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## The bank lending channel reconsidered

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Alistair Milne – Geoffrey Wood

# **The bank lending channel reconsidered**



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## **The bank lending channel reconsidered**

The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Bank of Finland.

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# The bank lending channel reconsidered

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## Abstract

It has been widely accepted that constraints on the wholesale funding of bank balance sheets amplify the transmission of monetary policy through what is called the ‘bank lending channel’. We show that the effect of such bank balance sheet constraints on monetary transmission is in fact theoretically ambiguous, with the prior expectation, based on standard theoretical models of household and corporate portfolios, that the bank lending channel attenuates monetary policy transmission.

We examine macroeconomic data for the G8 countries and find no evidence that banking sector deposits respond negatively and more than lending to tightening of monetary policy, as the accepted view of the bank lending channel requires. The overall picture is mixed, but these data generally suggest that deposits fluctuate procyclically and somewhat less over the business cycle than bank lending, and that total bank deposits, unlike bank lending, show little direct response to changes in interest rates. This suggests it is very unlikely that the bank lending channel amplifies monetary policy. Our paper has thus corrected a misunderstanding about the role of banks in monetary policy transmission that has persisted in the literature for some two decades.

Keywords: credit channel, monetary transmission, bank financing constraints

JEL classification numbers: E44, E52, G32

# Uudelleenarviointi: pankkien merkitys rahapolitiikan vaikutusten välittymisessä

Suomen Pankin keskustelualoitteita 2/2009

Alistair Milne – Geoffrey Wood  
Rahapolitiikka- ja tutkimusosasto

## Tiivistelmä

Suhteellisen yleisen käsityksen mukaan pankkeihin kohdistuvat tukkumarkkinoiden rajoitteet niiden rahoittaessa taseitaan voimistavat rahapolitiikan vaikutuksia taloudessa. Tässä yhteydessä puhutaan tavanomaisesti rahapolitiikan vaikutusten pankkikanavasta osana rahapolitiikan yleistä välittymismekanismia. Tässä työssä osoitetaan, että näiden rahoitusrajoitteiden vaikutukset rahapolitiikan välittymiseen ovat itse asiassa teoreettisesti epäselviä, vaikka tavanomaiset kotitalouksien ja yritysten varallisuuden määräytymistä selittävät teoreettiset mallit puoltavatkin ennakkokäsitystä pankkikanavasta rahapolitiikan vaikutuksia voimistavana tekijänä. Työn empiirisessä osassa tutkitaan G8-maiden tilastohavaintoja, joiden ei katsota tukevan oletusta, että pankkisektorin talletukset reagoisivat rahapolitiikan kiristämiseen negatiivisesti ja voimakkaammin kuin lainananto. Tämä oletus on sen käsityksen mukainen, että pankkikanava voimistaa rahapolitiikan vaikutuksia. Empiirinen näyttö ei kaiken kaikkiaan ole yksiselitteistä, mutta viittaa siihen, että talletukset vaihtelevat myötäsyklisesti ja jonkin verran lainanantoa vaimeammin. Toisin kuin pankkien lainananto, pankkitalletusten kokonaismäärä ei myöskään näytä merkittävästi reagoivan koron muutoksiin. Näiden tulosten perusteella ei ole ilmeistä, että pankkikanava voimistaa rahapolitiikan vaikutuksia. Tämä tutkimus siis osaltaan korjaa alan kirjallisuudessa jo muutaman vuosikymmenen vallinnutta väärinkäsitystä pankkien merkityksestä rahapolitiikan välittymisessä.

Avainsanat: luottokanava, rahapolitiikan välittyminen, pankkien rahoitusrajoitteet

JEL-luokittelu: E44, E52, G32

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# 1 Introduction

In any developed modern economy, bank balance sheets comprise a major part of the money stock. For example, at the end of 2006 bank deposits amounted to 83.8% of broad money (M3) in the United States, 101.3% of broad money (M3) in the Euro Area, and 121.6% of broad money (M4) in the United Kingdom.<sup>1</sup> Bank lending to the private sector constituted 70.6% of US broad money, 136.4% of Euro area broad money and 150.7% of UK broad money.<sup>2</sup> The behaviour of bank lending and bank deposits is therefore clearly important to policy makers. Nevertheless, despite a large volume of research, there is still no clearly established consensus about the response of banks to changes in monetary policy.

Much of the literature adopts the following perspective. The monetary authorities tighten monetary policy by reducing available reserves at the central bank. This in turn induces a contraction in broader measures of money by reducing ‘reservable’ deposits ie those deposits against which reserve requirements are calculated. This monetary contraction then operates through two different channels.

The first is the standard interest rate channel of monetary policy. Banks are prepared to pay more for overnight borrowing of reserves. Rates of return on non-bank assets must also rise, in order to persuade non-banks to hold less wealth in the form of reservable deposits. Over time these higher interest rates lower the demand for bank loans and also reduce the cash flows of firms and companies borrowing at short term rates of interest. As a result the rate of growth of aggregate demand and output and the rate of inflation decline.

Many argue that a second channel, the ‘bank lending’ channel, operates when at least some banks are liquidity constrained. Following a reduction in reserves and bank deposits, constrained banks are unable to substitute wholesale market funding for lost reservable deposits and so must reduce their lending by more than unconstrained banks. If some of their borrowers are also bank dependent, ie cannot themselves substitute other non-bank sources of finance for bank loans, then the consequence of this reduced loan supply is a larger decline in bank lending than would result from the interest rate channel alone.

This argument for an additional role for a ‘bank lending’ channel of monetary policy was originally developed by Bernanke and Blinder (1988), amending the standard ISLM model to incorporate an additional balance sheet induced contraction of the supply of credit, and by Stein (1998), who develops the model in a more rigorous fashion incorporating an adverse selection problem in the bank

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<sup>1</sup> All data in this paragraph are computed from International Financial Statistics, October 2007.

<sup>2</sup> The bank lending figures for the UK and Euro area substantially exceed the bank deposit base. The US is not so much different once allowance is made for loans repackaged into asset backed securities.

funding market. Investigations of the bank lending channel are reported by Bernanke and Blinder (1992), Kashyap and Stein (1995), Kashyap and Stein (2000) and several other researchers. Kashyap and Stein (2000) conclude, from their examination of a large panel of US bank accounting data, that amongst the smaller banks in their sample those that have lower liquidity ratios and therefore more likely to be constrained in their access to wholesale funding, do indeed respond more to changes in monetary policy than banks with higher liquidity ratios. However the results of several other empirical studies (for example Ehrmann et al, 2003) provide only mixed support for the prediction that constrained banks respond more to monetary policy than unconstrained banks.

Our paper reconsiders this bank lending mechanism. We show – in the analysis developed in Section 4 and Appendix 2 below – that this standard exposition of the bank lending channel is flawed, assuming as it does that monetary tightening results in an net increase in the demand of banks for wholesale funding. The correct logic, allowing for the possibility that bank demand for wholesale funding may either rise or fall following an increase of interest rate, is as follows:

- (i) If higher interest rates reduce the supply of bank deposits more than the demand for bank lending then constrained banks become more financially constrained, their effective marginal cost of funding rises, and their loan rates and volume of lending both decline by more than those of unconstrained banks. The bank lending channel then amplifies the interest rate impact of monetary policy.
- (ii) If higher interest rates reduce the demand for bank lending more than they reduce the supply of deposits then the opposite outcome emerges: constrained banks become less financially constrained, their effective marginal cost of funding falls, and their loan rates and volume of lending decline by less than those of unconstrained banks. The bank lending channel then attenuates the interest rate impact of monetary policy.

We will further argue that this correction to the understanding of the bank lending channel can have significant policy implications in situations, such as the present time, when bank funding is under strain.

We develop this argument as follows. The two sections following this introduction provide some supporting preliminary discussion. Section 2 reviews the principal contributions to the existing literature on the bank lending channel (Appendix 1 provides a fuller review of the large empirical literature). We argue in this section that the empirical results of Kashyap and Stein (2000) can be interpreted as reflecting either an amplifying or attenuating impact of the bank lending channel. Their work, while using a rich microeconomic data set, does not resolve the ambiguity of the sign of the bank lending channel.

Section 3 discusses a departure that we make from previous theoretical models of the bank lending channel. This is our assumption that the monetary policy instrument is the short term interest rate, not the stock of reserves with the central bank. We note that while reserves with the central bank (whether mandatory or not) play an essential role in the implementation of monetary policy, it is usually more convenient, as well as more in line with actual central bank practice, to treat reserves as we do as passively responding to the stock of reservable deposits.

Following these preliminaries Section 4 then discusses the extension of standard models of banking sector equilibrium to incorporate the impact of the level of market interest rates on bank funding, ie on the flows of bank lending, deposits, and wholesale borrowing, and hence on the margins between market and bank interest rates. We show that the margins between bank lending rates and market rates vary with the level of market rates when banks are ‘financially constrained’ ie when banks cannot freely access markets for wholesale borrowing; but that the impact of market interest rates on these margins is ambiguous, depending upon whether an increase of market interest rate produces a net increase or decrease in bank reliance on wholesale funding. Appendix 2 provides a full statement of our model and an extension to the case of imperfect substitution between loan and deposits and financial constraints that affect some banks but not others.

Sections 5 attempts to resolve the ambiguity in the sign of the bank lending channel through an empirical examination of aggregate quarterly data for the G8 OECD economies from 1970Q1 onwards (the sources of these data are described in Appendix 3). We first report the time series behaviour of bank deposits and loans, showing that in all countries the unconditional volatility of loan growth is higher than that of deposits; that is to say, in periods of monetary expansion loans grow by more than deposits while in periods of monetary contraction they fall by more than deposits. We also conduct vector auto regression analyses of the relationships between interest rates, bank deposits, bank lending, and nominal GDP and report the resulting impulse response functions for the relationship between interest rates, bank deposits, and bank lending. The results are far from clear cut, but they are consistent with the view that lending responds more strongly and often earlier than bank deposits to a shift in monetary policy. This implies that, if the deposits and loans of constrained banks behave similarly to those of the banking sector as a whole, then the bank lending channel will attenuate the impact of monetary policy.

Section 6 summarises our findings and provides some further discussion of the interaction between the bank lending channel and the closely related ‘bank capital channel’. The conventional exposition of the bank lending channel assumes that liquidity constraints do not alter in response to a shift in monetary policy. The ‘bank capital channel’ introduces the possibility that liquidity

constraints may become more binding following a tightening of monetary policy and become less binding following a loosening of monetary policy. Our analysis of the interaction between the bank lending channel and the bank capital channel also allows us to discuss the conduct of monetary policy in periods when the banking sector becomes critically undercapitalised, for example in Japan in the 1990s, and worldwide following the ‘credit crunch’ of the summer of 2007. We find that undercapitalisation and expectations of continued low growth of bank income can reinforce the attenuation of monetary policy created by the bank lending channel, leading in the most extreme cases to a deflation which monetary policy alone is powerless to escape.

## 2 The conventional view of the bank lending channel

This section restates the theory of the bank lending channel and assesses the most widely cited empirical study of its size, sign, and importance. The original theoretical presentation is Bernanke and Blinder (1988). They assume that banks hold three assets – reserves, loans, and short term bonds – and issue one liability – bank deposits. Loans and bonds are imperfect substitutes, both as sources of finance to borrowers and as assets held in bank portfolios. In consequence the stock of bank credit depends on the spread between bank loan and bond market rates of interest.

Bernanke and Blinder then discuss the implications for monetary transmission in an ISLM setting, arguing that a tightening of monetary policy results not only in the standard leftward shift in the LM curve but also at the same time – as bank loan rates increase in response to the monetary policy tightening and thus reduce the supply of investible funds to the market – in a leftward shift in the IS curve. They argue that the impact of bank balance sheets is thus to *amplify* the transmission of monetary policy. They note that the IS curve will be affected by disturbances to the supply or demand for bank credit (both of which will affect bank loan rates independently of market rates of interest) and argue that credit stock targeting can be preferable to monetary targeting when money demand is relatively unstable compared to credit demand.

In Stein (1998), in contrast to Bernanke and Blinder (1988), it is bank liability management rather than bank asset management that plays a key role in monetary transmission. This is a more formal model of the capital market frictions limiting bank access to wholesale market funding. His banks hold two assets – reserves and loans – and issue two liabilities – insured deposits and wholesale market liabilities (eg certificates of deposit). He considers a separating equilibrium generated by adverse selection between smaller more opaque banks, unable to

access wholesale liabilities and therefore relying exclusively on deposits for funding their lending, and larger transparent banks, able to access additional wholesale liabilities freely at market rates of interest.

Stein (1998), like Bernanke and Blinder (1988), concludes that the impact of bank balance sheets on loan supply amplifies the impact of monetary policy, but his model predicts that this amplification will be limited to constrained banks that are unable to substitute wholesale finance for a monetary policy induced reduction in bank deposits. He also points out that for these constrained banks a disturbance to bank deposits, eg an inflow of deposits financed by sale of other assets, will affect the supply of bank credit.

A substantial empirical literature – reviewed in Appendix 1 – investigates the magnitude of this bank lending channel. This literature has reached a consensus on one point – that it is extremely difficult to separately identify the impacts of bank loan supply and bank loan demand using aggregate data. Therefore the more informative empirical studies use individual bank accounting data. It is however widely accepted that even with individual bank data it is difficult to disentangle the impact of loan demand and loan supply. As a result there is not yet a consensus on the importance of the bank lending channel in monetary transmission.

The most widely cited of the micro-econometric studies of the bank lending channel is Kashyap and Stein (2000).<sup>3</sup> Their data comprise the US call report data available for all US commercial banks. This source provides Kashyap and Stein (op. cit.) with nearly one million bank-observations covering 1976Q2 to 1993Q2. Their specification seeks to control for the impact of bank loan demand by examining, in particular, differences in behaviour between large and small banks.

They apply a two-stage estimation procedure. In the first stage they estimate cross-sectional regressions of the change in the log of bank lending, using four lags of the dependent variable together with Federal Reserve district dummy variable and the lagged value of the ratio of securities plus federal funds sold to total assets (their bank liquidity ratio). In the second stage they conduct univariate times series regressions, regressing the coefficient on the bank liquidity ratio – estimated from the first-stage cross-sections for each time period – on the current and four lagged values of a measure of the stance of monetary policy plus a linear time trend and also (in an extended bivariate specification) on the current and four lagged values of the growth of GNP.

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<sup>3</sup> While we reinterpret their results, we must praise the highly professional attitude taken by Kashyap and Stein (2000) towards the public dissemination of their data. They went to considerable lengths to correct for breaks in the call report data. The documentation of their data work together with the complete and updated US call report data is maintained on the Federal Reserve Bank of Chicago website. This resource offers the opportunity for further research, testing directly the relationship between bank funding and monetary transmission.

They conduct this estimation procedure for two measures of bank lending, commercial and industrial loans and total loans, and for three alternative indicators of the stance of monetary policy: the negative of the Federal-Funds rate; the Boschen-Mills (1995) indicator of the stance of monetary policy based on the reading of FOMC documents; and the Bernake-Mihov (1998) indicator of the stance of monetary policy based on a general VaR specification (in all cases a higher value of the monetary policy indicator represents a loosening of monetary policy.) They also estimate separately for three different size classes of banks: small banks falling in the 0–95th percentile of the size distribution; middle sized banks falling in the 95–99th percentiles of the size distribution; and large banks in the 99–100th percentile, and for both their univariate (monetary policy only) and bivariate (monetary policy plus GNP growth) second stage specifications.

Their discussion highlights the sum of the second stage coefficients on the current and lagged indicator of the stance of monetary policy, reported in their Table 3 page 417. They find that for large banks the sum of these coefficients is always positive and in most cases statistically significant at the 5% or 1% level ie following episodes of monetary policy tightening (when the monetary policy indicators are negative) there is a negative relationship between liquidity and growth of bank lending (so large banks with more liquid balance sheets are revealed to have reduced their lending by more than large banks with less liquid balance sheets). For small banks they obtain precisely the opposite result, the sum of the second stage coefficients on the indicator of the stance of monetary policy is always negative and mostly statistically significant. For both large and small banks these coefficient estimates are larger and of even greater statistical significance in the bivariate version of the second stage specification, including also current and lagged GNP growth. For commercial and industrial lending the difference in the sum of coefficients between small and large banks, is always statistically significant at the 1% level. For total lending the difference in coefficients is statistically significant at this level only in the bi-variate specification, not in the univariate specification.

Kashyap and Stein (2000) summarise their results as follows (page 425): ‘Within the class of small banks changes in monetary policy matter much more for the lending of those banks with the least liquid balance sheets.’ They place particular emphasis on the major coefficient differences between large and small banks, on the grounds that loan supply effects should be relatively unimportant for large banks and hence that the difference in estimates between small and large banks are a relatively clean estimate of loan supply impacts uncontaminated by the impact of loan demand. They conclude that their analysis reveals strong empirical support for a statistically and quantitatively important link between bank liquidity and bank loan supply of the kind set out in Stein (1998) ie that the bank lending channel does amplify monetary policy transmission.

Do the findings of Kashyap and Stein (2000) resolve the question of whether the bank lending channel amplifies or attenuates the impact of monetary policy? The answer is no, they do not. Their findings, while consistent with the view that small financially constrained banks are forced to respond more to changes in monetary policy than are small financially unconstrained banks, can readily be re-interpreted as reflecting an entirely different mechanism. Many small banks, for reasons of either commercial interest or concern for the welfare of their customers, offer implicit hedging of loan interest rate risk. Such banks will maintain narrow interest margins and offer their customers relatively cheap lending facilities during periods of tight monetary policy, in return for offering somewhat less generous lending rates, and operating with relatively high interest margins, during periods of loose monetary policy. Only small banks with strong community presence and ongoing rather than transient customer relationships can operate in this way. Such banks can be expected also to hold a relatively high proportion of liquid assets, to permit the resulting variability of their net interest income over time. This is a simple alternative explanation of the Kashyap and Stein (2000) finding that more liquid small banks respond less to monetary policy than less liquid small banks, but this explanation has nothing to do with the impact of financial constraints of the bank lending channel. Their research, while providing valuable insight into bank behavior, provides no conclusive evidence on the sign of the bank lending channel.<sup>4</sup>

Can the results of Kashyap and Stein (2000) and other related studies be interpreted as arising because liquidity constraints bind more tightly during periods of monetary contraction and less tightly during periods of monetary expansion? The empirical tests conducted in this literature are inappropriate for testing this hypothesis. If monetary policy is amplified by a tightening of bank liquidity constraints then the largest impact should *not* be observed for the smallest, most illiquid, and least capitalized banks, since these are already the most severely liquidity constrained, but for banks at intermediate levels of size, liquidity, or capitalization for whom liquidity constraints begin to bind.

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<sup>4</sup> Kashyap and Stein (2000) were aware of this possible bias. On pages 415–416 they note that the difference in coefficient estimates for small banks could reflect not amplification of monetary policy via the bank lending channel but heterogenous risk aversion, with some relatively ‘conservative’ banks responding less to monetary policy and at the same time operating a more liquid balance sheet, in comparison to other less ‘conservative’ banks. Their defense against this criticism is to argue (a) that there is another bias running in the opposite direction, with some banks with relatively cyclically sensitive portfolios also preferring to hold a more liquid balance sheet (b) with the further maintained assumption that large banks can never be liquidity constrained, their finding that the lending of large liquid banks respond *more* to monetary policy than that of large illiquid banks shows that the second of these two biases dominates the first. However this does not settle the matter since it is possible that even large banks can be liquidity constrained. In this case the observed coefficients estimates for large banks could arise because there is an attenuation of the monetary policy response of less liquid large banks.



### 3 The role of bank reserves in monetary policy

This section explains our decision to assume that the instrument of monetary policy is the short term interest rate, with required reserves responding passively to changes in deposits. Reserve requirements do not matter for the transmission of monetary policy, at least in developed financial systems. They are effectively a tax on commercial banking operations, with the tax rate depending on the extent that they are unremunerated, the level of short term interest rates, and the excess reserves they lead banks to hold over what they would hold from commercial prudence. But the level of this tax is too small to make much difference to banks choice of assets and liabilities and in any case central banks in developed financial markets do not alter required reserve ratios as part of their conduct of monetary policy. Banks determine their lending and funding decisions according to their view and those of the financial markets on the future course of market interest rates; and also on the ability of banks to obtain finance from these markets and the terms on which this finance is made available.

In our analysis of monetary transmission we could assume that either the supply of reserves or the short term rate of interest is the policy instrument. The level of short term policy rates  $r$  determines the demand for bank deposits  $D(r)$  and hence, for a required reserve ratio of  $\beta$ , the demand for reserves  $R(r) = \beta D(r)$  with the central bank. Provided this function  $R(r)$  is one-to-one mapping then any monetary policy can be described either in terms of movements in reserves or of short term interest rates. It is a matter only of modelling convenience which approach is used. Applied correctly both must yield the same answer.

The choice of monetary instrument, between a monetary stock (whether the monetary base or some broader measure of money) or an interest rate (whether overnight or at some longer time horizon), is not just a matter of convenience in a stochastic setting. If economic relationships are disturbed by shocks that arrive after the decision over the monetary policy instrument is made, then one instrument may be more successful than another in achieving the ultimate policy target (see Poole, 1970). This important insight does not matter to our analysis, since our model is, for the sake of tractability, deterministic.<sup>5</sup>

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<sup>5</sup> The supply of reserves by the central bank also plays a further important role in stressed market situations, for example following those following the 9/11 terrorist attacks or in the wake of the credit crisis of the summer of 2007, which produce a sudden and unanticipated increase in demand for safe liquid assets. In these situations the central bank must by a classic lender of last resort operation provide additional liquidity in order to maintain confidence in bank liabilities. Such liquidity shocks do not need to be modelled in order to understand the role of banks in monetary transmission, for the central bank response is explicitly intended to prevent any change in monetary policy stance.

## 4 An alternative view: bank balance sheets as an attenuator of monetary policy transmission

This section examines how changes in monetary policy, operating through the policy interest rate (denoted by  $r$ ), affect both the volumes of bank loans, deposits and wholesale funding (denoted by  $L$ ,  $D$  and  $W$ ) and bank interest rates on these assets and liabilities (denoted by  $r_L$ ,  $r_D$ , and  $r_W$ ). Banks compete with financial markets on both sides of their balance sheets and so a change in the market rate of interest directly affects both the demand for bank loans and the supply of deposits and wholesale funds. We show that in this case bank balance sheet constraints can attenuate monetary policy transmission.

Our aim is to extend an otherwise standard model in order to analyse the impact of the aggregate level of interest rates on bank funding (Appendix 2 provides a fuller exposition). For this task it is appropriate to work with a reduced form model in which the interest rate coefficients reflect both the direct and indirect impacts of monetary policy on bank funding flows (the direct impacts are the standard interest elasticities for the demand for lending and the supply of deposit and wholesale funding; the indirect effects are those additional impacts of interest rates on bank funding that arise for a number of other reasons, for example improved cash flows or net worth of bank borrowers or changes in expectations about future aggregate demand and output, leading customers to borrow more from banks or to increase their bank deposits). Empirical evidence suggests that the direct response of bank loan demand to long term interest rates is rather small, but this is consistent with our analysis.

Since we are concerned only with the impact of small movements of interest rates we can assume constant interest-semi elasticities (exponential functions) of aggregate reduced form demand for lending and aggregate reduced form supply of wholesale and insured deposit funding, allowing us to use a version of the standard Klein-Monti model of banking competition to model the impact of the policy rate  $r$  on the banking sector.<sup>6</sup>

There are  $N$  identical banks, indexed by  $n$ , in Cournot quantity competition. As in Stein (1998), we distinguish four assets and liabilities in the balance sheet identity for bank  $n$ <sup>7</sup>

$$L^n + R^n = D^n + W^n \quad (4.1)$$

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<sup>6</sup> Klein (1971), Monti (1972). We follow closely the exposition in Freixas and Rochet (1997) chapter 3.

<sup>7</sup> This focus on liability management and the use of wholesale funding is not material to our argument, we could equally well adopt the Bernanke and Blinder assumption that the banks hold liquid assets (bonds) and make no use of wholesale borrowing.

These assets and liabilities are

$L^n$  = loans

$R^n$  = non-interest bearing required reserves, responding passively to the reserve requirement according to  $R^n = \beta D^n$

$D^n$  = insured deposits

$W^n$  = other funding, including equity capital and wholesale debt finance.

We assume the following equations for the aggregate volumes of banking sector loans, deposits, and wholesale finance

$$\sum_{n=1}^N L^n = L(r, r_L) = L^0 \exp(-v_L r) \exp(-\varepsilon_L (r_L - r)) \quad (4.2a)$$

$$\sum_{n=1}^N D^n = D(r, r_D) = D^0 \exp(v_D r) \exp(\varepsilon_D (r_D - r)) \quad (4.2b)$$

$$\sum_{n=1}^N W^n = W(r, r_W) = W^0 \exp(v_W r) \exp(\varepsilon_W (r_W - r)) \quad (4.2c)$$

The loans of different banks are perfect substitutes for each other ie borrowers may be bank dependent but they are not dependent on individual banks. Similarly there is perfect substitutability between the deposits of different banks and also between the wholesale liabilities of different banks. Perfect substitutability implies, as shown in equations (4.2a, 4.2b, 4.2c), that aggregate assets and liabilities are functions of the monetary policy rate  $r$  and sector wide bank interest rates on loans, deposits and wholesale funding.

Banks then seek to maximise one period profits (net interest margins)

$$\pi^n = r_L L^n - r_D D^n - r_W W^n \quad (4.3)$$

taking account of the impact of their borrowing and lending on bank interest rates (through (4.2a), (4.2b), (4.2c)) and subject to the balance sheet constraint (4.1) and the reserve requirement  $R^n = \beta D^n$ .

Before discussing the equilibrium outcome, we comment on the key parameters. Three elasticity parameters –  $\varepsilon_L$ ,  $\varepsilon_D$  and  $\varepsilon_W$  – capture the substitutability of bank and non-bank assets and liabilities. The parameter  $\varepsilon_L$  reflects the extent to which borrowers are bank dependent. In the limiting case  $\varepsilon_L \uparrow \infty$  borrowers can perfectly substitute other sources of finance eg commercial paper or bond issuance, and bank loan rates have no impact on borrower credit and money transmission. As we establish shortly, a necessary condition for the existence of a bank lending channel is that the sum of these elasticities is finite:  $\varepsilon_L + \varepsilon_D + \varepsilon_W < \infty$ , ie not only are bank borrowers ‘bank dependent’ but also banks

themselves face rising costs of funding as they expand deposit and wholesale liabilities.

These parameters determine how the volume of aggregate banking sector assets and liabilities respond to the various margins between the market interest rate  $r$  and the rates on bank instruments. The standard Klein-Monti model is a limiting case where  $\epsilon_w \uparrow +\infty$ . In this case wholesale funding to the banking sector is available in infinitely elastic supply (no banks are financially constrained) and can fully substitute for any variations in the supply of deposits (ie change in  $D_0$ ) or fully match any variation in the demand for bank lending (ie a change in  $L_0$ ).

We further amend the standard Klein-Monti model by introducing a monetary policy (market interest rate) impact on aggregate bank assets and liabilities, through the parameters  $v_L$ ,  $v_D$  and  $v_W$ . We think of these as a shorthand for the impact of market interest rates (monetary policy) on aggregate, economy wide, flow of funds, both for retail investors and wholesale market participants. A structural interpretation of our model suggests a priori that these three parameters all have positive signs. In the event of a monetary policy tightening the intertemporal shift of consumption and investment expenditures (with reduced expenditure today and higher expenditure in future periods) can be expected to lead to a decline of both bank and market financing and an increase in both retail and wholesale portfolios. However it is possible that in reduced form the indirect impact of a tightening monetary policy could lead to a net decline of bank deposits ie the sign of  $v_D$  and  $v_W$  is ultimately an empirical matter. The relative magnitude of these latter parameters is not critical, although we expect in a small open economy that  $v_W < v_D$  because wholesale funds are collected on a global market which is scarcely (and for many countries not at all) affected by domestic interest rates.

The first order conditions for bank profit maximisation with respect to balance sheet volumes are the following interest rate margin equations, where margins depend upon aggregate demand elasticities and the number of banks (these equations are derived in Appendix 2, note that the reserve requirement  $\beta$ , because it is a tax on deposits, enters the margin equation for retail deposits but not for lending)

$$r_L - r_W = \frac{1}{N(\epsilon_L + v_L)} + \frac{1}{N(\epsilon_W + v_W)} \quad (4.4a)$$

$$r_D(1 - \beta) - r_W = \frac{1 - \beta}{N(\epsilon_D + v_D)} + \frac{1}{N(\epsilon_W + v_W)} \quad (4.4b)$$

These two margin equations, together with the banking sector balance sheet identity (4.1), determine the three endogenous bank interest rates and hence banking sector equilibrium.

The limiting case in which  $\epsilon_w \uparrow +\infty$ , provides the benchmark for assessing both the sign and magnitude of the bank lending channel. In this special case banks access an infinitely elastic supply of wholesale funding for bank lending and hence bank wholesale rates always equal short term market rates ( $r_w = r$ ) and both bank loan rates and bank deposit rates move in line with market rates. Since the margins between bank loan and deposit rates and market rates are unaffected by monetary policy, bank balance sheets then neither amplify nor attenuate the impact of monetary policy, and the reduction in bank lending is determined solely by the demand for bank lending as determined by the aggregate interest rate loan demand elasticity  $v_L$ .

We compare against this benchmark the response of bank lending to changes in monetary policy when banks have only limited access to wholesale finance and hence are liquidity constrained. When banks are liquidity constrained then there is a positive shadow price of internal funds  $r_w = \frac{1}{N(\epsilon_L + v_L)} + \frac{1}{N(\epsilon_w + v_w)}$ .

Assuming an exponential supply of wholesale funding this shadow price is given (see Appendix 2) by

$$\lambda = (\epsilon_w + v_w)^{-1} (\ln(W^n / W^0) + N^{-1}) \quad (4.5)$$

ie this shadow price depends on the interest rate elasticity of the supply of wholesale funding, on the volume of wholesale funding utilized relative to what is available, as well as on the number of banks competing for wholesale funds. In line with the previous literature on the bank lending channel we assume that liquidity constraints are not directly affected by shifts of monetary policy ie that  $W_0$ ,  $\epsilon_w$ , and  $v_w$  all remain constant. Section 6 discusses the possibility that monetary policy may directly affect liquidity constraints for example a tightening of monetary policy might alter wholesale funding available to banks  $W^0$ , perhaps because of an impact of monetary policy on bank capital.

Equation (4.2a) indicates that, relative to the standard benchmark, the direction of the bank lending channel depends on the direction of change of the interest rate margin  $r_L - r$ . If this margin increases, following a monetary policy tightening, then the bank lending channel amplifies the impact of monetary policy on bank lending (the Bernanke-Blinder, 1988; and Stein, 1998, prediction.) If this margin decreases then the impact on bank lending is attenuated.

The response of this margin depends upon a simple condition that emerges directly from the solution of the model. Consider an increase in short term market rates of interest of  $\Delta r$ . From equations (4.4a) and (4.4b) it is apparent that all bank

interest rates move together  $\Delta r_L = \Delta r_D = \Delta r_W$ : As shown in Appendix 2, in order to maintain the aggregate banking sector balance sheet constraint, the response of these banking sector interest rates to a change in monetary policy then must satisfy

$$\frac{\Delta r_L}{\Delta r} = \frac{\Delta r_D}{\Delta r} = \frac{\Delta r_W}{\Delta r} = 1 - \frac{v_L L + v_D D(1 - \beta) + v_W W}{\epsilon_L L + \epsilon_D D(1 - \beta) + \epsilon_W W} < 1 \quad (4.6)$$

where the strict equality obtains under our prior that all the various parameters ( $v_L$ ,  $v_D$ ,  $v_W$ ,  $\epsilon_L$ ,  $\epsilon_D$ ,  $\epsilon_W$ ) are positive and finite ie our priors imply – contrary to Bernanke-Blinder (1988) and Stein (1998) – that the bank loan- market rate interest margin declines following a tightening of monetary policy and therefore that the bank lending channel attenuates the impact of monetary policy.

The economic intuition underlying (4.6) has already been outlined in our introduction. Suppose that market interest rates and bank interest rates increase in line with market rates of interest ie that  $\Delta r_L = \Delta r_D = \Delta r_W = \Delta r > 0$ . In this case loans decline by  $v_L L$  while deposits (net of reserves) increase by  $v_D D(1 - \beta)$  and wholesale bank funding increases by  $v_W W$ . But this leaves banks with an excess of funding (loans have declined while both deposits and wholesale funding have increased) so this cannot be an equilibrium (the only exception is if one of these three assets and liabilities is in infinitely elastic supply in which case a small change in an interest margin can restore the banking sector balance sheet constraint.) In order to restore the banking sector balance sheet constraint, the banks must absorb this additional funding, and to do this they lower the various bank interest rates in order to generate greater loan demand and reduce the volume of deposit and wholesale finance. This excess funding available to banks when monetary policy is tightened leads to a reduction in the bank loan – market rate of interest margin  $r_L - r$  and this in turn explains why the bank lending channel can be expected to attenuate, rather than amplify, the impact of monetary policy on bank lending.

The Bernanke and Blinder (1988) and Stein (1998) prediction that the bank lending channel amplifies the impact of monetary policy on bank lending emerges under alternative parameter assumptions, when<sup>8</sup>

$$v_L L + v_D D(1 - \beta) + v_W W < 0 \quad (4.7)$$

in which case a monetary tightening leads to an outflow of bank funds and an increase in the reduction in the bank loan – market rate of interest margin  $r_L - r$ .

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<sup>8</sup> Stein assumes that a subset of banks are unable to access wholesale funding at all, in which case the relevant condition is that for these banks:  $v_L L + v_D D(1 - \beta) < 0$ .

If our analysis is correct, and the sign of the bank lending channel is indeed theoretically ambiguous, then there must be expositional mistakes in these previous models. With the additional insight provided by our own model, these mistakes are easily located

- Bernanke and Blinder (1988) argue that since bank loan rates rise when interest rates are tightened the IS curve must be shifted to the left by a tightening of monetary policy. This misleads because it does not recognize that in the standard ISLM model, when bank balance sheets have no impact on monetary policy, bank loan interest rates move in line with market rates of interest. If bank loan rates respond more than one for one to changes in market rates of interest then the IS curve moves to the left following a monetary tightening. If, as we argue is more likely to be the case, and is undeniably possible, bank loan rates respond less than one for one to market rates of interest then the IS curve moves to the right and the impact of monetary policy is attenuated.
- Stein (1998) argues that following a monetary tightening constrained banks are unable to replace a loss of deposits with wholesale finance and hence must reduce their lending by more than unconstrained banks. This argument is flawed, relying as it does on the unstated assumption that banks lose more deposits than loans following a monetary tightening. If as we argue there is a deposit inflow following a tightening of monetary policy there is instead a reduction of demand for wholesale funding by constrained banks and once again the impact of monetary policy is attenuated.

We have reached our conclusions using a very simple model of banking equilibrium. Does the same conclusion still hold under alternative specifications of banking competition? A problem with using the basic Klein-Monti specification is that all banks are funding constrained to the same degree. Appendix 2 explores a more general model, relaxing the Klein-Monti assumption that the deposits (and the loans) of different banks are perfect substitutes, and instead assuming imperfect substitution between the loan and deposit products of different banks, with elasticities of substitution of  $\eta_L$  and  $\eta_D$ .

This second specification allows us to develop a version of the model corresponding more closely to Stein (1998), with two groups of banks one constrained the other unconstrained. With the assumption that  $v_L > 0$  we reach the same conclusion as before ie that the impact of financial constraints on banks is to attenuate the impact of monetary policy on bank lending. The Stein (1998) results are restored only if, following a rise of interest rates, there is a deposit outflow from financially constrained banks that exceeds the decline in demand for their lending.

In our model the margins between bank interest rates (the right hand side of the first order conditions (4.4a) and (4.4b)) remain constant. There are several reasons for thinking that bank loan supply might increase and loan margins contract in a monetary policy expansion (or bank loan supply might reduce and loan margins increase in a monetary policy contraction.) Reasons for expecting such a loan supply amplification of monetary policy include the following

- (i) a monetary policy expansion might promote greater competition between banks, and a narrowing of bank margins, as they attempt to claim an increased share of an expanding market.
- (ii) structural shifts in banking competition can also have monetary policy implications. For example, the liberalization of banking markets and the rapid innovation in structured credit markets since the mid-1980s has increased bank access to wholesale funding, thus reducing interest margins and contributed to relatively rapid growth of the stock of bank credit. It is possible that monetary policy might affect the pace of such structural change, by reducing the costs of bank funding and increasing loan supply in a monetary expansion.
- (iii) monetary policy might affect banks' assessments of their portfolio risks. Following a monetary policy expansion banks may consider default less likely and be willing to lend at lower interest margins.

Such loan supply effects may play an important role in monetary transmission. Such supply shifts also help to explain why it is relatively difficult to predict the response of bank lending to changes of interest rates. But these loan supply effects do not alter our main finding, that financially constrained banks will respond less than unconstrained banks to shifts in monetary policy if a monetary tightening leads to a net inflow of funding (lending falling more than deposits) and so reduces their funding requirements.

There is however a possibility that a monetary policy tightening might reduce the book net worth or the market capitalization of financially constrained banks and hence reduce the amount of wholesale funding available (at a given cost of funding  $r_w$ ). This 'bank capital channel' could in some circumstances substantially reduce  $W_0$  in equation (4.5) have a major impact on the supply of bank loans. This mechanism might offset or even reverse the impact of the bank lending channel as modeled in this section. We discuss this possibility in our concluding Section 6.



## 5 Evidence provided by aggregate data

This section examines the response of bank deposits and lending to monetary policy changes, as revealed by aggregate data on bank lending, bank deposits, GDP and interest rates for the G8 countries.<sup>9</sup>

Figure 1, panels (a)–(h), present aggregate macroeconomic and banking data, detrended using the Hodrick-Prescott filter. There is less consistency of definition for these banking variables across countries than for the macroeconomic variables. The banking data are also affected by both reporting problems and by structural changes in the banking industry. Nonetheless some conclusions can be drawn, about whether monetary policy increases or reduces the demand by the banking sector for wholesale funding, and hence on the likely sign of the bank lending channel

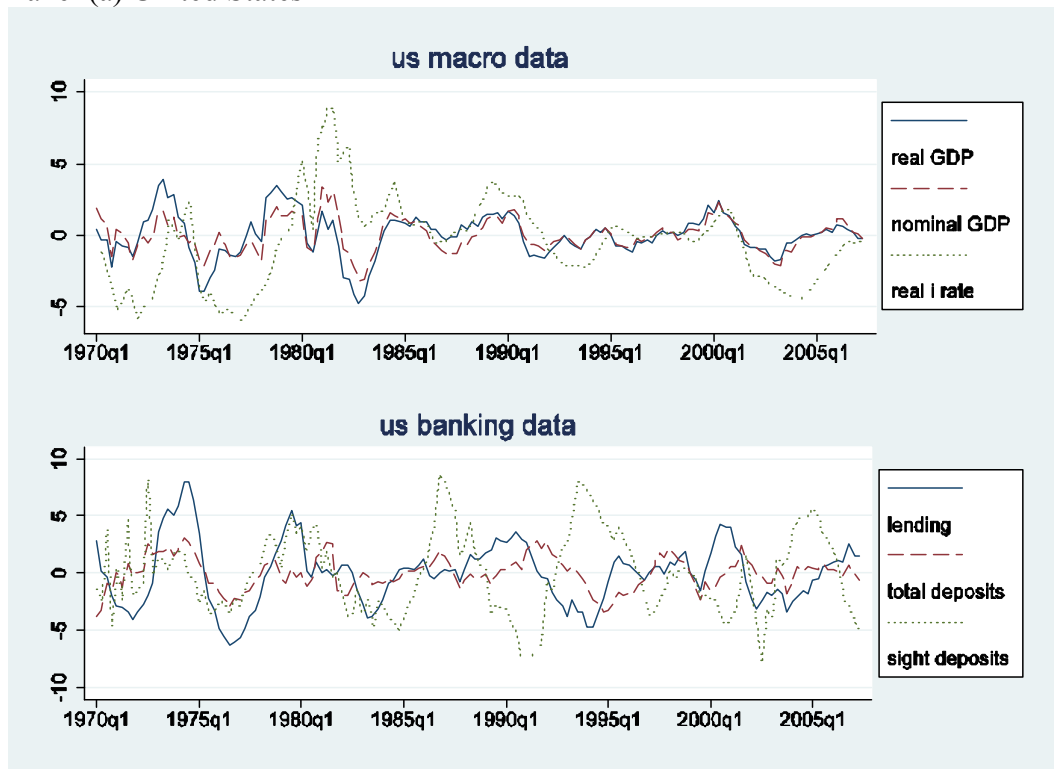
- For the seven countries where a comparison can be made (we do not have a long enough time series for the UK) sight deposits fluctuate very much more than total bank deposits. This suggests that, while it may be true that a tightening of monetary policy can reduce holdings of sight deposits, most of this impact is a shift between sight and time deposits with a relatively small overall effect on bank wholesale funding requirements.
- For all eight countries bank lending fluctuates pro-cyclically and with these movements either co-incident, or (eg in the United States) slightly leading movements in real and nominal GDP.
- In six of the eight countries (the exceptions are France and Italy) the cyclical movements in total bank deposits occur at about the same time and in the same direction as the movements in nominal and real GDP, with some indication eg for the US that the deposit movements lag those of bank lending. In the United States, the United Kingdom, Australia and Canada (but not in Germany or Japan) the amplitude of the cyclical deposit movements appear to be somewhat less than those of total bank deposits. This suggests that movements in bank funding requirements over the business cycle, whether induced by monetary policy or by aggregate shocks, are procyclical and relatively small. If the bank funding movements of liquidity constrained banks are similar then the bank lending channel will have a relatively small attenuating impact on monetary transmission over the course of the business cycle.

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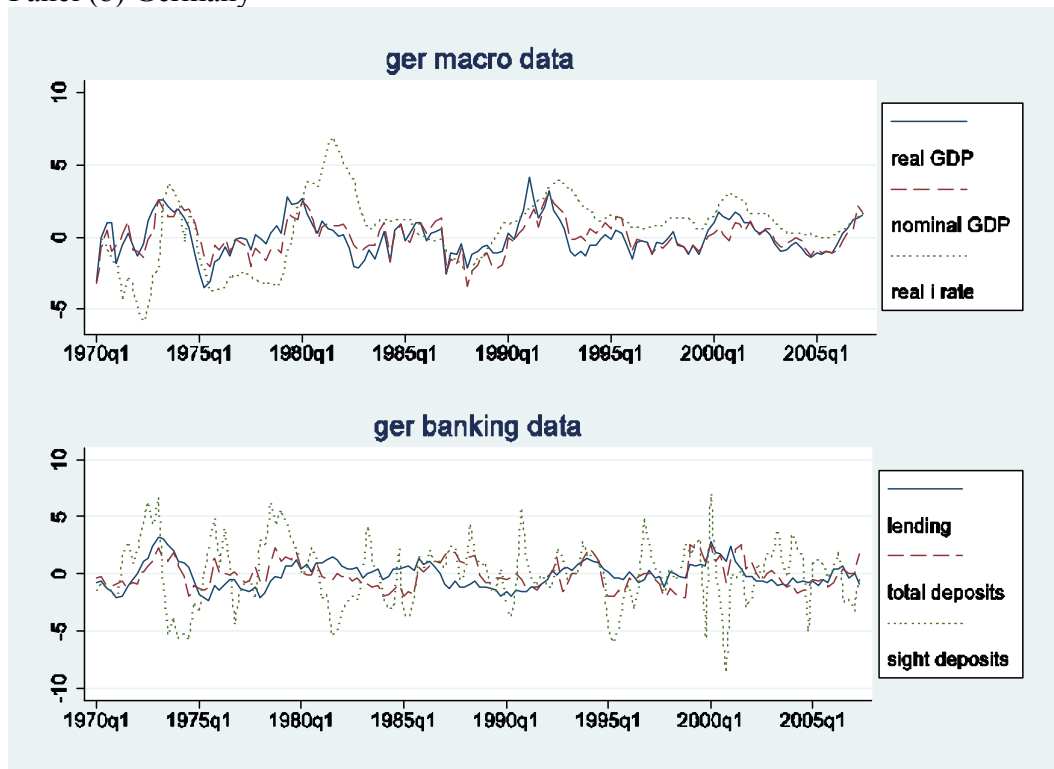
<sup>9</sup> Our data sources, together with a number of adjustments to the banking data to correct for both reporting breaks and seasonality, are described in Appendix 3

Figure 1. **Aggregate data, HP trend adjusted**

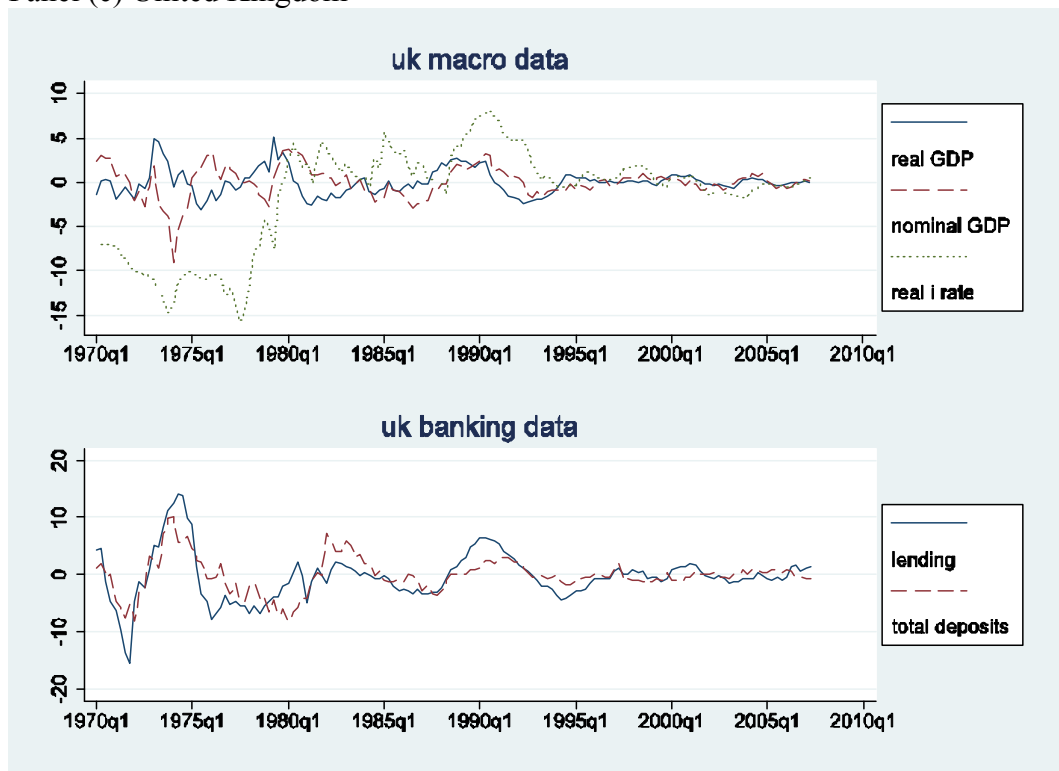
Panel (a) United States



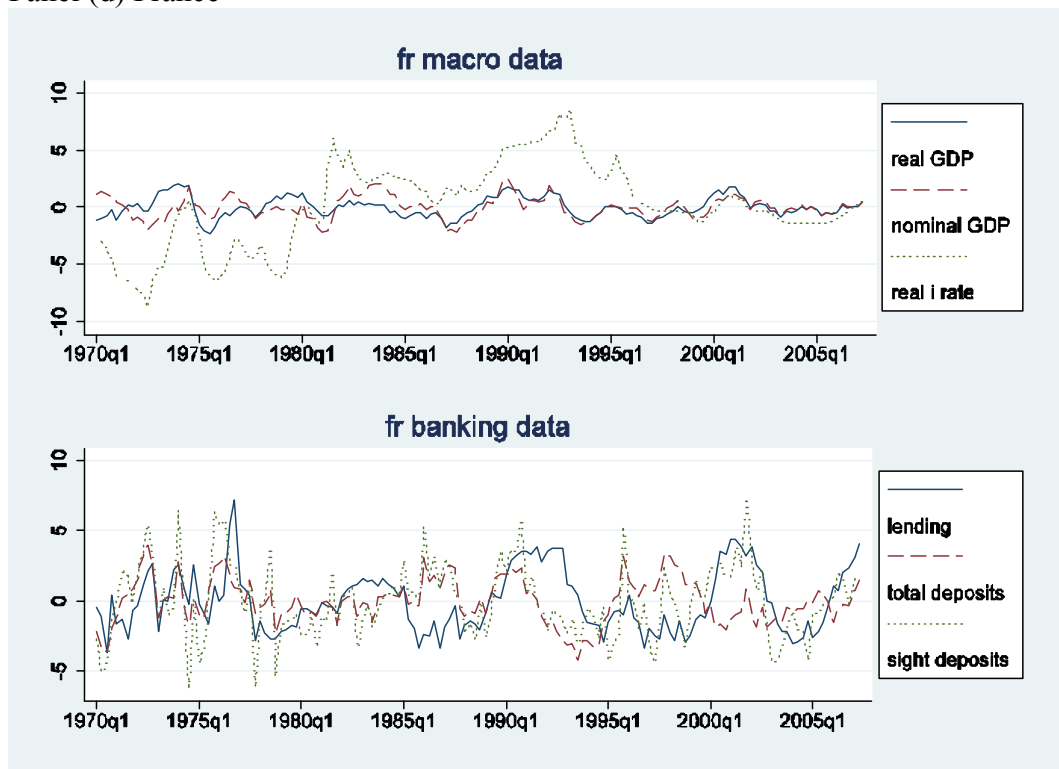
Panel (b) Germany



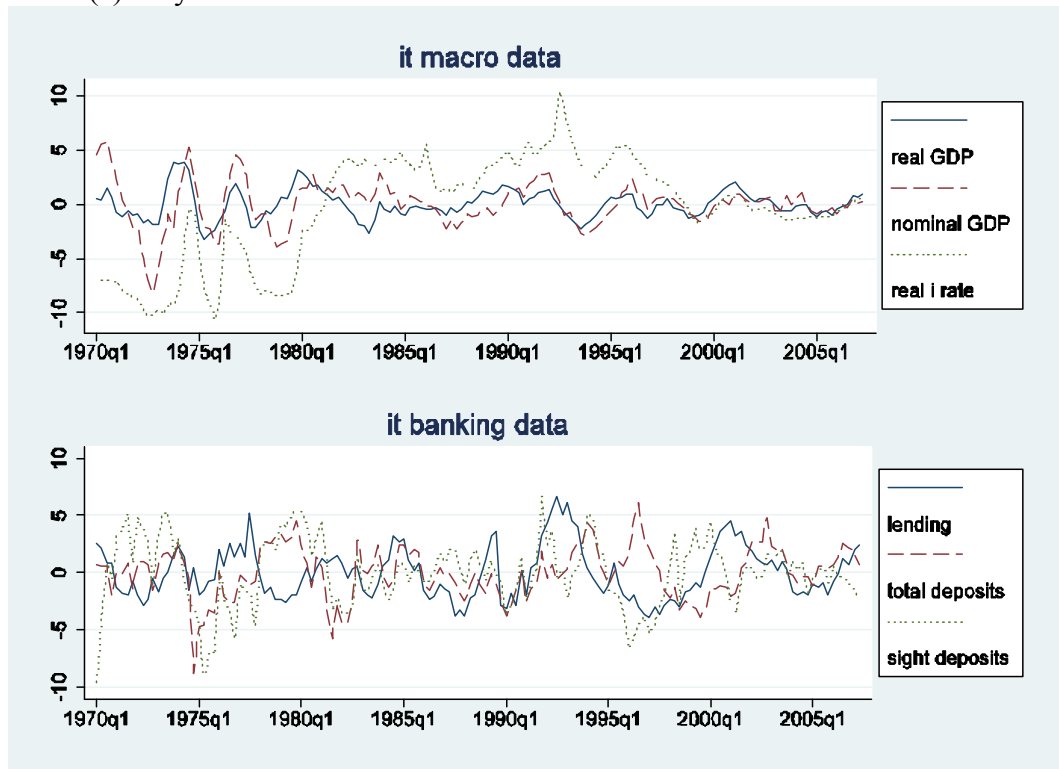
Panel (c) United Kingdom



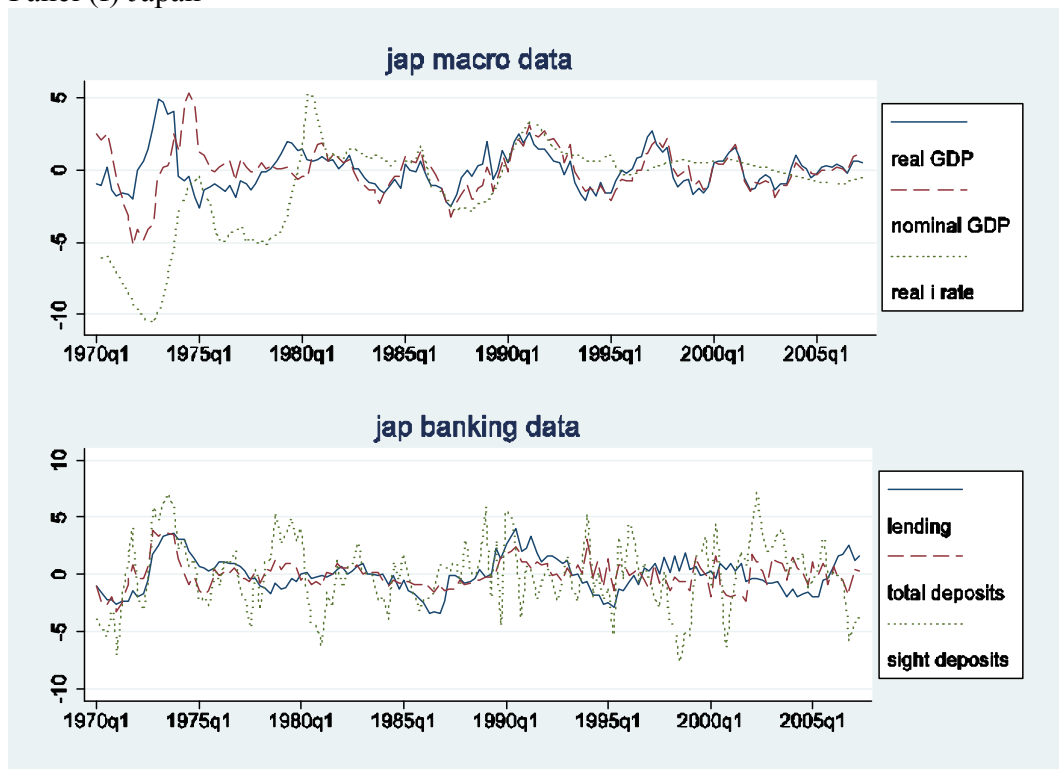
Panel (d) France



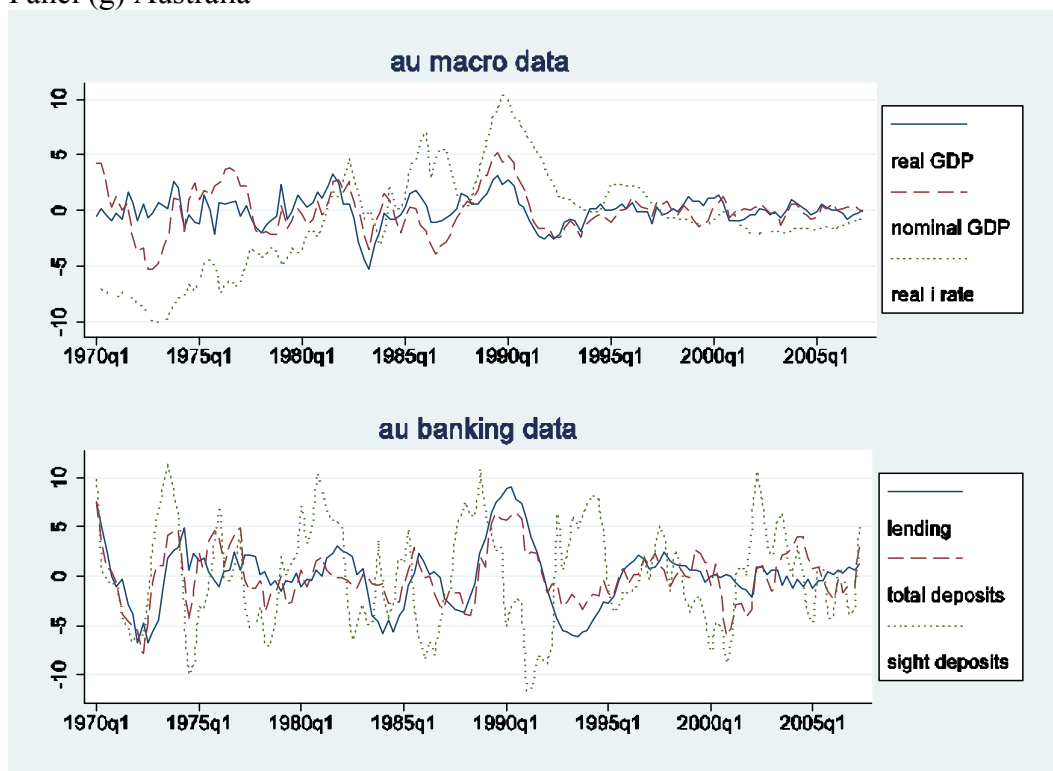
Panel (e) Italy



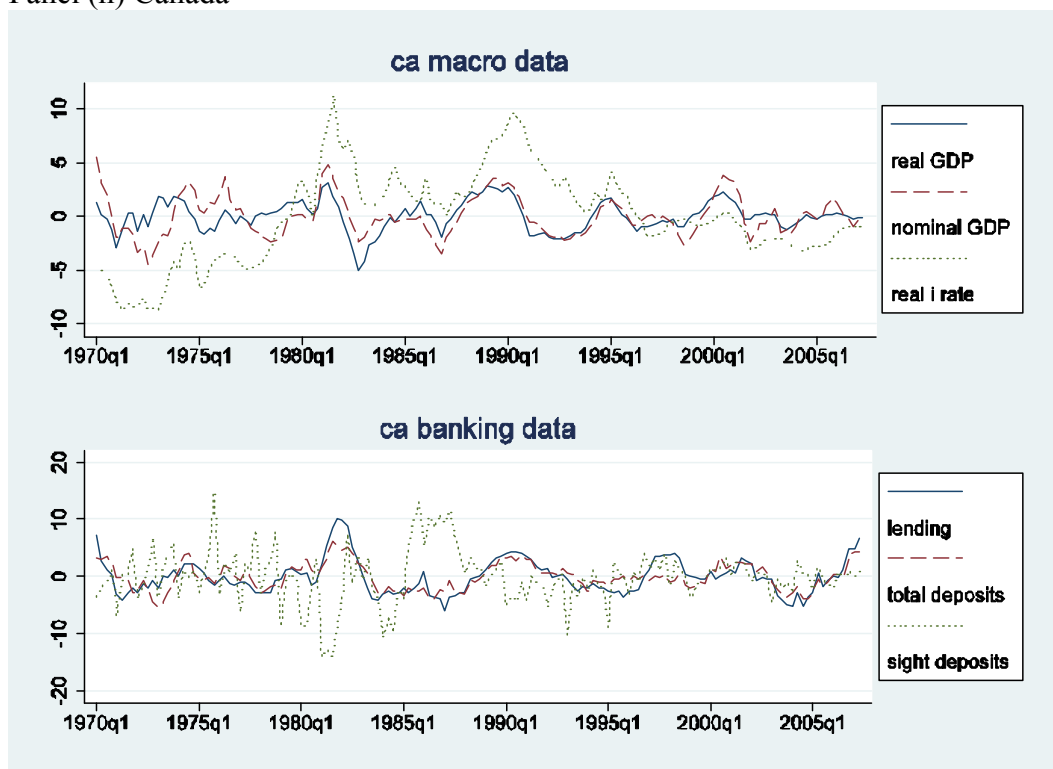
Panel (f) Japan



Panel (g) Australia



Panel (h) Canada



- In both France (during the 1980s and early 1990s) and in Italy (during the 1990s), there are substantial differences in the cyclical movements in bank deposits and in bank lending, indicating that in these two countries during these periods there have been some relatively large shifts in bank funding requirements. But there is no obvious consistent pattern to these movements and in the case of France the overall magnitude of the cyclical fluctuations again appears somewhat smaller for deposits than for loans.
- These charts also display the movements in a measure of real interest rates (the nominal market rate of interest less the rate of growth in the smoothed nominal GDP from the Hodrick-Prescott Filter). This also moves procyclically, indicating that it is difficult to disentangle the impact on bank loans and deposits of interest rates from the impact of cyclical movements in nominal and real output. While deposits typically do rise during periods when real interest rates are rising, we cannot say simply from visual inspection whether this is due to an interest rate impact or simply an increase in the demand for deposits driven by real and nominal income growth. Our prior, that monetary tightening reduces the level of deposits, cannot be tested from this visual inspection.

As an alternative way of comparing the magnitude of cyclical fluctuations, we estimated, allowing for correlation between the error terms, the following bivariate regressions for aggregate bank loans and total bank deposits

$$\Delta \ln L = \alpha_1 \Delta \ln L_{-1} + \alpha_2 \Delta \ln L_{-2} + \alpha_3 \Delta \ln L_{-3} + \beta_1 \Delta \ln D_{-1} + \beta_2 \Delta \ln D_{-2} + \beta_3 \Delta \ln D_{-3} + \varepsilon_L \quad (5.1a)$$

$$\Delta \ln D = \gamma_1 \Delta \ln D_{-1} + \gamma_2 \Delta \ln D_{-2} + \gamma_3 \Delta \ln D_{-3} + \delta_1 \Delta \ln L_{-1} + \delta_2 \Delta \ln L_{-2} + \delta_3 \Delta \ln L_{-3} + \varepsilon_D \quad (5.1b)$$

Table 1 reports the resulting standard errors (for changes in the log) of both aggregate bank deposits and aggregate bank loans obtained from these regressions for the eight countries. Single period standard errors (rows (1) and (2)) are similar for loans and deposits, but in order to examine cyclical volatility it is more appropriate to look at the unconditional standard errors, allowing for the impact of the estimated dynamics from the lagged dependent variables and correlation of residuals. Comparison of these unconditional standard errors (whether single equation, reported in rows (3) and (4) or joint equation, reported in rows (5) and (6)) provides an alternative quantitative comparison of the magnitude of cyclical fluctuations in deposits and lending. This comparison is consistent with the visual evidence provided by Figure 1, with a much greater level of cyclical volatility in

Table 1. Standard errors and granger causality tests from bivariate regressions

		US	GER	UK	FR	IT	JA	AU	CA	
Standard errors (%)	One period	Loans	1.06	0.66	1.71	1.51	0.81	1.11	1.49	
		Deposits	0.93	1.04	1.71	1.33	2.02	1.24	1.83	1.30
	Unconditional	Loans	3.24	8.84	5.38	4.12	3.83	5.44	5.00	5.36
		Deposits	1.07	2.57	2.39	1.33	3.49	3.57	2.88	1.71
	Bivariate unconditional	Loans	2.85	13.75	3.44	3.11	2.63	3.22	3.17	3.71
		Deposits	1.01	2.42	2.29	1.26	3.36	3.43	2.83	1.76
Granger pvalues	Deposits to lending	0.021	0.026	0.001	0.128	0.194	0.009	0.003	0.664	
	Lending to deposits	0.299	0.001	0.000	0.974	0.040	0.000	0.000	0.003	

The univariate unconditional standard errors are estimates of  $\sqrt{E(\Delta L \Delta L) / D_{-1}, D_{-2}, D_{-3}}$  and  $\sqrt{E(\Delta D \Delta D) / L_{-1}, L_{-2}, L_{-3}}$ . The bivariate unconditional standard errors are estimates of  $\sqrt{E(\Delta L \Delta L)}$  and  $\sqrt{E(\Delta D \Delta D)}$ . These measure the expected variance of  $\Delta L$  and  $\Delta D$  around their unconditional means.

the growth rate of bank lending than in the growth rate of bank deposits, for all countries except Italy and (when comparing joint unconditional standard errors) Japan.

Table 1 also reports p-values for a Granger causality test, for both the impact of lagged deposits on lending growth and of lagged lending on deposit growth. These show that in six of the eight countries lagged growth of lending is statistically significant (at the five per cent level) in predicting the growth of bank deposits while in four of the eight countries lagged deposits are statistically significant in predicting the growth of bank lending. However, while providing some evidence that changes in bank deposits may affect bank lending, this bivariate specification does not distinguish a relationship arising because of balance sheet funding constraints from a shock affecting bank customer demand.

Finally, in order to investigate the impact of macroeconomic developments on bank balance sheets, we estimated a vector auto regression model for all eight countries using the sample period 1975q1–2007q2 with four variables: the level of nominal interest rates ( $i$ ), and the rates of growth of aggregate bank deposits ( $\Delta \ln D$ ), aggregate bank lending ( $\Delta \ln L$ ), and of nominal GDP ( $\Delta \ln Y^n$ ), and three lags<sup>10</sup>

$$\Delta \ln D = a(L_3)(\Delta \ln L, \Delta \ln D, \Delta \ln Y^n, i) + \varepsilon_D \quad (5.2a)$$

$$\Delta \ln L = \Delta \ln D + b(L_3)(\Delta \ln L, \Delta \ln D, \Delta \ln Y^n, i) + \varepsilon_L \quad (5.2b)$$

$$\Delta \ln Y^n = \Delta \ln D + \Delta \ln L + c(L_3)(\Delta \ln L, \Delta \ln D, \Delta \ln Y^n, i) + \varepsilon_Y \quad (5.2c)$$

$$i = \Delta \ln D + \Delta \ln L + \Delta \ln Y^n + d(L_3)(\Delta \ln L, \Delta \ln D, \Delta \ln Y^n, i) + \varepsilon_i \quad (5.2d)$$

and with orthogonal shocks. ie our VaR has the ordering  $\Delta \ln D, \Delta \ln L, \Delta \ln Y^n, i$ .<sup>11</sup>

Figure 2 shows the impulse response functions obtained from this vector autoregression. These show a statistically significant response of bank lending to monetary policy in five of the eight countries (the United States, Germany, France, Australia, and Canada, but a statistically significant response of total bank deposits to monetary policy only in Italy. There is a response on the 95% threshold in both Germany and Australia, but in the case of Germany this is quickly reversed (the VaR estimates appear to have imaginary roots) and in Australia the

<sup>10</sup> We avoided using the first five years of the sample because of the very substantial negative real interest rates found (in Figure 1) for 1970–1974, suggesting that the relationship between bank balance sheets, nominal GDP, and interest rates cannot have been structurally stable over this early period.

<sup>11</sup> In any VaR analysis the results can be very sensitive to the ordering of variables. We found it difficult to get any meaningful results if the interest rate  $i$  preceded any of the other variables (for example if  $i$  precedes  $\Delta \ln L$  we found that a positive shock to interest rates resulted in an immediate rise in bank lending, a result which presumably reflects a monetary policy reaction to rising bank lending not a structural relationship), but provided the interest rate  $i$  appears last in the ordering, changing the order of the remaining variables made relatively little difference to the results.



response occurs after a long lag. In the case of both Japan and the United Kingdom there is no evidence of any statistically significant response of the banking sector to monetary policy at all. Thus for only one of the eight countries – Italy – is characterization of the behaviour of aggregate bank balance sheets consistent with a tightening of monetary policy increasing bank funding constraints.

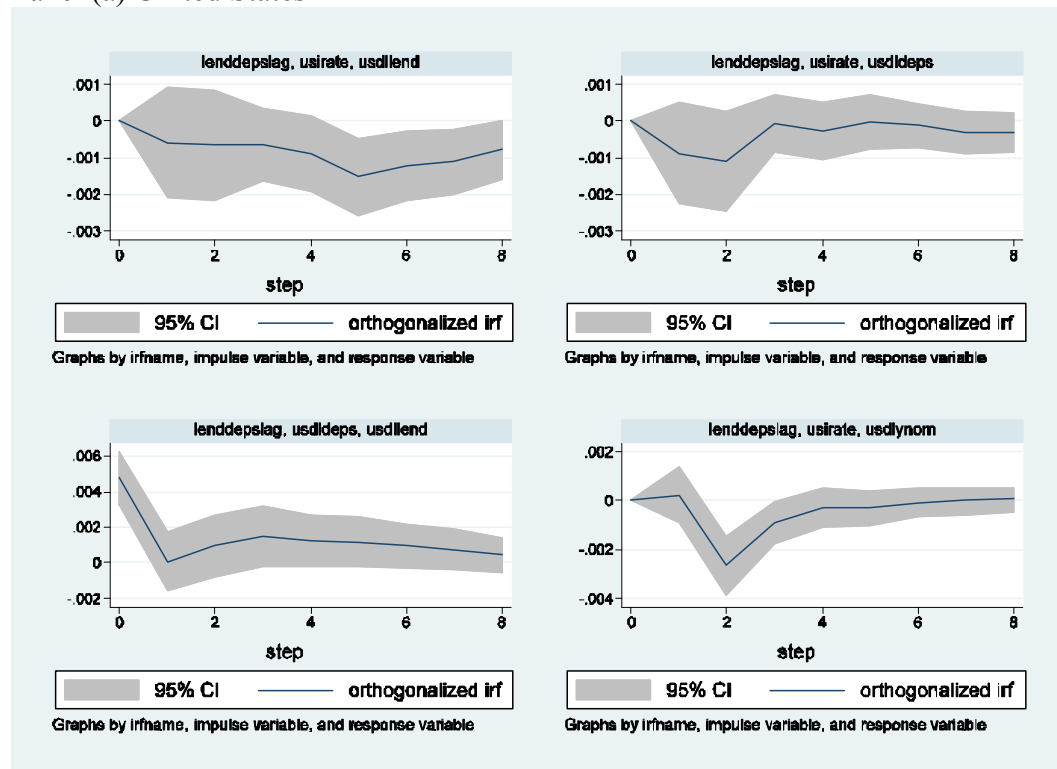
The impulse responses also report the response of bank lending to a shock to total deposits. On a one-period basis this appears consistent with a bank lending channel, because a shock to bank deposits results in a one period increase in bank lending, but this is not sustained and in any case could be interpreted as a demand shock to lending being financed out of increases in the entire balance sheet, from deposits as well as wholesale sources of funding. Finally we report the impact of interest rates on the growth of nominal incomes. In the four English speaking countries, the United States, the United Kingdom, Australia, and Canada there is a statistically significant reduction in the growth of nominal GDP following a shock to interest rates, after a lag of two to three quarters.

These vector autoregressions do not provide a clear-cut answer as to whether a tightening of monetary policy increases or reduces bank funding constraints, but they are consistent with our inspection of the detrended aggregate data and the standard errors from our estimated bi-variate regressions. Of the eight G8 countries, only for Italy do we find any evidence that aggregate bank deposits respond more than aggregate bank lending, either over the business cycle or in response to a shift of monetary policy. In most countries the behaviour of aggregate bank deposits over the business cycle can be explained by contemporaneous movements of nominal and real GDP. While this means that a tightening of monetary policy can reduce banking sector deposits, bank lending falls at the same time and the overall effect of monetary policy does not appear to be large enough to create a substantial net increase in the demand for bank wholesale funding.

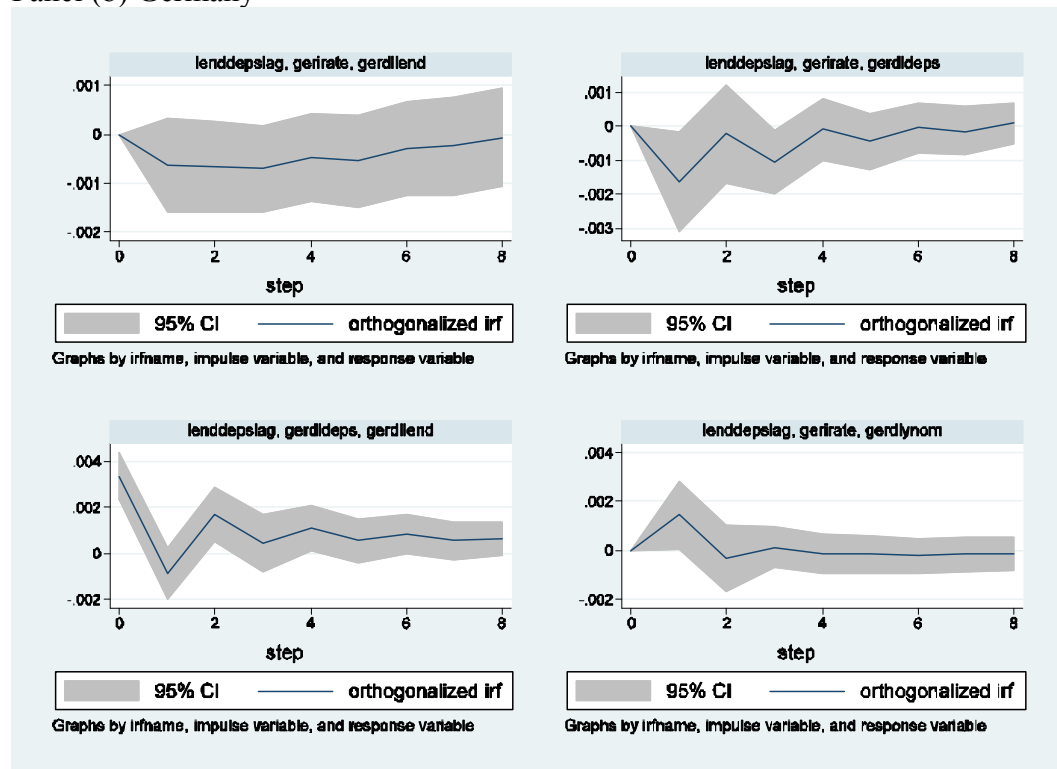
Figure 2.

## Orthogonalised impulse response functions

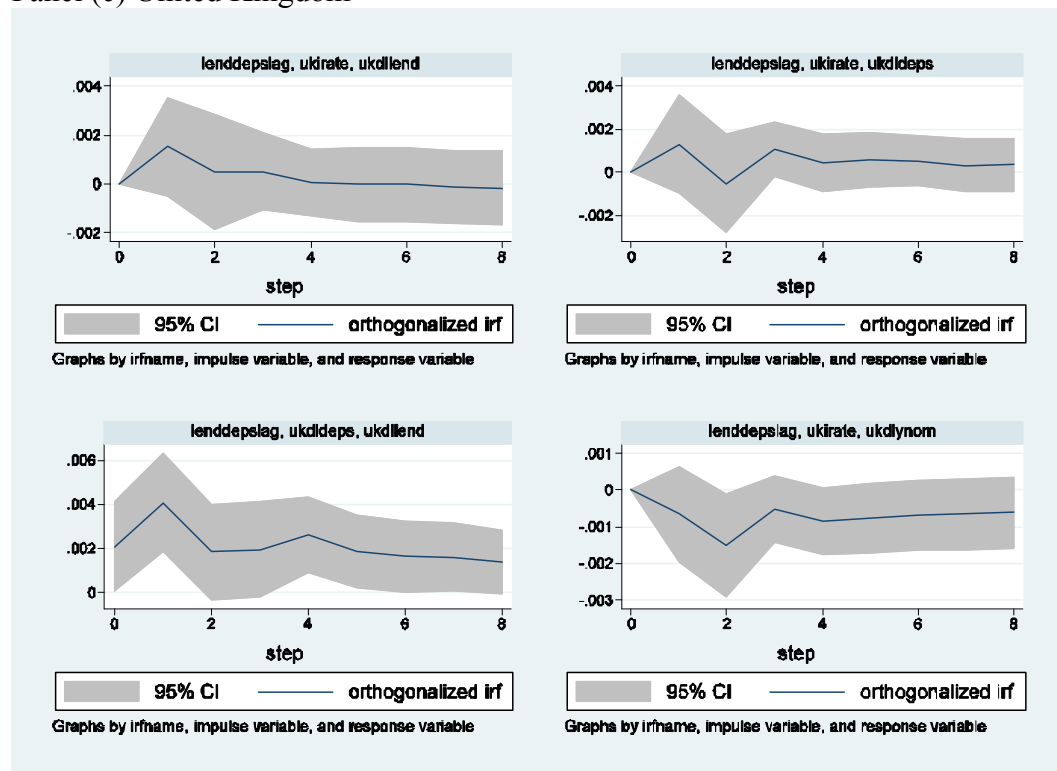
Panel (a) United States



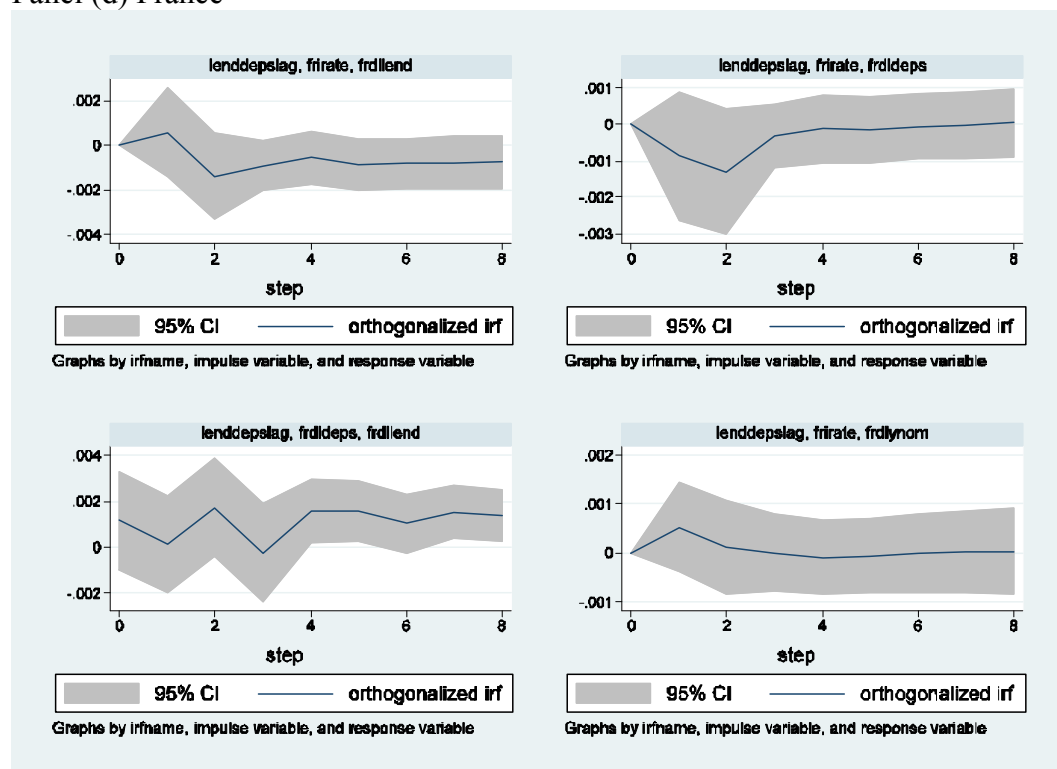
Panel (b) Germany



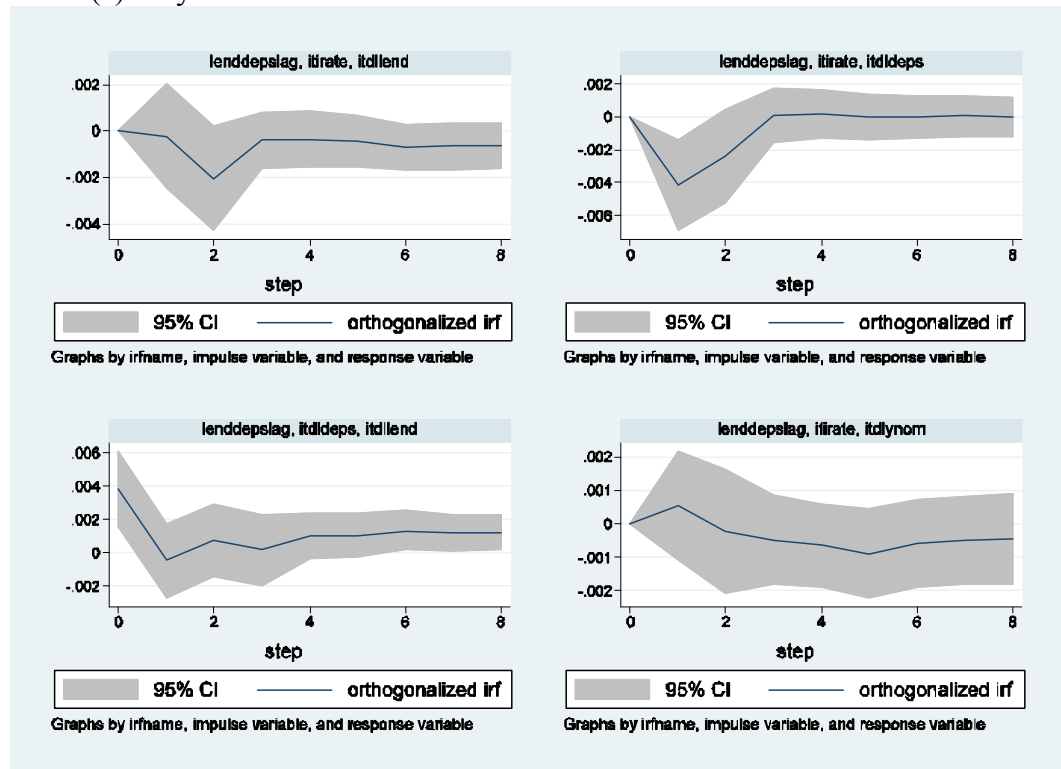
Panel (c) United Kingdom



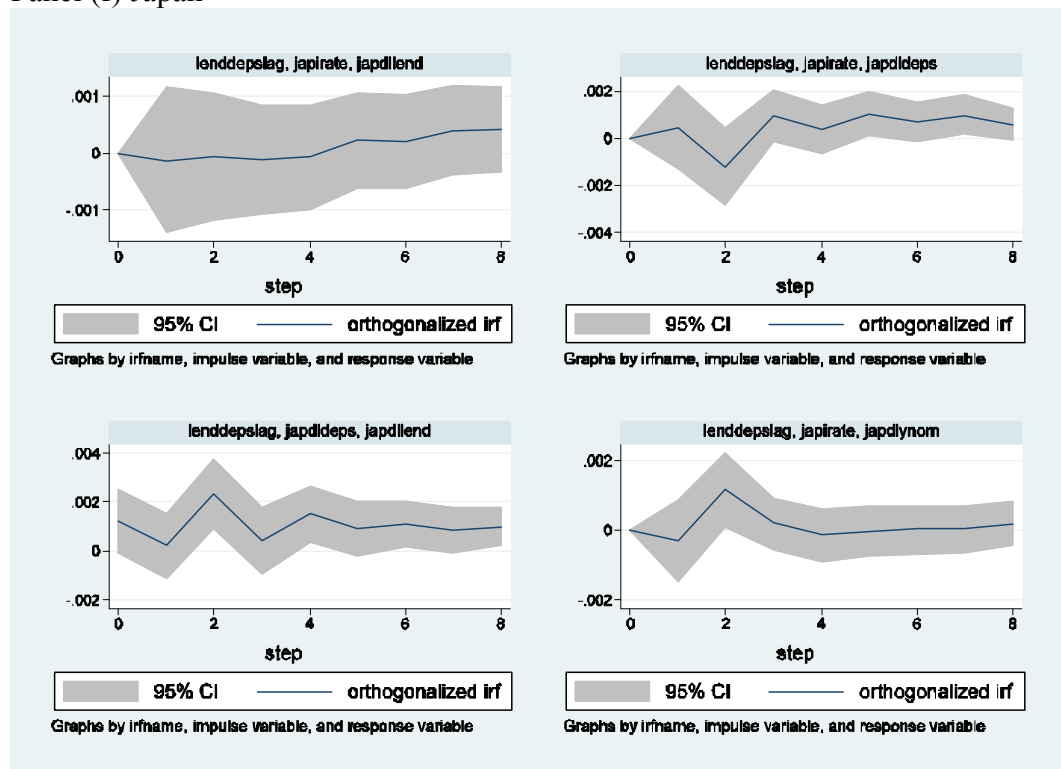
Panel (d) France



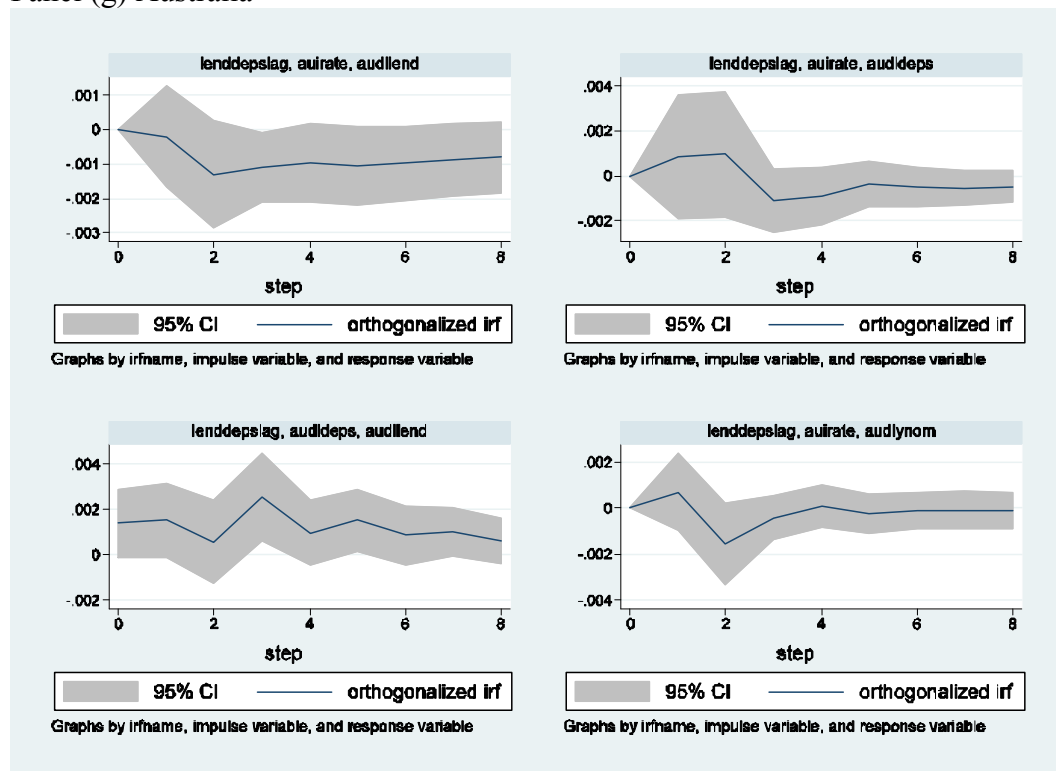
Panel (e) Italy



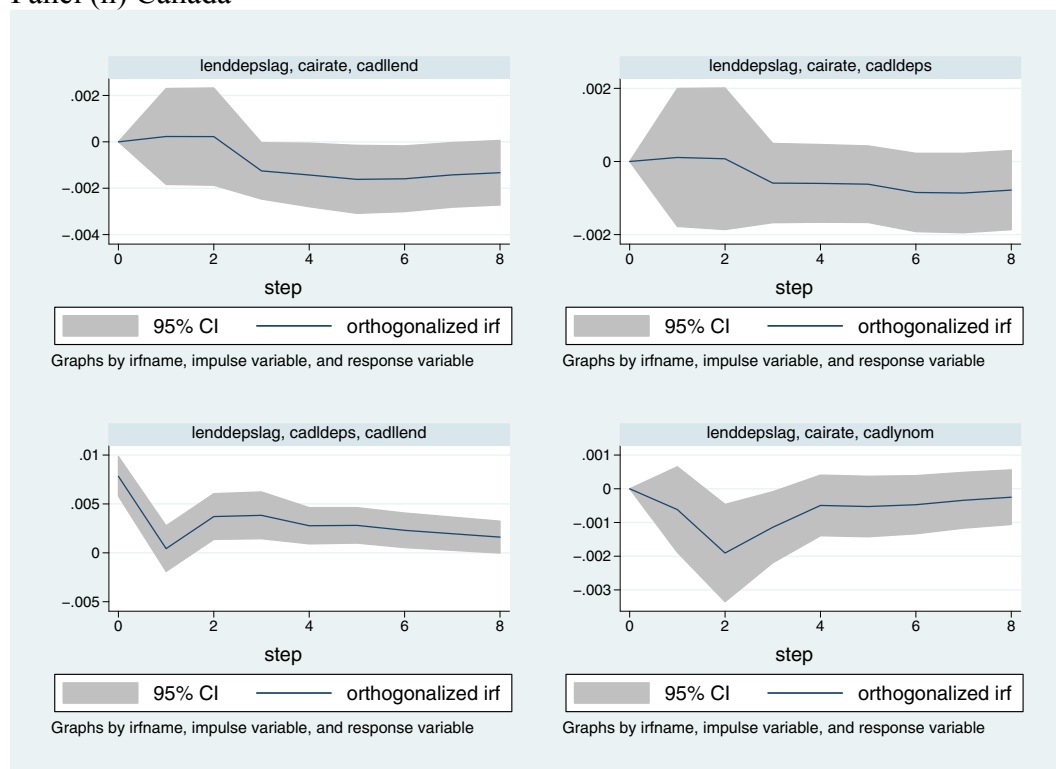
Panel (f) Japan



Panel (g) Australia



Panel (h) Canada



## 6 Conclusions

It has been widely accepted that constraints on the wholesale funding of bank balance sheets amplify the transmission of monetary policy through what is called the ‘bank lending channel’. We show that the effect of such bank balance sheet constraints on monetary transmission is in fact theoretically ambiguous, with an amplifying effect only when a tightening of monetary policy leads to a net outflow of funds, ie deposit outflow exceeding the decline of lending, in constrained banks. But if a tightening of monetary policy leads to a net inflow of funds into constrained banks then the bank lending channel attenuates the impact of monetary policy.

We examine macroeconomic data for the G8 countries and find no evidence that banking sector deposits respond negatively and more than lending to tightening of monetary policy, as the accepted view of the bank lending channel requires. The overall picture is mixed but these data generally suggest that deposits fluctuate procyclically and somewhat less over the business cycle than bank lending, and that total bank deposits, unlike bank lending, show little direct response to changes in interest rates. Shifts in monetary policy thus affect bank lending more than they affect bank deposits, and therefore, to the extent that banks are balance sheet constrained, the bank lending channel will attenuate not amplify the response of bank lending to monetary policy. While it is possible that the asset and liability response for some individual banks might be different, (for example a bank whose loan business is focused in markets that are relatively interest rate insensitive), the evidence we have examined suggests it is very unlikely that the bank lending channel amplifies monetary policy when the entire banking sector, and not just a section of it, is considered. Our paper has thus corrected a misunderstanding about the role of banks in monetary policy transmission that has persisted in the literature for some two decades.

The principal argument that can be made against this conclusion is as follows. Our analysis shows that, in theory, the bank lending channel can either amplify or attenuate the transmission of monetary policy. However the balance of available empirical evidence suggests that in practice a tightening of monetary policy reduces the amount of available to banks from wholesale markets and the resulting increase in liquidity constraints will amplify the impact of monetary policy on bank lending. Therefore, while the ‘bank lending channel’ may not operate exactly as described in the literature, it still provides a reasonable and tractable characterisation of monetary policy transmission.

It may be true that a tightening of monetary policy, on at least some occasions, increases bank liquidity constraints, but this is *not* the mechanism explored in the literature on the bank lending channel. To avoid confusion this should therefore be called something different. We believe that the appropriate

name is the ‘bank financial accelerator’ since the underlying idea is essentially the same as in the corporate financial accelerator, that deterioration in net worth (or other measures of balance sheet strength) leads to a reduction in both assets and liabilities.

In terms of our theoretical model presented in Section 4, we can think of the bank financial accelerator as a tightening of monetary policy reducing  $W_0$  (the supply of bank wholesale funding) in our equation (4.5). We can see from equations (4.4) and (4.5) that such a reduction in  $W_0$  will then raise the shadow price of internal funds, increase the margin between bank interest rates and market rates, and hence both reduce the stock of bank lending  $L$  and increase the stock of bank deposits  $D$ .

Even when allowing for this mechanism, our analysis still has important implications for the conduct of empirical tests for the role of bank balance sheets in monetary transmission. Many empirical papers have followed the example of Kashyap and Stein (2000), seeking to test for the presence of the bank lending channel by interacting various bank balance sheet measures (size, liquidity, capitalisation, either measured directly or using these variables to allocate banks into different categories) with a measure of the stance of monetary policy. These papers have tested the hypotheses that smaller, less liquid, and less well capitalised banks respond relatively more than other banks to changes in monetary policy. Our analysis implies that the bank lending channel may play a role in monetary policy transmission even when this hypothesis is rejected (as it often is, the literature is far from reaching any consensus about the sign and magnitude of such bank-balance sheet monetary policy interactions).

The appropriate way to test for the presence of the bank lending channel arising because of differences in behaviour between constrained and unconstrained banks is to examine the hypothesis that banks constrained by reasons of size, liquidity, or capitalisation exhibit a relatively strong relationship between deposit inflows and loan growth compared to other unconstrained banks. If this is the case then there will be an amplifying or attenuating impact on monetary policy transmission according to whether a monetary tightening reduces or increases deposits at these constrained banks.

A quite different test is needed to test for the presence of a bank financial accelerator. Here it must be shown that a *decline* in measures of bank size, liquidity, or book or market capitalisation results in an increase in liquidity constraints and a decline of bank lending.

To conclude our paper we briefly discuss the literature on the bank capital channel and argue that, just like the bank lending channel, the bank capital channel yields no clear theoretical prediction about transmission of monetary policy. In at least some circumstances it attenuates rather than amplify monetary policy ie the prevailing view that bank balance sheets amplify the impact of monetary policy transmission must still be rejected. We argue moreover that this

point is important to formulating an appropriate policy response to the current ‘credit crunch’ affecting the global banking system.

There is a fairly extensive literature on the bank capital channel. Theoretical contributions, for example Holstrom and Tirole (1997), show that the availability of bank capital can limit the extent to which banks provide monitored credit. But these analyses assume that bank capital is exogenous; they do not incorporate any link between monetary policy and bank capital. In other contributions (for example Diamond and Rajan (2001)), bank capital is endogenous. But these models explain long term desired capitalisation, not the effects of monetary policy on bank capital and the resulting impact on bank loan supply.

Perhaps most relevant is the now fairly extensive literature on the dynamics of bank capital buffers, protecting the bank against the potential costs of illiquidity and recapitalisation.<sup>12</sup> Banks hold a margin of capital as a buffer for absorbing fluctuations in earnings and asset values resulting from monetary policy, macroeconomic, market or other developments. In normal periods of operation these fluctuations will be within the expected range of outcomes, in which case bank capital will not then much affect the supply of bank lending. But occasionally such losses may be much bigger than anticipated and it is then that the availability of bank capital is likely to affect the supply of lending.

The bank capital channel can create pro-cyclical fluctuations in bank lending. In a recession, when bank capital – measured on either a balance sheet or market value basis – falls below desired levels then this can trigger a reduction in available wholesale funding which in turn reduces the supply of bank lending. It is also now well understood that countercyclical changes in bank capital requirements (for example those that are introduced by the Basel II accord) may exacerbate these cyclical fluctuations in bank loan supply.<sup>13</sup> But the impact of monetary policy on bank loan supply via the bank capital channel, just like the impact of bank monetary policy via the bank lending channel, is theoretically ambiguous.

The bank capital channel impact of monetary policy is ambiguous because bank net worth, whether measured in book or market values, may either rise or fall following a loosening of monetary policy. This point is obvious for book value capital. A loosening of monetary policy lowers short term interest rates relative to long term rates, and to the extent that banks operate using short term

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<sup>12</sup> Theoretical models of such ‘buffer stock’ holdings of bank capital include Passmore and Sharpe (1994), Baglioni and Cherubini (1994); Calem and Rob (1996); Froot and Stein (1998); Milne and Whalley (1999); Milne (2002); Van Den Heuvel (2002); Milne and Whalley (2003); Milne (2004); Van den Heuvel (2004); Estrella (2004); Puera and Keppo (2006); and Zhu (2006) as well as a small empirical literature (see Jokipii and Milne (2008) for an empirical contribution and further citations).

<sup>13</sup> Kilponen and Milne (2008) analyse the interaction of banking sector book capital and optimal monetary policy, finding that the resulting impact on output-inflation tradeoffs is small and only arises at all if bank loan rates have a ‘cost channel’ impact on marginal costs of production.



funding for long term interest rate yielding assets, this increases bank net interest income and hence eventually the book value of bank capital. At the same time the cost of many bank liabilities are not sensitive to market rates of interest at all, so lower market rates of interest can reduce bank net interest income and lower capital. There is a similar ambiguity for the market value of bank capital. There little direct impact from short term rates of interest, but market values of bank capital depend critically on expectations of future bank earnings, of nominal and real income growth, and of long term interest rates, and these may or may not respond to shifts of monetary policy.

In the extreme, of which Japan in the early 1990s is be a good illustration, monetary policy is unable to shift expectations of continued weakness of nominal and real income growth. In such a case, even when monetary policy reduces short term market interest rates to or close to zero, the demand for bank lending remains low and capital constraints, partly through the low market value of bank assets, continue to limit the supply of funds to banks, and thus the expectations of low growth of incomes and of prices are confirmed.

Although the macroeconomic data for Japan described in Section 5 provide no clear evidence on monetary transmission, their experience of monetary deflation in the early 1990s supports our view that the bank balance sheets can attenuate rather than amplify the impact of monetary policy. If the bank lending channel or bank financial accelerator had been playing a quantitatively important amplifying role, then the Bank of Japan would have found it much easier than they in fact did to use monetary policy to stimulate deposit growth.

Japan was able to begin its escape from monetary deflation only when, later in the 1990s, Japanese banks finally properly recognised the scale of loan losses occurred in the ‘bubble economy’ of the late 1980s and were properly recapitalised by the Japanese government. We conclude that constraints on bank balance sheets not only limit the impact of monetary policy, but do so to a greater extent when the banking sector is as a whole is severely undercapitalised. Expansionary monetary policy is then not enough on its own to solve a systemic under-capitalisation of the banking sector.

Such systemic undercapitalisation has once again recently emerged for banks in the US and Europe, with the high level of losses on sub-prime mortgage securities and other structured credit products, and the resulting ‘credit crunch’ in which banks worldwide have been no longer able use mortgage backed securities to raise low cost wholesale funding. It appears – consistent with our analysis – that these funding problems have made it very difficult for banks to respond fully to relaxation of monetary policy. The situation therefore requires not just expansionary monetary policy response, but also the recognition of bank losses and a restoration of net worth through the issue of new capital, exactly the actions that have been adopted by financial authorities world wide in October of 2008 in response to the worsening global banking crisis.

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# Appendix 1

## Empirical studies of bank lending and monetary policy

Many studies examine the bank lending channel and the more general issue of the role of bank credit in monetary transmission. Bernanke and Gertler (1995) review the role of credit in monetary policy transmission, making the helpful distinction between the balance sheet channel (also sometimes referred to as the financial accelerator) and the bank lending channel. The balance sheet channel arises when changes in the net worth of bank-dependent borrowers leads to an increase in their cost of raising external finance. Most often this is interpreted as an increase in bank monitoring costs, a mechanism which appears in several theoretical models including Holmstrom and Tirole (1997).

The bank lending channel focuses not on borrowers, but on the effect of credit market imperfections on the intermediation function of banks. Kashyap and Stein (1994, 1995) state the following conditions for the presence of a bank lending channel: (a) that some borrowers are bank dependent and cannot easily substitute other forms of finance for bank lending; and (b) bank loan supply is affected by bank balance sheet characteristics. Such supply impacts might arise through the conventional bank lending channel mechanism but they might equally occur because of constraints on net worth (equity capital). Topi (2003) usefully contrasts the conventional bank lending channel, as modeled by Bernanke and Blinder (1988) and Stein (1998), with the impact of capital constraints on the supply of bank loans, arguing that the impact of capital constraints is likely to be much more important. Other theoretical models of bank intermediation emphasise the role of bank capital on loan supply, but do not model the transmission mechanism of monetary policy.

There is a large body of evidence consistent with the presence of a balance sheet channel. An influential study is Gertler and Gilchrist (1994) who find that bank lending to small manufacturing firms varies much more than does bank lending to larger firms, with changes in the net worth of firms. A large number of other studies (reviewed by Bernanke and Gertler, 1995) which report cash flow impacts on inventory and fixed capital investment also support the presence of a balance sheet channel. The balance sheet mechanism is now routinely introduced into dynamic general equilibrium models of monetary policy (beginning with Bernanke, Gertler, and Gilchrist, 1999).

There is also a large empirical literature – using similar specifications to the studies of corporate balance sheet effects – suggesting that capital, capital regulation, and bank profits all affect the supply of bank lending. These include Peek and Rosengreen (1993) who examine the role of capital regulations in the New England ‘capital crunch’ of the early 1990s, and Peek and Rosengreen

(1997, 2000) who find convincing evidence that the deterioration of balance sheets of Japanese banks in the early 1990s had a significant impact on the loan supply of their US subsidiaries. Similarly Houston and James (1998) and Houston, Marcus and James (1997) find that holding company cash flows, in addition to cash flows of individual subsidiaries, provide a strong additional explanation of bank lending growth, a strong indication of a bank loan supply effect. Milne, Donaldson and Tang (2007) find similar evidence using international panels of bank accounting data, based on departures of individual bank capital ratios from their median observed values.

Other I studies are focused on the supposed amplifying impact of the bank lending channel on monetary policy. Bernanke and Blinder (1992), section IV, estimate a monthly vector autoregressive model of the relationship between the Federal funds rate, the unemployment rate, the log(CPI) and bank balance sheet variables ie a specification similar to that we explore in our Section 4. The relationships of the model are identified by the assumption that the Federal funds rate (used to measure the stance of monetary policy) is unaffected by other current variables. They then examine the relationship between monetary policy innovations – ie shocks to the Federal Funds rate – and the subsequent evolution of aggregate bank loans and deposits (reported in their Figure 4). They find that deposits fall in response to a tightening of monetary policy but this reduction is completed after some 8 months. They find that loans also fall, initially slowly, but eventually, after 24 months, by about twice as much as deposits. To quote (page 903) ‘Loans seem to respond slowly to monetary policy innovations – which makes economic sense because loans are contractual commitments, and which also explains why loans are not particularly useful in forecasting. However, loans do eventually respond substantially to a change in the funds rate, with a timing that coincides closely to the response of the unemployment rate.’ They argue that this is evidence that loan supply is important in the transmission of monetary policy, even though monetary stocks are better predictors of aggregate demand than lending stocks. However, as they admit, this loan response could be due to shifts in loan demand rather than loan supply, so their findings must be regarded as inconclusive at least with regard to the presence of a bank lending channel.

Kashyap, Wilcox, and Stein (1993) find that declines in corporate bank lending following monetary policy contractions are accompanied by an increase in the volume of commercial paper issuance, ie reduced bank lending is partly offset by a greater use of other external funding by borrowers who are not dependent on banks for financing. Hence, they maintain, the decline in bank lending is likely to reflect, at least in part, a shift in loan supply. This conclusion is however contested by Ohliner and Rudebusch (1996), who argue that the offsetting may instead be a consequence of a decline in the demand for external finance from smaller firms, which are unable to access the commercial paper market, combined with an increase in the demand for external finance from larger firms.

Kashyap and Stein (1995, 2000) seek to resolve this identification problem by using individual bank data. Kashyap and Stein (1995) find that lending by small banks responds more to changes in monetary policy than does lending by large banks. They argue that this may be due to small banks finding it more difficult than large banks to access forms of finance alternative to reservable deposits, but acknowledge that their result may be due to differences in loan demand between small and large banks. Kashyap and Stein (2000) find that ‘amongst smaller banks in our sample, the impact of monetary policy is significantly higher for those with lower ratios of cash and securities’. They argue that this is a loan supply impact, since they are controlling for bank size and this finding is consistent with the prediction of the conventional model of the bank lending channel, that constrained, ie illiquid banks, will respond more than unconstrained banks to changes in monetary policy.

Other studies (Kishan and Opiela, 2000; Altunbas, Fazylow and Molyneux, 2002; Kishan and Opiela, 2005) argue – by appeal to the conventional model of the bank lending channel – that banks with relatively low capital ratios will be constrained in their ability to borrow on wholesale markets and therefore should respond to changes of monetary policy by more than unconstrained banks with relatively high capital ratios. They report evidence that banks with low capital ratios do indeed respond more to monetary policy than banks with high capital ratios, both in the US (Kishan and Opiela, 2000) and in Europe (Altunbas, Fazylow and Molyneux, 2002). Kishan and Opiela (2005) claim that bank lending channel should be asymmetric, that constrained banks should respond by more than unconstrained banks to a tightening of monetary policy than they do to a loosening of monetary policy, and report econometric results supporting this hypothesis.

Further specifications similar to that adopted by Kashyap and Stein (2000) have been estimated using European data sets (many of these studies were conducted as part of an ECB research network and published in Angelini, Kashyap and Mojon eds., 2003). These investigations have not produced clear results. Favero, Giavazzi, and Flabbi (2001) do not find evidence of a bank lending channel, whereas King (2000) reports evidence of a bank-lending channel in France and Italy, Ehrmann, et al (2003) also reports rather mixed results, finding that smaller banks respond more to monetary policy than large banks, but in some specifications more liquid banks turn out also to be more responsive (the opposite of what is suggested by the conventional model of the bank lending channel). They also report the outcome of estimating the same specification estimated using quarterly supervisory report data for the largest Euro zone countries, France, Italy, Germany, and Spain (these regressions are run separately for each country, confidentiality restrictions prevent these data being shared outside of individual national member banks of the system of European central banks and thus prevent them combining the datasets into one), finding that



less liquid banks respond more to monetary policy than more liquid banks. In none of their estimates are less capitalised banks more responsive to monetary policy than more capitalised banks.

To summarise, there is persuasive evidence that the balance sheet channel results in some borrowers, notably smaller firms, responding more than others to changes in monetary policy and there is a substantial body of evidence for related impact of bank profits on the supply of bank lending; but evidence of a bank lending channel through which monetary policy transmission has a relatively large impact on the lending of illiquid or undercapitalized banks is much less conclusive.

## Appendix 2

### Banking market equilibrium

There are  $N$  banks of equal size indexed by  $n = 1 \dots N$ . The only assets of these banks are loans and non-interest bearing reserves. The only liabilities are deposits and wholesale borrowing. The balance sheet constraint is thus  $L + R = D + W$ . Non interest bearing reserves are determined by reserve requirements  $R = \beta D$  so the balance sheet constraint can be rewritten as  $L = (1 - \beta)D + W$

Bank interest rates and resulting loan and deposit volumes are described by an amended version of the standard Klein-Monti model.<sup>14</sup> We make two amendments to this model: (a) we introduce additional parameters to capture the substitution between bank loans or deposits and the corresponding forms of market intermediation (for example commercial paper as a substitute for bank lending and money market mutual funds holding this commercial paper as a substitute for bank deposits); (b) we relax the assumption that the loan or deposits of two different banks are perfect substitutes for each other, allowing us to investigate the situation where the loan and deposit rates of the constrained banks can differ from those of the unconstrained banks.

The loan and deposit interest rates of bank  $n$  are  $r_L^n$  and  $r_D^n$ . Aggregate loan, deposit and wholesale funding rates are given by

$$\begin{aligned} r_L &= \frac{1}{N} \sum_{n=1}^N r_L^n \\ r_D &= \frac{1}{N} \sum_{n=1}^N r_D^n \\ r_W &= \frac{1}{N} \sum_{n=1}^N r_W^n \end{aligned}$$

Loans, deposits and wholesale funding of bank  $n$  are given by

$$\begin{aligned} L^n &= L^0 \exp(-v_L v_L^n) \exp(-\varepsilon_L (r_L^n - r)) \exp(-\eta_L (r_L^n - r_L)) \\ D^n &= D^0 \exp(v_D v_D^n) \exp(\varepsilon_D (r_D^n - r)) \exp(\eta_D (r_D^n - r_D)) \\ W^n &= W^0 \exp(v_W v_W^n) \exp(\varepsilon_W (r_W^n - r)) \exp(\eta_W (r_W^n - r_W)) \end{aligned}$$

Where the  $v$  parameters represent elasticities with respect to the level of interest rates, the  $\varepsilon$  interest elasticities of substitution between bank assets or liabilities

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<sup>14</sup> Klein (1971), Monti (1972). For a textbook presentation see Freixas and Rochet (1997) Chapter 3.

and market intermediated finance, and finally  $\eta$  are the interest elasticities of substitution between assets and liabilities of different banks.

For consistency with the Klein-Monti specification we assume that competition is in loan and deposit volumes ie banks choose interest rates and business volumes assuming all other banks maintain their loan and deposit volumes constant and adjust their interest rates accordingly.

The analysis utilises the following lemma:

**Lemma 1.** The elasticity of the assets and liabilities  $L^n$ ,  $D^n$ , and  $W^n$  by bank  $n$  with respect to its interest rates  $r_L^n$ ,  $r_D^n$  and  $r_W^n$ , taking account of the change in interest rates charged by other banks, are given by

$$\begin{aligned}\frac{1}{L^n} \frac{\partial r_L^n}{\partial L^n} &= \frac{1}{v_L + \varepsilon_L} \frac{v_L + \varepsilon_L + \eta_L}{N(v_L + \varepsilon_L) + \eta_L} = \theta_L \\ \frac{1}{D^n} \frac{\partial r_D^n}{\partial D^n} &= \frac{1}{v_D + \varepsilon_D} \frac{v_D + \varepsilon_D + \eta_D}{N(v_D + \varepsilon_D) + \eta_D} = \theta_D \\ \frac{1}{W^n} \frac{\partial r_W^n}{\partial W^n} &= \frac{1}{v_W + \varepsilon_W} \frac{v_W + \varepsilon_W + \eta_W}{N(v_W + \varepsilon_W) + \eta_W} = \theta_W\end{aligned}$$

**Proof.** Consider the response required of bank  $m$ , following a change in the interest rate of bank  $n$ , in order to maintain a constant level of lending. We have

$$\frac{\partial L^m}{\partial r_L^n} = +L^m \left[ \eta_L \frac{\partial r_L}{\partial r_L^n} - (v_L + \varepsilon_L + \eta_L) \frac{\partial r_L^m}{\partial r_L^n} \right] = 0$$

All banks change their interest rates by the same amount, so

$$\frac{\partial r_L}{\partial r_L^n} = \frac{(N-1) \frac{\partial r_L^m}{\partial r_L^n} + 1}{N}$$

And hence

$$\frac{\partial r_L^m}{\partial r_L^n} = \frac{\eta_L}{N(v_L + \varepsilon_L) + \eta_L}$$

and so

$$\frac{\partial r_L}{\partial r_L^n} = \frac{v_L + \varepsilon_L + \eta_L}{N(v_L + \varepsilon_L) + \eta_L}$$

which establishes the lemma for the case of lending L. The same proof applies also to deposits and wholesale borrowing QED.  $\square$

### All banks constrained to the same degree

We consider first the case discussed in detail in the main text, corresponding to Bernanke and Blinder (1988), when all banks are constrained to the same degree with  $\varepsilon_w < \infty$ . We assume that the volume of lending is adjusted to maintain the balance sheet constraint (1). There are then two first order conditions, one with respect to the volume of deposits D and the other with respect to the volume of wholesale funding, for the maximization of the profits of bank n as given by equation (4.3)

$$r_L^n + \frac{\partial r_L^n}{\partial L^n} L^n - r_D^n - \frac{\partial r_D^n}{\partial D^n} D^n = r_L^n - r_D^n - (\theta_L + \theta_D) = 0$$

$$r_L^n + \frac{\partial r_L^n}{\partial L^n} L^n - r_W^n - \frac{\partial r_W^n}{\partial W^n} W^n = r_L^n - r_W^n - (\theta_L + \theta_W) = 0$$

In this case where all banks are constrained to the same amount we may assume that  $\eta_L = \eta_D = \eta_W = 0$ , thus yielding equation (4.4) of the main text. We can then solve for the bank interest rates, for lending, deposits, and wholesale borrowing, using the balance sheet constraint (1).

Using these first order conditions, the comparative statics of a change in monetary policy or in other exogenous parameters can then be set out as follows

$$\begin{bmatrix} 1 & -(1-\beta) & 0 \\ 1 & 0 & -1 \\ -\varepsilon_L L & -\varepsilon_D D(1-\beta) & -\varepsilon_W W \end{bmatrix} \begin{bmatrix} \Delta r_L \\ \Delta r_D \\ \Delta r_W \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ (v_D - \varepsilon_L)L + (v_D - \varepsilon_D)D(1-\beta) + (v_W - \varepsilon_W)W & \frac{L}{L_0} & \frac{D}{D_0} & \frac{W}{W_0} \end{bmatrix} \begin{bmatrix} \Delta r \\ L^0 \\ D^0 \\ W^0 \end{bmatrix}$$

so

$$\Delta r_L = \Delta r_D = \Delta r_W = \frac{\varepsilon_D D + \varepsilon_W W + \varepsilon_L L}{(v_D + \varepsilon_D)D + (v_W + \varepsilon_W)W + (v_L + \varepsilon_L)L} \Delta r \leq \Delta r$$

If the elasticities  $\epsilon_w$ ,  $\epsilon_D$  and  $\epsilon_L$  are all positive and finite, we obtain equation (4.6) of the main text with strict inequality on the right hand side.

As a final step, for this case where all banks are constrained to the same degree, we have analysed the determinants of the shadow price of internal funds, relative to the market rate of interest  $r$ . The marginal cost of wholesale borrowing is:  $r_w + N^{-1}(\epsilon_w + v_w)^{-1}$  so the shadow price of internal funds (the difference between this marginal cost and market rate of interest  $r$ ) is given by

$$\lambda = r_w - r + N^{-1}(\epsilon_w + v_w)^{-1}$$

and substituting for  $r_w - r$  using the exponential supply function for wholesale funding we obtain

$$\lambda = (\epsilon_w + v_w)^{-1}(\ln(W^n / W^0) + N^{-1})$$

showing that the shadow price increases with the amount of wholesale borrowing.

### Constrained and unconstrained banks

We now extend the analysis of the main text discussing a second case corresponding to Stein (1998) where the  $N$  banks are divided into  $N^u$  unconstrained banks (indexed by  $n = 1 \dots N^u$ ) who can access wholesale capital markets and  $N^c = N - N^u$  constrained banks ( $n = N^u + 1 \dots N$ ) who cannot. We now have  $\epsilon_w = +\infty$ ,  $\eta_L < +\infty$  and  $\eta_D < +\infty$ . We denote the fraction of constrained banks by  $\lambda = \frac{N^c}{N} = \frac{N - N^u}{N}$ . Constrained banks are all subject to the identical constraint that their ratio of deposits to loans exceeds some minimum level

$$\frac{D}{L} = 1 - \frac{W}{L} \geq 1 - \omega$$

Now aggregate market loan and deposit rates for the entire market are given by

$$r_L = \frac{1}{N} \sum_{n=1}^N r_L^n = \frac{N^u r_L^u + (N - N^u) r_L^c}{N} = (1 - \lambda) r_L^u + \lambda r_L^c$$

$$r_D = \frac{1}{N} \sum_{n=1}^N r_D^n = \frac{N^u r_D^u + (N - N^u) r_D^c}{N} = (1 - \lambda) r_D^u + \lambda r_D^c$$

where

$$r_L^u = \frac{1}{N^u} \sum_{n=1}^{N^u} r_L^n$$

$$r_D^u = \frac{1}{N^u} \sum_{n=1}^{N^u} r_D^n$$

$$r_L^c = \frac{1}{N - N^u} \sum_{n=N^u+1}^{N^c} r_L^n$$

$$r_D^c = \frac{1}{N - N^u} \sum_{n=N^u+1}^{N^c} r_D^n$$

The marginal source of funding for these banks is wholesale finance. The first order conditions for optimal loan and deposit choice of these banks are then

$$r_L^n - r + \frac{\partial r_L^n}{\partial L^n} L^n = 0$$

and

$$r - r_D^n - \frac{\partial r_D^n}{\partial D^n} D^n = 0$$

from which the loan and deposit rates of unconstrained banks are given by

$$r_L^u = r + \theta_L$$

and

$$r_D^u = r - \theta_D$$

The constrained banks have no access to external finance. Their first order condition for profit maximization is

$$r_L^n + \frac{\partial r_L^n}{\partial L^n} L^n - r_D^n - \frac{\partial r_D^n}{\partial D^n} D^n = 0$$

And so their loan and deposit interest rates are related according to

$$r_L^c - r_D^c = \theta_L + \theta_D$$

Indicating that loan and deposit rates of the constrained banks both respond to the same extent to changes in market interest rates or to loan or deposit demand.

To solve for these interest rates write the volume of lending and deposits of constrained banks as

$$\begin{aligned} L^c &= L^0 \exp(-(v_L + \varepsilon_L + (1-\lambda)\eta_L)r_L^c + \varepsilon_L r + (1-\lambda)\eta_L r_L^u) \\ &= L^0 \exp(-(v_L + \varepsilon_L + (1-\lambda)\eta_L)r_L^c + (\varepsilon_L + (1-\lambda)\eta_L)r + (1-\lambda)\eta_L / \theta_L) \end{aligned}$$

and

$$D^c = D^0 \exp((v_D + \varepsilon_D + (1-\lambda)\eta_D)r_D^c - (\varepsilon_D + (1-\lambda)\eta_D)r - (1-\lambda)\eta_D / \theta_D)$$

Since the constraint binds we have

$$\begin{aligned} (v_D + \varepsilon_D + (1-\lambda)\eta_D)r_D^c + (v_L + \varepsilon_L + (1-\lambda)\eta_L)r_L^c - (\varepsilon_D + \varepsilon_L + (1-\lambda)(\eta_D + \eta_L))r \\ - (1-\lambda)(\eta_D \theta_D + \eta_L \theta_L) = \ln \frac{D^c}{L^c} - \ln \frac{D^0}{L^0} \end{aligned}$$

Combining with the first order condition for interest rates we obtain

$$\begin{aligned} &\begin{bmatrix} (v_L + \varepsilon_L + (1-\lambda)\eta_L) & v_D + \varepsilon_D + (1-\lambda)\eta_D \\ 1 & -1 \end{bmatrix} \begin{pmatrix} r_L^c \\ r_D^c \end{pmatrix} \\ &= \begin{bmatrix} (1-\lambda)(\eta_D \theta_D + \eta_L \theta_L) & \varepsilon_D + \varepsilon_L + (1-\lambda)(\eta_D + \eta_L) & 1 & -1 \\ \theta_D + \theta_L & 0 & 0 & 0 \end{bmatrix} \begin{pmatrix} 1 \\ r \\ \ln(1-\omega) \\ \ln \frac{D^0}{L^0} \end{pmatrix} \end{aligned}$$

From this we obtain the response of constrained bank interest rates to a change in market rates of interest

$$\frac{\partial r_L^c}{\partial r} = \frac{\partial r_D^c}{\partial r} = \frac{\varepsilon_D + \varepsilon_L + (1-\lambda)(\eta_D + \eta_L)}{v_L + v_D + \varepsilon_L + \varepsilon_D + (1-\lambda)(\eta_L + \eta_D)} < 1$$

This expression shows that, provided there is less than perfect substitutability between the loans and deposits of different banks and between bank and market intermediation, the interest rates of constrained banks respond less than one for one to changes in market rates of interest.

The aggregate response of bank loan and deposit volumes is a bit more complicated, because we must allow for the competitive interaction between constrained and unconstrained banks. We can show that (proof omitted) that the response of aggregate bank lending to any given change in short term interest

rates is still reduced provided some banks are subject to constraints on their access to wholesale finance.



## Appendix 3

### International data collection

We collect two measures of bank deposits, a narrow measure eg sight deposit accounts and a broader measure including also savings/time deposits. Our preferred measure of bank credit, where available, is bank credit to the non-bank private sector. Real and nominal GDP are taken from the OECD main economic indicators database. Money market rates of interest are taken from the IMF International Financial Statistics (Although IFS also provides real and nominal GDP series, these, although generally consistent with OECD MEI, have a small number of breaks – for real GDP in Canada, and Japan and nominal GDP in France and Italy.) MEI also correct for breaks such as German unification, so MEI is the better source of data to use for time series econometrics.

IFS also reports bank deposit and lending data, but there are many breaks in these series. We therefore as far as possible use national sources, which are more consistent over time, for our bank deposit and loan data, using IFS only where there is no other data source. For two of our Eurozone countries (Italy, and France) we use harmonized ECB banking statistics for the period 1997Q1–2007Q2. While our GDP data are seasonally adjusted, there is evident seasonality in some of the banking data, for whole or part of the period. We correct for this seasonality and for reporting breaks as described below.

#### **These national sources are as follows**

GERMANY: (German banking data from the Bundesbank webpages goe back to the early 1950s, so we make no use of the IMF International Financial Statistics Database for German banking data).

Demand:

OU0115

Lending to domestic non-banks (non-MFIs) / Total /

All banks

Taken from:

[http://www.bundesbank.de/statistik/statistik\\_zeitreihen.en.php?lang=en&open=banken&func=list&tr=www\\_s100\\_mb3031\\_02\\_01](http://www.bundesbank.de/statistik/statistik_zeitreihen.en.php?lang=en&open=banken&func=list&tr=www_s100_mb3031_02_01)

OU0191

Deposits and borrowing from non-banks (non-MFIs) /

Total / All banks

Taken from:

[http://www.bundesbank.de/statistik/statistik\\_zeitreihen.en.php?lang=en&open=banken&func=list&tr=www\\_s100\\_mb3435\\_01\\_01](http://www.bundesbank.de/statistik/statistik_zeitreihen.en.php?lang=en&open=banken&func=list&tr=www_s100_mb3435_01_01)

OU0192

Sight deposits of non-banks (non-MFIs) / All banks

Taken from:

[http://www.bundesbank.de/statistik/statistik\\_zeitreihen.en.php?lang=en&open=banken&func=list&tr=www\\_s100\\_mb3435\\_01\\_02](http://www.bundesbank.de/statistik/statistik_zeitreihen.en.php?lang=en&open=banken&func=list&tr=www_s100_mb3435_01_02)

The German data are reported in Deutsche Mark until December 1998 and in Euro thereafter. We convert all pre-1998 data to Euro at the fixed exchange rate of 1 euro = 1.95583 DM

We must also allow for the break the German banking series in 1990.06 as a consequence of the re-unification with the former East Germany. Here we splice the series, assuming that the growth of all banking variables between 90.05 and 90.06 is the average growth rate of 89.12–90.05 and 90.06–91.01.

Definitions used by the Bundesbank:

[http://www.bundesbank.de/download/presse/publikationen/geldpolitik\\_bundesbank\\_199610\\_en.pdf](http://www.bundesbank.de/download/presse/publikationen/geldpolitik_bundesbank_199610_en.pdf)

Demand deposits: held with credit institutions (giro money, sight deposits) which can be used as money by issuing cheques, direct debits or credit transfers.

Sight deposits are part of the generally accepted  $\square$  means of payment ( $\square$  money).

NB: It seems that the definitions changed with the implementation of the euro. In particular, there was a change in the definition of an MFI. Building associations and money market funds now have to supply data and banks that only receive deposits from MFIs no longer have to. This should, however, make very little difference to our results, as according to Stefan Bruncken of Deutsche Bank:

‘The breaks in the time series that were caused by this change were not significant, given the low businessWHAT MEAN? of these institutions. With respect to the joiners, money market funds (around 40 institutions) had to be included in the reporting population for monetary statistics for the first time. Nevertheless, reporting did not start from scratch as the collective investment undertakings had been already used to reporting supervisory data for their money market funds. The inclusion of money market funds caused minor breaks at the highest aggregation level including all types of MFIs, ie the aggregated and consolidated balance sheet of MFIs. Time series relating to credit institutions only remained unaffected. A special case were building and loan associations: they met

the MFI definition and had also reported balance sheet data to the Bundesbank in the past; insofar no change occurred.”

([http://www.czso.cz/sif/conference2004.nsf/bce41ad0daa3aad1c1256c6e00499152/18832c2b59f25436c1256edd00334500/\\$FILE/Brunken.pdf](http://www.czso.cz/sif/conference2004.nsf/bce41ad0daa3aad1c1256c6e00499152/18832c2b59f25436c1256edd00334500/$FILE/Brunken.pdf))

There is clear seasonality in all the German banking series from 1970Q1 until 2001Q4. Thereafter the seasonality seems to disappear. We therefore include quarterly dummies in German banking regressions up to 2001Q4 and adjust for this seasonality in the descriptive charts.

US: Assets and Liabilities of Commercial Banks in the United States. Historical monthly data back to 1973 are taken from:

<http://www.federalreserve.gov/releases/h8/data.htm>

The specific series we use are (i) Total loans and leases in bank credit (b1020a.txt) (ii) Total loans and leases in bank credit less security related lending (b1030a.txt) and *less* other loans and leases (b1103a.txt) (iii) total deposits (b1058a.txt) (iv) transaction deposits (b1059a.txt)

We correct for the following breaks in the transaction deposit series. Between 09/81 and 10/81 there is a one month fall in recorded transaction deposits from 396.8 to 341.4 bn dollars. Between 12/83 and 01/84 there is a one month jump in recorded transaction deposits from 358.1 to 455.9 bn dollars. There is also a ten per cent jump in transaction deposits in Sept 2001 which falls off again in Oct 2001 (possible a consequence of the 9/11 terrorist attacks) and a somewhat smaller 5% one month fall in transaction deposits in Sept 2002 which recovers the following month. In these two cases, our Q3 money stock is the average of Aug and Oct, not the Sept figure.

We splice the time series for lending, time deposits, and total deposits from the IMF International Financial Statistics, for 1957–1972. There are no reported breaks in these series.

There is no evident seasonality in the US banking data.

## FRANCE/ ITALY

We have used IMF IFS data, spliced as necessary for breaks, prior to 1997 and used monthly ECB data thereafter (from

[http://www.ecb.int/stats/money/aggregates/bsheets/html/outstanding\\_amounts\\_index.en.html](http://www.ecb.int/stats/money/aggregates/bsheets/html/outstanding_amounts_index.en.html))

The ECB data and the IMF IFS data both exhibit evident seasonality in all the French and Italian banking series, but the season fluctuations are much more

pronounced in the IMF IFS data. We therefore apply separate season adjustments to the two sets of data, again by regression on quarterly dummies.

JAPAN:

Monthly data back to 1993M10 can be found at:

[http://www.boj.or.jp/en/theme/research/stat/asli\\_fi/index.htm](http://www.boj.or.jp/en/theme/research/stat/asli_fi/index.htm)

We use total deposits, sight deposits (sum of current deposits and ordinary deposits), credit to non-bank sector (total loans and bills discounted) and credit to non-financial sector (credit to non-bank sector less lending on bills and less loans to financial sector).

The IMF IFS is used prior to 1994 with adjustment of breaks as necessary

UK:

The UK is problematic because its financial institution data are extremely fragmented. The IMF International Financial Statistics provides a series for total credit to the non-bank private sector (with breaks in 72Q4, 81Q4 and an obvious data error in 75Q2) back to 1963Q1. The Bank of England publishes a monthly series for net sterling lending to the non-bank financial sector by monetary institutions back to June 1982. We combine these two series, break adjusting the IFS data.

IFS also provide a total demand, time, and savings deposit series back to 1963Q1 (with a fairly substantial break in 81Q4 and a much smaller break in 75Q2). We can get Bank of England data on total retail deposits (combining the data series for banks and for building societies) from June 1982. The resulting measures are fairly close in 1982, so we splice these together to construct a total deposit series from 1963 onwards.

A sight deposit series is more difficult. There is nothing in the IFS database. We found annual bank of England data for total sight deposits of banks from 1973 until 1986, then monthly data combining resident banks and building societies from Sept 1986. With some interpolation, with reference to older published statistics, there was some prospect of obtaining a quarterly series back to 1973 or possibly earlier, but we did not use this data for our analysis.

There is evident seasonality in the UK total deposit and lending data from 1973 until 1980 (for bank lending) and until 1982 (for deposits). We seasonally adjust by using the residual for a regression on four season dummies over this period.

## AUSTRALIA

We obtain lending data from September 1976 onwards, via <http://www.rba.gov.au/Statistics/Bulletin/index.html>, Table D02 of the statistical bulletin. We use total lending by banks and non-banks (the share of non-banks declines substantially over time).

Data for total deposits of banks and of building societies is obtained from the same source (Tables B03 and B07), providing monthly deposit data back to January 1989. There is no information on sight deposits from these sources.

For earlier data and for sight deposits we use IMF IFS.

There is evident seasonality in the Australian total deposit and sight deposit data but not lending data; we adjust the seasonality by regression on quarterly dummies.

## CANADA

We use the IFS statistics for bank deposits and credit. In 2001Q4 there is a substantial break in all the banking series (they increase by more than 50%). We assume the growth rate at this point is the same as in the subsequent quarter.

## SPREADSHEET ORGANISATION

All data manipulations are carried out in Excel.

Quarterly data reported by international organisations (the IMF *International Financial Statistics* are downloaded into the Excel 2003 workbook maindata.xls (spread sheets GDPV for nominal GDP, GDPQ for real GDP, mmrate for the monetary policy rate (quarterly average).

We also have a spread sheet of treasury bill rates which are used for some earlier periods when money market rates are unavailable.

There are separate worksheets containing the banking data for each individual country (except Canada).

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