = (1 - 0.02)k_{t-1} + 0.02inv_t$$

where the coefficients reflect the labour share of income and the depreciation rate of capital. As we show in the next section, this will provide a crude way of ensuring the impact on inflation from a rise in activity is not overstated by assuming no effect on the capital stock from higher investment. But care must be taken in interpreting any persistent change in potential supply over the horizon of our simulations as steady-state result. In particular, we make no allowance for the fact that steady-state labour input (*lstar*) might also respond to QE. This is treated as exogenous in our system. More generally, the idea that QE is non-neutral in steady state is clearly contentious given the irrelevance result of Cúrdia and Woodford (2011) discussed in the introduction. But it is well known that non-neutrality results can emerge quite naturally given the IS-LM-CC structure that we are adopting. As we discuss below a steady-state impact on potential supply will emerge if there is a permanent effect of QE on the cost of capital. That in turn implies the shift in the ratio of money to other assets induced by QE persists forever in our portfolio balance framework. In reality of course that will depend on future QE operations and other monetary policy, fiscal policy and debt management decisions.

3 Policy Experiment—QE

We now use the model described in the previous section to study the effects of QE in the United Kingdom at a sectoral and aggregate level. Between March 2009 and November 2012 the Monetary Policy Committee purchased £375bn of government bonds in three phases. The aim of the policy was to increase the money holdings of the non-bank private sector (specifically pension funds and asset managers). That would induce a rebalancing of portfolios which should lead to an increase in the prices of government bonds and other close substitutes and a fall in their yields. In turn, the implied rise in the value of portfolios and the lower cost of external finance should lead to a boost in consumption and investment spending in the economy.

3.1 Relationship to Previous Research

Our model is well suited to investigate the portfolio rebalancing effects of QE. Like the earlier work by Bridges and Thomas (2012) the money holdings of NIOFCs are explicitly modelled and the portfolio re-balancing implications for yields and asset prices can be explored. And like Bridges and Thomas (2012) and Cobham and Kang (2012) we can examine the implications of the increase in money holdings and asset prices that result from QE for nominal spending in the economy. But our model also contains a number of useful features that allow us to study some additional mechanism.

First, as we noted in Section 2, there are a variety of ‘leakages’ in the banking and PNFC sectors that offset the injection of money from QE. In particular, we model the portfolio re-balancing by banks and non-financial companies explicitly. Bridges and Thomas (2012) and Cobham and Kang (2012) used counterfactual evidence from the money counterparts and flow of funds to try and estimate the impact of QE on the money supply over the course of the first £200bn of purchases made by the MPC. Both concluded

Assets	Liabilities
Lending to households	Household money
Lending to PNFCs	PNFC money
Lending to NIOFCs	↑ **NIOFC money**
Overseas lending	Overseas deposits
↑ **Gilt holdings**	Non deposit liabilities

FIG. 2. Implications for the Consolidated Balance Sheet of the Banking System

that because of various 'leakages' the impact of QE on broad money was significantly less than £200bn. And those leakages reflected portfolio re-balancing by both banks and private non-financial companies. We build on both these studies. Rather than treating them as an exogenous offsetting impact on the money supply, we can 'endogenize' the QE leakages and examine their implications for the economy more explicitly.

Second, our model explicitly includes lending unlike Bridges and Thomas (2012). This allows us to explore the role of lending in the transmission of QE. A common misconception about QE, at least as carried out in the United Kingdom, is that the key aim of the policy was chiefly to increase bank lending by increasing reserves and setting off a money multiplier-driven increase in bank lending. In fact it was the direct effect of asset purchases on the broad money stock and the subsequent portfolio rebalancing by non-banks that was the main aim of the programme. QE in the United Kingdom was not seen as dependent on any increase in bank lending, as illustrated in Fig. 2. Notwithstanding this, there could be indirect effects, both positive and negative, on bank lending that might occur as a result of the portfolio rebalancing.[9] On the one hand, portfolio re-balancing in response to the initial increase in the money supply might lead asset managers to invest in the long-term debt and equity issued by banks which could lower the marginal cost of raising these funds and which in turn might affect loan rates and the supply of credit. On the other hand, the lower cost of finance in capital markets might lead non-financial companies to substitute capital market finance for bank debt leading to fall in the demand for credit. Our model allows us to explore these offsetting effects.

Third, QE may have *non-neutral* effects on output in both the short run and over the longer term. Aside from the Modigliani–Miller type arguments raised by Wallace (1981) and Cúrdia and Woodford (2011) regarding the

[9]See McLeay *et al*. (2014).

irrelevance of the central bank balance sheet, other theoretical models that include money suggest an increase in the money supply is only perfectly neutral in the long run if two assumptions hold:[10]

(a) the money supply increase is introduced as a helicopter drop
(b) the drop is distributed proportionately in line with existing money holdings.

But QE is an open market operation that involves an exchange of bonds for money. So it is not a helicopter drop of money and a proportionate change in prices will not be sufficient to restore all real variables back to their initial levels in this type of model. A permanent shift in the ratio of money to bonds is likely to require permanently lower bond yields that will affect the cost of capital and the capital stock in the longer term. In Section 2 we incorporated a simple production function in the model that allows us to analyse any persistent impact that operates via the capital stock.

Furthermore, as discussed in Bridges and Thomas (2012), QE affects the distribution of money holdings as it initially increases the bank deposits of the NIOFC sector. If the long-run demand for money differs across sectors and if direct participation in asset markets is limited to the asset managers in the NIOFC sector, this is likely to mean a different transmission to asset prices and the real economy than if assets were purchased directly from households and firms and implied a more equally distributed increase in money holdings. The empirical estimates discussed earlier suggest the money demand of households and PNFCs depend on (and interacts with) income, activity and the spread of deposit rates over borrowing rates. In contrast the money demand of NIOFCs depends on, and interacts with, financial asset values and financial market yields. That means an increase in money holdings concentrated in the NIOFC sector will largely show up as an increase in asset prices in the short run in order that money demand is made equal to supply. It will only affect consumption and investment in the medium term as households and PNFCs respond to higher wealth and a lower cost of capital market finance. That increase in spending will ultimately lead to a more even distribution of money holdings in the longer term as the transactions demand for money by both households and companies increases and they undertake various transactions with the NIOFC sector to obtain those money balances. But initially it means QE will lead to an initial overshooting of real asset prices. This short-run non-neutrality would even occur even if goods prices were flexible in our model and is synonymous with the liquidity effect found in the theoretical literature on limited participation and liquidity effects (e.g. Fuerst, 1992). This is an important reason for adopting a sectoral approach as this effect might get easily masked using an aggregate approach. An

[10]See Gale (1982) for example.

additional motivation for the sectoral approach is that it also allows us to trace through how the money created by QE might be expected to flow through to households and non-financial companies. This means that an analysis of sectoral money data can be important in monitoring the effectiveness of QE over time.

3.2 Simulating the Effect of QE on the Economy

To explore the effects of QE using our model we will build up the channels and sectoral effects in two stages.[11] First, we start with the initial increase in deposits that arises from QE and look at the portfolio-rebalancing channel *holding loan rates and the supply of credit fixed*. Then we consider the impact of QE through the various bank lending channels. In each case we discuss the implications for output both in the short run and in steady state.

3.2.1 Stage 1: QE and Portfolio-Rebalancing Holding the Supply of Credit Fixed

3.2.1.1 The Direct Effect on Broad Money. The aim of the programme of asset purchases in the United Kingdom was to purchase gilts from asset managers or NIOFCs in the non-bank private sector. These purchases were implemented through the creation of the asset purchase facility or APF (see Benford *et al*., 2009) which obtained a loan from the Bank of England which was used to purchase the assets. These purchases were settled in terms of bank deposits. As such, the initial first-round impact of APF asset purchases was an increase in reserves on the asset side of private banks' balance sheets and, as a counterpart, an increase in their deposit liabilities to NIOFCs in the non-bank private sector—i.e. an increase in broad money. When the APF, Bank of England and private bank balance sheets are consolidated the initial impact shows up as an increase in gilt holdings on one side of the balance sheet and non-financial company money holdings on the other as in Fig. 2.

Between March 2009 and November 2012 the MPC purchased £375bn of government bonds in three phases, as shown in Chart 1. In Phase 1, between March 2009 and January 2010, the MPC purchased £200bn of assets, in Phases 2 and 3 the MPC bought an additional £175bn of assets between October 2011 and November 2012. To look at the portfolio rebalancing by NIOFCs in isolation, we introduce the implied 'phased in' sequence of asset purchases into the aggregate money supply identity via the *qe* term, holding other elements of the balance sheet constant, other than NIOFCs money which, as noted earlier, is treated as a residual element of the

[11]Note that the way we bolt the sectoral blocks together means it is difficult to produce standard error bands around simulations of the full system. So the focus here is on the different channels of QE and their sectoral implications.

balance sheet. This ensures that the initial QE increase leads to an equivalent rise in NIOFC deposits.

In the NIOFC system of equations the prices and relative yields of non-monetary assets (the determinants of financial companies' demand for money) now need to change to make financial companies willing, in aggregate, to hold the higher stock of deposits. Note that bank rate and other safe rates of return are assumed to be held fixed here. That means deposit rates are also fixed so the change in relative yields is entirely due to changes in term and risk premia on bonds and equities.

Some of this change in yields would happen instantaneously with the initial purchases of gilts. But some sellers of gilts may not want to simply swap gilts for money, but rather exchange money for gilts as an intermediate step to purchasing other assets such as equities and corporate bonds. Given that these asset purchases would in turn transfer money to other financial companies, the initial purchases would set in motion a whole set of transactions that may spill over into many asset markets until yields and prices move sufficiently to make the financial sector willing to hold the extra deposits—the so-called hot potato effect.

The lags in the NIOFCs' VECM system are consistent with frictions so that this 'hot potato' effect takes some time to filter through the asset markets. But if markets were efficient and frictionless, you might assume that prices should adjust immediately in anticipation of this process to stop anyone wanting to do any transactions. This might seem a more appropriate assumption for the case of QE. The policy of asset purchases was transparently announced such that market participants knew the scale of the purchases. In contrast, the average lagged relationship that is picked up in the VAR is likely to reflect the impact of a wide range of unanticipated increases in NIOFC money holdings occurring in the past, which may have taken more time to filter through the system as a whole. In the case of QE, one might therefore expect asset prices to jump or move more quickly to eliminate any incipient monetary disequilibrium in the financial company sector. That would imply ignoring the dynamics in the VECM and using just the long-run demand for money by NIOFCs to work out the impact on asset prices—i.e. it would involve inverting the long-run money demand function for NIOFCs. This leads to a more immediate impact on asset prices as we show later in Chart 2.

3.2.1.2 The Indirect Effects on Broad Money, Portfolio Rebalancing by Banks and PNFCs. Although QE directly injects money into the NIOFC sector, the impact on broad money of QE is likely to be less than the 'one for one'—the 'QE leakages' as discussed in Bridges *et al.* (2011), Cobham and Kang (2012) and Bridges and Thomas (2012). In particular the fall in yields and increase in asset prices resulting from QE is likely to lead to portfolio rebalancing by other agents in the economy, most notably banks and

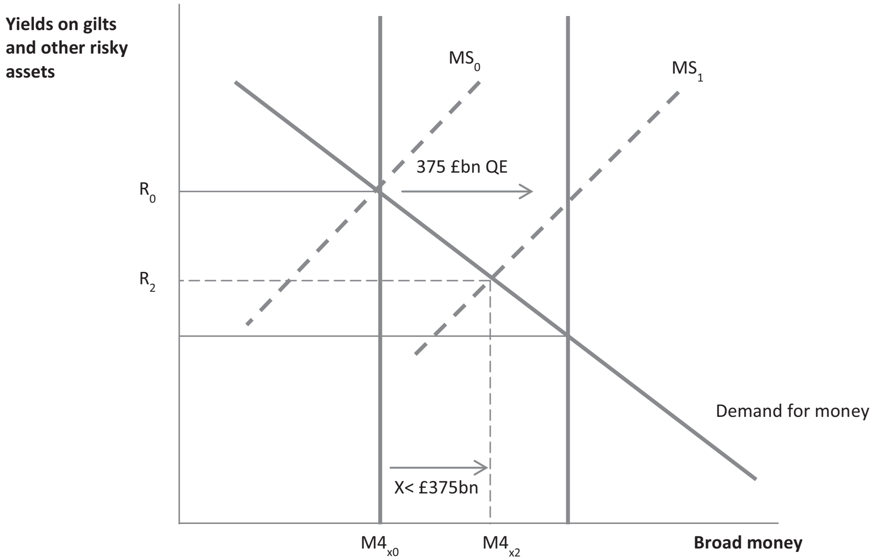

FIG. 3. Portfolio Rebalancing by Banks and Private Non-Financial Corporations—Upward Sloping Money Supply Curve

non-financial companies. And that might induce an offsetting fall in the supply of money. This is shown in Fig. 3 where the money supply schedule is positively related to yields on risky assets. In this case QE is likely to lead to a smaller increase in the money supply and a smaller fall in yields than the simple inelastic case.

First, consider the effect on PNFCs. QE leads to a fall in yields on corporate debt and a rise in equity prices. This would lower the cost of borrowing for companies in capital markets. Consequently, this may encourage corporates to use this cheaper source of funding to repay existing loans from banks, thus reducing the level of bank lending in the economy. The non-bank purchasers of corporate debt and equity would ultimately have to pay for this by reducing their deposits with banks. These would be transferred to non-financial companies who would use them to pay down debt and reduce the supply of money. This effect is captured in the PNFCs' lending equation where we estimate that lower corporate bond yields have a negative effect on bank lending, as shown in the equations in the online appendix.

Next, consider the portfolio rebalancing behaviour of banks. In Section 2.5 we discussed two effects QE may have on the structure of the banking system's balance sheet. First, QE may lead to commercial bank sales of government debt. As yields fall (and prices rise) on gilts, banks may be induced to change the composition of their liquid asset holdings. If banks sell gilts to the non-bank private sector, this will increase non-bank private sector gilt holdings and, in aggregate, a drawdown of their deposits, again reducing

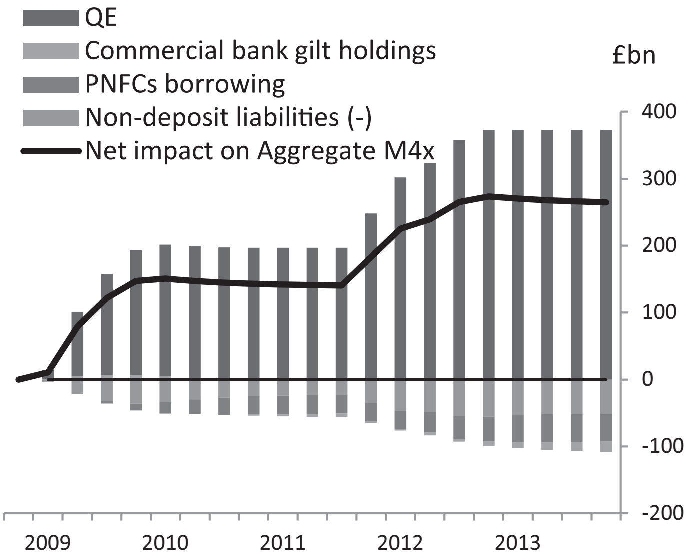

Chart 1. The Sectoral Transfer of Money under Quantitative Easing

the supply of money. As noted earlier the equation for banks' holdings of gilts suggests they are negatively related to the yield on five-year gilts relative to wholesale deposit rates.

In addition, higher prices and lower yields on risky assets apply as much to bank-issued debt and equity as they do to non-bank issuers. If banks respond to lower yields by increasing their long-term bond and equity issuance that would work to reduce the money supply in the short run, the domestic purchasers of bank bonds and equities would ultimately have to pay for these by reducing their deposits with the UK banking system. This would be reflected in a shift between deposit and non-deposit instruments on the liability side of banks' balance sheets and again would work to offset the initial effect of QE in increasing the money stock. Again, as noted in Section 2.5, our system captures this by relating banks' non-deposit liabilities negatively to the spread between five-year yields and deposit rates.

In the longer term, to the extent that bank issuance improves the capital and lowers the funding costs of the banking system that may influence loan rates and the willingness of banks to lend. We discuss this effect more in the next section. Here we concentrate on the short-run destruction of money that occurs when banks issue more long-term debt and equity.

Chart 1 shows how our sectoral model predicts these different effects will play out in terms of their impact on the money supply. It shows that the impact of QE on the money supply is only about 70% of the amount of asset purchases made—£375bn of QE leads to an increase in the broad money

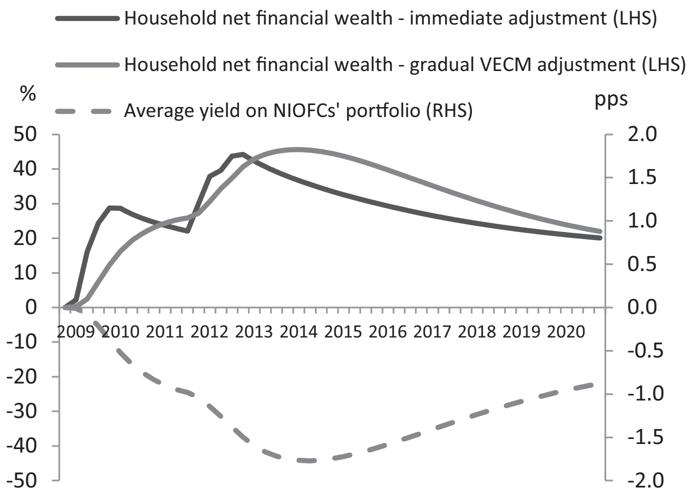

Chart 2. The Impact on Asset Prices and Yields

supply of just over £260bn. By 2014 the main leakage comes from an increase in banks' non-deposit liabilities of around £50bn reflecting an increased issuance of debt and equity by banks relative to what otherwise would have been the case. It also suggests there was capital market substitution by PNFCs of around £40bn and a reduction in commercial bank gilt holdings of around £15bn. These leakages are similar in size to the leakages found in Bridges and Thomas (2012) and Butt *et al.* (2012) using a simple counterfactual analysis of the relevant M4x balance sheet counterparts.[12] They found that the impact of QE on the money supply amounted to around 60% of the amount of the asset purchases made—around £225bn.

3.2.1.3 The Impact on Asset Prices and Household and Corporate Spending. Combining the results of Sections A and B allows us to analyse the macroeconomic impact of QE. Chart 2 shows the combined impact of portfolio rebalancing by NIOFCs, banks and PNFCs on asset prices using real household net financial wealth and the average yield on NIOFCs' portfolio holdings as summary measures. We show the impact when there is both an immediate and a gradual response of asset prices as discussed earlier in sub-section A. In each case the peak impact on real financial wealth peaks at

[12]The M4x counterpart approach uses the banking system's balance sheet identity to express movements in M4x in terms of all the other balance sheet items on the banking system's balance sheet. To estimate the QE leakages Bridges and Thomas (2012), Cobham and Kang (2012) and Butt *et al.* (2014) looked at the relevant M4x counterparts over the period asset purchases were made and compared them with an appropriate historical counterfactual to work out how much might be attributable to the impact of QE.

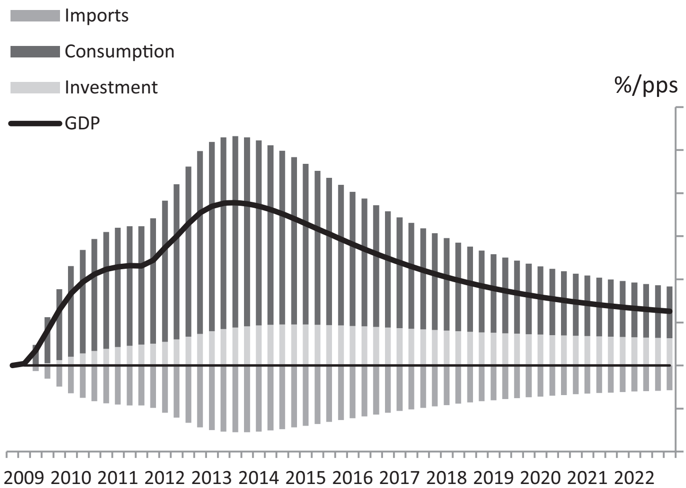

Chart 3. The Gross Domestic Product Response of Quantitative Easing by Component

around 40%, with the gradual adjustment occurring just over a year after that of the immediate case. This is consistent with a peak fall in the average yield on NIOFCs' portfolio of around 175 basis points in the gradual adjustment case.

The rise in asset prices and financial wealth in turn raises desired consumption and investment spending plans by households and PNFCs (by increasing wealth and lowering the cost of capital) as described in Sections 2.2 and 2.3. In the immediate asset price adjustment case the (local) peak effect on GDP from the increase in consumption and investment is just over 1.5% after the first phase of QE and occurs around the middle of 2011. The subsequent asset purchases during QE2 and QE3 then lead to an eventual peak impact of 2.5% in the level of GDP by the end of 2013. These results are in line with the range of macroeconomic estimates discussed by Joyce *et al.* (2011) but are slightly weaker and have more persistent effects than Bridges and Thomas (2012) who used a simpler set of sectoral models.

As in Bridges and Thomas (2012) we conduct this exercise holding lending fixed and not allowing further money creation by banks (we relax this in the next section). To finance higher spending plans, households and firms ultimately need more money balances. Given the assumption that there is no additional money creation by banks, households and PNFCs can only obtain the additional money balances they need from the non-bank financial sector. They cannot borrow against their higher financial wealth. Households have to tap into their higher wealth directly by cashing in investments that they have with an investment fund, and PNFCs respond to the lower cost of capital by issuing on the capital markets to the non-bank financial sector

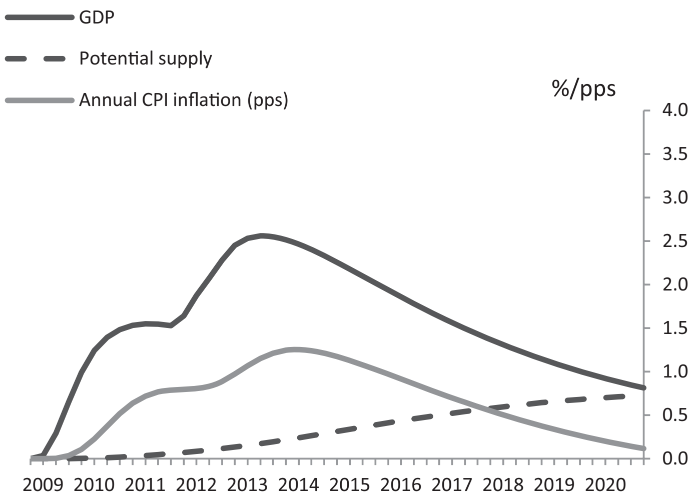

CHART 4. The Response of the Output Gap and Inflation

directly. This leads to a gradual transfer of money holdings from the NIOFC sector to the household and PNFC sectors (Chart 1). Our model suggests that around half of the aggregate increase in money holdings gradually moves out of the financial sector and into the household and corporate sectors as a result of the portfolio rebalancing effects. It is important to note that, at this stage, we are still keeping Bank Rate and loan rate spreads unchanged.

As corporates issue more bonds and the amount of money the NIOFC sector is required to hold declines so too do asset prices. This leads to asset prices declining somewhat from their peak. So, as discussed earlier, asset prices and financial market yields exhibit overshooting (Chart 2) and start returning to their initial level. This is almost exactly the liquidity effect predicted by limited participation models, where money is initially injected into asset markets that forces real yields down. But the yields then subsequently rise as money spreads to the other sectors of the economy. The reason for this is demonstrated in Chart 3 in aggregate demand space. As consumption and investment spending respond to the initial fall in yields and higher asset prices, this raises the demand for money (by households and companies) and forces yields back towards their initial level. Whether they return to their initial level depends on whether QE is ultimately neutral in steady state.

Chart 4 shows the effect on potential output and inflation. The estimated peak impact on inflation that occurs at the start of 2014 is just over 1%. The effect of higher investment on the capital stock is sufficient to increase potential output by a small amount by 2014, although this builds over time and ultimately has an impact of around 0.75% by 2020. Mechanically that reflects the fact that yields (term and risk premia) are permanently reduced as a result of QE, which in turn affects the cost of capital in steady state and potential output. The velocity of circulation of money (the ratio of nominal spending to GDP) is also permanently affected by QE.

3.2.2 Stage 2: QE and the Role of Bank Lending. In the previous section we simulated our model holding loan rates and the supply of credit fixed.[13] The results of the previous two sections have shown that QE can increase broad money and spending in the economy without directly leading to, or requiring, a boost to bank lending. This is important because one commonly heard criticism of QE is that it has failed to encourage banks to lend in large quantities. And bank lending has been weak since 2008, including during QE periods. But increasing the provision of credit from the banking sector was not central to the policy as designed in the United Kingdom.

Importantly, the reserves created in the banking sector do not play a central role in the transmission mechanism of QE even though this is often cited as the key mechanism through which QE affects the economy. This is because banks cannot directly 'lend out' the reserves created by QE. Those banks can only use them to make payments to each other, but they cannot 'lend' them on to other agents in the economy, who do not hold reserve accounts. Moreover, the new reserves are not mechanically multiplied up into new loans and new deposits as predicted by the money multiplier theory. The newly created reserves do not, by themselves, meaningfully change the incentives for the banks to create *new* broad money by lending. The reasons for this are discussed in Butt *et al.* (2012) and McLeay *et al.* (2014).

Even if the increase in reserves does not *directly* affect lending, QE can lead to an indirect increase in bank lending. First, the increase in activity and asset prices from portfolio rebalancing may increase the demand for credit by households and companies. Second, the reduction in yields on bank debt and equity discussed in the previous section may affect bank funding costs at the margin and lead banks to charge lower loan rates. The first of these factors is already built into our sectoral lending equations. The second can be accommodated by allowing the reduction in financial market term and risk premia shown earlier to feed into our loan pricing equations over and above the impact of Bank Rate and swap rates.

Charts 5 and 6 show the consequences of allowing these lending feedbacks to operate. These additional channels lead to an increase of bank lending of £175bn by 2014 and over £500bn by 2020. Most of the positive impact comes from lower funding costs, but higher activity and asset prices also contribute positively to lending. These offset the impact of capital market substitution discussed in the previous section. If we combine the lending impact with the endogenous leakages of the previous section it would

[13]Mechanically, we have also held lending and deposit rates fixed.

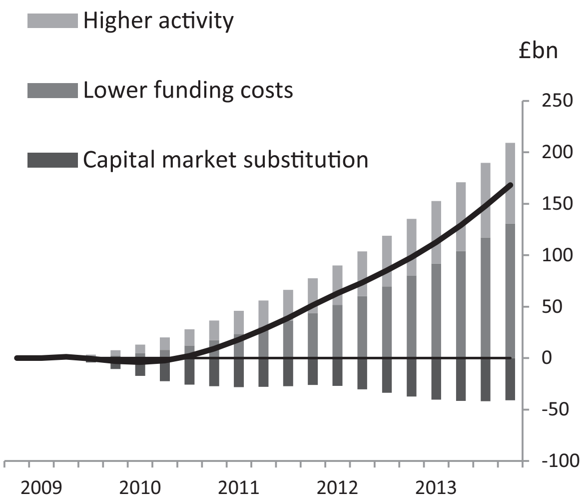

CHART 5. The Potential Impact of Quantitative Easing on Bank Lending

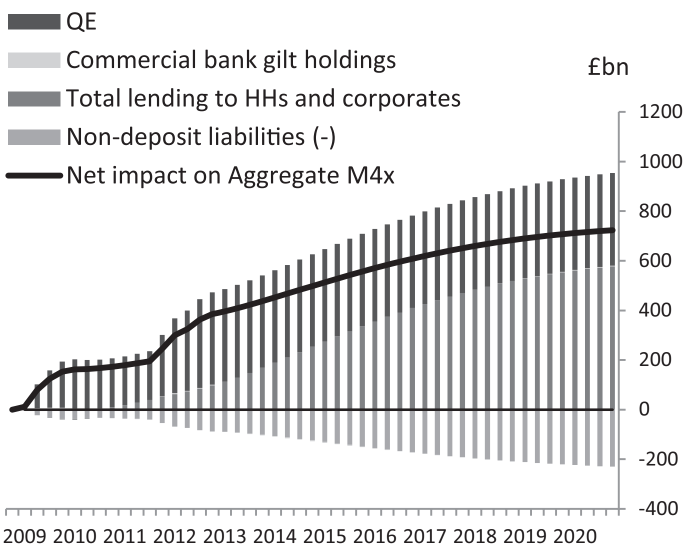

CHART 6. The Impact on Money When Quantitative Easing Affects Bank Lending

suggest QE could have increased the money stock by around £450bn by the start of 2014 and £750bn by 2020, in other words double the amount of asset purchases (Chart 6). That is enough to increase the peak GDP impact to just under 6% and increase the long-run potential output effect to over 3% given the effect of lower loan rates on the cost of capital (Chart 7).

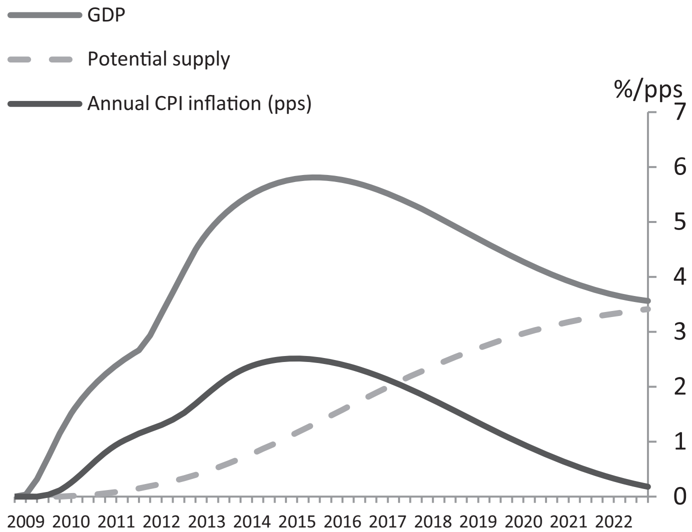

Chart 7. The Gross Domestic Product Impact When Quantitative Easing Affects Bank Lending

This suggests the lending channel of QE could be quite powerful even if it is not working through a money multiplier mechanism. But how plausible are these effects? Chart 8 shows that these effects depend on loan rates falling by 200bps as a result of QE. Given loan rate spreads have remained persistently high over the recent crisis this might seem implausible given the implied counterfactual would have been for even higher spreads. This is the subject of the final section.

4 Evaluating the Counterfactual

In this section we evaluate what our results suggest about the counterfactual behaviour of the economy—i.e. what would have happened to money, credit and activity in the absence of QE if our results are representative of the impact. Charts 9–14 show the data for GDP growth (real and nominal), credit growth, money growth, credit spreads and velocity compared with a counterfactual where the impact of QE from our sectoral model is removed. We look at two counterfactuals. The first counterfactual removes the impact that embodies the endogenous QE leakages discussed in Stage 2. The second counterfactual additionally removes the possible impact of QE on bank lending. The results suggest that the recovery in GDP growth from 2010 would have been much weaker in the absence of QE, and annual GDP growth would have been negative throughout 2012. Money in the absence of QE would have fallen by over 5% on either counterfactual in 2010. These are

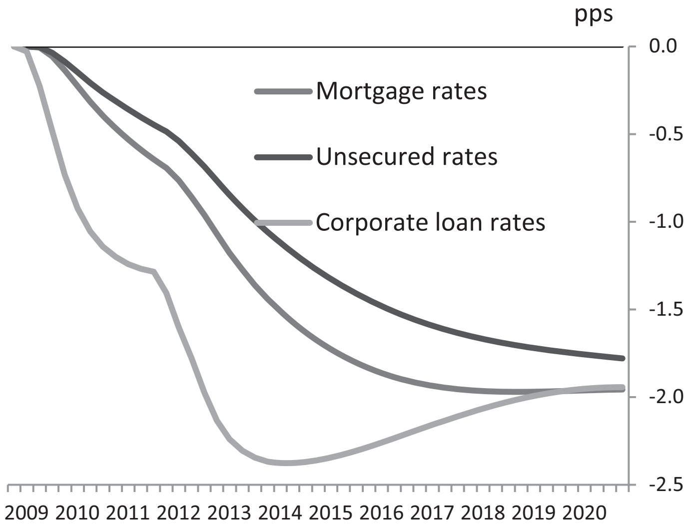

CHART 8. The Effect of Lower Funding Costs on Loan Rates

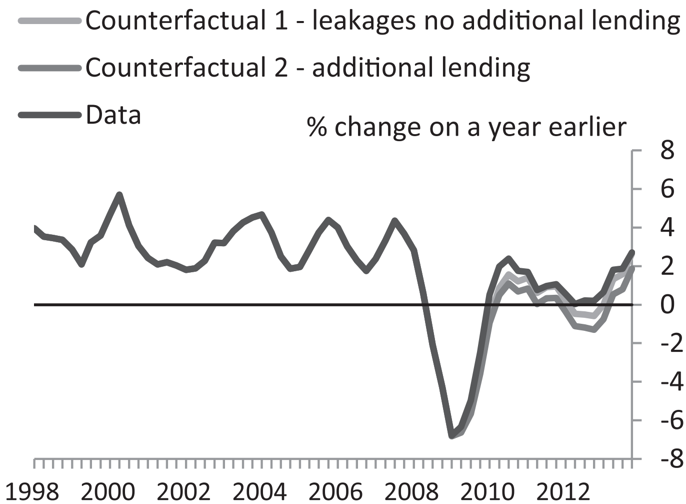

CHART 9. Real Gross Domestic Product Counterfactuals

similar to the results of Bridges and Thomas (2012) and Cobham and Kang (2012). And our second counterfactual would have suggested the stock of credit would have fallen by around 3–4% over the past year rather than remaining flat. That of course is highly dependent on QE affecting funding costs and loan rates. Chart 13 shows that for this to be plausible QE would

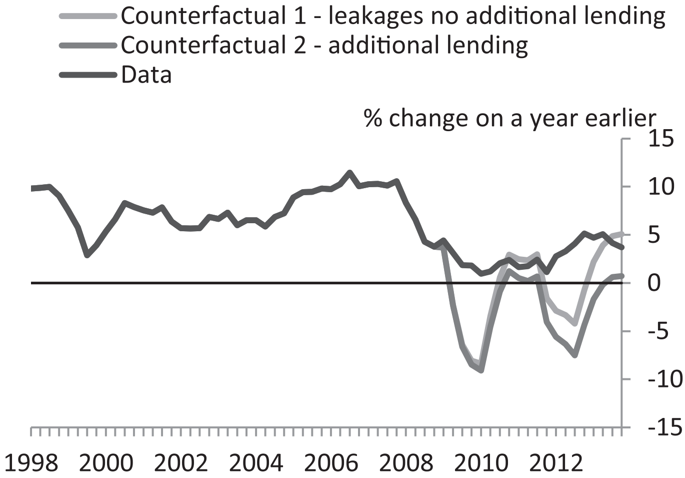

Chart 10. M4x Counterfactuals

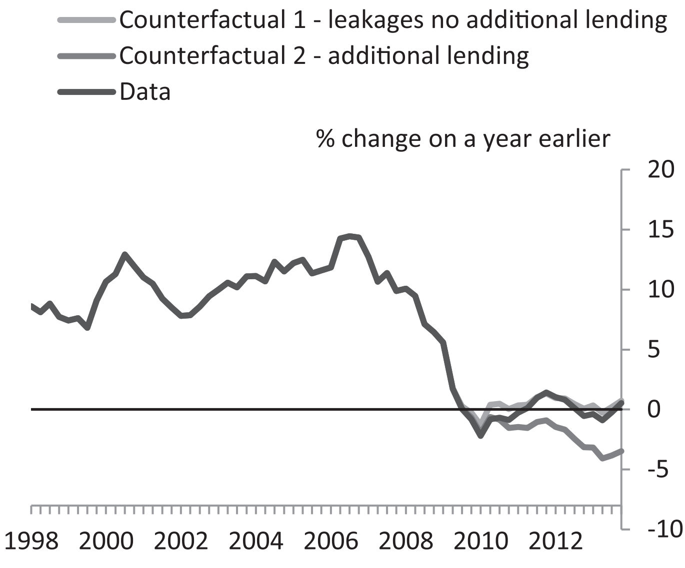

Chart 11. M4 Lending Counterfactuals

have to account for most of the fall in loan rate spreads since the peak of the crisis. Given that other policies and factors were also influencing loan rate spreads over this period, this is likely to be an overestimate of the impact of QE on credit, so the results here probably represent an upper bound of the effect of QE on credit. But without a joint analysis of the other factors affecting credit spreads over this period it is difficult to be sure.

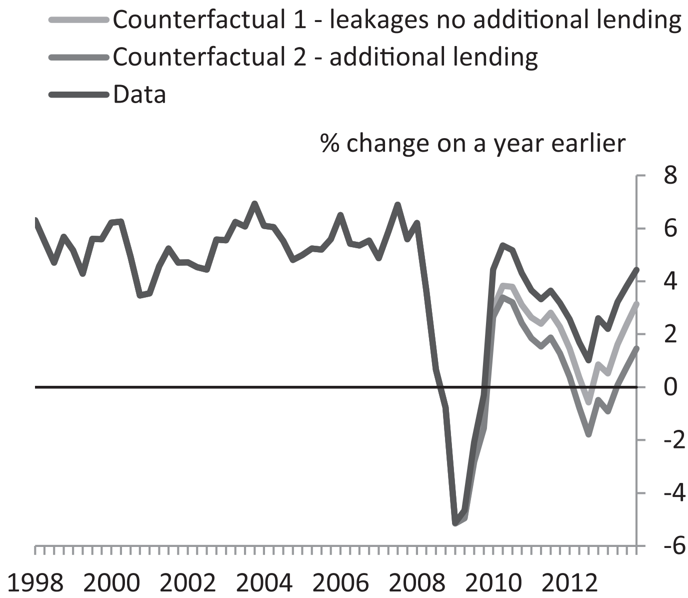

Chart 12. Nominal Gross Domestic Product Counterfactuals

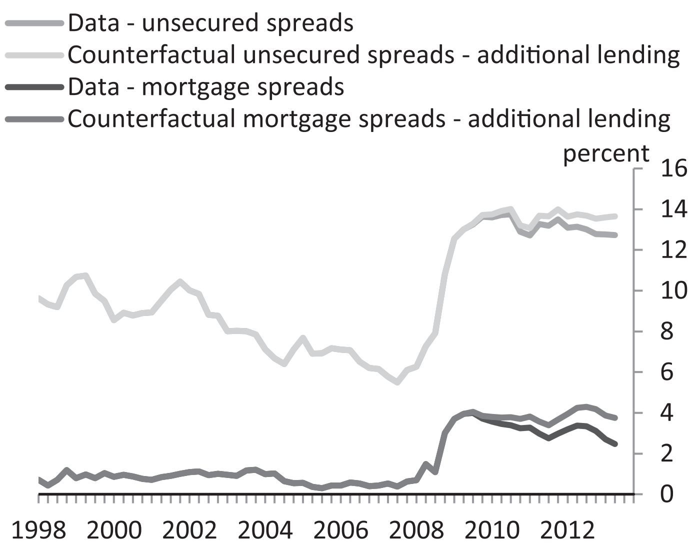

Chart 13. Loan Spread Counterfactuals

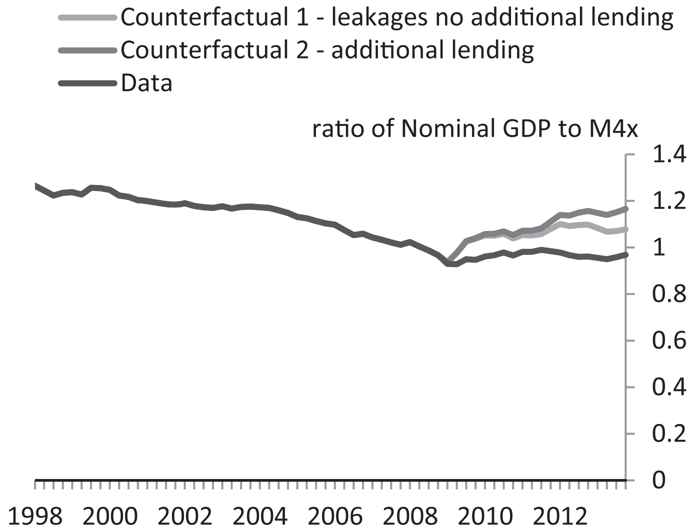

Chart 14. Velocity Counterfactuals

5 Conclusions

This paper has outlined a sectoral empirical model of money and credit in the United Kingdom that can be used for analysing unconventional monetary policies such as QE. Our approach allows us to build on previous papers by looking at the endogenous portfolio response of banks, financial companies and non-financial companies in one model. It also allows us to look at the joint impact of such policies on both the prices and quantities of different assets, their subsequent effects on GDP and the feedback loops from higher activity back on to the quantities and prices of assets.

Our baseline results support the estimates of the impact of QE found by other studies, based on either feeding in event study impacts on asset prices into VAR models and/or using estimates of the impact on monetary aggregates into empirical monetary models. We show that QE may have non-neutral effects. This works through a short-term liquidity effect as QE initially increases the money holdings in the financial sector of the economy that results in an overshooting of asset prices that only dissipates as money is transferred to other sectors. The non-neutrality may also persist over the longer term through an effect on velocity, the capital stock and potential output because it may require a permanent change in term and risk premia for the economy to hold the higher money balances generated by QE. But our results also suggest the impact of QE is sensitive to the assumption about whether, and to what extent, QE may have affected bank lending, through both the feedback effect from higher activity on to the demand for credit and the potential effect QE may have had on bank funding costs. In future work we intend to use the model for assessing the impact of credit spreads and quantities on the economy and the various policies that affect that, e.g. the funding for lending scheme and macroprudential policies.

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