A comparison of liquidity management tools in seven Asian economies[1]

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Abstract

We develop a simple theoretical model and then use bank data from seven Asian economies to investigate the effects on bank lending of different liquidity management tools used by central banks. We find that hiking reserve requirements to sterilise foreign exchange purchases will retard bank lending growth more than the issuance of central bank bills does, and that smaller and weaker banks are affected disproportionately by changes in reserve requirements.

Keywords: Liquidity management, bank loan supply.

JEL classification: C23, E52, G21.

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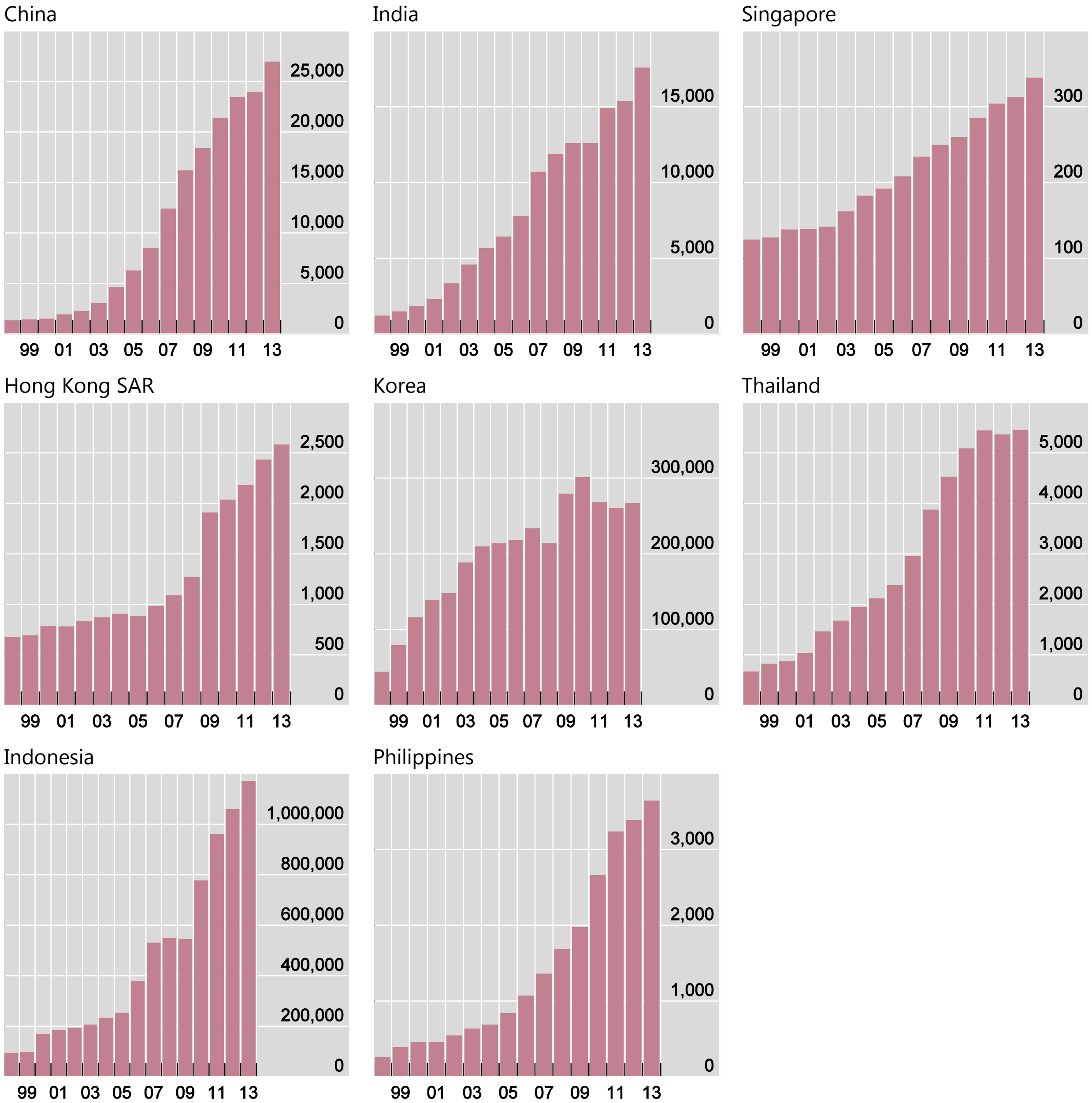
1. Introduction

Faced with sustained capital inflows in recent years, many Asian central banks have intervened heavily in foreign exchange markets to check the pressure on their currencies to appreciate. As a consequence, foreign exchange reserves have rapidly accumulated, as shown in Graph 1. Graph 2 illustrates further that increases in foreign assets account for nearly all of the change in the size of the central bank balance sheets in the region over recent years. In the absence of offsetting policy actions, these increases in the size of the balance sheet will create excess banking system reserves. To mitigate this effect, central banks have resorted to using sterilisation tools

Foreign exchange reserves

In domestic currency, billions

Graph 1



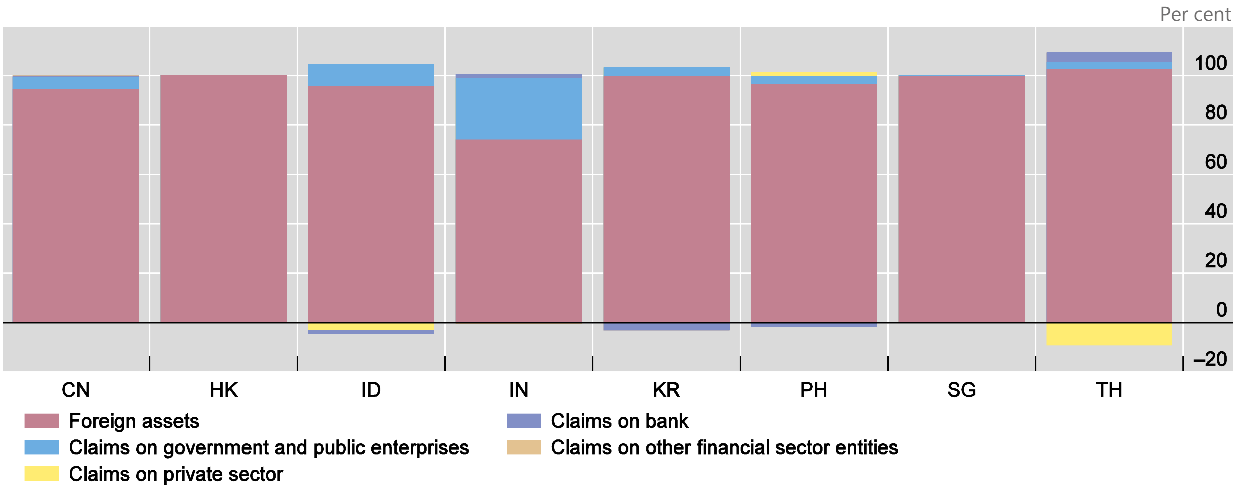
Source: IMF, *International Financial Statistics.*

in an effort to absorb the liquidity created by the foreign exchange intervention, thus maintaining monetary independence.[4]

Change in composition of central bank assets in emerging Asia, 2002–13[1]

As a percentage of change in total assets

Graph 2



CN = China; HK = Hong Kong; ID = Indonesia; IN = India; KR = Korea; PH = Philippines; SG = Singapore; TH = Thailand.

[1] Up to January 2013 for KR.

Sources: IMF *International Financial Statistics*; BIS calculations.

Reserve requirements and other liquidity management tools, such as central bank bills,[5] have come into widespread use as sterilisation tools. As shown in Graph 3, the central banks of Korea and Thailand have issued significant quantities of bills, accounting for 4.7% and 11.5% of their respective banking system assets as of 2013. China, Indonesia and the Philippines, on the other hand, have relied heavily on changes in reserve requirements. In fact, China's voluminous increase in reserves has been largely offset by the ratcheting up of the required reserve ratio from 6% in 1999 to 20% in 2013.

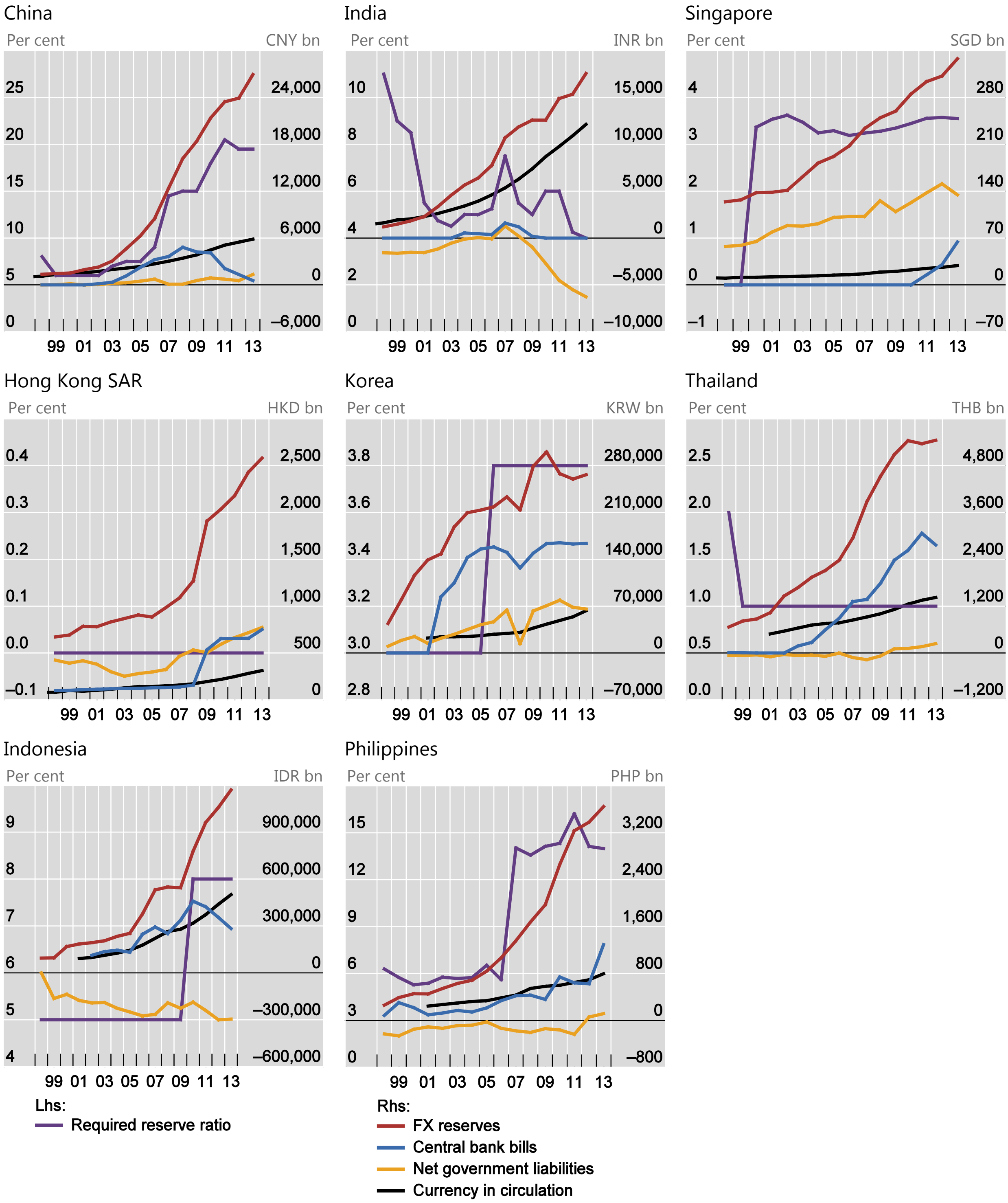
Another way to characterise economies' differing degrees of reliance on the various tools is to illustrate the link between the change in foreign exchange reserves and the size of liabilities associated with sterilisation. Table 1 displays the coefficient from simple linear regressions of the change in central bank bills and a change in required reserves (computed as the change in the required reserves ratio × lagged bank deposits), respectively, on the change in foreign exchange reserves. The regression equations are estimated economy by economy over the 1999–2013 period (or else the longest period for which data are available), and each includes a constant. The results illustrate the variation in the use of sterilisation instruments: required

4 See the discussion in Ho and McCauley (2008), who document that policy rates have generally remained close to target levels in Asian economies, despite high levels of foreign exchange intervention, as evidence of successful sterilisation and the maintenance of monetary policy independence.

5 Throughout this paper, we include special deposit accounts (for the Philippines) and term deposits (for Indonesia) in our definition of central bank bills, given their similar characteristics. Precise definitions, by country, are available upon request.

Policy tools

Graph 3



Sources: IMF; Bloomberg; CEIC; Datastream; national sources; BIS.

reserves dominate in sterilisation operations in China, while central bank bills play a larger role in Hong Kong SAR, Korea, Singapore and Thailand, and both tools are important in Indonesia, India and the Philippines.[6]

Effects of change in FX reserves on:

Table 1

	ΔCB bills	Δrequired reserves
China	0.08	0.66
Hong Kong SAR	0.54	-
Indonesia	0.20	0.21
India	0.29	0.23
Korea	0.25	–0.01
Philippines	0.35	0.21
Singapore	0.36	0.00
Thailand	0.24	0.00

Source: Authors' calculations

The efficacy of these tools in reducing excess reserves ("draining liquidity") is not in doubt. However, actions may have unintended consequences for the financial system generally, and for bank lending in particular. Requiring banks to hold additional reserves is costly, while issuing central bank bills alters the composition of assets in the financial system. Using bank-level data from seven Asian economies, our goal is to assess the two tools' impact on loan supply, and the extent to which the effects depend on bank-specific characteristics.

Emerging Asia provides a rich environment in which to investigate these effects for at least three reasons. First, there is considerable variation in the choice of tools, both across different economies and over time.[7] Second, the large scale of foreign exchange intervention in recent history has resulted in greater use of liquidity management tools, increasing the likelihood that we will be able to identify the effects of different tools more easily than might be possible using data for other regions.

Third, these liquidity management tools have been used to substantially sterilise foreign exchange intervention. To the extent that this has been successful, we are able to examine the effect of liquidity management conditional on the stance of monetary policy. That is, where liquidity management is used primarily to offset the effect of foreign exchange intervention and maintain the stance of monetary policy, rather than to change the stance of monetary policy, we may be able to avoid confounding the effect of the use of liquidity management tools with changes in the stance of monetary policy.

The closest papers to ours are those that looked at the effect on the behaviour of banks of central bank policies associated with foreign exchange intervention. For example, Cook and Yetman (2012) studied the effects of foreign exchange

6 In the case of Hong Kong SAR, we treat the issuance of Exchange Fund Paper as equivalent to central bank bills, given their similar characteristics. However, they are officially considered to be part of the monetary base in Hong Kong and are often used by banks to manage liquidity; see Cook and Yetman (2012, p 50) for a discussion.

7 See Ma et al (2011) for a detailed discussion of the use of different liquidity management tools in China, where it appears that the use of tools depends in part on their relative cost of implementation.

intervention on a number of key ratios for 55 banks in Asia over the 2003–07 period using Compustat data. One result from their paper is that a 1 percentage point increase in foreign exchange reserves is associated with a 1% decline in bank loans relative to total bank assets, largely driven by a fall in the aggregate size of loans, suggesting that reserves accumulation crowds out bank lending. They also found that this effect is larger for banks that started with high loan-to-deposit ratios. One important difference between their approach and the one taken here is that they focused on the effect of growth in foreign exchange reserves – an asset on the balance sheet of the central bank – whereas we assess the effect of different central bank liabilities.

Also focusing on the relationship between the behaviours of central banks and commercial banks, Gandanecz, Mehrotra and Mohanty (2014) examined 79 banks from 24 emerging market economies over the 2001–11 period using Bankscope data. They found that increased bank holdings of government securities and holdings of available-for-sale securities (which includes central bank paper) as a share of credit to the private sector led to an expansion in credit to the private sector over time, especially for well capitalised banks. This suggests that, rather than crowding out lending by banks, the issuance of central bank bills may allow some banks to increase the aggregate size of loans that they make. Our approach differs from Gandanecz et al (2014) in that we focus on 69 banks, all from emerging Asian economies, that have engaged in high levels of foreign exchange intervention. We also compare the effects of two different tools that may be used to manage liquidity changes in response to foreign exchange intervention, rather than focusing solely on the effect of an increase in a proxy for central bank securities, and consider interactions with a range of bank characteristics, in addition to the degree of capitalisation.

The next section sketches a simple conceptual framework for thinking about the effects on the banking system of alternative sterilisation tools. Section 3 discusses the considerations involved in the formulation of the regression model. Section 4 introduces the data and the results are presented in Section 5. Finally, Section 6 discusses policy implications and conclusions.

2. Sterilisation and its effects on the financial system

This section develops a framework for thinking about the possible effects of sterilisation policies on bank lending, similar in spirit to Bianchi and Bigio (2014). The basic idea is that banks finance illiquid loans by issuing deposits, taking into account the need to hold sufficient liquid reserves to settle claims by other banks when funds are transferred between institutions. The quantity of loans versus liquid assets therefore reflects a trade-off between maximising the returns on the banks' loan portfolios and reducing liquidity risks. In our context, foreign exchange intervention, and the use of liquidity management tools of various kinds by the central bank, influences both the assets and liabilities on the banks' balance sheets, and therefore the optimal quantity of lending.

Before getting to the banking model, it is useful to begin with a simple, abstract accounting of how sterilisation affects the balance sheets of the financial sector and the central bank. Figure 1 depicts a stylised central bank balance sheet. On the asset side, the central bank holds foreign exchange reserves (X) and government bonds

(*GB*). The liability items include bank reserves (*R*, made up of required reserves [*RR*] and excess reserves [*ER*]) central bank bills (Q^B) and government deposits (*GD*).[8]

A stylised central bank balance sheet — Figure 1

Assets	Liabilities
X	$R = RR + ER$
GB	Q^B
	GD
	currency

For the purposes of this paper, we will largely ignore *GB*, on the grounds that the region's central banks hold relatively small quantities of government debt, and the size of these holdings varies little over time (as seen earlier in Graph 2). We will also ignore *GD* since government balances at the central bank are to a large extent exogenous and not used for monetary purposes.

Now consider a capital inflow, in which a foreign investor uses dollars to buy a local currency-denominated financial asset, *A*. In other words, domestic residents (although not necessarily banks) own more *X* and less *A*. With no offsetting transfer of assets, this would put pressure on the currency to appreciate and generate a current account deficit.

Responding to the exchange rate pressure, the central bank intervenes in the foreign exchange market, purchasing *X*. What else adjusts to ensure that the central bank's balance sheet remains balanced? If left unsterilised, the purchase of *X* increases *R*. Netting out the transactions: the *A* held by the financial system is lower, and *R* is higher.

Initially at least, the increase in *R* is in the form of excess reserves and leads to a decline in the interest rate and an expansion in loans and deposits, stimulative effects that may conflict with monetary policy objectives. One sterilisation option is to short-circuit this effect by raising the required reserve ratio. This has no effects on the aggregate balance sheets of the private financial system and the central bank, but it increases banks' demand for bank reserves, constraining deposit-taking and lending.

Alternatively, the central bank could sterilise the effect of their intervention in other ways. In many countries outside Asia, the standard means of sterilisation is for the central bank to sell off some of its government bonds, leaving the liability side of the balance sheet unchanged. Netting out the transactions, in the private sector, *A* is lower and *GB* is higher; the increase in *X* on the central bank's balance sheet is offset by the reduction in *GB*. There are no monetary implications, and the financial effects are likely to be small to the extent that *A* and *GB* are close substitutes in investors' portfolios. However, as noted earlier, in the Asian region, central banks hold very few government bonds (especially relative to the scale of foreign exchange intervention in recent years), so this is not an option. This also limits the ability to use reverse repos

8 Why Q^B? Because central bank bills are liquid assets, and the *B* distinguishes central bank-issued *Q* from liquid assets from other sources, such as the government.

(the temporary sale of government securities) to offset the expansionary effects of intervention.

Another alternative is for the central bank to issue its own non-monetary liabilities, Q^B, possibly by first using R to pay for the X and subsequently absorbing the additional R by exchanging it for Q^B.[9] When the dust has settled, the private sector owns less A and more Q^B; the central bank owns more X and owes more Q^B. In terms of the accounting, this combination of transactions is not unlike sterilisation through the sale of government bonds. However, to the extent that central bank bills are closer substitutes for reserves than the government bonds it would have sold, had that been an option, the increased supply of Q^B may have subtle effects on affect banks' portfolio choice and lending decisions.

To see how this works, consider a generic model of banks' portfolio allocation and deposit-taking. The bank's objective is to maximise profits generated by the interest on a portfolio of assets that includes loans (L), liquid assets (Q, including but not limited to central bank bills, Q^B) and reserves (R), minus the interest rate on deposits (D). The bank is subject to a reserve requirement, $R \geq \phi D$, where ϕ is the required reserve ratio. The marginal cost of raising funds by taking new deposits is the deposit rate plus the "reserves tax" (since reserves are remunerated at a lower rate of interest than that received on loans). If the interest rate on reserves is the deposit rate, for example, then the marginal funding cost is given by $r^D + \phi(r^L - r^D)$.

The mechanistic "money and banking textbook" approach to solving for the bank's optimal behaviour is a special case of this model with $Q = 0$ and a binding reserve constraint (at the prevailing lending and deposit rates, banks have more lending opportunities than they can satisfy, given the level of reserves in the system). Banks are at a corner solution. Assuming no currency "leakage," a unit increase in R increases D by the factor $1/\phi$. The impact on deposits can be neutralised by raising ϕ by $1/D$ times the change in reserves. But with D constant, forcing banks to hold a higher level of reserves will crowd out lending one-for-one, as $L = (1-\phi)D$. In addition, increasing the required reserve ratio will increase the cost of raising new loanable funds through additional deposit taking.

The impact of an exogenous increase of Q^B in this setup depends on where those liquid assets end up. To take the polar case, suppose $r^Q > E(r^L) - \mu$, where μ represents the cost of intermediation (generally an increasing function of L). In this case, banks would choose to purchase the entire stock of Q^B (again putting them at a corner solution). The increase in Q again crowds out L one-for-one. On the other hand, the issuance of Q^B does not increase banks' marginal cost of funds financed by new deposit taking. (Note that the cost of funds is not relevant in the mechanistic scenario since it is assumed that $E(r^L) - \mu > r^D + \phi(r^L - r^D)$.)

Things get a little more interesting when banks are not at a corner, and optimal levels of Q and D are both likely to vary in response to central bank actions. For this to be the case we need banks to have some motivation for holding excess reserves and liquid assets, whose rates of return are presumably less than the lending rate, even when adjusted for intermediation costs. One plausible story is that excess reserves (ie any R in excess of ϕD) and Q are likely to yield liquidity services, providing a buffer against adverse liquidity shocks (unanticipated interruptions in funding,

9 This may be thought of as equivalent to a standing facility in which banks deposit excess reserves at the central bank.

interbank payments or deposit outflows, for example). The volume of excess reserves and liquid assets banks choose to hold will then involve trading off the marginal benefit of liquidity against the opportunity cost of holding those low-return assets.

A simple, partial equilibrium framework is one in which banks maximise:

$$\max \mathrm{E}(r^L)L + r^Q Q + r^R R - r^D D - g(ER,Q) \qquad (1)$$

with respect to D and Q, where $ER = R - \phi D$ (excess reserves), taking all three interest rates as exogenous.[10] The g function represents a Diamond-Dybvig (1983) expected illiquidity cost, where $\partial g/\partial ER$ and $\partial g/\partial Q$ are both negative (more liquid assets of either type lower the expected illiquidity cost). In addition, it is reasonable to assume that $\partial^2 g/\partial ER \partial Q > 0$, meaning that an increase in Q reduces the marginal benefit of holding additional R.

The balance sheet identity imposes a constraint on the volume of loans, $L = D - Q - R$. Required reserves are set by the central bank, and may be treated as exogenous from banks' standpoint. While we have glossed over many other realistic aspects of bank behaviour (for example, we could add an intermediation/monitoring cost that banks pay, as an increasing function of L), these are not essential to our analysis. In addition, our model focuses on the liquidity dimension of banks' optimisation problem, ignoring the potentially important role of capital.

The bank's first-order condition with respect to D is given by:

$$\mathrm{E}(r^L) - r^D = -\phi \partial g/\partial ER. \qquad (2)$$

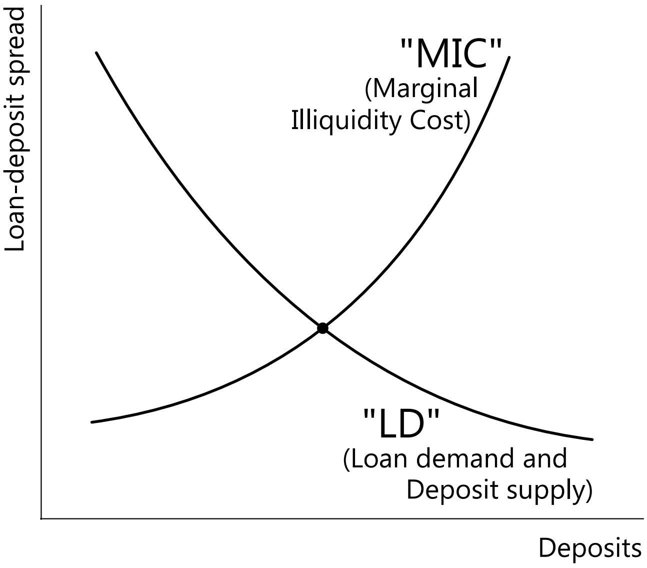
The interpretation of the first-order condition is as follows. Suppose an Indonesian bank takes an additional rupiah in deposits and makes a new loan. The marginal benefit of the transaction is the spread between the deposit and loan rates. Making the loan reduces excess reserves by ϕ, however; the marginal cost associated with the liquidity reduction is $\phi \partial g/\partial ER$.

The first-order condition is depicted in Figure 2. The downward-sloping "LD" (Loan-Deposit) curve embodies the assumptions that private-sector loan demand makes the lending rate a decreasing function of the volume of loans, and deposit supply is an increasing function of deposits. The upward-sloping curve "MIC" (Marginal Illiquidity Cost) curve shows the marginal cost of illiquidity, as a function of D, conditional on a given level of Q. Equation (2) is satisfied at the intersection of the two curves.

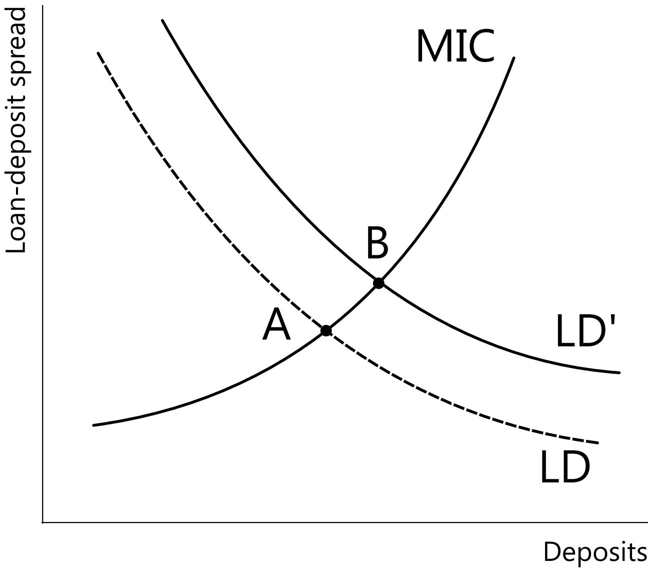
Now consider the effect of an increase in R, along with an increase in ϕ calibrated to leave the levels of deposits and excess reserves unchanged. If banks did not take any additional deposits, the volume of lending would decrease and the loan rate would rise. This is shown in Figure 3 as an upward shift in the LD curve to LD'. The increase in the loan-to-deposit spread gives the bank an incentive to hold fewer excess reserves and therefore deposits increase. The quantitative impact on lending depends on the marginal liquidity benefit of reserves: low if the benefit is small (eg shallow MIC, plentiful liquidity), high if liquidity is scarce (steep MIC, scarce liquidity).

10 The assumption of exogenous interest rates means the model should be interpreted as representing the aggregation of individual price-taking banks.

Lending benefits and illiquidity costs Figure 2



An increase in the reserve requirement Figure 3



The first-order condition with respect to *Q* is similar:

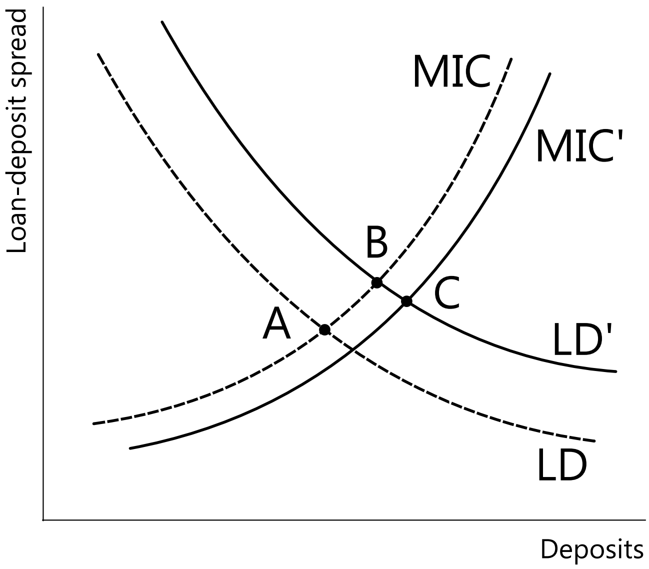
$E(r^L) - r^Q = -\partial g/\partial Q.$ (3)

The interpretation is as follows. Suppose a bank reallocates a rupiah from liquid assets to make a new loan. The benefit is the spread. The cost is the forgone liquidity provided by the asset. The equilibrium spread should therefore reflect the marginal benefit of the liquidity provided by the asset.

Consider first the case in which the banking system absorbs the entire increase in Q^B, which would occur if $r^Q > E(r^L) - \mu$. In this case, bills are so attractive relative to loans that banks will be happy to absorb the full increase in supply.

The first-order effect would be one-for-one crowding out, as before. However, the increase in *Q* on the balance sheet makes the bank more liquid, and this reduces the need to hold excess reserves as a liquidity buffer. (This is reflected in the assumption about the cross partial derivative.) Banks will lend more, narrowing the loan-to-deposit interest rate spread relative to what it would otherwise have been, until it reflects the reduction in $\phi\partial g/\partial ER$. This is shown as an outward shift in the MIC curve in Figure 4.

An increase in central bank bills Figure 4



There is no reason to expect that all of the newly issued Q^B will remain in the banking system, however. The volume of liquid assets banks choose to purchase will depend on their yield relative to the expected return on loans. Thus, the bank's optimal choices of *D* and *Q* will be determined by the joint solution to the two first-order conditions, plus the balance sheet constraint, along with a downward-sloping loan demand curve (giving $E(r^L)$ as a function of *L*) and an upward-sloping deposit supply curve (giving r^D as a function of *D*).

In this situation, the issuance of central bank bills affects bank lending only to the extent that the increase in Q^B drives up r^Q. This in turn will depend on the extent of the market for liquid, domestic currency-denominated bill-like assets from other sources, such as short-term government debt. The impact on r^Q of an increase in Q^B is more likely to be large if comparable liquid assets are in short supply.

While obviously not a fully articulated economic model of banking behaviour, this framework suffices to illustrate two points about the effects of issuing central bank bills, vis-à-vis increasing reserve requirements:

1. To the extent that central bank bills provide liquidity services, banks' purchases of those assets will tend to have a smaller impact on loan supply than an increase in reserve requirements; and
2. When banks are free to choose the optimal portfolio allocation across loans and liquid assets, the impact on bank lending of central bank bill issuance will depend on the size of the issuance relative to the relevant market, and the demand for liquid assets elsewhere in the financial system.

Both considerations suggest that sterilisation using central bank bills is likely to have smaller effects on loan supply than a change in required reserves of a comparable magnitude.

3. Empirically assessing the effects of sterilisation on bank lending

Our empirical work follows the general strategy developed by Kashyap and Stein (2000). Their objective was to assess the impact of US monetary policy, and how the effects differed depending on bank characteristics. Using bank-level data from 1976 to 1993, they found that the impact of monetary policy on lending was strongest on banks which had less liquid balance sheets, or were relatively small. The same approach has been taken by a number of more recent papers, such as Ippolito et al (2013).

Our approach is similar to the Kashyap-Stein "one-step" specification, in that it involves regressing changes in bank-level lending growth on aggregate economy-level variables representing sterilisation policies (in this case, changes in required reserves and central bank bills), interacting these variables with bank attributes. However, an important difference between our work and that of Kashyap and Stein is our use of two different policy measures based on the central bank balance sheet, rather than a scalar indicator of the stance of monetary policy.

For the purposes of modelling the impact of sterilisation, we will make two additional simplifications to the stylised balance sheet in Figure 1. One is to consolidate government assets and liabilities, *GB* and *GD*, into net government liabilities, *NGL*. We do this because *GB* is small in most economies in our sample and has varied little in recent years, as illustrated in Graph 2, even as foreign exchange reserves have been rapidly accumulating in Asia. Thus it does not appear to be used for sterilisation purposes. Similarly, *GD* is likely to be driven by non-monetary considerations. We will therefore include *NGL* in the regression as a control, but do not focus on its effects on loan growth.

The second simplification is to ignore the quantity of currency in the economy, which is typically supplied elastically to meet transactions requirements. Consequently, currency follows a relatively smooth trend, as shown in Graph 3, and the effect of any variable growing at a constant rate will be absorbed into the intercept term.

Ignoring the bank- and economy-specific controls and the interaction terms for the moment, the starting point for the empirical analysis is an equation of the form:

$$\Delta L_{ijt}/A_{ijt-1} = \beta_0 + \beta_1\,\Delta X_{jt} + \beta_2\,\Delta Q^B_{jt} + \beta_3\,\Delta RR_{jt} + \beta_4\,\Delta ER_{jt} + \beta_5\,\Delta NGL_{jt}$$
$$+ \text{ bank attributes} + \text{economy controls} + \text{interaction terms,} \qquad (4)$$

where X is foreign exchange reserves, Q^B is the bills (and similar liabilities) issued by the central bank, RR is required reserves, ER is excess reserves and NGL is net government liabilities. The i subscript indexes banks, j economies and t time.

This specification fails to take into account the adding-up constraint on the balance sheet, however. Leaving currency growth aside, changes in the four categories of liabilities should (approximately) equal the change in foreign exchange reserves. If the balance sheet depicted in Figure 1 were complete, then the five regressors would be highly correlated (*perfectly* correlated in the absence of random fluctuations in the currency component). In practice, however, our idealised taxonomy is likely to omit some quantitatively significant balance sheet items, which will reduce the correlation. If we regress the change in FX reserves on the changes in other balance sheet items listed in equation (4) in levels, for example, we obtain R^2's of 0.8 or above for five of the economies in our sample, the only exceptions being Thailand (0.5) and the Philippines (0.2).[11] We will therefore estimate two versions of the regressions. One drops the change in foreign exchange reserves (ΔX), consistent with the assumption that foreign exchange intervention accounts for the most of the variance in ΔQ^B and ΔR; the second includes ΔX along with the other balance sheet variables.

An additional twist is that an expansion in the volume of deposits will increase the level of required reserves, RR, even in the absence of a change in the required reserve ratio. The raw ΔRR is therefore not an appropriate gauge of sterilisation. In its place we use a variable intended to capture the impact of a change in the required reserve ratio on the level of required reserves *for a given level of deposits*,

$$\Delta RR^*_{jt} = (\phi_{jt} - \phi_{jt-1})D_{jt-1} \,, \qquad (5)$$

where ϕ is the required reserve ratio. We correspondingly replace the change in excess reserves with

$$\Delta ER^*_{jt} = \Delta R_{jt} - \Delta RR^*_{jt} \,, \qquad (6)$$

where ΔR_{jt} is total reserves, to preserve the underlying adding up constraint between central bank balance sheet elements.

To account for size differences across economies, and for the scale of the policy interventions relative to the sizes of the respective financial systems, all of the central bank variables are expressed as shares of the sum of total banking system assets plus government debt.

We include five bank-level variables in the regression: lags of the log of total assets, the Tier-1 capital ratio, the ratio of liquid to total assets and non-performing loans (NPL) as a share of total assets, as well as the long-term bond rating of the bank. The bond rating is the long-term foreign currency credit rating from Capital Intelligence, converted to numerical scale, where a higher number indicates a more highly rated bank.

Finally, the regressions include interaction terms involving the policy variables and each of the four bank attributes in turn, intended to assess the policies'

[11] We considered including Singaporean banks in our sample. However, there is no detectable link between the balance sheet policy tools and foreign exchange intervention in the case of Singapore (the R^2 in this regression is 0.0), so they are excluded from our panel.

differential effects across banks. With these modifications and additions to equation (4), our basic regression model becomes:

$$\Delta L_{ijt}/A_{ijt-1} = \kappa_i + \alpha_1 \ln(A)_{ijt-1} + \alpha_2 (K/A)_{ijt-1} + \alpha_3 (Q/A)_{ijt-1} + \alpha_4 (NPL/A)_{ijt-1} + \alpha_5 LTRating_{jt} + \delta_1 \Delta\ln(Y)_{jt} + \delta_2 \Delta r_{jt} + \beta_1 \Delta X_{jt} + \beta_2 \Delta Q^B_{jt} + \beta_3 \Delta RR^*_{jt} + \beta_4 \Delta ER^*_{jt} + \beta_5 \Delta NGL_{jt} + \gamma_1 Z_{ijt-1} \Delta Q^B_{jt} + \gamma_2 Z_{ijt-1} \Delta RR^*_{jt} + \gamma_3 Z_{ijt-1} \Delta ER^*_{jt} + \gamma_4 Z_{ijt-1} \Delta NGL_{jt}, \quad (7)$$

where A is bank assets, K is Tier-1 capital, Q is liquid assets, NPL is non-performing loans, $LTRating$ is the long-term foreign-currency bond rating of the bank, r is the short-term interest rate (the policy rate), Y is real GDP and κ_i is a bank fixed effect. (Ideally, we would also include a bank-level measure of excess reserves, but these data are available for only a very small number of banks.) The Z variable represents one of the five bank attributes included in the regression (L/A, K/A, Q/A, NPL/A or $LTRating$). As mentioned earlier, the policy variables are normalised by the lagged sum of the economy's total banking assets and government debt.

4. Data

Our bank data are drawn from Bankscope. We focus on "commercial banks", "savings banks" and "cooperative banks" from those economies for which there has been a high degree of foreign exchange intervention in recent years and for which there are more than two years of (annual) data available. To ensure that our results are not driven by small banks, we restrict our attention to those for which there are long-term bond ratings available in the Bankscope database, which are likely to account for the lion's share of total banking system assets in each economy. Our sample includes banks from seven economies: China, Hong Kong SAR, India, Indonesia, Korea, the Philippines and Thailand.

We also collect bank characteristics from Bankscope to use in our regressions: bank size – defined as the log of total assets measured in millions of US dollars, Tier-1 capital ratio, liquid assets as a share of total assets, reserves for non-performing loans as a share of total assets and long-term foreign-currency bond rating. These variables typically enter with a one-year lag due to concerns about endogeneity.

At each stage, data were checked carefully, and observations that defied plausibility, or likely reflected extraordinary bank-specific factors that might unduly influence our results, were dropped. These included observations where Tier-1 capital or total bank capital exceeded the total value of bank assets, gross loans (or gross loans plus liquid assets) exceeded total assets, the change in gross loans from one year to the next was more than 90% of total assets, liquid assets were more than five times as large as deposits plus short-term funding, gross loans were less than 9% of total assets, or Tier-1 capital was negative.

Once the data sample was cleaned up, we are left with data for 69 banks, with start dates that vary by bank, anywhere from 2005 to 2012, with final observations in our data set typically for 2013. Data for Malaysia and Chinese Taipei were also considered but dropped due to the small number of observations. Those from Singapore were also excluded because we could find no link between balance sheet policy tools and foreign exchange intervention in Singaporean data, as mentioned in the previous section.

The total number of bank-year observations used in our regressions is 445. Table 2 displays the total number of bank observations, by economy and by year, for which all the variables included in our regressions are available. Table 3 displays the share of total bank assets that these banks represent, for each year and economy, which average 50%.

Number of bank observations, by economy and year — Table 2

	06	07	08	09	10	11	12	13	Total
China	2	7	7	10	10	10	10	7	63
Hong Kong	8	10	10	11	11	11	11	11	83
Indonesia	5	7	7	8	8	8	8	7	58
India	1	12	12	15	16	17	18	18	109
Korea					4	4	7	7	22
Philippines	2	8	8	8	8	8	8	8	58
Thailand	6	6	6	6	7	7	7	7	52
Total	24	50	50	58	64	65	69	65	445

Sources: Bankscope; authors' calculations.

Share of total bank assets included in sample, by economy and year, % — Table 3

	06	07	08	09	10	11	12	13	Mean
China	4	51	48	62	62	61	58	41	48
Hong Kong	66	69	72	72	73	73	75	71	71
Indonesia	20	46	40	52	47	45	45	36	41
India	4	30	36	66	70	75	79	83	55
Korea					22	15	34	33	26
Philippines	16	59	51	57	56	54	57	58	51
Thailand	49	47	35	37	51	47	51	47	45
Mean	27	50	47	58	54	53	57	53	50

Sources: Bankscope; IMF; authors' calculations.

Descriptive statistics of our key bank-level variables included in the regressions are given in Table 4. The following graphs display the bank-specific characteristics of the resulting data set. Graph 4 illustrates that, for some banks, all of their assets are divided between loans and liquid assets. But for most, their portfolio lies well below the 45-degree line, indicating that they hold some other illiquid assets, in addition to loans. Graph 5 illustrates that, for most of the observations in our sample, reserves for non-performing are small as a share of total assets. Graph 6 shows that large banks' capital ratios are clustered around 10%, while there is much more dispersion among smaller banks. Graph 7 suggests that there is a positive correlation in our data between the level of Tier-1 capital and the share of liquid assets on the bank balance sheet. Graph 8 suggests that there is surprisingly little relationship between the level of Tier-1 capital and the long-term credit rating of banks in our sample. However, Graph 9 illustrates a strong relationship between bank size and credit rating, such that larger banks are rated more highly than smaller ones.

Summary bank-level descriptive statistics

Table 4

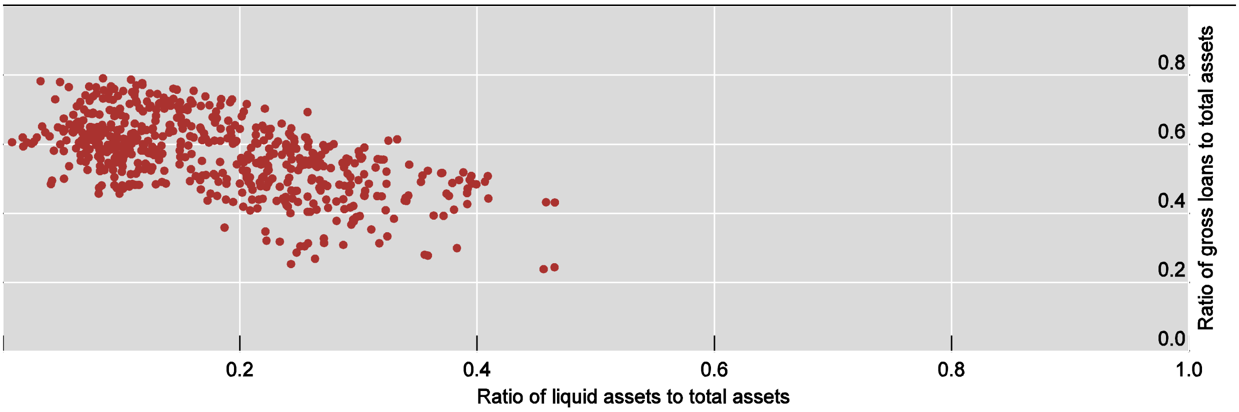
	Mean	Standard deviation	Percentiles		
			10	50	90
Change in loans / lagged assets	0.100	0.099	0.005	0.086	0.214
Tier-1 capital ratio	0.111	0.036	0.076	0.104	0.156
Liquid assets / total assets	0.185	0.096	0.074	0.180	0.308
Reserves for NPLs / total assets	0.015	0.013	0.003	0.011	0.032
Long-term bond rating[1]	13.4	2.6	10	13	17

[1] Bond ratings are converted from a letter scale to a numerical scale which ranges in our sample from 5 (C) to 20 (AA).

Sources: Bankscope; authors' calculations.

Relationship between the ratio of liquid assets to total assets and the ratio of gross loans to total assets

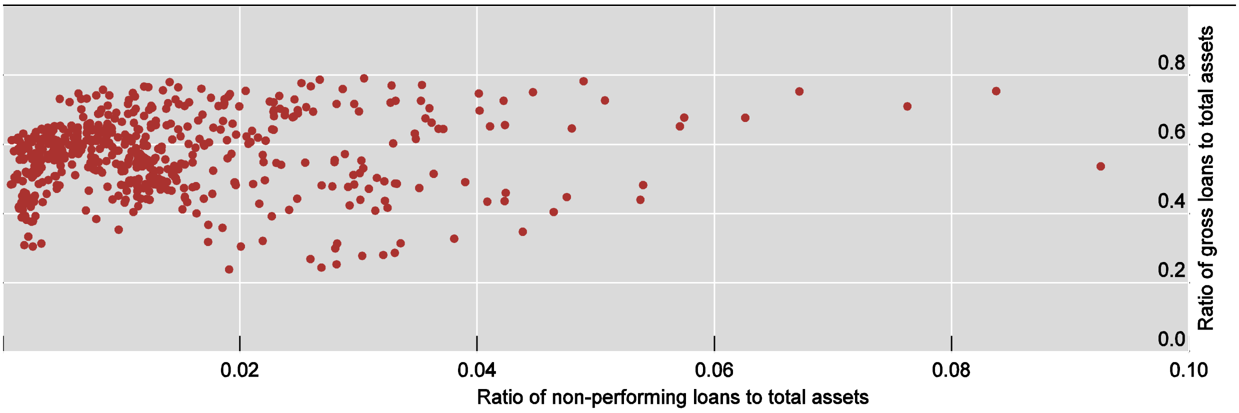
Graph 4



Sources: Bankscope; authors' calculations.

Relationship between the ratio of reserves for non-performing loans to total assets and the ratio of gross loans to total assets

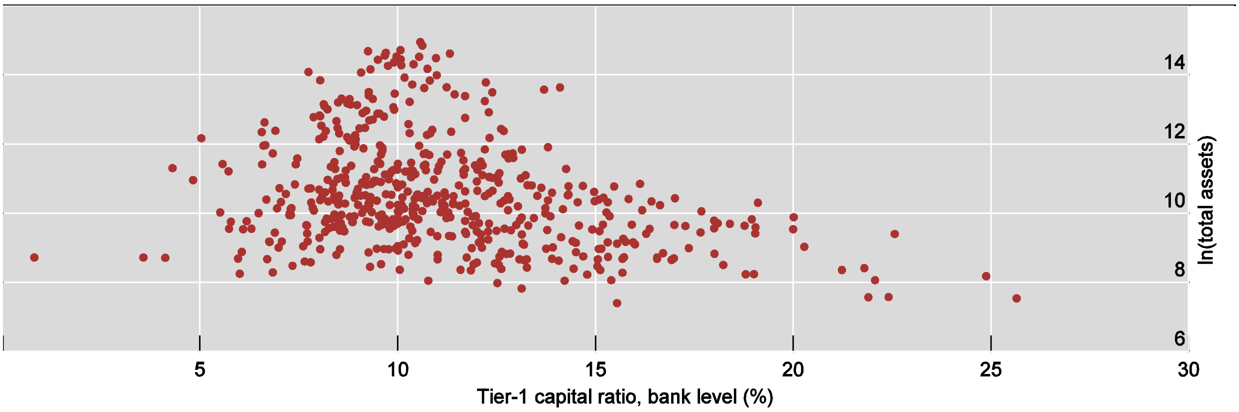
Graph 5



Sources: Bankscope; authors' calculations.

Relationship between Tier-1 capital ratio and total assets

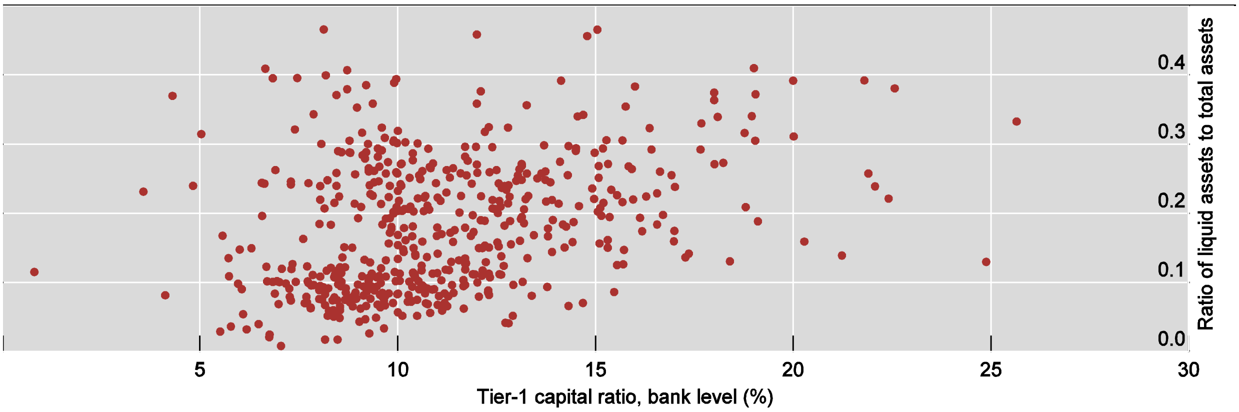
Graph 6



Sources: Bankscope; authors' calculations.

Relationship between Tier-1 capital ratio and the ratio of liquid assets to total assets

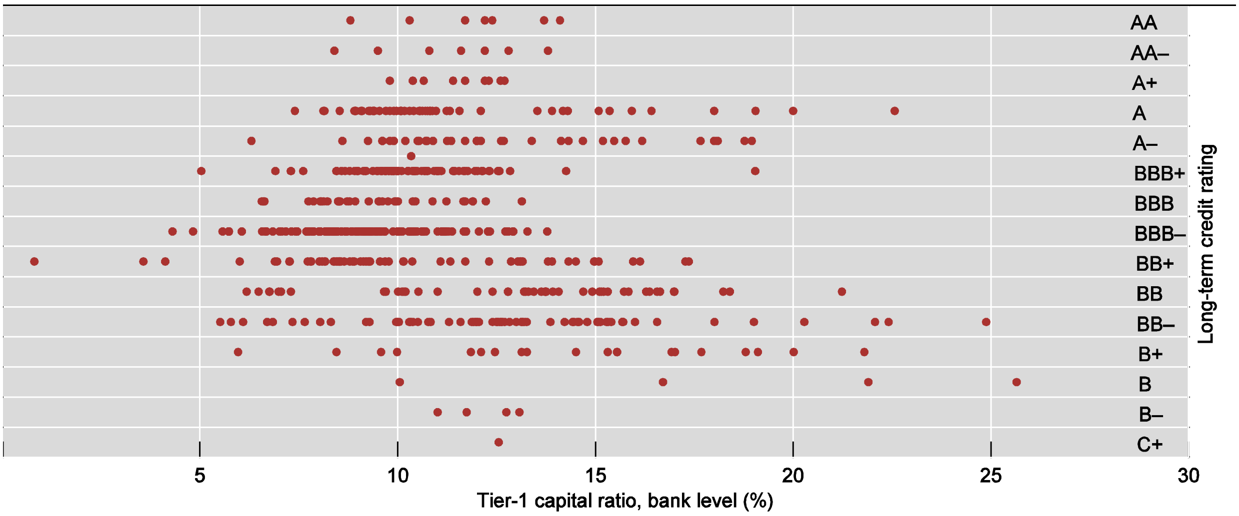
Graph 7



Sources: Bankscope; authors' calculations.

Relationship between Tier-1 capital ratio and long-term credit rating

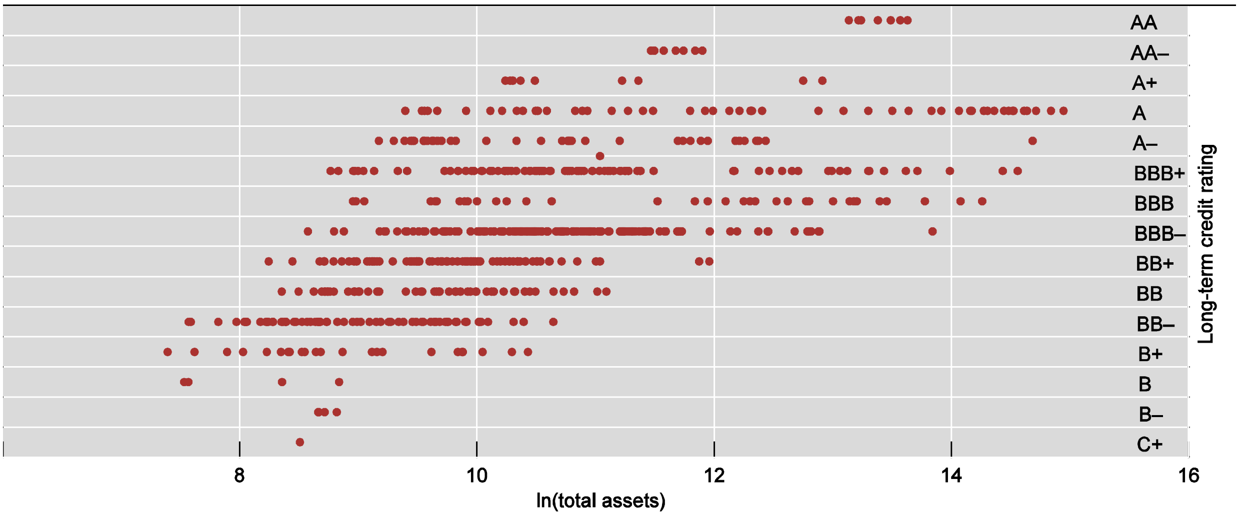
Graph 8



Sources: Bankscope; authors' calculations.

Relationship between total assets and long-term credit rating

Graph 9



Sources: Bankscope; authors' calculations.

Most of the central bank balance sheet data are taken from national sources. In the cases of Indonesia and the Philippines, we supplement the central bank securities series by including additional instruments that behave in a very similar way to central bank securities, and are also heavily used as liquidity management tools. For Indonesia we proxy this as the sum of BI certificates and term deposits. For the Philippines, where the central bank is unable to issue its own securities, we use Special Deposit Accounts instead. In order to avoid confounding FX intervention with changes in the local currency value of existing reserves, the ΔX in our regressions is the change in the dollar value of foreign exchange reserves, converted to local currency at the previous year's exchange rate.

5. Results

The first step in the empirical analysis is to estimate a bank-level loan-growth model. This consists of equation 7, but without the policy variables (the terms involving the β coefficients) or the interaction terms (involving the γs).

The first column of Table 5 shows the results with the regression that includes only the bank-level variables. The parameter estimates are plausible and, except for the ratio of liquid to total assets, statistically significant. Loan growth is higher for small and well capitalised banks with a low level of reserves for non-performing loans, and those with higher long-term bond ratings.

The remaining four columns report the results of regressions that also include year fixed effects (column 2), economy-level data (column 3), both (column 4) and year × economy fixed effects (column 5). The main takeaway is that the inclusion of the aggregate variables has relatively little effect on the coefficients on the bank-level variables, although the statistical significance of the various coefficients varies across specifications. The coefficients are not generally affected by the inclusion of year and year×economy fixed effects, although the coefficient on the capital ratio becomes (insignificantly) negative in one case.[12]

Bank loan growth regressions

Table 5

		Year	Macro	Year+macro	Year*economy
Lagged size	–0.136***	–0.264***	–0.135***	–0.267***	–0.213***
	(–6.26)	(–6.24)	(–5.70)	(–6.02)	(–6.69)
Lagged capital ratio	0.660***	0.295	0.521**	0.362	–0.201
	(3.23)	(1.40)	(2.15)	(1.62)	(–0.70)
Lagged liquid assets	0.083	0.265**	0.160	0.232**	0.123
	(0.79)	(2.56)	(1.45)	(2.14)	(1.21)
Lagged NPL reserves	–1.601***	–0.474	–1.624***	–0.657	–1.601***
	(–2.85)	(–0.82)	(–3.01)	(–1.03)	(–2.79)
Long–term rating	0.023***	0.018**	0.023***	0.015*	0.017**
	(2.95)	(2.56)	(3.20)	(1.94)	(2.34)
Real GDP growth			0.065	–0.387*	
			(0.37)	(–1.95)	
Change in interest rate			1.304***	0.306	
			(3.10)	(0.51)	
Year effects	N	Y	N	Y	N
Year × economy effects	N	N	N	N	Y
Observations	445	445	445	445	445
Within R-squared	0.230	0.398	0.266	0.408	0.676
Between R-squared	0.0000	0.0033	0.0003	0.0017	0.0066
Overall R-squared	0.0064	0.0081	0.0109	0.0069	0.0354

Source: Authors' calculations.

To give an idea of the quantitative importance of the different explanatory variables, consider the results including year dummies and macro variables (the second column from the right). Mean loan growth is 10% per year across our sample of banks, and mean Tier-1 capital is 11%. A 1 percentage-point increase in Tier-1 capital is associated with a 0.4 percentage points more loan growth, as a share of total assets. For liquid assets, the average level is 18% of total assets, and a 1 percentage-point increase in this ratio is associated with 0.23% faster loan growth. NPLs have a quantitatively larger effect: their average level is 1.5% of total assets, and a 1 percentage-point increase is associated with a 0.7 percentage point reduction in loan growth.

Some of the estimated coefficients on the macro variables are a little puzzling, however. When no year fixed effects are included, the coefficient on the change in the interest rate is positive, suggesting that tighter monetary policy increases loan growth. This may result from the fact that the central bank is responding to economic conditions, possibly including loan growth, in setting the interest rate. Correctly identifying the impact of monetary policy would require a proxy for exogenous policy

12 The small number of banks for some economies in the early part of the sample means that some of the year×economy dummies cannot be estimated.

change (ie "shocks"). Fortunately this is not our objective, and therefore beyond the scope of our study.

Bank loan growth regressions

Table 6

	With FX		Without FX	
Lagged size	–0.118***	–0.276***	–0.131***	–0.277***
	(–4.32)	(–6.08)	(–5.23)	(–6.37)
Lagged capital ratio	0.612**	0.316	0.528**	0.307
	(2.52)	(1.36)	(2.12)	(1.30)
Lagged liquid assets	0.146	0.211*	0.169	0.212*
	(1.35)	(1.95)	(1.53)	(1.95)
Lagged NPL reserves	–2.00***	–0.461	–1.528***	–0.405
	(–3.64)	(–0.71)	(–3.10)	(–0.65)
Long–term rating	0.025***	0.017**	0.024***	0.017**
	(3.21)	(2.42)	(3.21)	(2.38)
Real GDP growth	0.157	–0. 326	0.109	–0.343*
	(0.83)	(–1.45)	(0.60)	(–1.70)
Change in interest rate	1.488***	0.513	1.278***	0.469
	(3.72)	(0.82)	(2.84)	(0.81)
Change in FX reserves	0.633**	–0.084		
	(2.07)	(–0.22)		
Change in CB bills	0.020	–0.044	0.112	–0.033
	(0.24)	(–0.56)	(1.45)	(–0.46)
Change in required reserves	–0.686	–1.62**	0.167	–1.539***
	(–1.15)	(–2.44)	(0.34)	(–2.80)
Change in excess reserves	0.008	–0.035	0.246	–0.006
	(0.02)	(–0.10)	(0.60)	(–0.02)
Change in net gov liabilities	–0.829*	–0.989**	–0.605	–0.959**
	(–1.82)	(–2.26)	(–1.38)	(–2.21)
Year fixed effects	N	Y	N	Y
P-value for exclusion of CB bills and required reserves	0.48	0.016	0.30	0.021
Sum of coefficients on FX and required reserves	–0.05	–1.54***		
Sum of coefficients on FX and CB bills	0.65**	0.04		
Net impact of increase in required reserves and decrease in CB bills	–0.71	–1.58**	0.05	–1.51***
Observations	445	445	445	445
Within R-squared	0.287	0.425	0.273	0.425
Between R-squared	0.0005	0.0017	0.0007	0.0017
Overall R-squared	0.0180	0.0072	0.0136	0.0071

Source: Authors' calculations.

The next step is to estimate a model that includes the policy variables (the terms involving the βs in equation 7). The results are reported in Table 6. The inclusion of the policy variables leaves the estimates of the coefficients on the bank and macro variables largely unchanged.

The results for the policy variables are mixed, in terms of both interpretation and statistical significance. The first column, which includes the change in foreign exchange reserves but excludes year dummies, indicates that purchases of foreign exchange have positive and statistically insignificant effects on bank lending. This makes sense at some level: macroeconomic booms tend to be associated with strong bank lending and capital inflows, which prompt foreign exchange intervention. The relationship is therefore not likely to be causal. This is consistent with the fact that the effect disappears when year fixed effects are included, as shown in the second column, which are likely to be picking up region-wide exchange rate pressures.

Reassuringly, increases in required reserves tend to reduce bank lending in three of the four specifications, included the two where the estimate is statistically significant. In contrast, the estimated coefficients on the change in central bank securities are small and never statistically significant. Interestingly, the coefficients on the two sterilisation variables are *jointly* highly significant in the cases with year fixed effects, reflecting the fact that the two policies are often adjusted concurrently.

Interpreting the individual coefficients on the balance sheet variables is tricky, however. This is because the coefficient on the change in foreign exchange reserves is the effect of intervention *holding the other balance sheet variables constant*. Since the omitted balance sheet item is some unspecified "other" category, it is not clear exactly what policy this corresponds to. Similarly, the coefficient on the central bank securities variable captures the increase in that liability category and a reduction in the mysterious "other" category.

It is therefore more informative to look at linear combinations of coefficients that represent well defined policies. One such policy is an increase in foreign exchange reserves, accompanied by an increase in required reserves, corresponding to the sum of the estimated β_1 and β_3. The negative coefficient, significant when year fixed effects are included, indicates that this combination of policies tends to result in a decline in bank lending. Also of interest is the impact of an increase in foreign exchange reserves accompanied by an increase in central bank securities, the sum of β_1 and β_2. This is small, but positive, suggesting that sterilising foreign exchange purchases with issuance of central bank securities appears to promote bank lending.

Care is required in interpreting this result, however. Again, the reason is that both policies are heavily affected by macroeconomic developments: a booming economy and rapid loan growth tends to be associated with appreciation pressure, foreign exchange purchases *and* sterilisation. Further, the use of liquidity management tools could be used to try to offset excessive loan growth that results from factors other than foreign exchange intervention. This will tend to bias the parameter estimates upwards, explaining the large positive coefficients on central bank bills and the weak statistical significance of the coefficient on required reserves.

Fortunately, the two sterilisation variables' joint dependence on macroeconomic conditions can be finessed by examining the *difference* between the respective coefficients. To the extent that the two are affected proportionately by macro factors, subtracting β_2 from β_3 will give the relative impact of increasing the reserve requirement vis-à-vis purchasing central bank bills. Or, to put it another way, it would capture the effect on bank lending of increasing the former and reducing the latter by the same amount.

The results show that increases in reserve requirements generally slow lending growth, compared with the issuance of central bank bills (although the effect is statistically insignificant in the specifications without year fixed effects). This is consistent with the predictions of the stylised model sketched in Section 2. In terms of the magnitudes involved, if reserve requirements are increased to offset a reduction in central bank bills, and the size of each change is equal to 1 percentage point of the sum of total domestic bank assets plus domestic currency local bonds, our point estimates indicate that this leads to a slowdown in loan growth, as a share of total bank assets, of around 1.5 percentage points.

The next question is whether the policies affect different banks in different ways. To see whether this is the case, we interact the two liquidity management tools with lagged values of the four bank characteristics already included in the regression. The results are presented in Table 7.

Regressions with interactions between policies and bank attributes — Table 7

	Bank attribute (Z)				
	Size	Capital	Liquidity	NPL reserves	LT rating
Change in CB bills	1.265***	–0.271	0.063	–0.133	0.253
	(2.75)	(–0.83)	(0.21)	(–0.89)	(0.33)
Change in required reserves	3.497*	–4.693***	–1.762*	–3.106***	3.0486
	(1.75)	(–3.19)	(–1.74)	(–3.53)	(1.65)
Change in excess reserves	0.354	0.475	0.025	0.373	0.407
	(0.94)	(1.21)	(0.07)	(0.98)	(1.02)
Change in net gov liabilities	–0.917**	–0.805*	–0.969**	–0.806*	–0.861*
	(–2.06)	(–1.79)	(–2.31)	(–1.82)	(–1.95)
Central bank bills × Z	–0.140***	1.211	–0.458	4.032	–0.029
	(–2.75)	(0.64)	(–0.34)	(0.60)	(–0.40)
Required reserves × Z	–0.462***	28.77**	1.005	87.37**	–0.399**
	(–2.74)	(2.54)	(0.33)	(2.36)	(–2.49)
Observations	445	445	445	445	445
Within R-squared	0.436	0.436	0.425	0.433	0.433
Between R-squared	0.0024	0.0025	0.0017	0.0022	0.0022
Overall R-squared	0.0081	0.0078	0.0071	0.0078	0.0077
Relative impact of raising required reserves and reducing central bank bills					
10th percentile of Z	–0.573	–2.290***	–1.721*	–2.760***	–0.461
	(–0.82)	(–2.91)	(–1.84)	(–3.22)	(–0.66)
Average Z	–1.148**	–1.347**	–1.566**	–1.779***	–1.690**
	(–2.12)	(–2.49)	(–2.46)	(–3.25)	(–2.60)
90th percentile of Z	–1.889***	–0.159	–1.381***	–0.416	–3.047**
	(–3.06)	(–0.25)	(–2.74)	(–0.61)	(–2.56)

Note: regressions include year fixed effects.

Source: Authors' calculations

As in the previous set of regressions, the coefficients on the policy variables are hard to interpret, given the relationship between those variables and macroeconomic conditions. In addition, interpreting the interaction terms requires knowing something about the scale of the bank attributes. Consequently, rather than describe the individual parameter estimates, we will focus on the same linear combinations of coefficients, discussed above in the context of Table 6, evaluated at the mean, 10th and 90th percentiles of the distributions of the attributes.

The column labelled "Size" reports the parameter estimates, and the estimated effect of a policy of increasing reserve requirements and reducing central bank bills by a corresponding amount, from a regression in which the policy variables are interacted with the log of total assets. The results show that the impact on lending is more pronounced for large banks. For banks at the 90th percentile of the size distribution, a policy shift of a magnitude corresponding to 1% of total banking system assets plus local currency government securities slows loan growth by a statistically significant 1.9 percentage points, compared with a statistically insignificant 0.6 percentage points for banks at the 10th percentile. A formal test does not reject the hypothesis of equal effects, however, due to the imprecision of the estimate for small banks.

We also see differences when we distinguish between banks on other dimensions. As shown in the "Capital" column, a policy of shifting away from central bank bills and toward reserve requirements has a disproportionately large effect on banks with low levels of capital: 2.3 percentage points (significant at the 1% level) for banks at the 10th percentile, compared with 0.2 (statistically insignificant) for those at the 90th percentile. The difference is sufficiently large in this case for us to reject the hypothesis of equal coefficients at the 5% level. Banks with low NPL reserves are also more strongly affected: 2.76 (significant at the 1% level) at the low end of the distribution, versus an insignificant 0.42 for those with a high level of NPL reserves; the hypothesis of equal coefficients is rejected at the 5% level. Finally, highly rated banks (the "LT rating" column) are more responsive to the substitution of reserve requirements for central bank bills, with a reduction in loan growth of 3.0 percentage points versus 0.5 for those with low ratings. The difference is significant at the 10% level.

There is virtually no difference between the estimated responses of high-liquidity and low-liquidity banks, however. As shown in the "Liquidity" column, the impact is approximately 1.5 for all banks. This is somewhat surprising, as one might have expected relatively illiquid banks (ie those with low levels of excess reserves) to be disproportionately affected by actions that would drain or sequester reserves. The explanation for this finding might simply be that our measure of liquidity – total liquid assets as a share of total assets – is too broad, as it includes much more than just bank reserves. Interacting the policy variables with a variable capturing banks' reserve positions is likely to have revealed significant differences on this dimension, but unfortunately bank-level data on excess reserves are not available.

Taken together, the results in Table 7 indicate that large, highly rated banks with few non-performing loans are relatively more affected by a policy of shifting away from central bank bills and towards reserve requirements for sterilisation purposes. A reasonable conjecture is that these are the banks for which the level of reserves is a constraint, or at least a first-order consideration in their lending and deposit-taking decisions. Small banks with low credit ratings and high levels of non-performing loans are likely to be constrained on margins other than liquidity. The result that low-capital banks are more sensitive to the policy is a little puzzling in this context, as one might expect their lending to be constrained by capital rather than reserve requirements; but this result may be due to the strong negative correlation between size and capital ratio.

As a final robustness exercise, we investigate the relative impact of raising reserve requirements and reducing central bank bills dropping one economy from the sample at a time. We report these results, including one bank attribute at a time in the regressions, in Table 8. The results are most sensitive to the exclusion of China, an economy which has alternately made vigorous use of both central bank bills and reserve requirements at various points over our sample, and hence considerably improves our ability to identify a separate effect of the two tools. Regardless, in most cases we consider, an increase in reserve requirements and offsetting reduction in central bank bills has a negative effect on the growth of bank lending. And, with no exceptions, all statistically significant coefficients are negative. A robust result in our sample is thus that increasing reserve requirements has a larger negative effect on bank lending than issuing central bank bills.

Relative impact of raising required reserves and reducing central bank bills Table 8

		Bank attribute (Z)				
		Size	Capital	Liquidity	NPL reserves	LT rating
All economies	10th percentile of Z	–0.57	–2.29***	–1.72*	–2.76***	–0.46
	Average Z	–1.15**	–1.35**	–1.57**	–1.78***	–1.69**
	90th percentile of Z	–1.89***	–0.16	–1.38***	–0.42	–3.05**
Ex CN	10th percentile of Z	0.30	–0.59	0.12	–1.08	0.43
	Average Z	–0.05	0.13	0.20	–0.26	–0.50
	90th percentile of Z	–0.41	1.00	0.31	0.97	–1.68
Ex HK	10th percentile of Z	–0.28	–2.27*	–1.51	–2.45**	–0.25
	Average Z	–0.87	–1.28	–1.35	–1.42	–1.24
	90th percentile of Z	–1.61	0.02	–1.14	–0.01	–2.39*
Ex ID	10th percentile of Z	–0.65	–2.23**	–2.38	–2.90**	0.01
	Average Z	–0.97	–1.41***	–1.68*	–1.72**	–2.00**
	90th percentile of Z	–1.39	–0.44	–0.81	0.13	–3.79**
Ex IN	10th percentile of Z	0.35	–2.21***	–1.91*	–3.50***	0.01
	Average Z	–0.78	–1.19**	–1.56**	–1.86***	–1.78***
	90th percentile of Z	–2.31***	0.13	–1.22**	0.04	–3.38***
Ex KR	10th percentile of Z	–0.57	–2.39***	–1.82*	–2.96***	–0.46
	Average Z	–1.18**	–1.40**	–1.63**	–1.85***	–1.66**
	90th percentile of Z	–2.03***	–0.12	–1.41***	–0.31	–3.23***
Ex PH	10th percentile of Z	–1.79	–3.43***	–2.10*	–1.27	–1.50
	Average Z	–2.08*	–2.14***	–2.57***	–2.54***	–2.27**
	90th percentile of Z	–2.47***	–0.40	–3.21***	–4.37***	–3.21***
Ex TH	10th percentile of Z	–0.96	–1.80**	–0.98	–2.43***	–0.70
	Average Z	–1.14*	–1.35**	–1.41**	–1.86***	–0.73
	90th percentile of Z	–1.39**	–0.79	–1.88***	–1.16**	–0.75

Note: regressions include year fixed effects.

Source: Authors' calculations.

6. Summary and conclusions

Heavy foreign exchange intervention in the Asian region, together with varying use of sterilisation methods, provides a useful laboratory for investigating the effects of different liquidity management tools on bank lending. Based on a simple theoretical model developed in Section 2, we suggested that hiking reserve requirements to sterilise foreign exchange purchases will retard bank lending growth more than the issuance of central bank bills.

We then tested this prediction using bank-level data from seven Asian economies, and found that the evidence is generally supportive. Because foreign exchange intervention and sterilisation both respond to macroeconomic conditions, which are closely linked with bank lending, it is hard to sort out the absolute effects of individual sterilisation policies. However, it is still possible to say something about their relative effects. The main finding is that relaxing reserve requirements and instead issuing bills will increase loan growth. There is also evidence suggesting that smaller and weaker banks are affected disproportionately by changes in reserve requirements.

We have focused on central bank bills (and close substitutes such as term deposits) and required reserves as sterilisation tools. But, in fact, many central banks use a wider range of tools to manage the liquidity effects of foreign exchange intervention, such as accepting short-term deposits from banks and other standing facilities. To draw implications of our results for these alternative tools, one possibility is that the distinguishing feature of central bank bills is that is that they are market-based instruments; banks are not typically forced to hold them, but are instead responding to price incentives when they choose to do so. In contrast, required reserves are, by definition, a non-market-based tool that is imposed on banks. There are other possible distinguishing characteristics as well. For example, where non-banks are able to purchase central bank bills this may dilute the negative effects of sterilisation on credit growth. But we leave further investigation of these issues to future work.

Our results have implications for the use of liquidity management tools that are likely to extend beyond Asia. For example, many advanced economies have engaged in quantitative easing that has had the effect of rapidly expanding central bank balance sheets and the quantity of liquidity in the banking system. If or when conditions "normalise" in these economies, central banks may be faced with the need to rapidly absorb excessive liquidity in order to achieve domestic policy objectives. While the source of excess liquidity is very different from that characterising the Asian experience, the implications of different tools that may be used to soak up the surplus liquidity for bank lending are likely to bear parallels with those outlined here.

References

Bianchi, J and S Bigio (2014): "Banks, liquidity management and monetary policy", *NBER Working Paper*, no 20490.

Cook, D and J Yetman (2012): "Expanding central bank balance sheets in emerging Asia: a compendium of risks and some evidence", *BIS Papers*, no 66, pp 30–75.

Diamond, D and P Dybvig (1983): "Bank runs, deposit insurance, and liquidity", *Journal of Political Economy*, vol 91, no 3, pp 401–19.

Gandanecz, B, A Mehrotra and M Mohanty (2014): "Foreign exchange intervention and the banking system balance sheet in emerging market economies", *BIS Working Paper*, no 445.

Ho, C and R McCauley (2008): "The domestic financial consequences of reserve accumulation: some evidence from Asia", in R Rajan, S Thangavelu and R Parinduri (eds), *Exchange rate, monetary and financial issues and policies in Asia*, World Scientific (Singapore) pp 117–53.

Ippolito, F, A Ozdagli and A Perez (2013): "Is bank debt special for the transmission of monetary policy? Evidence from the stock market", *Federal Reserve Bank of Boston Working Paper*, no 13/17.

Kashyap, A and J Stein (2000): "What do a million observations say about the transmission of monetary policy?", *American Economic Review*, vol 90, no 3, pp 407–28.

Ma, G, Y Xiandong and L Xi (2011): "China's evolving reserve requirements", *BIS Working Papers*, no 360.