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SIMPLE BANKING: PROFITABILITY AND THE YIELD CURVE

by Piergiorgio Alessandri* and Benjamin Nelson§

Abstract

How does bank profitability vary with interest rates? We present a model of a monopolistically competitive bank subject to repricing frictions, and test the model's predictions using a unique panel data set on UK banks. We find evidence that large banks retain a residual exposure to interest rates, even after accounting for hedging activity operating through the trading book. In the long run, both level and slope of the yield curve contribute positively to profitability. In the short run, however, increases in market rates compress interest margins, consistent with the presence of non-negligible loan pricing frictions.

JEL Classification: E4, G21.
Keywords: banking profitability, net interest margin, interest rates.

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'The business of banking ought to be simple; if it is hard it is wrong' (Bagehot 1873, Ch. IX).

1 Introduction[1]

What is the relationship between profitability and interest rates? This is an old question, but one on which the events of the last three years and the debate on macroprudential policy cast an entirely new light. If interest rates have a systematic effect on bank profitability, and if in the short run profitability is a major determinant of bank capital, it follows that monetary policy may have implications for financial system resilience. These implications might be particularly strong for 'unconventional' policy interventions whose proximate objective is to affect the slope of the yield curve under near-zero policy rates. Many central banks have engaged in such "credit" or "quantitative" easing over the last three years (Wieland, 2009); and there is circumstantial evidence that in the US the intervention caused a sell-off of bank stocks, triggered by concerns that profitability would be impaired by a flat yield curve (Financial Times, 2011).

We begin our analysis by studying a simple partial equilibrium model where profit-maximising banks set interest rates on loans subject to repricing frictions. In equilibrium, the net interest margin (NIM) is positively related to short-term interest rates, as banks raise their loan rates and shrink their lending quantities in response to higher funding costs. But short-run and long-run effects can differ: if banks borrow short and lend long, and if their interest rates are not fully flexible in the short run, banks will be exposed to 'repricing' and 'yield curve' risk (BCBS, 2004). We test these propositions using a new, unique panel data set containing information on the UK activities of UK and foreign banking groups for 1992–2009. We find evidence of a systematic effect of market interest rates on bank profitability. In the long run, high yields and a steep yield curve boost banks' income margins. In the short run, though, an increase in short-term yields depresses income, which is consistent with the presence of frictions affecting the repricing of banks' assets and liabilities in an asymmetric way.

As the 2008 crisis has shown, modern banking involves a lot more besides the traditional maturity transformation alluded to by Bagehot. Trading income is an important component of banks' profits, and it is affected by hedging activities intended to manage interest rate risk generated in the banking book, *inter alia.* We find indeed that market yields affect net interest margin and trading income in opposite directions. Even after accounting for hedging, however, large banks appear to retain a residual exposure to UK interest rates: the interest rate effects in the banking book 'pass through' into operating profits, as captured by our simple banking model.

We present two applications of our estimated model. First, we explore the interaction

[1]The authors wish to thank David Aikman, Charles Calomiris, Leonardo Gambacorta, Lavan Mahadeva, Jack McKeown, three anonymous referees and seminar participants at the Bank of England, the Bank for International Settlements and Banca d'Italia for useful comments and discussions. We are grateful to Jon Bridges, Courtney Escudier and Amar Radia for their help in compiling the bank panel data set used in this paper. All remaining errors are ours.

of level and slope effects and short and long-run multipliers by running a 'monetary policy shock' through the model. We use a medium-size vector autoregression (VAR) to identify structural monetary policy shocks, and use the impulse responses to trace the path for bank profitability implied by our microeconometric estimates. A typical policy tightening raises short-term rates and flattens the yield curve, thus depressing banks' income through two distinct channels. This effect is fairly short-lived, and somewhat attenuated by hedging, but economically significant. For central banks with dual objectives, the existence of such a link between bank profits and monetary policy might reinforce the case for having two sets of instruments: one set to manage the balance between aggregate demand and supply, and another to enhance financial stability.

Second, we use our estimated NIM equation to decompose the sources of UK bank profitability since 1992. Our results suggest that a *secular* decline in interest rates contributed strongly to a compression in bank margins over the period, which passed through into banks' return on assets (ROA). Our data suggest that banks increased leverage to prevent the fall in ROA from affecting their return on equity (ROE), providing a link between our paper and the growing literature on the 'risk-taking channel' of monetary policy (eg Borio and Zhu (2008)).

Our work has a number of important implications for the banking literature. It corroborates the 'bank capital view' of the short-run transmission of monetary policy shocks (eg Van den Heuvel (2007) and Gambacorta and Mistrulli (2004)), which posits that monetary contractions depress banks' profits and erode their capital buffers. Furthermore, it provides two useful inputs for the recent and rapidly growing Dynamic Stochastic General Equilibrium (DSGE) literature on credit and financial intermediation. Our results show indeed that (a) the 'traditional banking' assumption incorporated in most of these models (see Section 2) remains empirically plausible, despite the radical transformation that banks' activities underwent in the last two decades; and (b) pricing frictions in credit markets can be economically significant and thus worth modeling.

The remainder of this paper proceeds as follows. In the next section we relate our work to the literature. Section 3 presents a simple theoretical model of banks' NIMs. Sections 4 and 5 discuss our unique data set and our empirical approach. Section 6 presents our key findings which relate nominal rates to NIMs. The impact of interest rates on profitability is assessed in Section 7, we present two applications of our model in Section 8, and conclude in Section 9.

2 Related literature

Banks' pricing behaviour is central to the way they interact with the rest of the economy. Gerali *et al* (2010) develop and estimate a DSGE model with an imperfectly competitive banking sector, a key feature of which is an imperfect pass-through from policy rates to loan rates due to pricing frictions. They find that banks attenuate the impact of transitory monetary policy shocks, mostly because of stickiness in bank interest rates. We study a similar framework in partial equilibrium below. Meh and Moran (2009) and Gertler and

Karadi (2011) abstract from pricing frictions (banks issue one-period loans in the first case, and buy equity stakes in firms in the second), and reach the opposite conclusion: monetary policy shocks are amplified by the banking sector through a financial accelerator channel. Finally, Andreasen *et al* (2013) extend the Gertler-Karadi (2011) model to explicitly include maturity transformation, and find that this feature significantly reduces the response of the economy to both productivity and monetary policy shocks.[2] Maturity transformation and pricing frictions thus appear to be crucial factors in determining whether banks dampen or amplify monetary policy shocks in the short run.

They are also important ingredients in the literature on interest rate risk. Drehmann et al (2010) and Alessandri and Drehmann (2010) develop a model where risk-neutral banks price loans subject to a known repricing schedule and stochastic fluctuations in interest rates and default frequencies, examining the interaction between credit and interest rate risk and its implications for the capital buffer of a representative bank. A similar model is embedded in RAMSI, a systemic risk model currently used at the Bank of England (Alessandri *et al* (2009), Aikman *et al* (2009)); the channel is of obvious relevance from a systemic perspective given that interest rate risk is not fully diversifiable in the aggregate. The microeconometric evidence discussed in this paper provides support for some of the assumptions that underpin these models, and can in principle be used to calibrate some of their parameters.

A number of papers study the impact of macroeconomic dynamics and changes in the structure of the banking sector on bank profitability. As Albertazzi and Gambacorta (2009) note, the co-evolution of these variables is of renewed interest given a new focus on macro-prudential policy among central banks and academics interested in systemic stability (Borio and Shim (2007), Bank of England (2009) and Hanson *et al* (2010)). Much of the literature pre-dates the recent financial turmoil. Examples include Flannery (1981), Hancock (1985), Bourke (1989), Demirguc-Kunt and Huizinga (1999), Saunders and Schumacher (2000), Corvoisier and Gropp (2002), Lehmann and Manz (2006) and Beckmann (2007). Not surprisingly, the role of interest rates has received significant attention. Most papers document the existence of a positive correlation between long rates, or long to short-rate spreads, and banks' profits or interest income margins, which is typically interpreted as a consequence of their maturity transformation function.

For short-term interest rates (typically taken to be three-month Treasury bill yields) the conclusions are more ambiguous. Their impact on profits is estimated to be positive e.g. by Demirguc-Kunt and Huizinga, (1999), negative by Hancock (1985), and insignificant by Albertazzi and Gambacorta (2009). [3] Gambacorta (2008) studies the price-setting behaviour of a group of large Italian banks looking directly at the average interest rates on loans and deposits. The two rates are found to respond in a similar fashion to changes in short-term

[2]Interestingly, the findings of both Gerali *et al* (2010) and Andreasen *et al* (2011) are at odds with Van den Heuvel's (2007) 'bank capital view': in Van den Heuvel's partial equilibrium model, maturity transformation amplifies monetary policy shocks. Andreasen *et al* (2011) discuss the reasons behind this difference.

[3]A further complication is that it is not possible to focus on 'first moments' only: volatility matters as well. Saunders and Schumacher (2000) argue that risk aversion and uncertainty on transaction volumes generate a positive relationship between banks' margins and interest rate volatility, and document that this was indeed the case for EU and US banks in the early 1990s. This channel is not the focus of this paper, but we control for it in our empirical analysis.

market rates in the short run, but the long-run pass-through is higher for the loan rate, which implies a positive effect of market rates on the spread earned by banks in equilibrium. This result also emerges from our study, and we provide a theoretical explanation for it. Consistent with Hancock (1985), we find that income is affected by relative movements of interest rates at different maturities. Furthermore, we find that changes in rates of any given maturity can have radically different short and long-run implications for banks' interest margins. The short-run dynamics provide evidence of a 'bank capital channel' for monetary policy (eg Van den Heuvel (2007) and Gambacorta and Mistrulli (2004)).

Maturity transformation exposes banks to interest rate risk which can be mitigated in various ways. First, banks can hedge interest rate risk by holding interest rate derivatives in the trading book. Flannery (1981) finds that large banks effectively hedge market rate risk by assembling asset and liability portfolios with similar average maturities. Gorton and Rosen (1995) find a similar offsetting movement between the value of interest rate derivatives and banking book income flows, noting that commercial banks as a whole appear to take the same side in derivatives contracts. More recently, Purnanandam (2007) finds the tendency to hedge risk to be stronger for banks more exposed to financial distress. The use of derivatives is also found to confer immunity to monetary policy shocks. Esposito *et al* (2013) reach similar conclusions for Italy. Their analysis shows that Italian banks typically use derivatives and the restructuring of on-balance sheet exposures as complementary risk management tools, and that their net exposure to interest rate risk in the aftermath of the 2008 crisis was low on average but very heterogenous across institutions.

A second way in which banks can eliminate overall income risk is by diversifying their income structures. For some time there was a view that sources of non-interest income may provide a diversification benefit to banks (eg through fees and commissions on banking or trading activities). Evidence in Smith *et al* (2003), Stiroh (2004), Stiroh and Rumble (2006), and Lepetit *et al* (2008) casts doubt on this view: non-interest income may not reduce overall income risk if it is associated with inherently risky trading activities. Consistent with these studies, we take an holistic view of UK banks' income-generating activities and assess the extent to which non banking book income flows help to reduce the cyclicality of bank income, and particularly its sensitivity to interest rates. Our data suggests that these mitigating factors played a role in the United Kingdom, but did not completely compensate the traditional interest income channel: interest rates matter for modern, sophisticated banks as well as for traditional banks.

A related, important mechanism through which interest rates can affect bank behaviour is highlighted by the 'risk-taking channel' literature. Loose monetary policy can stimulate risk-taking through a 'search for yield' effect, possibly reinforced by explicit nominal return targets, or through its effects on asset prices, leverage and credit standards (Borio and Zhu (2008), Adrian and Shin (2009), and Maddaloni and Peydró (2011)).[4] De Nicolò *et al* (2010) discuss an additional, countervailing mechanism linked to risk-shifting. If low market rates translate one to one into lower deposit rates but are not entirely passed through to loan rates,

[4]Empirical evidence on the risk-taking channel is presented e.g. by Gambacorta (2008) and Altunbas *et al* (2010) and Delis and Kouretas (2011)).

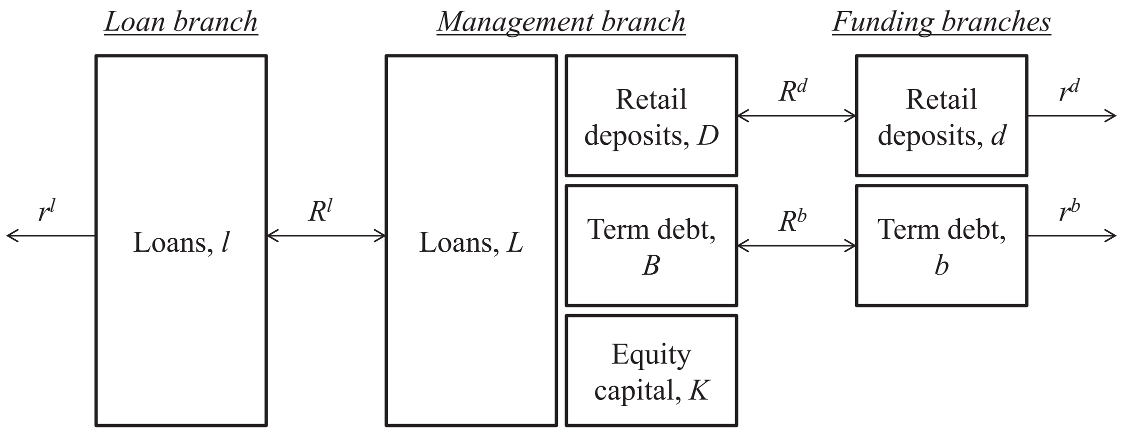

Figure 1: Schematic of the model. Management branch raises funding from retail deposit and term debt branches, combines this with equity capital, and on-lends to the loan branch. Upper case R^i, $i = l, d, b$ denote internal returns; lower case r^i, $i = l, d, b$ denote returns received from (paid to) final borrowers (liability holders).

they will boost a bank's profits and increase its franchise value, weakening the risk-shifting motive. We share with this strand of work the conclusion that nominal interest rates matter for banks, and that monetary policy is not neutral from a banking and financial stability perspective. Our results, like those in Gambacorta (2008), are consistent with an asymmetric pass-through to deposit and loan rates. Furthermore, we find that this asymmetry is not removed or compensated by either hedging or income diversification.

3 Theory

3.1 Model set-up

We begin with a theoretical model that follows closely the treatment of banking in Gerali et al (2010). Because of our interest in the effects of both the level and slope of the yield curve, we extend this set-up to include two forms of debt liability – term debt issuance and deposits. The inclusion of the former allows us to map the implications of changes in long rates for bank profitability, in addition to the short rate set by the central bank.

The economy is populated by an exogenously given mass of monopolistically competitive banks, indexed by $j \in [0, J]$, which supply 'differentiated products' loans to final borrowers, and issue 'differentiated products' debt products to households. We consider a partial equilibrium version of this model.[5] It is useful to divide a given bank j's operations into four branches: a loan branch, a deposit branch, a term debt branch, and a management branch. This aids the exposition of the bank's pricing problem and the determination of its balance sheet composition. A schematic appears in Figure 1. We describe the problems faced by these branches next.

[5]Gerali et al (2010) also distinguish between household and corporate borrowers. To simplify matters, we consider one generic type of final borrower here.

Management branch The balance sheet of the management branch is:

$$L_t(j) = D_t(j) + B_t(j) + K_t(j), \tag{1}$$

where L denotes loans to final borrowers, D denotes retail deposits, B denotes term debt (or 'bonds'), and K denotes bank capital. The problem of the management branch is to maximise the bank's discounted cash flow subject to exogenous capital and liquidity (i.e. term debt) targets, deviations from which incur quadratic costs. After suppressing bank index j, the objective is given by:

$$\begin{aligned}\max_{\{L_t,D_t,B_t\}} E_0 \sum_{t=0}^{\infty} \beta^t [D_{t+1} + B_{t+1} + K_{t+1} - L_{t+1} \\ + \left(1 + R_t^l\right) L_t - \left(1 + R_t^d\right) D_t - \left(1 + R_t^b\right) B_t - K_t \\ - \frac{\kappa_k}{2}\left(\frac{K_t}{L_t} - v\right)^2 K_t - \frac{\kappa_b}{2}\left(\frac{B_t}{L_t} - \lambda\right)^2 B_t],\end{aligned}$$

where β is the bank's rate of time preference, R_t^i, $i = l, d, b$, denote the returns on loans, deposits and term debt, v denotes the bank's exogenous steady state capital ratio, λ denotes the bank's exogenous steady state liquidity ratio, and $\kappa_i, i = k, b$ parameterise the bank's targets and the costs of deviating from them.[6]

The maximisation is subject to the balance sheet constraint (1) and the law of motion for bank capital:

$$K_t = (1 - \delta_k)K_{t-1} + \pi_t,$$

where δ_k is the exogenous payout ratio out of past capital, and π_t is bank profit in period t. A restriction on the parameter δ_k is necessary in order for the steady state of the model to be consistent with the bank meeting its capital and liquidity targets (see Appendix B). Using the balance sheet constraint, the management branch's objective can be written as a static problem:

$$\max_{\{L_t,D_t,B_t\}} R_t^l L_t - R_t^d D_t - R_t^b B_t - \frac{\kappa_k}{2}\left(\frac{K_t}{L_t} - v\right)^2 K_t - \frac{\kappa_b}{2}\left(\frac{B_t}{L_t} - \lambda\right)^2 B_t.$$

The first-order conditions with respect to loans and term debt are then respectively:

$$\begin{aligned}R_t^l &= R_t^d - \kappa_k\left(\frac{K_t}{L_t} - v\right)\left(\frac{K_t}{L_t}\right)^2 - \kappa_b\left(\frac{B_t}{L_t} - \lambda\right)\left(\frac{B_t}{L_t}\right)^2, \\ R_t^d &= R_t^b + \kappa_b\left(\frac{B_t}{L_t} - \lambda\right)\frac{B_t}{L_t} + \frac{\kappa_b}{2}\left(\frac{B_t}{L_t} - \lambda\right)^2,\end{aligned}$$

[6] The model does not describe the determination of (optimal or otherwise) long-run capital and liquidity ratios. It is better thought of as a model describing (a) how banks' pricing decisions would reflect temporary deviations from these target ratios, which are taken to be completely exogenous; and (b) how banks' loan rates would vary with permanent shifts in market interest rates, holding the ratios, and hence the funding structure of the bank, fixed.

The second of these can be re-written as:

$$\kappa_b \left(\frac{B_t}{L_t} - \lambda\right)\left(\frac{B_t}{L_t}\right)^2 = \left[R_t^d - R_t^b - \frac{\kappa_b}{2}\left(\frac{B_t}{L_t} - \lambda\right)^2\right]\frac{B_t}{L_t},$$

such that the first gives:

$$R_t^l = \left(1 - \frac{B_t}{L_t}\right)R_t^d + \frac{B_t}{L_t}R_t^b + \frac{\kappa_b}{2}\left(\frac{B_t}{L_t} - \lambda\right)^2\frac{B_t}{L_t} - \kappa_k\left(\frac{K_t}{L_t} - v\right)\left(\frac{K_t}{L_t}\right)^2.$$

This expression describes how the management branch sets the rate R_t^l at which it passes funds on to the final loan branch, as a function of the internal costs of retail deposits and term debt respectively, together with the bank's liquidity and capital ratio positions. For example, when the bank is undercapitalised relative to its target v, the final term is positive, such that the rate the management branch charges the loan branch for funds rises. Deviations from the liquidity ratio target incur similar costs. Finally, note that when the bank attains its capital ratio v and its liquidity target λ in steady state, this expression becomes:

$$R^l = (1 - \lambda)R^d + \lambda R^b,$$

such that the bank's internal loan rate is simply a weighted average of its internal cost of funds, where the weight λ is the bank's desired liquidity ratio.

Loan branch The loan branch borrows funds $L_t(j)$ from the management branch at internal rate $R_t^l(j)$, and makes loans of $l_t(j)$ to final borrowers at loan rate $r_t^l(j)$. Its balance sheet is thus $L_t(j) = l_t(j)$. The branch faces a Dixit-Stiglitz loan demand curve for its loan variety j given by:

$$l_t(j) = \left(\frac{r_t^l(j)}{\bar{r}_t^l}\right)^{-\varepsilon_l}\bar{l}_t \tag{2}$$

where $\bar{l}_t$ and $\bar{r}_t^l$ index aggregate quantities and loan rates, taken as given by bank j, at time t. The parameter $\varepsilon_l > 1$ is the elasticity of substitution between loan varieties. In choosing its loan rate $r_t^l(j)$, the bank is subject to adjustment costs a la Rotemberg, parameterised by $\gamma_l > 0$. The loan branch's problem is to solve

$$\max_{\{r_t^l(j)\}} E_0\sum_{t=0}^{\infty}\beta^t\left[r_t^l(j)l_t(j) - R_t^l(j)L_t(j) - \frac{\gamma_l}{2}\left(\frac{r_t^l(j)}{r_{t-1}^l(j)} - 1\right)^2\bar{r}_t^l\bar{l}_t\right],$$

subject to loan demand (2). In a symmetric equilibrium (dropping the j index), the loan branch's first-order condition is:

$$1 - \varepsilon_l + \varepsilon_l\frac{R_t^l}{r_t^l} - \gamma_l\left(\frac{r_t^l}{r_{t-1}^l} - 1\right)\frac{r_t^l}{r_{t-1}^l} + E_t\beta\gamma_l\left[\left(\frac{r_{t+1}^l}{r_t^l} - 1\right)\left(\frac{r_{t+1}^l}{r_t^l}\right)^2\frac{l_{t+1}}{l_t}\right] = 0,$$

which governs the dynamics of the bank's loan rate. In steady state, the first-order condition simply reduces to:

$$r^l = \mu^l R^l,$$

such that the loan branch charges a markup $\mu^l \equiv \varepsilon_l/(\varepsilon_l - 1) > 1$ determined by the elasticity of substitution between varieties over its average internal cost of funds, R^l.

Deposit branch The deposit branch borrows funds $d_t(j)$ from savers at rate $r_t^d(j)$, and lends quantity $D_t(j)$ on to the management branch at internal rate $R_t^d(j)$. The balance sheet identity is given by $d_t(j) = D_t(j)$. The deposit branch faces an analogous problem to the loan branch. In particular, the deposit branch faces a Dixit-Stiglitz deposit supply curve for its deposit variety j given by:

$$d_t(j) = \left(\frac{r_t^d(j)}{\bar{r}_t^d}\right)^{-\varepsilon_l} \bar{d}_t \tag{3}$$

where $\bar{d}_t$ and $\bar{r}_t^d$ index aggregate deposit quantities and deposit rates, taken as given by bank j, at time t. The parameter $\varepsilon_d < -1$ is the elasticity of substitution between deposit varieties.

As in Gerali et al (2010), the deposit branch can alternatively lend at the interbank rate r_t set by the central bank, such that by arbitrage, $R_t^d(j) = r_t$, where r_t is set by the monetary authorities. Deposits, being short-term, can be repriced every period, which we capture by assuming zero costs of adjustment on deposit rates. As a result, the deposit branch's problem is:

$$\max_{\{r_t^d(j)\}} E_0 \sum_{t=0}^{\infty} \beta^t \left[r_t D_t(j) - r_t^d(j) d_t(j) \right],$$

subject to deposit supply (3). In a symmetric equilibrium (dropping the j index), the deposit branch's first-order condition is:

$$r_t^d = \mu^d r_t,$$

where $\mu^d \equiv \varepsilon_d/(\varepsilon_d - 1) < 1$ is a mark-down below the interbank rate. In steady state, the first-order condition simply reduces to $r^d = \mu^d r$.

Term debt branch The debt branch borrows funds $b_t(j)$ from savers at rate $r_t^b(j)$, and lends quantity $B_t(j)$ on to the management branch at internal rate $R_t^b(j)$. The term debt branch faces a Dixit-Stiglitz deposit supply curve for its debt variety j given by:

$$b_t(j) = \left(\frac{r_t^b(j)}{\bar{r}_t^b}\right)^{-\varepsilon_b} \bar{b}_t \tag{4}$$

where $\bar{b}_t$ and $\bar{r}_t^b$ index aggregate debt quantities and interest rates, taken as given by bank j, at time t. The parameter ε_b is the elasticity of substitution between varieties.

The term debt branch faces an analogous problem to the deposit branch, with the exception that, by virtue of being long-term, debt issued by the term debt branch is slow to re-price. We capture this by imposing price adjustment costs analogous to those borne by the loan branch. The debt branch's problem is thus:

$$\max_{\{r_t^b(j)\}} E_0 \sum_{t=0}^{\infty} \beta^t \left[R_t^b(j) B_t(j) - r_t^b(j) b_t(j) - \frac{\gamma_b}{2} \left(\frac{r_t^b(j)}{r_{t-1}^b(j)} - 1 \right)^2 \bar{r}_t^b \bar{b}_t \right],$$

subject to debt supply (4). In a symmetric equilibrium (dropping the j index), the branch's first-order condition is:

$$-(1-\varepsilon_b) - \varepsilon_b \frac{R_t^b}{r_t^b} - \gamma_b \left(\frac{r_t^b}{r_{t-1}^b} - 1 \right) \frac{r_t^b}{r_{t-1}^b} + E_t \beta \gamma_b \left[\left(\frac{r_{t+1}^b}{r_t^b} - 1 \right) \left(\frac{r_{t+1}^b}{r_t^b} \right)^2 \frac{b_{t+1}}{b_t} \right] = 0,$$

which governs the dynamics of the bank's deposit rate. In steady state, the first-order condition simply reduces to:

$$r^b = \mu^b R^b,$$

where $\mu^b \equiv \varepsilon_b/(\varepsilon_b - 1)$ is the debt branch's mark-up. By analogy with the deposit branch, the term debt branch can lend into term debt markets at wholesale rate $r_t^\tau > r_t$, where τ is a mnemonic for 'term premium'. By arbitrage, $R_t^b = r_t^\tau$ in the debt branch's first-order condition, and in steady state, the debt rate satisfies $r^b = \mu^b r^\tau$.

Branches combined The cash flow of the combined banking branches in period t is as follows. First, the bank raises deposits d_t, term debt b_t, inherits an increase in bank capital of $K_t - K_{t-1}$, and makes new loans of l_t. It receives returns on last period's loans $\left(1 + r_{t-1}^l\right) l_{t-1}$, pays returns to depositors on last period's stock of deposits $\left(1 + r_{t-1}^d\right) d_{t-1}$, and pays the return due to bond holders $(1 + r_{t-1}^b) b_t$. Combining all branches of the bank yields cash flows in period t of:

$$\begin{aligned}\pi_t &= d_t + b_t + K_t - l_t \\ &+ \left(1 + r_{t-1}^l\right) l_{t-1} - \left(1 + r_{t-1}^d\right) d_{t-1} - \left(1 + r_{t-1}^b\right) b_{t-1} - K_{t-1} - Adj_t\end{aligned} \tag{5}$$

where Adj_t captures the sum of all quadratic adjustment cost terms described above. Using the balance sheet constraint at t and $t-1$, this can be written:

$$\pi_t = \left(r_{t-1}^l - r_{t-1}^d\right) l_{t-1} - \left(r_{t-1}^b - r_{t-1}^d\right) b_{t-1} + r_{t-1}^d K_{t-1} - Adj_t$$

3.2 Steady state analysis

We define the steady state of the model as that in which the bank achieves its capital and liquidity targets, v and λ (see Appendix B for the parameter values that ensure this). In the steady state, the profits of the bank are $\pi = \left(r^l - r^d\right) l - \left(r^b - r^d\right) b + r^d K$. Using this, we can define the net interest margin according to:

Definition 1 *The bank's net interest margin (NIM) is given by π_t/l_t, such that in steady* *state:*

$$NIM \equiv \frac{\pi}{l} = r^l - (1 - v - \lambda) r^d - r^b \lambda \tag{6}$$

The steady state net interest margin has properties summarised in the following Proposition:

Proposition 1 *(a) The steady state net interest margin is increasing in the steady state short rate, r; (b) The steady state net interest margin is increasing in the term premium $r^\tau - r$ when the bank's monopoly power in loan markets exceeds that in debt markets, $\mu^l > \mu^b$.*

Proof. See Appendix A. ■

Due to its market power, the bank can pass increases in its funding cost r through to final borrowers. Higher loan rates depress demand, contracting the bank's balance sheet.So while the bank maintains the spread between assets and liabilities, it does so on a smaller balance sheet. As a result, the NIM must rise.

The same logic applies to part (b) of the Proposition. Here, a rise in the 'long run' market rate on term debt r^τ causes the bank to re-price loans, raising the loan rate and moving along the loan demand curve. As long as the bank's ability to pass on higher costs in the loan market is sufficiently high relative to the mark-up it faces in debt markets (ie if $\mu^l > \mu^b$), the NIM will rise. In concentrated banking systems such as the UK's, a relatively high loan mark-up is plausible. In other banking systems, the monopoly power in loan markets may be less potent and this condition may not hold. A condition that guarantees a positive pass-through from higher term debt rates and a higher NIM is $\mu^b < 1$, which corresponds to a situation in which banks are able to issue term debt at below prevailing market rates r^τ. This could occur if, for example, bank debt is subject to an implicit subsidy from the state, which cheapens its funding relative to other institutions seeking to borrow at similar maturities.

3.3 Re-pricing frictions and dynamic simulations

The loan and deposit rate adjustment cost parameters γ_i, $i = l, b$, can be thought of as a reduced-form way of capturing maturity mismatch. To see this, consider a bank that can reprice some fraction $1 - \eta_l$ $(1 - \eta_b)$ of its loans (debt) each quarter, by analogy with Calvo sticky price adjustment. Then the Rotemberg parameter γ_i, $i = l, b$ is related to this repricing frequency according to:

$$\gamma_i = \frac{(\varepsilon_i - 1)\, \eta_i}{(1 - \eta_i)(1 - \beta\eta_i)},$$

(see eg Keen and Wang (2007)), where β and ε_i are the discount rate and price elasticity as defined above. The γ_i parameters are monotonically increasing in the fraction of loans and bonds that can not be repriced, η_i. For example, when η_i goes to unity the corresponding γ_i tends to infinity. Hence, these parameters pin down the maturity structure of the balance sheet. Noting that deposits are instantaneously repriced, we can interpret γ_l and $\gamma_l - \gamma_b$ as indices of the maturity mismatches between the loan portfolio and short and long-term debt respectively. These are crucial in determining the short-run response of the net interest margin (NIM) to interest rate shocks. Shocks that raise the short rate r, i.e. the cost of deposits, will temporarily compress the margin as long as γ_l is sufficiently large. An increase in long rates could have the same effect if term debt is faster to re-price than loans. In this case, increases in the slope of the yield curve r^τ would compress a bank's NIM too.

Thus, in general, changes in either of the interest rates will have different implications in the short run and in the long run. To illustrate, we consider some dynamic simulations of the model. Table 1 contains details of the calibration we use to illustrate the model's short-run properties. Our calibration is intended purely to be indicative. We set the mean short-term interest rate to 3%, and the term premium to 5%. We choose mark-up parameters to yield a loan rate of 6.25%, deposit rate of 1.8% and term debt rate of 7.6%. The bank targets a capital ratio of 10%, and a liquidity ratio of 25%. The resulting mean NIM is around 3%. We choose re-pricing costs such that 30% of a bank's loans can be re-priced each period, which gives $\gamma_l = 16.11$, and we set the equivalent parameter for term debt (γ_b) to 95% of this level. We set the parameters capturing the cost of deviating from the desired capital and liquidity ratios to 11.49, from Gerali et al (2010). The bank's discount rate is set to 0.99.

Figure 2 shows the short-run dynamic response of the model to interest rate shocks. The top panel shows the impact of a temporary (but persistent) 25 basis point shock to short rates r_t, while the bottom panel shows the impact of a temporary (but persistent) 25 basis point shock to the term premium r_t^τ. In both cases, the impact of the cost shock is to temporarily compress the net interest margin in the short run, owing to the greater severity of repricing frictions on loans relative to debt. Once loans become re-priced, however, the NIM recovers, rising above its steady state value, before returning to equilibrium once the interest rate shocks have receded.

The model presents us with some testable implications. First, by Proposition 1, the *level* of short-term interest rates should matter positively for the steady state 'long-run' net interest margin. Similarly, for a given level of short rates, higher long rates should also boost the NIM when part (b) of the Proposition holds, and banks' loan market power is sufficiently large. Second, *changes* in short-term interest rates should be negatively related to the net interest margin, which is consistent with banks running maturity mismatched banking books. The model also implies that, for a given short rate, a change in the slope of the yield curve should also compress NIMs when loans re-price more slowly than term debt. We turn next to an examination of these dynamics empirically.

4 Data

We use data collected by the Bank of England on a quarterly basis for the UK activities of all deposit-taking UK entities of UK and non-UK resident banks with assets over £5billion. The data were 'quasi-consolidated' into groups, resulting in 44 active groups over the sample, which runs from 1992 Q1 to 2009 Q3. The proliferation of groups is the result of the convention adopted over the treatment of merger activity. When two banks merge an entirely new entity is created, while its constituent parts cease to operate separately. As discussed

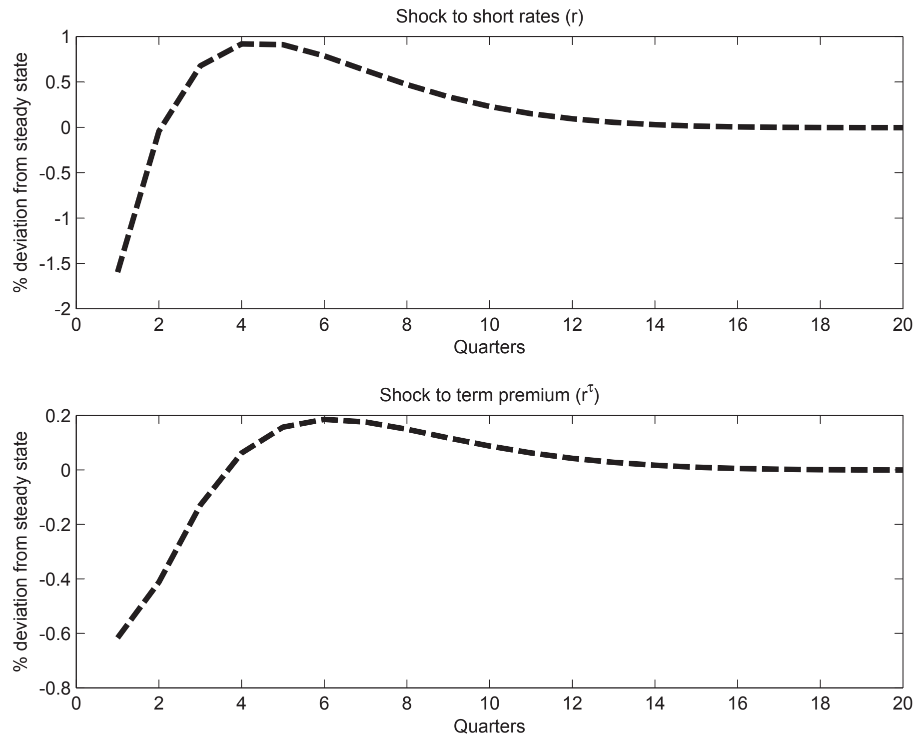

Figure 2: Dynamic response of net interest margin following unanticipated positive temporary shocks to short rates (top panel) and term premium (bottom panel)

below, we implicitly assume this does not change the basic dynamics of profitability, but allow it to affect the level of the newly created entity's profitability through its individual effect. Note that, in our data, derivatives are netted and recorded as an entry on the liability side of the balance sheet.

In the data reported by banks to the Bank of England, interest income (and interest expense) on loans to (and deposits from) customers is reported on a gross basis, without any income flows relating to the hedging of eg interest rate risk included. All income relating to this type of activity is reported in the trading income returns. We therefore think of the net interest income data as 'unhedged'. Trading income also includes revaluation profits or losses arising from holding trading instruments held on a mark-to-market basis. Such instruments include foreign exchange contracts, traded securities, and derivatives.

In our baseline regressions we present results for the full sample of banks, together with a focus on a sub-sample of the main UK commercial banks, which contains around 21 quasi-consolidated groups existing over the period 1992-2009 once mergers and acquisitions are accounted for. For net interest income, we also have data on UK building societies, namely smaller, retail-funded institutions akin to credit unions (US) or cooperative banks (EU). We report results for both groups of institutions separately where appropriate, together with pooled results (which include small foreign-owned UK subsidiaries) for comparison. The behaviour of these sub-groups might differ for a number of reasons. For instance, large banks have significant trading activities through which they can hedge interest rate risk,

Table 1: Model calibration

Parameter	Description	Value
μ^l	Loan mark-up	1.4717
μ^d	Deposit mark-down	0.6
μ^b	Debt mark-down	0.95238
v	Capital ratio	0.1
λ	Liquidity ratio	0.25
κ_k	Cost of deviating from v	11.49
κ_b	Cost of deviating from λ	11.49
γ_l	Loan re-pricing	16.1129
γ_b	Debt re-pricing	15.3073
$\bar{r}$	Mean short rate	0.03
$\bar{r}^\tau$	Mean term rate	0.08
m_l	Loan demand	1
m_b	Debt supply	0.21863
δ	Profit payout ratio	0.318

and may therefore be able to take larger interest rate positions through their banking books than building societies. Furthermore, large banks were active in securitisation markets, particularly in the second half of the sample, whereas building societies were not. Hence, building societies implicitly work as a 'control group' for a phenomenon (the progressive growth of securitisation) that we cannot explicitly account for due to data limitations.

Some simple descriptive statistics appear in Table 2 for the pooled sample. Net interest income is the largest source of income, around 2.3 times as large as fee income and around 13 times as large as trading income. By far the most volatile source of income is through trading activities: the coefficient of variation for trading income is around 7.3, or 6-7 times as large as that for net interest income and net fee income. Both mean and median operating profit have fallen relative to total assets over the sample period, from around 0.4% in 1992 to around 0.2% in 2008. This reflects declines in both NIM and fee income. Trading income, for which we have data from only 1997 Q1 onwards, was volatile throughout the sample period. We turn next to more formal econometric evidence.

5 Empirical approach

5.1 Econometric model and estimation strategy

Our empirical analysis is based on the following general specification:

$$\begin{aligned} y_{it} &= \alpha y_{it-1} + \beta' X_{it} + \gamma' M_t + \varepsilon_{it}, \quad |\alpha| < 1, \\ \varepsilon_{it} &= \eta_i + v_{it}, \end{aligned} \tag{7}$$

where, for every bank $i = 1, ..., N$ at time $t = 1, ...T$, $y_{it} \equiv Y_{it}/A_{it-1}$ represents income component Y_{it} (eg net interest income) normalised by (lagged) total assets, X_{it} is a vector of bank-specific controls, M_t is a vector of macroeconomic variables, η_i is a bank effect, and

Table 2: Descriptive statistics

Variable	No. Obs	Mean	Std. Dev.	Min	Max
NIM	2074	0.374	0.366	-0.189	6.109
Trading/TA	1207	0.029	0.210	-0.811	1.281
OpProf/TA	1508	0.267	0.403	-0.697	3.819
OpProf/K	1463	2.738	4.807	-13.146	40.656
GTA	3976	4.527	51.709	-100.0	28.0
LEV	3971	0.904	0.120	0.012	1.612
GDP	4367	0.547	0.580	-2.398	1.423
R^{3m}	4367	6.064	2.816	0.400	14.500
$SLOPE$	4367	0.330	1.674	-4.566	3.861
VOL^{libor}	4209	0.155	0.163	0.013	1.301
$CONC$	4095	0.077	0.013	0.059	0.104
$GFTSEvolume$	4169	0.038	0.157	-0.236	0.812

All variables in per cent, except LEV (ratio of debt liabilities to assets).

v_{it} is an idiosyncratic disturbance.

We deal with an unbalanced panel where N and T are reasonably large and of approximately the same magnitude. A number of different estimators with different bias and variance characteristics can be used in this context. It is well known that OLS and within-groups estimates of α are biased in opposite directions, even in large samples (see Bond (2002)). The GMM estimator proposed by Arellano-Bond (1991), and the 'system' GMM extension developed by Arellano-Bover-Blundell-Bond (1995, 1998), do not have these limitations. The latter has well-documented advantages when the data is highly persistent. This is an extremely desirable feature in our context, because our data set includes various macroeconomic series of which some (including, crucially, interest rates) display strong autoregressive behaviour. However, these estimators were developed for 'large N, small T' panels, and deviations from 'large N, small T' can result in small sample biases that make the asymptotic properties of the System GMM approach essentially irrelevant. [7]

Our preferred set of estimates is based on a System GMM estimation where the instrument count is controlled by adopting an extremely parsimonious model specification and by collapsing the instrument set as advocated by Roodman (2009). Rather than relying exclusively on a single supposedly 'optimal' estimation strategy, though, we explore the data using a range of alternatives, and discuss the robustness of our results in Section 6.2 and in more detail in the annex.

5.2 Explanatory variables

Throughout, we use the following common set of explanatory variables. The bank-specific regressors we use are leverage (LEV, defined as the ratio of debt to total assets) and balance sheet growth (GTA defined as the growth rate of total assets). On the macro side, we use real

[7] The bias can affect the estimates of both coefficients and standard errors, but can also invalidate Hansen's specification test, which makes the problem extremely hard to detect (Roodman (2009)).

quarterly UK GDP growth (GDP) to capture real activity. The interest rate measures we use are three-month government borrowing rates (R^{3m}), ten-year government rates (R^{10y}), which we use to construct a measure of the yield curve slope ($SLOPE = R^{10y} - R^{3m}$), and three-month Libor volatility (VOL^{libor}) (quarterly, annualised). The three-month government bond yield is a good proxy for the monetary policy stance: its correlation with the quarterly average of the Bank of England official rate between 1989 and 2009 is 0.998. We consider alternative measures of short rates and yield curve slope as robustness checks. First, we use the three-month interbank rate (R^{ib}) as an alternative measure of short rates, and we use the three-year government rate to construct an alternative measure of slope ($SLOPE^{3y}$). Second, we include measures of short rates and slope derived from a Nelson-Siegel yield curve model ($NSshort$ and $NSSlope$ respectively). In our trading income regressions, we also use the three-month interbank spread ($IBSpread$). Other macro regressors include FTSE volatility (VOL^{FTSE}) (quarterly, constructed from daily returns, then annualised), FTSE volume growth ($GFTSEvolume$), a sterling exchange rate index volatility measure (VOL^{ERI}) (constructed as the FTSE measure), and a Herfindahl index capturing sector concentration ($CONC$).[8]

Under System GMM, by default we treat bank-specific variables X_{it} (eg leverage, asset growth) as endogenous in choosing our instrument set,[9] but assume that the macroeconomic series M_t are exogenous to the models.[10] The validity of these assumptions can be formally tested as long as the models are over-identified.

We allow lags of both long and short interest rates to enter our estimating equations. We parameterise the interest rate terms to yield a particularly appealing form. In particular, our explanatory variables include $\beta_0 R_t^{3m} + \sum_{j=0}^{k} \beta_j^{\Delta} DR_{t-j}^{3m} + \gamma_0 SLOPE_t + \sum_{j=0j}^{k} \gamma_j^{\Delta} DSLOPE_{t-j}$, where $\left(\beta_0, \gamma_0, \beta_j^{\Delta}, \gamma_j^{\Delta}\right)$, $j = 0, ..., k$ are coefficients to be estimated and D is the difference operator. This permits a clear separation between short rate and yield curve slope effects (through R^{3m} and $SLOPE$ respectively), together with a separation of long-run and short-run effects through levels terms ($R^{3m}, SLOPE$) and changes terms ($DR^{3m}, DSLOPE$) respectively.

6 The impact of interest rates on net interest margins

6.1 Key results

Table 3 contains our key results. Models (1)–(3) report fixed-effects regressions with one lag of the dependent variable, together with bank-specific controls, macroeconomic controls and interest rates. Columns (1)–(3) differ by the sample of banks studied. Column (1)

[8] This is constructed as the sum of the squared shares of each bank in the total assets of all banks, such that $H_t = \sum_{i=1}^{N} \left(\frac{A_i}{\sum_j A_j}\right)^2$. We smooth the series over the previous four quarters to capture the idea that the effects of competition may be slow-moving.

[9] Hence the assumption is that the elements of X_{it} are correlated with v_{it} and earlier, but uncorrelated with v_{it+1} and subsequent shocks. Then treat X_{it} as y_{it-1}: difference and use lags $X_{it-2}, X_{it-3}, ...$ (as in the case of y) in the difference equation, while using lagged differences as instruments in the levels equation.

[10] M_t is treated as strictly exogenous, ie is uncorrelated with all past, present and future values of v_{it}. Then all values of M_t are available as instruments.

Table 3: Net interest margin: key results.

	(1) FE MUK	(2) FE BSOCs	(3) FE MUK+BSOCS	(4) SysGMM MUK+BSOCs
NII/TA_{t-1}	0.35533***	0.49684***	0.38803***	0.19045**
	(4.51)	(6.11)	(5.34)	(2.40)
NII/TA_{t-2}				0.35521***
				(4.32)
GTA_{t-1}	-0.00248***	-0.00281***	-0.00265***	
	(-4.22)	(-3.44)	(-4.53)	
LEV_{t-1}	0.01153*	-0.00243	0.00901	
	(1.82)	(-0.86)	(1.33)	
GDP	0.00031	0.00008	0.00025*	
	(1.63)	(1.17)	(1.72)	
GDP_{t-1}	-0.00021	0.00002	-0.00009	
	(-1.38)	(0.38)	(-0.88)	
R^{3m}	0.00035**	0.00016***	0.00028***	0.00021**
	(2.48)	(3.92)	(2.77)	(2.15)
DR^{3m}	0.00015	-0.00028**	0.00002	-0.00006
	(0.57)	(-2.49)	(0.15)	(-0.38)
DR^{3m}_{t-1}	-0.00055*	-0.00002	-0.00041*	-0.00030**
	(-2.00)	(-0.17)	(-1.90)	(-2.13)
$SLOPE$	0.00030***	0.00019**	0.00025***	0.00019**
	(3.06)	(2.94)	(3.74)	(2.33)
$DSLOPE$	-0.00013	-0.00017**	-0.00013	-0.00019**
	(-1.00)	(-2.90)	(-1.69)	(-2.02)
$DSLOPE_{t-1}$	-0.00025	-0.00015**	-0.00022*	-0.00026**
	(-1.40)	(-2.25)	(-1.74)	(-2.27)
VOL^{libor}	0.00147**	0.00004	0.00093*	
	(2.13)	(0.12)	(1.82)	
$CONC$	-0.02876***	-0.00664*	-0.01640***	
	(-3.81)	(-2.15)	(-3.16)	
Const	-0.00754	0.00354	-0.00628	0.00054*
	(-1.34)	(1.32)	(-1.01)	(1.80)
N	739	548	1223	1224
Units	23	11	32	32
AvgT	32.13	49.82	38.22	38.25
Instruments				32
Hansen				26.87
Hansen p-value				0.26
AR2				-1.22
AR2 p-value				0.22

***,** ,* denote significance at 1%, 5%, and 10% respectively.
'FE' denotes fixed-effects estimation. 'SysGMM' denotes System GMM estimation.
'MUK' and 'BSOCs' denotes 'major UK banks' and 'building societies' respectively.

reports results for major UK banks (MUK), column (2) contains results for building societies (BSOCs), while column (3) reports the results using both sets of institutions.[11] Finally, column (4) reports a System GMM model, for comparison, which we discuss in further detail later. We place it in Table 3 for ease of subsequent comparison.

Table 3 suggests that the *levels* of both short rates (R^{3m}) and yield curve slope ($SLOPE$) contribute positively to banks' NIMs. This is consistent with our theoretical model. In particular, the model suggests that as short rates fall, banks reduce their loan rates and expand credit provision, putting downward pressure on the NIM as their balance sheets expand. It is interesting to note that different types of institution exhibit different sensitivities to both short rates and slope. In particular, the major UK banks group displays around twice

[11] Two of the building societies are also treated as major UK banks owing to their size in the UK mortgage market, so the sets are not entirely independent. The results are not sensitive to this classification.

the sensitivity to interest rates as the building societies. This greater interest rate exposure may be possible for larger commercial banks as they are able to undertake hedging activity through their trading books, allowing them to offset some of their exposures to rates.

The coefficients are both statistically and economically significant. For example, all else equal, for major banks (column (1)), a 100 basis points rise in short rates is associated with a rise in the NIM of around 0.035 percentage points per quarter, or 9.2% more income relative to the sample mean. Similarly, a 100 basis points rise in the yield curve slope would raise income by around 8% per quarter relative to the mean flow. Hence over interest rate cycles with variation in rates of this order of magnitude, the effects on income are economically significant.[12]

Our results also highlight the dynamic implications of interest rate *changes*. Table 3 clearly shows that DR^{3m} and $DSLOPE$ typically enter negatively and significantly. They are of a similar order of magnitude as the coefficients on the interest rate levels terms, and so are economically significant too. The negative short-run impact of interest rate changes suggests the presence of non-trivial short-run repricing frictions. Unexpected increases in rates initially compress banks' margins, and it is only in the long term, once re-pricing becomes possible, that higher interest rates contribute to higher NIMs. An implication of this finding is that the question of what the impact of a change in rates is in practice cannot be answered without taking a stance on (a) how yields of different maturities move relative to one another, and (b) how persistent their fluctuations are. In other words, one needs a macroeconomic model that tracks these factors jointly. We examine this issue in more detail in Section 8.1 by looking at yield curve dynamics extracted from a simple VAR.

6.2 Robustness analysis

The results discussed above reflect a number of modeling choices, some of which could have a material impact on the estimates. Our analysis is also subject to potential measurement issues: summarising the key features of the yield curve is not a trivial task. An accompanying supplementary appendix available upon request compares various estimation techniques ranging from OLS to GMM, as well as alternative instrumentation strategies within the GMM class. The supplementary appendix also deals with measurement issues; we replace the government bond yield used in our benchmark results with a three-month interbank rate, consider bonds with an intermediate maturity of three years, and replace observed market yields with measures of the level and slope of the UK yield curve based on a Nelson-Siegel model. Finally, in the supplementary appendix we also exploit the moderately 'large T' nature of our panel to investigate whether the implications of shifts in interest rates differ across banks. We find that such differences are typically not significant from a statistical point of view, and in any case uninteresting from an economic point of view. In short, pooling appears to be a valid choice and, subject to that, the key conclusions emerging from Table 3

[12]The magnitudes for building societies are smaller. For these institutions, the effect of a change in short rates is roughly half that of major banks, while the effect of a change in the yield curve slope is roughly two thirds that of major banks. Compare columns (3) and (4) in Table 3.

are robust with respect to both the specification of our regression model and the definition of the key covariates.

In order to gain a deeper understanding of the results in Table 3, a discussion in the supplementary appendix employs a break-down of market yields into (estimates of) expected real rates, inflation and term premia. Understanding whether the mechanism we identify operates through nominal or real interest rates is obviously important, not least because policymakers have far less control over the latter than the former. [13] The decomposition shows that income margins are driven mainly by term premia and inflation expectations and that real rates play essentially no role, supporting the conclusion that focusing on nominal rates is appropriate in this context.

7 Beyond NII: do interest rates affect profits?

It is all very well claiming that interest rates have systematic effects on net interest margins. But large banks manage their interest rate exposure through trading activities that aim, *inter alia*, to hedge interest rate risk. Were hedging 'complete', no interest rate effects would show up in final profitability, and the link between monetary policy and bank profitability that we are positing would be broken. To assess the extent of hedging activity, we turn next to trading book regressions, before examining operating profits directly.

7.1 The trading book

Our trading income data covers only major UK banks and is available since 1998 Q1. This results in around 27 observations for each of 19 banks. Trading income is much less persistent than other income flows, and it appears to be uncorrelated with most of the controls described in Section 4. We thus focus on fixed-effects regressions and adopt a more parsimonious specification than in the NIM case. We report the results in Table 4, with robust standard errors clustered by bank.

Columns (1)–(3) report trading income regressions for a truncated sample covering 1998 Q1– 2008 Q2, before the major eruption of financial distress in the UK system. Column (1) illustrates the level and slope of the yield curve are negatively but only marginally significantly associated with trading income flows. Column (2) adds the interbank spread to the model of column (1), which shows up strongly significantly and negatively. Column (3) combines the interbank spread and the three-month short rate to form the three-month interbank rate R^{ib}. The explanatory power of the interbank spread and the short-rate compound resulting in a significant negative effect of R^{ib} on trading flows. The yield curve slope also enters negatively and significantly in Column (3).

These negative terms therefore provide a natural offset to the positive effect of interest rates operating through the banking book. As discussed in Gorton and Rosen (1995), commercial banks may have strong incentives to attempt to hedge interest rate risk. Holding interest rate swaps, the income streams on which are reported in our trading income data, is

[13] The role played by nominal factors in driving banks' returns was at the centre of earlier work on the Nominal Contracting Hypothesis (see eg Flannery and James (1984)).

one means of doing this. These typically involve fixed-for-floating rate swaps. In this case, banks with short positions in interest rates pay floating rates and receive fixed rates – making them vulnerable to interest rate rises. The negative coefficient on short rates in model (3) is consistent with major banks taking these positions. The motive would be to achieve greater temporal match between interest receipts and payments, matching floating-rate liabilities to floating-rate assets. A second source of this effect may be through valuation effects of the traded securities themselves. As rates rise, future cash flows are more heavily discounted, reducing the mark-to-market value of securities held for trading.

A hedging interpretation may be attached to the negative coefficient on $SLOPE$ as well. The maturity profile of instruments held for hedging will often match that of the underlying exposure intended to be hedged. So where we observe a positive sign on the slope coefficient in the net interest income equation, we would expect, if anything, a negative sign on the slope coefficient in the trading equation to the extent that the bank intends to hedge across the maturity spectrum.

Extremely large moves in trading income were experienced during the crisis. The average trading book margin in our sample halved during the crisis, reflecting large losses experienced by some banks. The coefficient of variation for the whole sample is 7.2. Up to 2008 Q2 it was 6.5 but rose to 24 during the crisis. This extreme jump in volatility is likely to confound the identification of the interest rate effects in column (4), which uses the whole sample running until 2009 Q3.

7.2 Operating profit

Given the hedging motive and the evidence for active hedging through the trading book, what is the net impact of interest rates on operating profitability? We assess this by returning to our full specification running it instead on operating profits (before write-offs) normalised by (lagged) total assets, which forms a return on assets (ROA)-like variable. We report various specifications for major UK banks (for which we also have trading income data) in Table 5. All specifications report robust standard errors.

Columns (1) and (2) report static models, estimated via OLS and fixed effects respectively. They both point to positive significant impacts of yield curve level and slope on profitability, suggesting hedging through the trading book is incomplete: rates still matter for profitability. As with our NIM regressions, we next consider dynamic specifications, reported in columns (3) and (4) using OLS and fixed effects respectively. The signs of the coefficients are stable, even though the standard errors tend to be wider. We resort to System GMM regressions in columns (5) and (6). Again, we collapse the instrument set and control the lag limits in such a way as to prevent instrument proliferation. Column (5) includes an extra lag of the dependent variable and drops balance sheet growth and leverage as a means of further reducing the instrument count. In this model, the familiar pattern of interest rate effects is present and the implied effects are economically meaningful. Taking column (5) as a benchmark suggests a 100 basis points rise in short rates would raise the operating profit margin by around 0.04 percentage points per quarter. Relative to a mean

Table 4: Trading income. Major UK banks

	(1)	(2)	(3)	(4)
Sample:	1998-2008:2	1998-2008:2	1998-2008:2	1998-2009:3
GTA_{t-1}	0.00105***	0.00094***	0.00103***	0.00093**
	(3.26)	(3.01)	(3.22)	(2.43)
LEV_{t-1}	-0.00825	-0.00674	-0.00807	-0.00797^{+}
	(-1.34)	(-1.23)	(-1.31)	(-1.60)
R^{3m}	-0.00024^{+}	-0.00014		
	(-1.70)	(-0.86)		
$SLOPE$	-0.00022^{+}	-0.00026*	-0.00033**	-0.00026
	(-1.51)	(-1.87)	(-2.66)	(-1.46)
VOL^{FTSE}	-0.00075	0.00050	-0.00050	-0.00050
	(-0.73)	(0.38)	(-0.52)	(-0.31)
VOL^{ERI}	-0.00034	-0.00002	-0.00004	-0.00087
	(-0.32)	(-0.02)	(-0.04)	(-0.66)
Const	0.00866^{+}	0.00691^{+}	0.00886^{+}	0.00875*
	(1.67)	(1.53)	(1.66)	(2.05)
IB-Spread		-0.00107**		
		(-2.58)		
R^{ib}			-0.00031***	-0.00028^{+}
			(-3.01)	(-1.71)
N	511	511	511	558
Units	19	19	19	19
AvgT	26.89	26.89	26.89	29.37

$^{***},^{**},^{*},^{+}$ denote significance at 1%, 5%, 10%, and 15% respectively.

Table 5: Operating profit results (Major UK banks).

	(1) OLS	(2) FE	(3) OLS	(4) FE	(5) SysGMM	(6) SysGMM
$OpProf/TA_{t-1}$			0.23386**	0.01318	-0.07610	-0.03769
			(2.34)	(0.21)	(-0.67)	(-0.45)
$OpProf/TA_{t-2}$					0.00899	
					(0.15)	
GTA_{t-1}	-0.00034	-0.00051	-0.00085	-0.00033		
	(-0.45)	(-0.61)	(-0.82)	(-0.43)		
LEV_{t-1}	-0.01808**	0.00466	-0.01519***	-0.00013		
	(-2.54)	(0.57)	(-4.00)	(-0.02)		
GDP	0.00032	0.00056**	0.00035	0.00059**	0.00052*	
	(1.25)	(2.22)	(1.24)	(2.19)	(1.92)	
GDP_{t-1}	-0.00030	-0.00017	-0.00015	-0.00008	0.00003	
	(-0.94)	(-0.69)	(-0.56)	(-0.37)	(0.10)	
R^{3m}	0.00041**	0.00039**	0.00017	0.00025	0.00039**	0.00048***
	(2.10)	(2.39)	(1.02)	(1.55)	(2.10)	(3.20)
DR^{3m}	0.00030	-0.00006	0.00045	0.00001	0.00022	-0.00020
	(0.86)	(-0.19)	(1.34)	(0.03)	(0.70)	(-0.48)
DR^{3m}_{t-1}	-0.00006	-0.00023	-0.00020	-0.00033	-0.00062***	-0.00034
	(-0.24)	(-1.20)	(-0.67)	(-1.25)	(-2.59)	(-1.22)
$SLOPE$	0.00039**	0.00034**	0.00019	0.00027**	0.00048***	0.00052***
	(2.21)	(2.44)	(1.36)	(2.21)	(2.71)	(2.71)
$DSLOPE$	0.00006	-0.00011	-0.00005	-0.00017	-0.00034	-0.00037*
	(0.31)	(-0.52)	(-0.31)	(-0.85)	(-1.62)	(-1.78)
$DSLOPE_{t-1}$	-0.00003	0.00001	-0.00000	-0.00004	-0.00030	-0.00032
	(-0.15)	(0.05)	(-0.00)	(-0.18)	(-1.43)	(-1.29)
VOL^{libor}	0.00146	0.00109	0.00219	0.00142	0.00223*	
	(1.24)	(0.90)	(1.61)	(1.18)	(1.82)	
$GFSTEvolume$	0.00009	0.00034	-0.00012	0.00020	-0.00032	
	(0.20)	(0.84)	(-0.27)	(0.51)	(-0.75)	
Const	0.01662**	-0.00413	0.01447***	0.00071	-0.00009	0.00012
	(2.43)	(-0.52)	(3.74)	(0.12)	(-0.10)	(0.12)
N	720	720	702	702	677	702
Units		22		21	21	21
AvgT		32.73		33.43	32.24	33.43
Instruments					17.00	15.00
Hansen					3.14	5.55
Hansenp					0.37	0.48
AR2					-1.37	-0.25
AR2p					0.17	0.80

***,** ,*, denote significance at 1%, 5%, and 10% respectively.
Sample is major UK banks.
'OLS' denotes ordinary least squares estimation. 'FE' denotes fixed-effects estimation. 'SysGMM' denotes System GMM estimation.

quarterly operating profit margin of 0.27%, this constitutes a rise in the quarterly flow of profits of 14.4%. A 100 basis points rise in the slope of the yield curve would raise quarterly operating profit by around 18% relative to the mean. Over interest rate cycles where these swings in rates are plausible in magnitude, these constitute economically significant effects.

8 Applications

8.1 Profitability and monetary policy shocks

The coexistence of level and slope effects in the net interest income and trading income equations has an important general implication: in order to estimate the impact of changes in interest rates on bank profits, it is necessary to formulate an internally consistent model of how yields of different maturities move in response to economically interpretable macroeconomic shocks. Monetary policy shocks are an obvious candidate for this exercise: they typically account for a significant fraction of the volatility of the yield curve, especially at short maturities; they can be identified econometrically in a fairly reliable way; and they provide a direct link between our results and the evidence discussed in relation to DSGE models in section 2.

Focussing on unexpected changes in interest rates limits the scope of the analysis. Policy rates obviously move in response to changes in economic conditions, often in a predictable fashion, and any conclusion on the overall implications of e.g. a policy tightening ultimately depends on the assumptions one adopts on the role of its anticipated and unanticipated component (see eg. Cochrane, 1998). This means that the analysis carried out in this section does not fully capture the implications of a monetary policy decision, nor does it allow a comparison between the 'interest rate risk' stemming from genuine monetary shocks and that coming from policy decisions triggered by changes in fundamentals. At a minimum, though, the shocks can be seen as a narrative device that facilitates the interpretation of the dynamics revealed by our bank-level estimates.

We identify monetary policy shocks by estimating a medium-size vector autoregression (VAR). The model includes real output growth, consumer price inflation, and government bond yields with maturities of three months, three years and ten years, all of which are measured using the same data as above. To capture the small open economy nature of the United Kingdom, we also include three-month rates, inflation and output for the United States and the Euro Area. The VAR is estimated on quarterly data over the 1981 Q1-2009 Q4 period, using Bayesian techniques to cope with the relatively large dimensionality of the model. We rely on sign restrictions to identify monetary policy shocks (see eg Uhlig (2005)). In particular, we assume that a domestic monetary policy contraction depresses output growth and inflation in the United Kingdom and causes an increase in the three UK yields, but has no contemporaneous impact on the US and the Euro Area.[14]

The responses of the three-month, three-year and ten-year rates are displayed in Figure 3. Using these, we construct the impulse response for the net interest margin using the significant interest rate coefficients in Table 3 model (1) for major UK banks. For illustrative purposes, we assume that the initial shock is unanticipated, and its period-one effect is captured by the combined effect of the coefficients on R^{3m}, DR^{3m}_{t-1} and $SLOPE$. Thereafter, we assume that the model of the economy is known, such that the subsequent time profile for interest rates is known. In this case, since no further unexpected shocks occur, the paths for R^{3m}_t and $SLOPE$, together with the AR(1) dynamics of the estimated equation govern the path for the net interest margin. Figure 4 plots the result, together with a confidence interval computed using the 95% confidence band for interest rates generated by the VAR.[15] The similarity between Figure 4 and Figure 2 is striking. As Figure 4 shows, the short-run effect of the rise in interest rates is to compress the bank's interest margin. We interpret

[14] A supplementary appendix available on request provides more details on data, estimation and identification.

[15] That is, the figure abstracts from parameter uncertainty around our estimates of the effects of interest rates on the net interest margin.

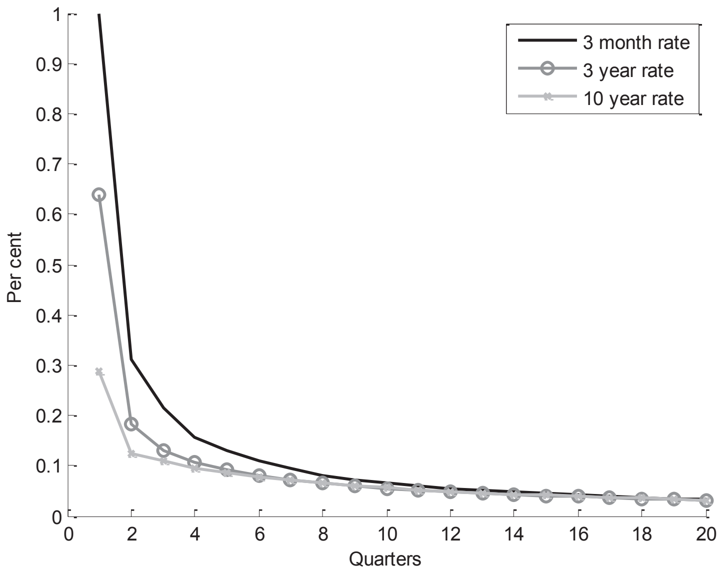

Figure 3: Estimated responses of three-year and ten-year rates to 100 basis points positive shock to three-month rates

this as evidence in favour of repricing frictions. The short-run negative effect is persistent mainly due to the AR(1) nature of the NIM equation, though the flattening of the yield curve also provides a drag on income. As the bank becomes able to reprice, it can pass on higher funding costs to borrowers, and shrink its asset base, raising the margin. In the long run, the effect converges to zero as interest rates return to their equilibrium levels.

8.2 Net interest margins and bank behaviour since 1992

Figure 5 decomposes major UK banks' NIMs using model (1) in Table 3. There has been a clear downward trend in the average NIM, as declining interest rates prompted banks to expand credit provision, scaling up their balance sheets. An interest rate cycle is clearly visible. In the beginning of the sample, reductions in short rates following the early 1990s recession pushed down on margins, but a steepening yield curve provided an offsetting source of revenue. The yield curve 'buffer' declined as rates rose in the lead up to Bank of England independence in 1997, while during the late 1990s an inverted curve largely offset the positive effect of short rates. As inflationary pressures subsided in the early 2000s, short rates came down and margins were further compressed, reinforced by a further period of yield curve inversion in the mid-2000s. The fitted values of the model suggest aggressive falls in short rates following the financial turmoil in 2008 should have compressed margins still further. But the data and the model diverge around this exceptional period: banks' margins were maintained above the level predicted by the model. It is likely that banks were unwilling to pass on rate cuts to borrowers as the crisis continued and credit risk was anticipated to rise. A positively-sloped yield curve propped up the income margin in 2009. According to our model, however, the marginal impact of Quantitative Easing on net interest margins must have been negative. Joyce *et al* (2010) estimate that asset purchases by the Bank

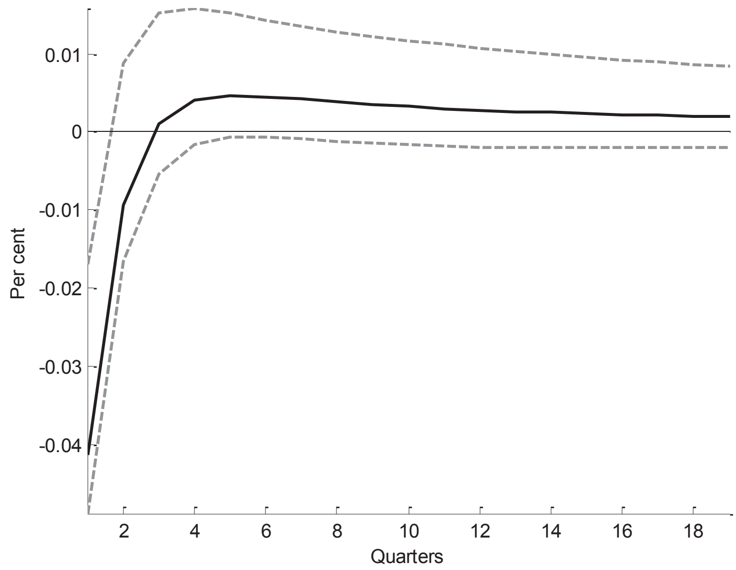

Figure 4: Impulse response of net interest margin (NII/A) to 100 basis points positive shock to the three-month rate, accounting for effects on long rates.

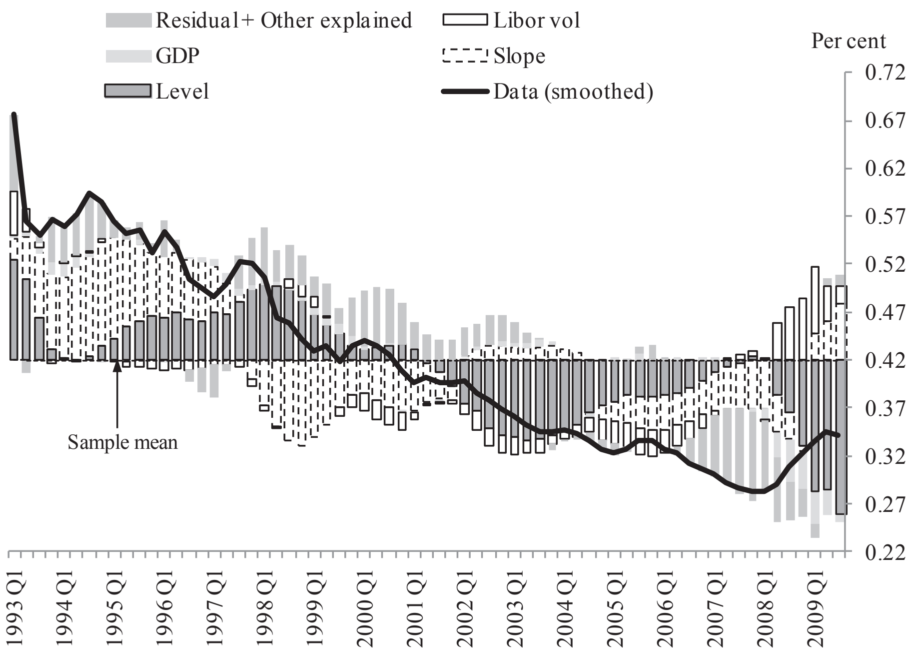

Figure 5: Decomposition of major UK banks' mean NIM, 1992-2009, based on model (3) in Table 3. The chart shows contributions of various macro and balance sheet factors in driving the NIM away from its sample mean

Table 6: Major banks mean profitability; % changes in components over different time periods

	OpProf/TA	OpProf/K	Leverage (TA/K)	NIM
Full sample	-68.5%	-82.2%	-43.6%	-70.7%
1997-2009	-46.7%	-47.7%	-1.9%	-28.9%
2002-09	-47.6%	-52.3%	-9.1%	-15.0%
Boom (1997-2006)	-24.2%	-2.7%	28.4%	-35.9%
Crisis (2007-09)	-20.0%	-34.5%	-18.1%	14.5%

TA = total assets; K = equity; NIM = net interest margin; OpProf = operating profits before write-offs.

of England lowered long-term yields by 100 basis points. A simple back of the envelope calculation suggests that, ceteris paribus, the implied reduction in net interest income for 2009 would have been of the order of £9 billion.

We also know that the period under study exhibited a significant build up in financial vulnerability. The long cycle in rates and the concomitant decline in bank margins may have prompted banks to adopt riskier business models, principally through taking on higher leverage. As our empirical results show, declining interest rates fed through into bank profitability, compressing banks' return on assets (ROA). But return on equity (ROE) did not decline, partly due to a well-known increase in leverage. Table 6 decomposes profitability for the 'average' major UK bank into the contributions made by NIM, leverage and ROE. It is a simple decomposition of the data expressed in percentage changes. As the table shows, for example, the NIM declined by around 70% over the full sample, consistent with Figure 5.

The table presents the decomposition over various subperiods. While the NIM declined substantially over 1997-2009, leverage was roughly flat over this period, such that ROE and ROA both fell too. But of course this period contains both boom and bust periods. The 'boom' sub-sample covering 1997-2006 illustrates banks' response to downward pressure on their NIMs. While ROA fell by around 24% over the boom, ROE remained stable. To maintain this steady ROE, leverage ballooned. In our sample, it grew by around 30% between 1997 and 2006. When the crisis struck, the pattern was reversed: a strong deleveraging was resisted by growth in the average NIM. But the scale of losses incurred elsewhere in the portfolio of banking activities ensured that ROE fell dramatically.

These changes suggest that increasing leverage generated significant (non risk adjusted) private returns during the boom. Our profits equation allows us to obtain a rough estimate of the magnitude of this private incentive. When we normalise profits before write-offs by equity and run our panel model, we find a positive and significant effect of leverage on this ROE-like variable (Table 7). We estimate the private incentives to raise leverage to be strong. For example, based on the fixed-effects regression reported in column (2), a doubling of leverage from five to ten would raise ROE by around 19% relative to the quarterly sample mean. A further doubling from ten to 20 would raise ROE before write-offs by around 10% relative to the quarterly sample mean. Our estimates support the idea that the private non risk adjusted returns to risk-taking through excessive leverage were significant.

Table 7: Operating profit over equity ('ROE') regressions. 'OLS' denotes ordinary least squares estimation. 'FE' denotes fixed-effects estimation. 'SysGMM' denotes System GMM estimation.

	(1) OLS	(2) FE	(3) FE	(4) SysGMM	(5) SysGMM
$OpProf/K_{t-1}$	0.40900***	0.29181***	0.29064***	0.17472*	0.20118*
	(5.08)	(3.31)	(3.36)	(1.84)	(1.96)
$OpProf/K_{t-2}$				0.13506***	0.15868***
				(4.50)	(5.92)
GTA_{t-1}	-0.00370*	-0.00268	-0.00176	-0.00096	-0.00039
	(-1.93)	(-1.28)	(-0.83)	(-0.55)	(-0.20)
LEV_{t-1}	0.01917*	0.05246***	0.05089***	0.05955**	0.04610^{+}
	(1.94)	(4.00)	(3.86)	(2.29)	(1.51)
R^{3m}	-0.00067	0.00061	0.00042	-0.00075	-0.00079
	(-0.62)	(0.61)	(0.38)	(-0.55)	(-0.62)
$SLOPE$	-0.00091	0.00034	0.00015	-0.00078	-0.00082
	(-0.74)	(0.41)	(0.21)	(-0.48)	(-0.57)
GDP			0.00308		
			(1.11)		
GDP_{t-1}			-0.00256		
			(-1.16)		
VOL^{libor}			0.01425		
			(1.07)		
VOL^{FTSE}			-0.00379		
			(-0.21)		
VOL^{ERI}			-0.01271^{+}		
			(-1.63)		
$GFSTEvolume$			0.00189		
			(0.44)		
$CONC$			-0.11048		
			(-0.80)		
Const	0.00069	-0.03295**	-0.02129^{+}	-0.03296	-0.02195
	(0.06)	(-2.34)	(-1.48)	(-1.40)	(-0.77)
N	1353	1353	1331	1302	1302
Units		40	40	40	40
AvgT		33.83	33.27	32.55	32.55
Instruments				236	45
Hansen				30.09	32.78
Hansenp				1.00	0.71
AR2				-1.03	-1.18
AR2p				0.30	0.24

Whole sample. ***,**,*,$^{+}$ denote significance at 1%, 5%, 10% and 15% respectively.

9 Conclusion

We investigate the systematic effect of interest rates on bank profitability using a new, unique panel data set containing information on the UK activities of UK and foreign banking groups for 1992 Q1 - 2009 Q3. The distinguishing features of our empirical analysis are that we model both interest income and trading income, we explicitly disentangle long-run and short-run dynamics, and we link our analysis of interest income flows to a partial-equilibrium model of bank behaviour. We find that high interest rates are associated with large interest income margins, and that the slope of the yield curve matters for interest income. Level and slope affect net interest income and trading income in the opposite direction, which is consistent with banks hedging interest rate risk through derivatives. Even after accounting for hedging, though, large banks appear to retain a residual exposure to UK interest rates.

We also provide evidence that maturity mismatches and repricing frictions matter, and that a rise in interest rates can temporarily decrease banks' income margins. Thanks to the coexistence of (a) level and slope effects and (b) long and short-run multipliers, our model provides a rich picture of the implications of a monetary policy shock on banks' profits. A typical policy tightening raises short-term rates and flattens the yield curve, thus depressing banks' income through two distinct channels. This effect is fairly short-lived, and somewhat attenuated by hedging. Higher rates have an unambiguously positive effect on bank profits in the long run. To the extent that they succeed in lowering long-term yields, unconventional monetary policy interventions based on asset purchases are predicted to depress income margins.

These results support that the stylised representation of banks used in the DSGE literature, which focuses on traditional banking activities, captures an aspect of banking that remains relevant despite the deep structural changes observed in recent years, such as the growth of trading and securitisation. They also point to the importance of explicitly accounting for pricing frictions in credit markets - an issue that has proved to be relevant and controversial in the DSGE debate.

Finally, our work suggests that monetary policy can have systematic effects on banks' profitability, and hence on their capital. This conclusion provides one possible motivation for the use of an independent macroprudential tool, and points to the existence of non-trivial interactions between the two instruments that should ideally be internalised by the policymaker.

A Proof of Proposition 1

Proof. Steady state interest rates are given by

$$r^l = \mu^l \left[(1-\lambda) r + \lambda r^\tau \right]$$
$$r^d = \mu^d r$$
$$r^b = \mu^b r^\tau$$

Then

$$NIM = \mu^l \left[(1-\lambda) r + \lambda r^\tau \right] - (1 - v - \lambda) \mu^d r - \lambda \mu^b r^\tau$$

Using this:

(a) Consider a rise in the short rate, r. Then

$$\frac{\partial NIM}{\partial r} = \mu^l (1-\lambda) - (1-v-\lambda) \mu^d$$
$$= \left[\mu^l - (1-v) \mu^d \right] - \lambda \left(\mu^l - \mu^d \right)$$

Note that the first term is always positive, as in a model excluding term debt ($\lambda = 0$). When $\lambda > 0$ there is an additional term, which captures the bank's ability to switch out of short term into long term debt. The final term is negative by $\mu^l > \mu^d$. However, note that $\frac{\partial NIM}{\partial r} > 0$ if:

$$\frac{\mu^l}{\mu^d} > \frac{1-v-\lambda}{1-\lambda}$$

The left hand side is greater than unity by $\mu^l > 1 > \mu^d$, while the right-hand side is less than unity by $v > 0$. Therefore the NIM will always be increasing in the short rate r in steady state.

(b) Consider a rise in the term premium $r^\tau - r$. For given r,

$$\frac{\partial NIM}{\partial r^\tau} = \left(\mu^l - \mu^b \right) \lambda$$

If the bank has monopoly power in term debt markets and is able to issue at $\mu^b r^\tau < r^\tau$, then the NIM is always increasing in the term premium by $\mu^l > 1 > \mu^b$. If not, then the impact on the term premium on the NIM depends on the relative competitiveness of bank loan and bank debt markets. Where banks' monopoly power in loan markets exceeds that in debt markets ($\mu^l > \mu^b$), then the NIM is increasing in the term premium. ■

B Steady state calibration for simulations

For the bank's two balance sheet ratios v, λ to be met in steady state requires that

$$\delta_k = \frac{\pi}{K} = \left(r^l - r^d \right) \frac{1}{v} - \left(r^b - r^d \right) \frac{\lambda}{v} + r^d$$

We also require a demand curve for aggregate loans, and a supply curve for term debt. For these, suppose:

$$\bar{l}_t = \frac{m_l}{1+\bar{r}^l_t}, \quad \bar{b}_t = m_b (1 + \bar{r}^b_t)$$

For the quantity of bonds to be consistent with the liquidity ratio, we need to choose m_b/m_l such that

$$\frac{\bar{b}_t}{\bar{l}_t} = \lambda = \frac{m_b(1+\bar{r}_t^b)\left(1+\bar{r}_t^l\right)}{m_l} \Rightarrow m_b = \frac{m_l}{(1+\bar{r}_t^b)\left(1+\bar{r}_t^l\right)}\lambda$$

Table 1 in the text contains the parameter values we use to simulate the model.

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