Expanding central bank balance sheets in emerging Asia: a compendium of risks and some evidence

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Abstract

Foreign exchange reserves have grown dramatically in emerging Asia over the past decade. Many of these reserves have been sterilised, via the issuance of non-monetary liabilities by central banks, with the sterilisation instruments held largely by domestic banks. We investigate the effects of this process on emerging Asian economies. We find evidence that long run economic performance may suffer, due to resource mis-allocation and reduced investment. We also find that while reserves appear to have helped to protect banks during periods of crisis, they have had little effect during more normal times. Finally, we examine the effect of reserves on central banks and monetary policy. We find that sterilisation appears to be incomplete in some cases, with reserves accumulation leading to higher levels of broad money, inflation and credit. Further, sterilisation costs, and losses due to currency appreciation, are a potential threat to central bank independence and may bias policy away from raising interest rates or allowing currency appreciation.

Keywords: Central bank balance sheets, reserves accumulation, sterilisation

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1. Introduction

Over the last decade, many central banks in emerging Asia have seen large balance sheet expansions. Graph 1 shows that there have been substantial increases in overall central bank assets relative to GDP in eight of nine major emerging market economies in Asia. The exception is Indonesia where the central bank was reducing its holdings of assets acquired as a legacy of the Asian Financial Crisis of the late 1990's. These asset expansions were primarily due to the build-up of foreign exchange reserves. With the exception of Indonesia, foreign exchange reserves constituted more than 80 percent of central bank assets for these nine in 2008, with a median share of 91 percent. Even in Indonesia, foreign exchange reserves have constituted more than half of central bank assets since 2006.

What induces central banks to accumulate large foreign exchange reserves? Arguably, central banks hold reserves as a precaution against the possibility of sudden stops of international capital flows. If emerging markets finance long-term projects with short-term external borrowing, precautionary reserves of foreign currency might allow the economy to avoid liquidating projects in the face of a cut-off of international lending (see Jeanne, 2007). Another possibility is that central banks were engaging in competitive exchange rate management for mercantilist motives. Aizenman and Lee (2007) find that the evidence favours precautionary, rather than mercantilist, motives, especially in the period immediately following the Asian Financial Crisis. Cheung and Qian (2009) argue that the precautionary motives were strengthened as emerging Asian countries sought to avoid becoming the most attractive targets for speculative attacks.

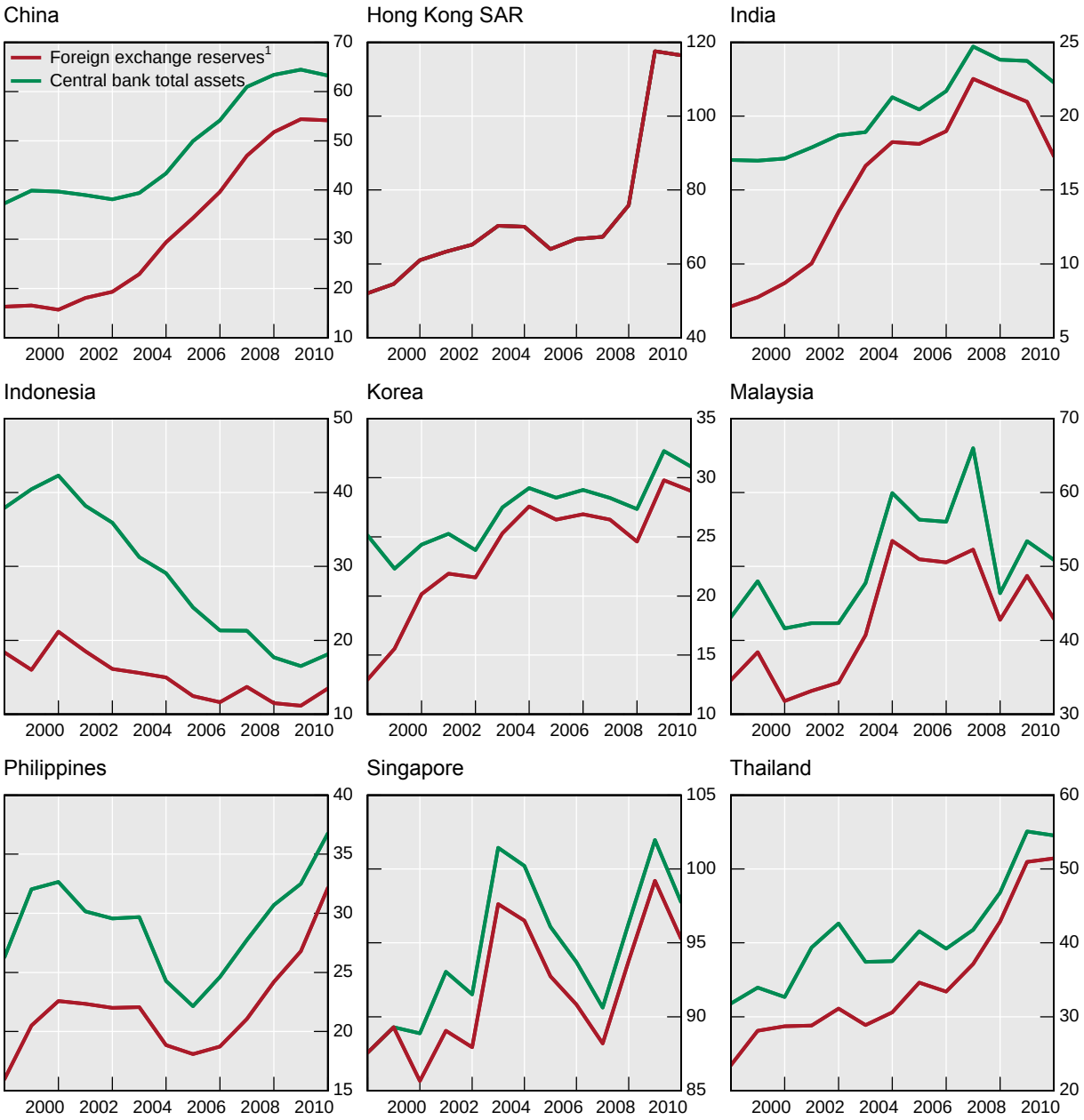
What, then, are the implications of high levels of reserves on economies in emerging Asia? This paper will catalogue some of the potential benefits and costs of accumulating large reserve positions on emerging economies. The benefits of exchange rate reserves may include reducing risks associated with external shocks. The costs include the direct financing costs of holding reserves (see Rodrik, 2006). In addition to these direct costs, we explore the potential for some other types of indirect costs. Beyond some level, reserve accumulation may be excessive. The over-accumulation of reserves may cause distortions in the economy and crowd out the accumulation of other sorts of assets important for long-run economic growth at a cost to the economy that exceeds any benefits from reduced risks. Potentially, the riskiness of the domestic financial system may also be influenced by the build up of its own balance sheet positions in the process of reserves accumulation. Finally, the concentration of financial wealth on the balance sheet of central banks may reduce the independence of monetary policy. Large stocks of foreign reserves may expose the central bank to possible credit and solvency risks and restrict monetary policy flexibility. We will investigate aggregate and firm-level evidence for each of these possible effects.

Traditionally, foreign exchange reserves were thought to play an important role in protecting the economy from volatile capital flows. To that end, a variety of benchmarks have been suggested of what constitutes "adequate" reserves related to international trade and international finance. A traditional rule of thumb related to international trade has recommended holding foreign reserves equal to 3-4 months of imports; in terms of international finance, the more recent Greenspan-Guidotti rule suggests holding reserves equal the total stock of outstanding short term debt (see IMF, 2011). Complying with the Greenspan-Guidotti rule allows the economy access to foreign funds to avoid liquidation during a sudden stop. Obstfeld, Shambaugh and Taylor (2009) argue that the role of foreign reserves may be broader during a "twin" crisis featuring both a domestic banking panic and a sudden stop in international capital flows (see Kaminsky and Reinhart, 1999). If domestic depositors attempt to switch domestic bank deposits into hard currency when international demand for the domestic currency is limited, central banks with ample excess foreign reserves may be able to provide this hard currency and limit exchange rate depreciations. Obstfeld, Shambaugh and Taylor (2009) argue that emerging economies therefore use broad monetary aggregates as a benchmark for reserves.

Graph 1

Foreign exchange reserves and central bank total assets

As percentage of GDP



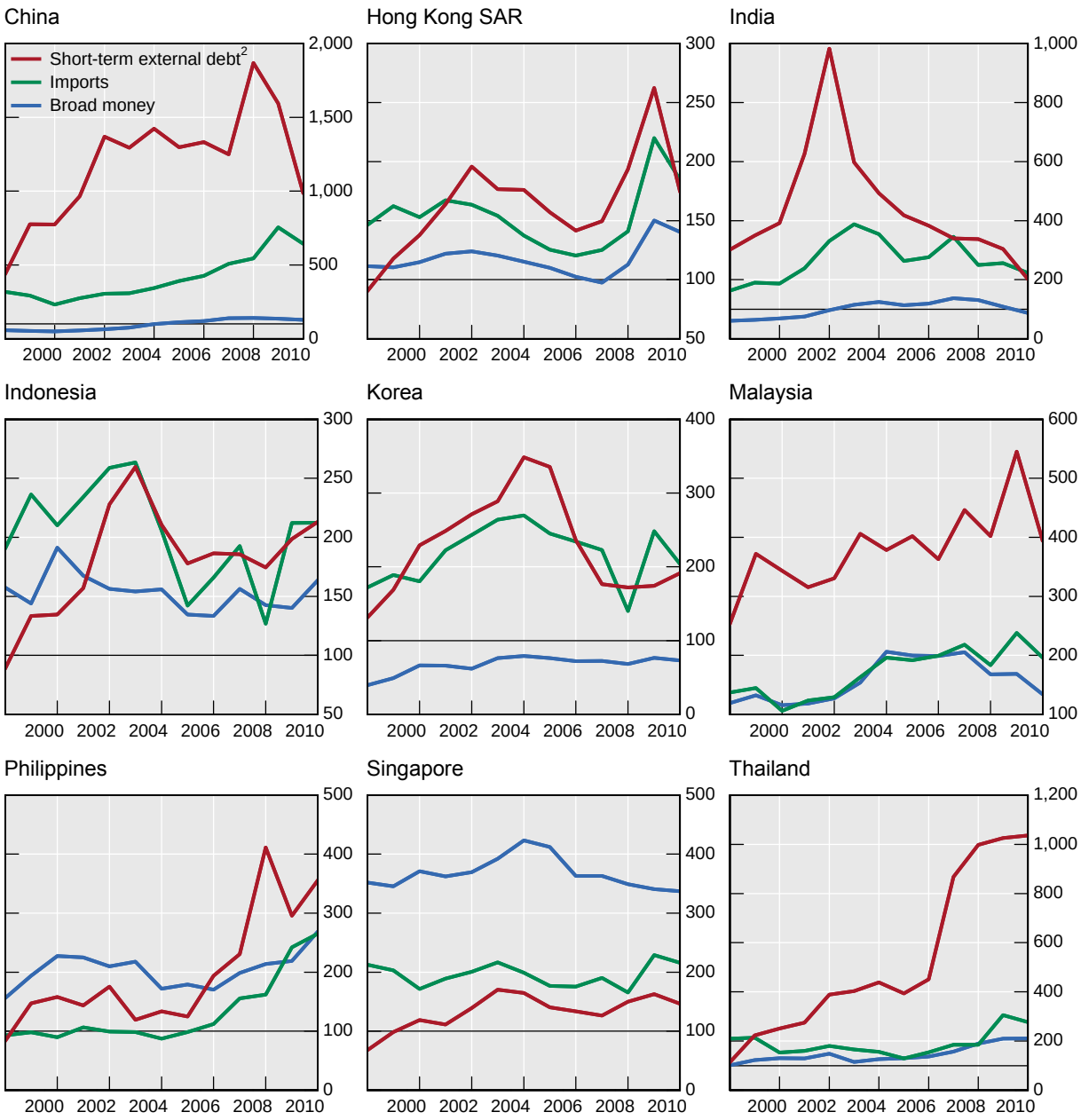
[1] Central bank foreign assets. For Hong Kong, domestic assets are not recorded in the IFS.

Source: IMF *IFS*.

Graph 2 plots reserve levels relative to three standards for adequacy using a level of 100 to indicate reserve levels corresponding to levels cited as being prudent (4 months of imports, 100% of outstanding short term debt and 20% of broad money). At present, these prudent standards are generally well exceeded by most economies in Emerging Asia.

Graph 2

Measure of adequacy of foreign reserves[1]



[1] 100 corresponds to "Adequate reserves", defined as 4 months of imports, total short term external debt and 20% of broad money respectively. [2] Short-term external debt comprises consolidated international claims of BIS reporting banks with a maturity up to and including one year, plus international debt securities outstanding with a maturity up to one year.

Sources: IMF *WEO*; Datastream; national data; BIS.

The implications of a large expansion in foreign exchange reserves may depend crucially on the nature of financing involving. When the central bank acts in foreign exchange markets to purchase foreign currency, there are two main ways in which it can finance these purchases (see Table 1 for a stylised representation). First it can increase the quantity of domestic money ("monetary liabilities") in circulation. However, ongoing increases in the domestic money supply would tend to result in a loss of domestic monetary policy control. The alternative is to sterilise the monetary effects of the accumulation of foreign exchange reserves.

Table 1

Central bank balance sheet

Assets	Liabilities
Net foreign assets • foreign reserves Net domestic assets • government securities	Monetary liabilities • currency • reserves Non-monetary liabilities • central bank securities Equity

Focusing on emerging Asia's experience with foreign reserves accumulation, Aizenman and Glick (2009) find that the monetary base does not vary with the size of foreign exchange reserves, indicating that central banks have generally matched increasing reserves accumulation with increased sterilisation.[2] Similarly, Ouyang, Rajan and Willett (2007) find that China successfully sterilised around 90% of its reserves accumulation over the 1999-2005 period. The instruments used for sterilisation vary across economies, but generally consist of selling market instruments or sterilisation bills; increasing required reserve ratios; using swaps or repurchase operations; or transferring Government deposits from commercial banks to the central bank.[3] For example, Greenwood (2008) argues that China's foreign exchange reserves are substantially sterilised using a combination of sterilisation bills and required reserves. Other measures can also play an important role in sterilisation. Yeow and Ying (2007), for example, argue that Singapore's compulsory Central Provident Fund, with a stock of approximately 60% of GDP and net contributions of around 3.5% of GDP per year, effectively sterilises a significant portion of reserves accumulation by withdrawing liquidity from the domestic banking system.[4]

Graph 3 gives an indication of how prevalent these methods are for central banks in emerging Asia. It displays the total stock of foreign exchange reserves and total non-monetary liabilities of the central banks, both measured in domestic currency units. Focusing on the link between reserves and non-monetary liabilities, defined as total liabilities less both the monetary base and foreign liabilities, there are strong links along at least two dimensions. For Hong Kong, Indonesia, Korea, the Philippines, Singapore and Thailand, non-monetary liabilities are of approximately the same magnitude as reserves. The same is also true for China until 2008, after which required reserve ratios played a larger role in sterilisation. Further, the correlation between the two series over 1999-2009 exceeds 0.95 for all economies except Hong Kong (0.91), Malaysia (0.74) and Indonesia (0.68).

[2] See, also, Filardo and Grenville (2011).

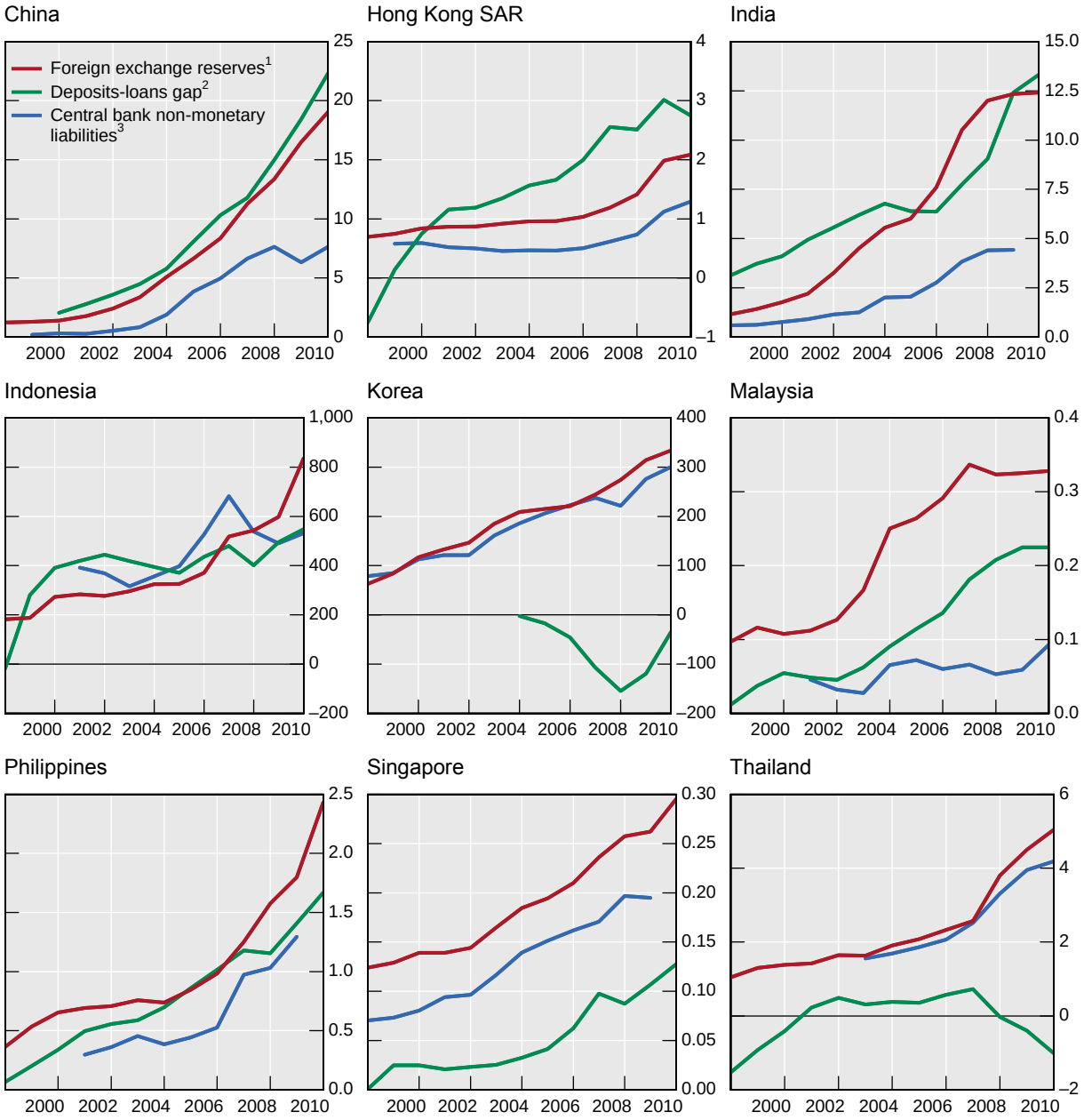
[3] See Mohanty and Turner (2005, 2006) for a more complete list and a discussion of the relative merits of different instruments.

[4] It is also possible to finance reserves accumulation via a reduction in assets instead, by selling government securities, for example. Given the large size of reserves accumulation seen in many economies in emerging Asia relative to the stock of saleable assets on central bank balance sheets, it is clear that most purchases must have been financed via the expansion of central bank liabilities rather than the sale of assets.

Graph 3

Foreign exchange reserves, deposits and loans and central bank non-monetary liabilities

In trillions of national currency



[1] Total reserves minus gold. [2] Deposits minus loans. [3] Total liabilities minus base money and foreign liabilities.

Sources: Bloomberg, CEIC, IMF IFS, national data.

To the extent that banks buy sterilisation bills or reserve requirements are raised, this drives a wedge between bank deposits and loans in the economy. Graph 3 also shows the deposit-loans gap, the difference between aggregate deposits and aggregate loans of the banking system, for the nine countries. There are strong links between reserves accumulation and the deposits-loans gap. For China, Indonesia, India and the Philippines banks had sufficient excess capacity on their balance sheets, beyond their loan portfolios, to approximately buy up the full stock of sterilisation bills, assuming complete sterilisation of the foreign reserves. And for all economies in our sample except Indonesia, Korea and Thailand the correlation between these two series exceeds 0.80.

The relationship between reserves and the deposits-loans gap is easy to explain. One characteristic shared by most methods of sterilisation is that they drive a wedge between loans and deposits in the banking system. For example, both increasing the required reserve ratio and issuing sterilisation bills, if the latter are purchased by banks, reduce the quantity of funds available for banks to extend credit for any given level of deposits. Graph 3 suggests that the effects of sterilisation are borne primarily by the banking system in this way, especially in those economies with relatively underdeveloped financial systems. Thus non-monetary liabilities of the central bank may be a good proxy for sterilisation for most emerging Asian economies.

The policy choice to hold a large stock of sterilised reserves changes both the balance sheet positions of the domestic banking system and the central bank. In this paper, we explore the impacts of some of these balance sheet changes over the last decade.

First, we examine some of the effects on the domestic banking system. In section 3, we explore the first order effects of reserve accumulation on bank balance sheets. We will develop a simple macroeconomic model embedding a relationship between sterilisation and bank balance sheets. This may have broader macroeconomic implications as banks are the key channel for credit creation in many Asian emerging markets. If purchases of sterilisation bonds by banks crowd out bank lending, the financing of sterilisation bonds may impinge on investment, increase global imbalances and reduce the long-term growth potential of the economy. Consistent with this, we find that there is a negative relationship between increases in foreign reserve holdings and the growth rate of bank lending for banks in some emerging Asian economies. Banks that have used their deposit bases to buy liquid sterilisation bonds appear to have reduced the credit that they make available to customers.

In section 4 we examine the second order effects of reserve holdings on the domestic banking system. Mohanty and Turner (2010) report that the risk exposures of the Asian banking system are lower now than at the time of the Asian crisis, due to a combination of favourable macroeconomic circumstances and improved regulatory performance. An important aspect of changing risk exposures of Asian banks is the degree to which they have increased their holdings of government debt reducing their perceived riskiness.

Hard currency reserve holdings may be most effective in extraordinary times. At the height of the recent crisis, in late 2008, the retrenchment of international capital flows was an external shock to emerging market banks (see Milesi-Feretti and Tille, 2010, and Blanchard, Faruqee and Das, 2010). We examine the effect of sterilised reserves holdings on the equity value of emerging Asian banks. We find that large central bank holdings of sterilised reserves appear to have mitigated the effects of the crisis on banks that rely on non-deposit funding.

We assess the degree to which foreign exchange reserve holdings more broadly influence banks' risk performance, focusing on the sensitivity of bank equity prices to different types of risks and how this sensitivity varies with the size of sterilised foreign exchange reserves. Generally, however, we find no strong evidence that holdings of sterilised reserves have protected emerging Asian banking systems from a variety of risks, including exchange rate risk, during more normal periods.

In section 5, we examine the macroeconomic policy impact of changes to central bank balance sheets entailed in the large holdings of sterilised reserves. Sterilised intervention can impose heavy financing costs on monetary authorities (Mohanty and Turner, 2005) which we quantify. Additionally, the process of sterilization, if incomplete, may undermine central bank objectives regarding price and monetary stability. There may thus be inflationary consequences as well. We provide evidence based on vector auto-regressions consistent with this: for some economies, increases in non-monetary liabilities tend to be followed by expansions in broad money and moderate increases in inflation.

Reserves accumulation may also negatively affect the functioning of the central bank. Financing the purchase of foreign assets with domestic liabilities incurs costs and exposes the central bank to exchange rate risk. A currency appreciation would lead to large capital

losses that might threaten central bank independence, for example. Such risks might affect the behaviour of central banks or the credibility of their policy choices. A central bank worried about an appreciating currency may be a central bank unable to fully confront inflation, for example. Consistent with this, we find evidence suggesting that long-run inflation expectations respond less to short-term policy tightening in countries with substantial foreign reserves in a panel data study of the impact of policy rates on the yield curve.

2. Background: The Role of Central Bank Balance Sheets in Monetary Policy

Historically, the role of central bank balance sheets in macroeconomic models has concentrated on the liquid liabilities constituting the monetary base. In both the Keynesian and Monetarist theories which dominated post-war monetary economics, central banking affects the economy through the liquidity preference of households and businesses for money. The Keynesian school, as exemplified by Baumol (1952) and Tobin (1956), isolated this liquidity preference as governing the trade-off between holding monetary assets and short-term bonds. Central bank activity is felt mainly through its impact on the relative price of these assets: the short-term interest rate.[5] Monetarist theory focused on the role of money as a (highly liquid) financial asset, part of the larger portfolio of households. Private agents make trade-offs between holding money and a wide variety of other assets. The demand for money is determined, not only by the short-term interest rate and the level of transactions as in the Keynesian theory, but also by the level of wealth and the return on alternative assets in the portfolio (see Friedman, 1956). Central bank operations to adjust the level of the money supply change the relative availability of various assets and therefore their yields (including those of physical capital and consumer durables; see Cagan, 1987), not just the short-term interest rate.[6]

Some strands of the international macroeconomics literature pointed specifically toward a role for asset holdings in central bank balance sheets. Portfolio balance theory (see Branson, 1977 and Dooley and Isard, 1982; Branson and Henderson, 1985 provide a literature review) focuses on the imperfect substitutability between domestic and foreign bonds in the portfolios of private investors due to their different risk properties. Sterilised and unsterilised interventions which change the asset composition of central bank balance sheets also change the relative supply of bonds, the relative prices of such assets and the currencies they are denominated in. Acquisition of foreign exchange reserves and its sterilisation would therefore have an impact on asset prices, exchange rates and the wider economy.

In more recent times, the trend toward general equilibrium modelling has reduced the focus on central bank balance sheets. In the New Classical school, central bank assets and liabilities are explicitly modelled as parts of the government balance sheets (see Sargent and Wallace, 1981). Moreover, intertemporal budget constraints of taxpaying wealth holders are intertwined with the wealth position of the government (see Barro, 1974). An influential paper by Wallace (1981) demonstrated that changes in the composition of the government's asset portfolio (which includes central bank balance sheets) would not affect the risk/return profile

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[5] Various strands of Keynesian theory have minimised the role of money either because money demand was thought to be so price elastic that changes in the money supply had little effect on the interest rate or aggregate demand was relatively unresponsive to changes in the interest rate

[6] Due to the complicated nature of the myriad transmission mechanisms, monetarist theory has tended to focus on the (purportedly) relatively stable relationship between aggregate money balances and aggregate spending.

of households nor change equilibrium prices of financial assets when markets are complete. This is because investors as taxpayers are the ultimate claimants on the government asset portfolio. Therefore, a change in the government's portfolio does not alter the risk profile of the representative or marginal investor or their willingness to hold assets at the margin. Investors optimise their portfolios such that private asset demand offsets changes in the government's positions. This Modigliani-Miller type result also implies that the manner in which a central bank chooses to finance reserves accumulation is irrelevant.

In an economy where the logic of Wallace (1981) holds true, central bank balance sheets are only important insomuch as the stock of money influences the economy through the liquidity preference channel. More recently, Eggertsson and Woodford (2003) have used this logic to show that in circumstances in which private agents have no effective liquidity preference for central bank monetary liabilities (in their case, at the zero lower bound for interest rates) then changes in the size and composition of central bank balance sheets have no equilibrium effects.

Wallace (1981) has immediate implications for understanding the portfolio balance effects of foreign exchange rate interventions since the foreign exchange reserves on central bank balance sheets are part of the overall government portfolio of which investors are the ultimate claimants. Obstfeld (1982) shows that the foreign currency denomination of central bank assets does not affect exchange rates. Backus and Kehoe (1989) show that equilibrium asset prices are only affected by the currency composition of government portfolios if the portfolio choice affects fiscal policy. Changes in the money stock may impact interest rates due to liquidity preference, but the composition of central bank assets and non-monetary liabilities are irrelevant for policy.

Woodford (2011) points out that a key condition for the irrelevance of central bank asset purchases is that investors are unconstrained in the purchase of individual assets. Conversely, in the presence of leverage constraints, central bank actions which allow the purchase of assets unattainable by private investors may have important effects. The financial crisis of 2008 brought new attention to the role of financial market constraints in the economy. A number of papers examine the effects of targeted central bank lending in the presence of constraints on asset purchases. Curdia and Woodford (2011) construct a model with heterogeneous consumers in which borrowers may have less than full access to the pool of private savings due to market segmentation. In their model, the level of direct central bank lending to credit-constrained private sector borrowers can affect real societal welfare. Ashcraft, Gârleanu and Pedersen (2011) construct a model in which only a fraction of bank assets are pledgeable as collateral. Central bank lending which demands lower collateral "haircuts" can relax credit conditions efficiently by lending at lower margins. Similarly, Reis (2009) describes a model in which financial intermediation is plagued by pledgeability concerns and information costs may reduce the funding for profitable investment projects.

3. Reserve Holdings and International Imbalances

In this section we develop a simple model of a small open economy, consistent with the stylised facts for emerging Asian economies outlined in the introduction, to examine the effect of sterilised reserves accumulation on the real economy. We then compare the empirical implications of our model with actual data. At the foundation of our model is a central bank accumulating foreign assets which must be financed through some channel. In the absence of borrowing constraints, this may be accomplished without changing real allocations of private sector agents. In the presence of borrowing constraints, however, the acquisition of foreign currency assets may crowd out other assets.

3.1 Model

Results in Graph 3 and Greenwood (2008) suggest that domestic banking systems play a central role in financing sterilised reserves, while Sheng (2008) notes that banks still play a dominant role in East Asia's financial system. The natural place to examine the effects of imperfections for Asian economies is therefore within the banking system. The following model describes one such possible interaction, focusing on the interactions between the financing of sterilised reserves and credit activities within a constrained banking system.

The model modifies a standard intertemporal approach to the current account along three dimensions: 1) bank intermediation is crucial to capital formation; 2) banking activity is limited by bank capital; and 3) central bank asset accumulation is financed through bank balance sheets.

Consider a two period neo-classical small open economy. There is a single freely traded numeraire good in the economy that may be used for consumption or capital investment. The good is produced in the economy by competitive firms. The economy is populated by a representative household that consumes, provides labour and is the residual claimant of firms' profits. Firms are assumed to finance investment through financial intermediaries. The central bank may also finance balance sheet expansions through the banking system. In one version of the model, bank funding will be limited to a multiple of its equity holdings.

Households

Consumers in the economy are endowed with L units of labour each period, normalised to $L = 1$. The households maximise the standard utility function:

$$\ln C_t + \beta \ln C_{t+1} .$$

Households face an external interest rate $R = 1/\beta$ at which they can save or borrow. Households gain income from wages, W_t , and, as residual claimants of the profits of firms, Π_t. There are no taxes in the first period. In the second period, they pay taxes or transfers based on any losses or gains of the central bank. In addition, the household begins with some initial debt which we assume satisfies $DEBT = \beta(\alpha\beta)^{\frac{1}{1-\alpha}}$ for normalisation purposes.[7] Their budget constraint is:

$$C_t + \frac{C_{t+1}}{R} = W_t + \Pi_t + \frac{W_{t+1} + \Pi_{t+1} - TAX}{R} - DEBT .$$

The first order condition assures consumption smoothing over time: $C_t = C_{t+1}$.

Firms

Firms have access to a Cobb-Douglas production function in capital, K_t, and labour, L:

$$Y_t = K_t^{\alpha} L^{1-\alpha} .$$

Capital depreciates fully every period. We assume that the initial stock of capital is equal to the optimal steady state level, $K_t = (\alpha\beta)^{\frac{1}{1-\alpha}}$. To finance capital for the second period, firms

[7] The initial endowment of capital generates wealth that encourages the running of a current account surplus. The initial debt level is set to offset this.

borrow funds from domestic financial intermediaries at a rate of R_t^L. Profits in each period are:

$\Pi_t = Y_t - W_t L$; $\Pi_{t+1} = Y_{t+1} - W_{t+1} L - R_t^L K_{t+1}$.

The first order conditions are:

$$W_t = (1-\alpha)\left(\frac{K_t}{L}\right)^{\alpha}; \quad W_{t+1} = (1-\alpha)\left(\frac{K_{t+1}}{L}\right)^{\alpha}; \quad R_t^L = \alpha\left(\frac{K_{t+1}}{L}\right)^{\alpha-1}.$$

Financial intermediaries

Financial intermediaries begin with some wealth, EQ_t, and get utility from consuming at time *t+1*. For the purposes of normalisation we assume that $EQ_t = \frac{1}{1+\chi}(\alpha\beta)^{\frac{1}{1-\alpha}}$. Financial intermediaries raise funds, D_t, in international financial markets at rate R and lend to domestic firms at rate R_t^L. They also hold central bank bonds paying return R_t^B. Their budget constraint it given by:

$K_{t+1} + B_t = D_t + EQ_t$,

and they earn profits of:

$R_t^L K_{t+1} + R_t^B B_t - RD_t$.

We consider two cases for banks. In the *unconstrained banks* case, financial intermediaries can borrow freely. The first order profit maximisation condition in this case is $R_t^L = R_t^B = R$. In the *constrained banks* case, we assume there is a borrowing constraint imposed exogenously for reasons similar to Kiyotaki and Moore (1997) so that $D_t \le \chi EQ_t$. If this is a binding constraint, the first order conditions are $K_{t+1} = (1+\chi)EQ_t - B_t$ and $R_t^L = R_t^B$. [8]

Central bank

The central bank buys foreign assets in the international financial markets, FX_t, which are financed with the issuance of bonds. The budget constraint is $B_t = FX_t$. The central bank imposes a tax in period 2 to cover its losses on its holdings of foreign reserves of $TAX = \left(R_t^B - R\right)B_t$. The central bank's reserves holdings are defined as a fraction of initial capital holdings, $FX_t = \rho K_t$.

Equilibria

<u>*Unconstrained banks:*</u> when banks face no constraints, $R_t^L = R_t^B = R = 1/\beta$. The central bank takes no losses, so $TAX = 0$. In this case, consumption, capital, output and wages are all smooth across time:

[8] From a regulatory perspective, there is typically no capital charge against banks for holding sterilisation bills, though this is at the discretion of national regulators under Basel II, and will remain so under proposed Basel III standards. We are therefore implicitly assuming that financing constraints are due to market imperfections.

$K_{t+1} = K_t = (\alpha\beta)^{\frac{1}{1-\alpha}}$; $Y_{t+1} = Y_t = (\alpha\beta)^{\frac{\alpha}{1-\alpha}}$; $W_{t+1} = W_t = (1-\alpha)(\alpha\beta)^{\frac{\alpha}{1-\alpha}}$.

Inserting these conditions and the debt equation into the households' intertemporal budget constraint, we obtain:

$$(1+\beta)C = W_t + \Pi_t + \frac{W_{t+1} + \Pi_{t+1}}{R} - DEBT_t,$$

Or:

$$\begin{aligned} C_t &= Y_t(1-\alpha\beta) \\ &= Y_t - K_{t+1} \end{aligned}$$

There is no trade imbalance ($NX_t \equiv Y_t - C_t - K_{t+1} = 0$), and the equilibrium outcomes of all variables are invariant to the level of foreign reserve holdings, ρK. In effect, the central bank is financing the purchase of foreign assets using foreign borrowings. This increases gross capital flows, but the net impact on the trade balance or any other real variables is nil. This is the world envisaged by Sargent and Wallace (1981), discussed in section 2, in which central bank balance sheets are perfectly offset by the decisions of other actors in the economy.

Constrained banks: in the case of constrained banks, bank lending is limited by bank capital, so the financing of foreign reserve holdings crowds out future capital accumulation and $K_{t+1} = (1-\rho)K_t$. Reduced capital accumulation reduces future income: $Y_{t+1} = (1-\rho)^{\alpha} Y_t$, and the lack of available funds pushes up the lending rate in the domestic economy:

$$R_t^L = R_t^B = \alpha\left(K_{t+1}\right)^{\alpha-1} = (1-\rho)^{\alpha-1} / \beta.$$

Given that $R = 1/\beta$, this implies a mark-up of the lending rate over the international cost of capital, raising the cost of central bank balance sheet expansion by:

$$TAX = \frac{(1-\rho)^{\alpha-1} - 1}{\beta}\rho K_t.$$

Inserting these conditions, along with the consumption smoothing condition, into the budget constraint, we obtain:

$$(1+\beta)C_t = (1+\beta(1-\rho)^{\alpha})(1-\alpha)Y_t + \alpha Y_t - \beta TAX - \alpha\beta^2 Y_t,$$

so that:

$$C_t = \left[\frac{1+\beta(1-\rho)^{\alpha}}{1+\beta}(1-\alpha) + \alpha - \alpha\beta + \frac{\left(1-(1-\rho)^{\alpha-1}\right)\alpha\beta\rho}{1+\beta}\right]Y_t.$$

Now there are also implications for other variables as well. We can write the trade balance, $NX_t \equiv Y_t - C_t - K_{t+1}$, as:

$$\begin{aligned} NX_t &= \frac{\beta}{1+\beta}\left[1-\alpha+\alpha\beta\rho+(1-\rho)^{\alpha-1}(\alpha+\rho-1)\right]Y_t \\ &= \frac{1}{\alpha(1+\beta)}\left[1-\alpha+\alpha\beta\rho+(1-\rho)^{\alpha-1}(\alpha+\rho-1)\right]K_t. \end{aligned}$$

Clearly, when $\rho = 0$, the trade balance is zero. Further, we can see that, for $0 < \rho < 1$:

$$\frac{dNX}{d\rho} = \frac{1}{1+\beta}\left[\beta + (1-\rho)^{\alpha-2}(2-\alpha-\rho)\right]K_t > 0$$

.

Thus, in the case of credit-constrained financial intermediaries, the financing of the acquisition of bonds will have a positive impact on the current account. Central bank balance sheet expansion therefore increases global imbalances through three channels: 1) the direct impact of borrowing from the domestic banking system will reduce investment; 2) low investment will in turn reduce future income which will reduce current consumption due to intertemporal consumption smoothing; and 3) the cost of central bank balance sheet expansion increases future taxation, further reducing current consumption.

3.2 Evidence

We test whether reserve accumulation acts to crowd out other types of assets, as predicted by our model, using data on balance sheets of 55 individual banks (Source: S & P Global Compustat) over the period year-end 2003 to year-end 2007 in five economies including Indonesia, South Korea, Malaysia, the Philippines and Thailand. These countries provide a useful test case as they had accumulated reserves to varying degrees over the sample period, yet they experienced roughly similar average real GDP growth over, from a low of 4.6% in Korea to a high of 5.9% in Malaysia (Source: World Bank World Development Indicators).

In Table 2, we report the results of regressions of growth rates in the asset positions of banks on a number of regressors including foreign reserves accumulation.[9] In column 1, we report the results of a regression of the percentage growth of the loan-to-asset ratio on the percentage growth of foreign reserves in US dollar terms, controlling for initial bank-specific factors at the end of 2003. We find that banks with relatively low leverage in 2003 had relatively higher growth in loans compared to deposits. Also, there is evidence of mean reversion in the sense that banks with relatively high levels of loans-to-assets in 2003 had lower rates of growth in loans-to-assets in the subsequent four years. Further, there is little evidence that the relative size of the banks was associated with growth in this ratio. More important for the predictions of our model, for each 1% increase in the level of reserves there is an approximately 1% decline in the growth of the quantity of loans relative to assets.

Columns 2 and 3 show that this result is driven by the effect of reserves growth on loans. The elasticity of real loan growth (i.e. deflated by the local CPI) with respect to growth in foreign reserves is approximately -1.25% while the accumulation of foreign reserves has relatively low association with growth in real assets by domestic banks. These results show that high initial capitalisation is significantly associated with subsequent growth in real banking assets, and especially with growth in real loans to customers. They suggest an association of reserve accumulation with significant crowding out of bank lending, as the banks finance the sterilisation of reserve purchases instead of providing credit.

[9] See the appendix for data definitions and sources.

Table 2

Impact of Reserve Accumulation on Bank Balance Sheets

	(1)	(2)	(3)	(4)	(5)
Dependent variable: % Growth in	**Loan/Asset Ratio**	**Real Loans**	**Real Assets**	**Loan/Deposit Ratio**	**Liquidity/ Asset Ratio**
% Growth in Reserves	-0.952***	-1.254***	-0.302	-1.527***	1.264**
	(0.176)	(0.409)	(0.342)	(0.214)	(0.508)
Initial Levels:					
Size	0.014	-0.045	-0.059	0.079***	-0.154***
	(0.016)	(0.064)	(0.058)	(0.028)	(0.049)
Capitalisation	1.051**	2.766***	1.715**	2.313***	-2.521
	(0.478)	(0.860)	(0.815)	(0.840)	(1.686)
Loan/Asset Ratio	-0.715**	-0.316	0.399		
	(0.284)	(0.391)	(0.280)		
Loan/Deposit Ratio				-0.187***	
				(0.037)	
Liquidity/ Asset Ratio					-2.747***
					(0.625)
Constant	0.881***	1.508*	0.627	0.329	1.565*
	(0.222)	(0.669)	(0.616)	(0.333)	(0.764)
Adj. R^2	0.509	0.297	0.114	0.769	0.487
Obs.	55	55	55	55	55

Heteroskedasticity Robust Standard Errors in Parentheses. ***, **, * indicates significance at 1%, 5%, 10% level respectively.

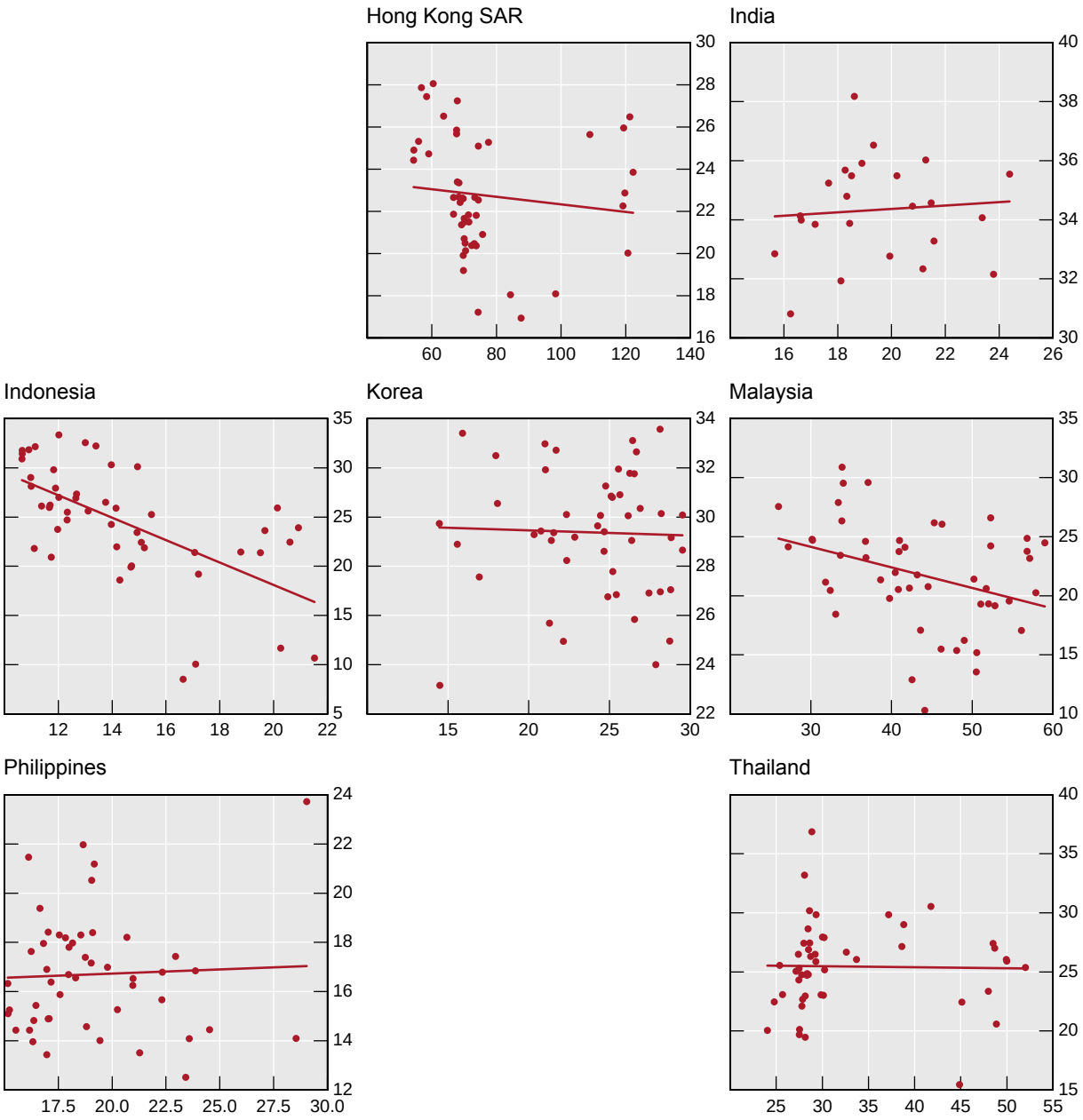
Column 4 reports the result of a regression of the loan-to-deposit ratio on foreign exchange accumulation and other bank specific factors. The results suggest that accumulation of foreign reserves is significantly associated with a decline in the loan-to-deposit ratio, consistent with deposits being used to purchase sterilisation instruments. Also, banks that were highly leveraged in 2003 subsequently reduced their loan-to-deposit ratio, arguably consistent with prudent management. Interestingly, relatively large banks were significantly more likely to increase their loan-to-deposit ratio.

Column 5 shows the flip side of column 1, reporting the association between the accumulation of foreign exchange reserves by the central bank and increases in the share of liquid assets held by banks. In this case, we define liquid assets as the sum of cash plus investment securities. We see that each percentage point increase in central bank foreign reserves is associated with an approximately 1.25% *increase* in the ratio of liquid assets to total assets. This is consistent with banks' increased holdings of sterilisation instruments (a liquid asset) coming at the expense of loans (an illiquid asset).

Graph 4

Reserves and investment[1]

As a percentage of GDP



[1] Horizontal axis: foreign exchange reserves as percentage of GDP; vertical axis: investment as percentage of GDP.

Source: IMF *IFS*.

The results in Table 2 are not driven by any single country. For each regression we drop, in turn, one of the five countries in the sample. In each case, the significant coefficient on the growth in reserves observed in columns 1, 2 and 4 are significant at the 5% level. The results in column 5 are slightly less robust. The statistically significant association between changes

in the liquid asset ratio and foreign reserves accumulation is significant at the 10% level when Korean or Philippine banks are dropped but is not significant when Malaysian banks are dropped. However, in each of these cases the coefficient remains economically large and is comparable in size to the results reported in Table 2.[10]

We also check whether the results are driven by other macroeconomic factors. We estimate versions of the regression in column 2 replacing the initial loan-to-asset ratio with some macroeconomic observation including: 1) the average CPI inflation rate between 2003 and 2007 (Source: IMF *IFS*); 2) the average real GDP growth rate between 2003 and 2007 (Source: World Bank *WDI*); 3) the average ratio of the current account to nominal GDP from 2003 and 2007 (Source: IMF *IFS*); and 4) the log of the 2003 in GDP per capita in 2005 PPP equivalent US dollars (Source: World Bank *WDI*). In each case, the association between central bank reserves accumulation and commercial bank lending growth is negative and significant at the 5% level. We also check whether the result is robust to our choice of start and end dates. We repeat the regression in column 2 using 1) growth rates over the period end-year 2003 to end-year 2006 and initial values at end-year 2003 and 2) growth rates over the period end-year 2004 to end-year 2007 and initial values at end-year 2004. In each case, we find the negative relationship between reserves accumulation and real loan growth is significant at the 5% critical value.

We briefly examine these possibilities further by plotting the relationship between reserves and investment, defined as a percent of GDP, for all economies for which data is available. Graph 4 illustrates indications of a negative relationship between investment and reserves accumulation, which is statistically significant for Indonesia and Malaysia.

4. The effect of large reserves on risks in the financial system

Accumulating foreign exchange reserves, largely financed through the issuance of non-monetary liabilities, may affect the stability of the financial system in a variety of ways. Some of these are positive and intentional. After all, one of the prime motives for central banks to accumulate foreign exchange reserves is precautionary. The capital outflows during the 1998 crisis confronted a number of emerging Asian economies with a shortfall of foreign currency. By accumulating large reserves, the central banks in some of these countries may hope to avoid such external constraints in future times of crisis. Using macroeconomic evidence, Aizenman and Hutchison (2010) show that countries that had accumulated substantial foreign exchange reserves (relative to international liabilities) were best able to avoid exchange rate depreciations during the international financial crisis. On a microeconomic level, Tong and Wei (2011) show that manufacturing firms that were intrinsically dependent on external sources of liquidity suffered worse equity outcomes during the crisis of 2008, suggesting that central banks' ability to alleviate liquidity constraints could be important during a crisis.

Other effects, however, may be less positive. If reserves are sterilised largely through increased reserve requirements or issuing sterilisation bills that are purchased by banks, offsetting decisions by those banks could in principle increase the overall riskiness of the financial system. For example, successful sterilisation may result in persistent interest rate differentials, and

[10] Results are robust to including the 9 largest banks from Chinese Taipei in the sample. Including 12 major Indian banks changes the results qualitatively unless one controls for differences in growth rates of real GDP, perhaps because India experienced greater reserves accumulation in part due to higher growth rates. Full results are available from the authors.

therefore persistent capital inflows, which have been identified as a contributory factor to the Asian Financial Crisis (Cavoli and Rajan, 2006; Takagi and Esaka, 2001).

In this section, we will provide evidence on the sign and size of the impact of foreign exchange reserves accumulation on the financial system. Primarily using bank-level data, we will examine the degree to which central bank reserves were able to alleviate liquidity constraints amongst emerging Asian financial intermediaries during the most recent crisis. We then further examine whether foreign reserves affected the risk profiles of these intermediaries prior to the crisis.

4.1 Crisis risk

To test the success of foreign exchange reserves as a means to alleviate liquidity shortages, we examine the relative performance of banks during the international financial crisis. We construct a weekly series of stock returns, R_t^j, defined as the log first difference of end-of-week stock prices, for a sample of banks for which equity price and balance sheet data were available for at least 6 years during the decade 2001-2010. In Table 3 we report the average (annualised) return on the shares of 46 emerging Asian banks from Indonesia, Korea, Malaysia, the Philippines and Thailand over the period 1 September 2008 to 30 April 2009. We see from the first column that in each country there is a large decline in the stock prices of the banks, ranging from 17% in Malaysia to nearly 60% in Korea, for an average of 40% across the five countries. In the second column we report the average difference between the returns on the individual banking stocks and the average market return for each of these countries. In Malaysia and Thailand the banking shares on average tracked the market. In the Philippines banking shares performed worse than the market and in Korea much worse. In Indonesia, banking shares actually outperformed the market.

Table 3

Bank equity performance

1 September 2008 – April 30 2009

	Average Return	**Average Excess Return**
Indonesia	-0.276	0.151
Korea	-0.590	-0.441
Malaysia	-0.170	-0.037
Philippines	-0.496	-0.151
Thailand	-0.556	-0.015
Total	-0.402	-0.081

In Table 4 we estimate a regression that specifies bank level determinants of crisis period excess returns (relative to the market). The bank level determinants from end of year 2007 balances sheets we examine are:

1. *Size*: The logarithm of total bank assets (AT from S & P Global Compustat) in US dollar terms converted from local currency using end of period exchange rate from the IMF *IFS*;

2. *Loan/Assets*: For each bank, the ratio of Loans/Claims/Advances-Customers-Total (LCUACU) to Total Assets (AT);

3. *NonCore*: The ratio of non-core deposits to assets defined for each bank as total liabilities (LT) less total customer deposits (DPTC) divided by total Assets (AT).

Table 4

Bank equity performance

1 September 2008 – April 30 2009

	Average Excess Returns					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Size	-0.094***	-0.104	-0.099***	-0.078***	-0.081**	-0.066***
	(0.034)	(0.102)	(0.034)	(0.028)	(0.033)	(0.024)
Loan/Assets	-1.164***	-1.177***	-1.912**	-1.254***	-1.194***	-0.893*
	(0.375)	(0.409)	(0.804)	(0.408)	(0.395)	(0.502)
Non-Core	-1.139**	-1.128**	-1.220***	-4.828**	-4.102*	-6.034***
	(0.459)	(0.434)	(0.431)	(2.307)	(2.177)	(2.174)
*NML*Size*		0.053				
		(0.433)				
*NML*Loan/ Assets*			4.460			
			(4.365)			
NML NonCore*				15.487*		19.155**
				(8.613)		(8.441)
FR NonCore*					10.595	
					(7.196)	
NML						-1.015
						(1.103)
PC GDP						0.072
						(0.059)
R^2	0.422	0.406	0.415	0.446	0.436	0.385
N	46	46	46	46	46	46

Heteroskedasticity consistent standard errors report in parenthesis. ***, **, * signify significance at the 1%, 5%, 10% level respectively.

The results in column 1 of Table 4 show the relationship between bank-level excess returns and these balance sheet indicators. The regression includes country dummies to abstract from country-level effects on the banking system. The coefficients on all three indicators are negative and statistically significant at the 5% level indicating that all of these were associated with relatively worse performance during the crisis period. Large banks are likely to have more international exposure than smaller banks, so it might not be surprising that the relatively larger banks had worse returns, given that the crisis was external to these economies. Banks with relatively greater quantities of loans on their balance sheets might

have faced worse performance due to greater credit risk or greater liquidity risk during the crisis. Also, banks that financed their assets through channels other than core deposits had relatively worse performance. The contraction in international money markets that occurred during the crisis may explain this result.

The above results are not strongly driven by any one country. We repeat the regressions in column 1 dropping banks from each of the five countries in turn. When Korean banks are dropped from the sample, non-core deposits are significant only at the 10% level. When either Malaysian or Indonesian banks are dropped from the sample, the coefficient on the loan to asset ratio is not statistically significant. However, in both of these cases the p-value is less than 0.15 and the coefficient estimates are comparable to the full sample. In all other cases, the coefficients are significant at the 5% level.

We next consider how the balance sheets of central banks in these countries might have affected these risk factors. In columns 2-4 we report the results of regressions that include an interaction between *NMR* (defined as the ratio of non-monetary domestic liabilities of the central bank to GDP in year 2007) with each of the three risk factors. We find that the interaction between sterilised reserves and either *Size* or *Loan*/*Assets* is insignificant at the 10% level. However, we find that the interaction between *NMR* and *NonCore* is positive and significant at the 10% level. Thus, banks with exposure to money markets tended to perform somewhat less poorly during the crisis if the central bank had large quantities of sterilised reserves. Central banks with substantial amounts of foreign reserves might have been able to use these to mitigate the double drain of foreign currency and domestic credit during the crisis.

In column 5 we report the results using the interaction between the ratio of total foreign assets (sterilised and unsterilised) to GDP and *NonCore*. Though this coefficient is positive, it is small and not statistically significant. In column 6, we report results of a regression that drops country dummies and includes a control for the natural logarithm of per capita GDP in PPP-converted 2005 US Dollars (from the World Bank WDI database) as well as the level of *NMR*. Interestingly, the adjusted R^2 in this regression is similar to the regression including country dummies. Here we see that the interaction term between *NMR* and *NonCore* is significant at the 5% critical value. These results provide some evidence that the acquisition of sterilised foreign reserves may have played some positive role in mitigating the effects of the crisis relative to what was seen during the Asian financial crisis of 1998.

4.2 Reserves and the Crisis

To see how sterilised foreign currency reserves are used in a crisis, it is interesting to examine the response of the Bank of Korea to the events of the autumn of 2008. During this season, Korean banks experienced capital outflows as foreign lenders withdrew their short-term funds (see Shin and Shin, 2011). Because of the reliance of Korean banks on foreign currency financing, this had some potential for damaging the Korean financial system (see Kim, 2010). Table 5 reports the response of the Bank of Korea's balance sheets during the second half of 2008, with month-by-month figures for foreign assets, the monetary base and non-monetary domestic liabilities. First, we see that there was a drain on the foreign reserves of the central bank, which declined from 294 trillion to as low as 227 trillion Won in November. Outflows were temporary and began reversing by December (and reserves have since risen to new highs). At the same time, the drain on reserves had very little impact on domestic liquidity. In October 2008 the domestic monetary base fell briefly but quickly recovered. Instead, the decline in the foreign assets of the central bank was balanced by a decline in non-monetary liabilities. In particular, the deposits of foreign exchange by the Ministry of Finance and Economics, which had been financed by the issuance of stabilisation bonds, were withdrawn. The holdings of excess reserves of foreign currency allowed policy makers to intervene in an illiquid foreign currency market without draining liquidity from the domestic market.

Table 5

Bank of Korea balance sheet

In trillions of won

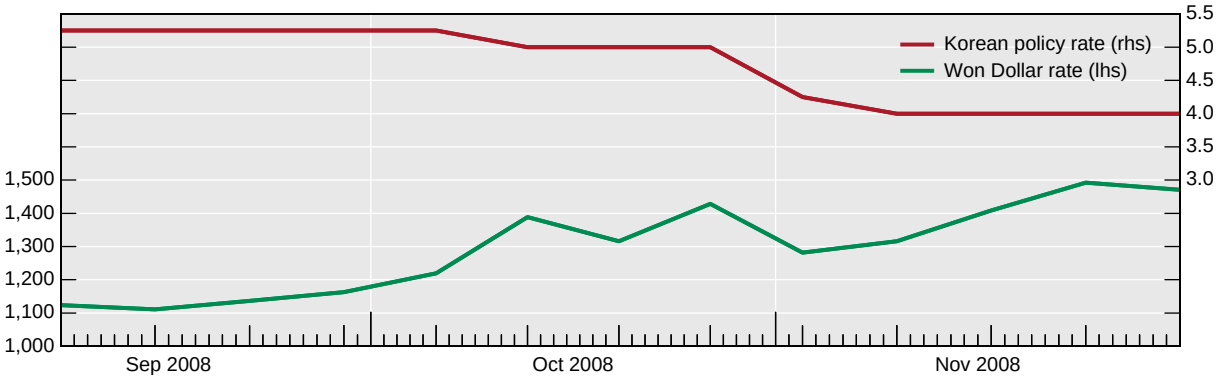
Date	Monetary base	Foreign assets	Non-monetary liabilities	Foreign exchange stabilisation funds
6/2008	52.271	294.938	246.355	59.975
7/2008	53.255	286.627	235.793	58.192
8/2008	55.071	285.282	237.227	58.118
9/2008	56.590	272.762	229.336	55.966
10/2008	51.113	240.181	207.510	25.491
11/2008	55.364	227.746	194.110	17.693
12/2008	61.335	257.970	221.248	20.938

Source: CEIC

Indeed, the Korean Won depreciated from 1000 won per dollar on 11 July 2008 to nearly 1500 by 23 November that year. At the same time, the Bank of Korea was able to reduce its policy rate (see Graph 5).

Graph 5

Korean exchange rate and policy rate



Source: Datastream

In fact, interbank interest rates actually declined during this period (Graph 6). Capital outflows in economies whose central banks smooth exchange rates can have a negative double drain effect. First, outflows drain loanable funds from capital markets. Second, they put downward pressure on exchange rates, inducing the central bank to drain money from the domestic economy through foreign exchange intervention. As shown in the Korean example, careful use of sterilised reserves may mitigate these risks. Indeed, Aizenman and Sun (2009) show that countries with high levels of international reserves relative to GDP did allow the greatest depletion of those reserves during the initial stages of the crisis.

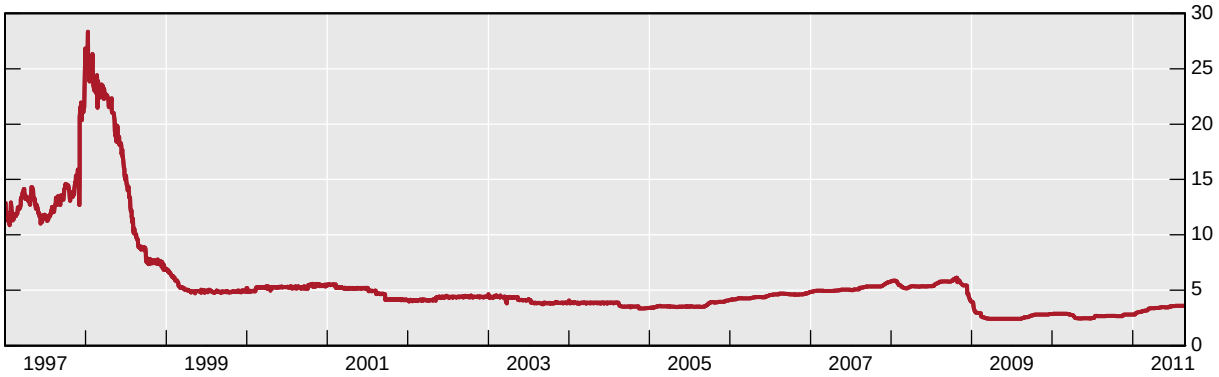
The degree to which foreign exchange reserves serves to protect financial institutions during a crisis may depend on the institutional arrangements governing the use of sterilisation instruments. As argued in the introduction, foreign exchange reserves are generally financed using sterilisation instruments. Many sterilisation instruments are assets which, for the

purposes of the commercial banking system, might be highly substitutable for monetary instruments. However, like government bills that traditionally play the role of secondary reserves, sterilisation instruments may not always be perfectly substitutable, particularly in a crisis situation, as we can illustrate using data from 1998 for Hong Kong.

Graph 6

Korean three-month interbank rate[1]

In per cent



[1] KORIBOR rate extended backwards beyond 2004 using the overnight call rate for interpolation.

Sources: Bloomberg; BIS calculations.

The Hong Kong currency board system requires that the monetary base, including bank notes and commercial bank reserves held at the central bank, be fully backed with US dollar assets. There are no reserve requirements in Hong Kong, but funds in the clearing accounts are used for the real-time settlement of interbank payments. In addition, the Hong Kong Monetary Authority intermittently exchanges non-interest paying reserves for liquid interest-bearing securities of varying maturities referred to as Exchange Fund paper (bills and notes). Though any parties can hold Exchange Fund paper, it is largely held by banks for liquidity purposes.[11] Meanwhile, clearing balances are typically small relative to the quantity of Hong Kong dollars being exchanged. At the end of 1998, the size of the clearing balances was approximately HK$2.5 billion relative to a GDP level of HK$1,293 billon in that year. Table 6 reports the size of Clearing Balances and Exchange fund paper in Hong Kong during the 1990's.

Given the small size of reserves held by banks and the operation of the currency board, relatively small quantities of capital flight may lead to significant interest rate volatility in the interbank market. Following the depreciations of some emerging Asian currencies during the financial crisis of 1998, market sentiment reflected a view that a similar devaluation in Hong Kong was possible, despite the fifteen-year continuous operation of the currency board. It is surmised that, in August 1998, some international hedge funds played on this sentiment by engineering large-scale short-selling of Hong Kong dollars by borrowing funds from Hong Kong banks and selling the funds in foreign exchange markets.[12] By the operations of the currency board, these sales reduced the aggregate amount of Hong Kong dollars available in reserve accounts. The resulting liquidity shortage caused extreme spikes in the interbank rate (HIBOR).

[11] Between 1999 and 2007, an average of 83% of Exchange Fund paper was held by banks (Source: HKMA Monthly Statistical Bulletin).

[12] See Goodhart and Dai (2003).

Table 6

Clearing balances and exchange fund paper in Hong Kong

In millions of HK dollars

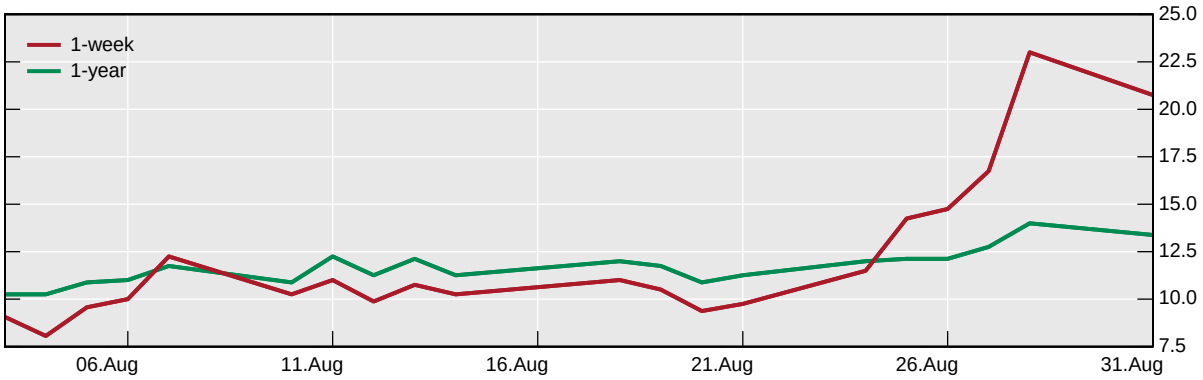
Year	Clearing balances	Exchange fund paper
1993	1,385	25,157
1994	2,208	46,140
1995	1,762	53,311
1996	474	83,509
1997	296	89,338
1998	2,527	98,334
1999	7,960	101,828
2000	669	109,288

Sources: HKMA Monthly Statistical Bulletin

Graph 7

Daily Hong Kong Interbank Offered Rates (HIBOR)

August 1998



Source: HKMA Monthly Statistical Bulletin.

Graph 7 shows the daily average interest rate for 1 week HIBOR during August 1998 along with 1 year HIBOR for comparison. Rates were already high during this period, relative to the US, reflecting fears of a future devaluation. In the final week of the month, we observe a large spike in weekly interest rates to above 22% on an annual basis with little movement in the longer rate, suggesting that this spike was the result of a deficit of short-run liquidity.

The Hong Kong government responded with a number of measures including an intervention in the domestic stock market. Perhaps as interesting were some technical changes in the monetary arrangements announced on September 5th (HKMA, 1998). In particular, the monetary authority announced that they were "removing the restriction on repeated borrowing in respect of the provision of overnight Hong Kong dollar liquidity through repo transactions using Exchange Fund Bills and Notes." From that point on, banks were able to use up to 50% of their Exchange Fund paper as collateral to borrow overnight Hong Kong dollar clearing balances from the discount window at a rate similar to a longer term average HIBOR rate. By sharply increasing the substitutability between Exchange Fund paper and

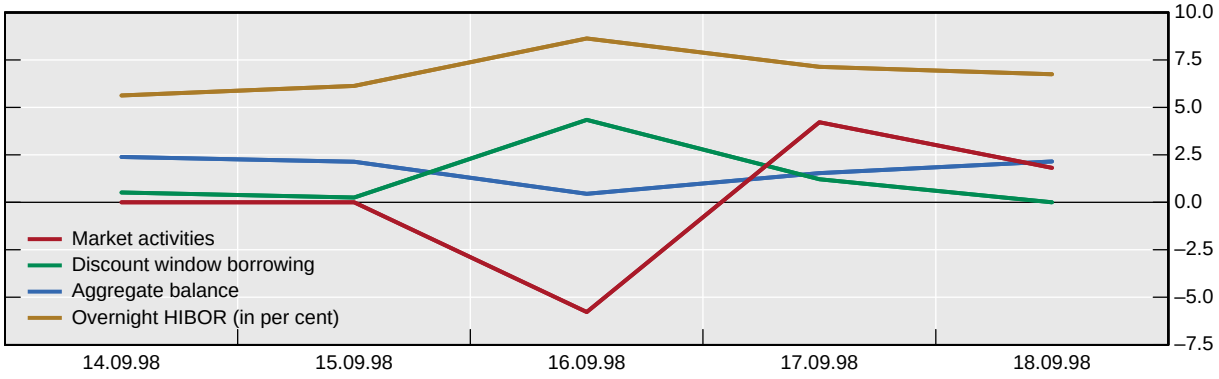
clearing balances, this procedural change markedly improved the liquidity of the Hong Kong dollar interbank market.

The results of this new regime may be seen in Graph 8. On September 16 1998 there was another sharp capital outflow, amounting to HK$5.8 billion, larger than the entire clearing balances at the outset of that week. This resulted in a large net drain from the system. However, this was offset by an increase in discount window borrowing of approximately HK$4.4 billion. The inflow of funds from the discount window limited the rise in the overnight interbank rate which increased by only 250 basis points (annualised) for a single day before reverting to normal levels. Thus, with the new institutional arrangements, large stocks of sterilisation bills served as a source of stability for the financial system during a period of extreme stress.

Graph 8

Hong Kong dollar interbank market

In billions of HKD unless otherwise specified



Source: HKMA Monthly Statistical Bulletin.

4.3 Exchange rate risk

It is possible that a large stock of sterilisation instruments could also help to insulate the banking system from currency risk. For each individual bank j in market m we estimate the OLS regression:

$$R_t^j = \alpha_0 + \gamma^S ds_t^m + \varepsilon_t ,$$

where R_t^j is the log first difference of the equity price of bank j and ds_t^m is the log first difference of the exchange rate (domestic currency per USD) of market m. We estimate the equation by OLS using a series of rolling regressions with three years of data starting in 2001 and running through 2008. The exchange rate exposure coefficient, γ^S, measures the unconditional co-movement between exchange rates and stock prices. A negative estimate of γ^S indicates that a banks' stock price tends to fall when exchange rates depreciate. For four of the five markets we report the mean estimate (across the banks in the sample) of γ^S for each of three year period between 2001 and 2009. However, as Malaysia operated a fixed exchange rate through 2005, we report the mean unconditional exposure using regressions based on one year samples to identify trends over the period 2006-2009.

For all of these countries and periods, the relationship is negative (Table 7). For Thailand the negative relationship seems to lessen over time, while the reverse is true for the Philippines. For Korea, the relationship shows a pronounced diminution in the period 2001-2006, with a reversal once the international financial crisis is included in the same period. Perhaps because of the shorter sample, the estimate for Malaysia appears unstable.

Table 7

Estimates of unconditional bank equity sensitivity to exchange rate movements (γ^S)

Sample Period	Indonesia	Korea	Philippines	Thailand	Sample Period	Malaysia
2001-2003	-0.27	-1.43	-0.42	-1.26		
2002-2004	-0.99	-1.36	-0.35	-2.00		
2003-2005	-1.15	-1.04	-0.57	-1.61		
2004-2006	-0.99	-0.67	-1.12	-2.20	2006	-0.79
2005-2007	-0.98	-0.72	-1.30	-0.77	2007	-1.83
2006-2008	-0.60	-1.08	-1.24	-0.89	2008	-0.74
2007-2009	-0.83	-1.30	-1.27	-0.62	2009	-1.08

There are two potential interpretations for the negative relationship between stock prices and exchange rates. First, exchange rate shocks from external sources might have a negative impact on the value of bank equity. Second, domestic macroeconomic shocks which have a negative impact on the stock market may also lead to decline in the value of the domestic currency. To abstract from the second effect we re-estimate controlling for broader market movements. For each individual bank j in market m we estimate the OLS regression:

$$R_t^j = \alpha_0 + \beta R_t^m + \phi^S ds_t + \varepsilon_t ,$$

where R_t^m is the log first difference of a broad market index for market m. The exchange rate exposure coefficient, ϕ^S, now represents the conditional correlation between exchange rates and an individual firm's stock price. Table 8 reports the estimates of coefficient ϕ^S.

Table 8

Estimates of conditional bank equity sensitivity to exchange rate movements (ϕ^S)

Sample Period	Indonesia	Korea	Philippines	Thailand	Sample Period	Malaysia
2001-2003	0.04	0.04	0.22	-0.11		
2002-2004	-0.39	0.05	0.31	-0.18		
2003-2005	-0.57	0.23	-0.11	-0.15		
2004-2006	-0.28	0.42	-0.36	-0.30	2006	0.17
2005-2007	-0.12	0.66	-0.24	0.03	2007	0.23
2006-2008	0.16	0.07	-0.01	-0.03	2008	0.06
2007-2009	0.06	-0.20	-0.28	0.31	2009	0.32

Here we see much less negative exchange rate exposure overall, with banks in Korea and Malaysia showing a positive response to exchange rate movements after broad market

movements are controlled for. This suggests that the financial system may be relatively less exposed to exchange rate movements than the stock market as a whole. We also see a pattern where the positive exposure of the Korean banking system increases until it reaches the period of the international financial crisis after which exposure turns relatively negative, while the negative exposures observed early in the decade amongst the banks of Indonesia and Thailand diminish, particularly in the period after 2005.

To understand the relationship between stock returns and exchange rate depreciation, we regress our estimates of conditional and unconditional exchange rate exposure on some market and bank specific factors. We estimate a fixed effects regression of γ^S for each bank in each period on country-period specific factors including the level of nom-monetary liabilities relative to GDP, real GDP growth and bank-period specific factors including the size of the bank assets and the degree of leverage. Each regression includes a bank-specific dummy variable, which soaks up all country effects, as well as year-specific dummies. Since the exchange rate exposures are calculated with overlapping samples, we estimate standard errors that are robust to heteroskedasticity and auto-correlation of unknown form. We report coefficients and standard errors in Table 9.

Table 9

Exchange rate exposure

	Unconditional exposure (γ^S)		**Conditional exposure (ϕ^S)**	
	(1)	**(2)**	**(3)**	**(4)**
Period	**2001-2009**	**2001-2007**	**2001-2009**	**2001-2007**
Non-monetary liabilities	6.19***	4.14**	-0.64	0.16
	(2.02)	(1.76)	(1.52)	(2.32)
Capitalisation	-0.18	3.00	1.83	4.68**
	(2.25)	(1.99)	(1.58)	(1.77)
Size	0.39	0.53**	0.40**	0.56***
	(0.40)	(0.22)	(0.18)	(0.20)
GDP growth	0.89	-24.23***	2.39	-9.44
	(10.03)	(8.28)	(6.34)	(10.51)
Obs.	317	215	317	215
Banks	55	53	55	53

Standard errors in brackets. ***, **, * indicates significance at 1%, 5%, 10% level respectively.

The first column reports the determinants of unconditional equity sensitivity to exchange rates. In this unbalanced sample there are 55 banks and 317 observations. Here the only statistically significant determinant is the ratio of non-monetary liabilities to GDP, implying that a high level of this measure of sterilised reserves is associated with a less negative exchange rate exposure. Possible explanations are that sterilised reserves allow the central bank to insulate the exchange rate from domestic shocks or the central bank to protect the value of domestic banks' equity from negative external shocks that weaken the exchange rate.

In column 2 we report results using data preceding 2008, before the height of the international financial crisis. We see that in these pre-crisis years, the effect of sterilised reserves on unconditional exposure is smaller but still significant at the 5% level. We are also able to detect that relatively large banks tend to have less negative exchange rate exposure in this period. Large banks might be able to use their size to overcome the fixed costs of using derivative instruments to protect against various currency mismatches or other financial exposures, for example. Exchange rate exposure is also cyclical, with more negative exposure during periods of rapid economic growth.

Columns 3 and 4 show the determinants of conditional exchange rate sensitivity. We see that controlling for aggregate stock market movements eliminates the significance of the country-level variables. The quantitative effect of non-monetary liabilities, in particular, is much reduced and insignificant at standard significance levels. These results suggest that a large stock of sterilised foreign exchange reserves offers no stronger protection from exchange rate shocks to banks than to the stock market as a whole. One interpretation is that sterilised reserves can help to insulate the economy from shocks but does not protect the financial system from external shocks beyond that. We also observe that exchange rate depreciations have smaller negative effects on the shares of large banks and (especially in the pre-crisis sample) well capitalised banks. This suggests that exchange rate shocks present risks to the financial systems in these markets that can be mitigated through conservative leverage or risk management.

4.4 Duration risk

Sterilisation involves risk transformation: banks are left holding sterilisation bills in exchange for some other asset. This risk transformation itself could increase the risk profile of the financial system. While credit risk and currency mismatch are unlikely to be negatively affected, since sterilisation instruments are issued by the central bank and in the same currency as most other assets and liabilities of domestic banks, banks may face heightened interest rate risk, or increased maturity mismatch, especially if sterilisation instruments are issued at longer maturities.

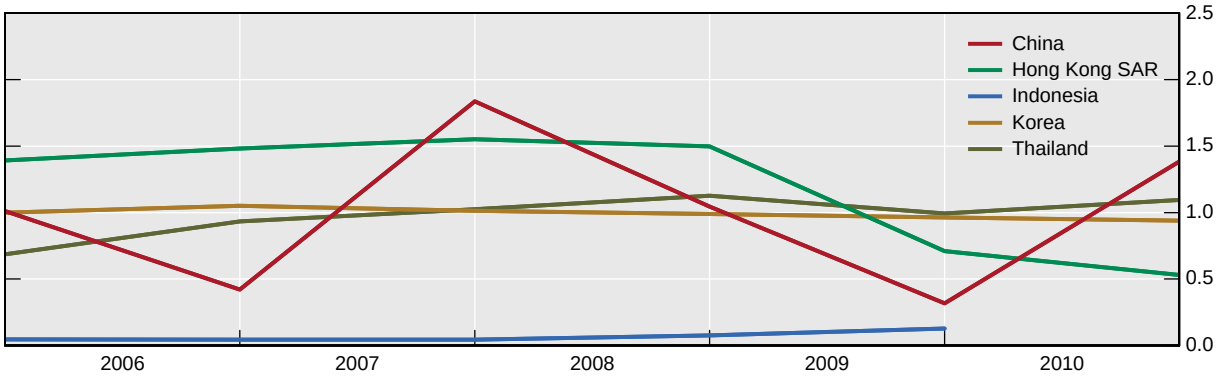
Graph 9 provides estimates of the average maturity of the outstanding stock of sterilisation bills for five economies for which data is available. For Indonesia only sterilisation bills at short maturities (up to 6 months) are issued, although the average length is increasing gradually. For Hong Kong, despite the rapid expansion of Exchange Fund paper issuance in recent years and a maximum maturity of 15 years, a growing share of paper is issued at 3 and 6 month maturities so that the average term to maturity is falling. For China, Korea and Thailand sterilisation bills have an average duration of approximately 1 year, and this has been stable for the past five years except in the case of China. Given the rapidly growing stock of sterilisation bills on bank balance sheets, and the historically low levels of interest rates globally, this could represent a growing source of interest rate risk within the banking system, although the risk appears to be small at this time.

Some central banks, including those in Malaysia, Singapore and Thailand, sterilise their reserves accumulation at least in part using foreign exchange swaps. While there is no publically available break-down on the maturity of these swaps, central banks are likely to be active at maturities where swaps markets are most liquid – that is, at maturities less than one year. This would limit concerns about effective interest rate risk due to swaps-based sterilisation.

Graph 9

Average maturity of outstanding sterilisation bills[1]

In years



[1] Average maturity is computed as a weighted average where the weights are outstanding bills of a given maturity as a share of total outstanding bills. The share is estimated based on the assumption that bill issuances are spread evenly over the year, and no bills are repurchased by the central bank before maturity. Thus the stock of sterilisation bills issued with maturity of 1 month are estimated as total issuance of such bills for the year divided by 12, and these are assumed to have an average time to maturity of 0.5 months. For bills with maturity exceeding one year, data for previous years is used to construct the stock of outstanding bills. For example, for bills issued with a maturity of 2 years, bills issued in the previous year with a maturity of 3 years are added, and the average time to maturity for the combined stock is assumed to be 1.5 years. For Indonesia, approximately 2% of all issued bills are SWBIs for which no term structure data is available. These are excluded from the calculations.

Sources: Dealogic; national data.

We can also use stock price data to test the market perception of the relationship between the stock of central bank non-monetary liabilities and the sensitivity of commercial banks' net worth to interest rates. We construct a measure of the yield curve as $yc_t = i_t^{10} - i_t^{Pol}$ where i_t^{10} is the 10 year sovereign yield from Datastream and i_t^{Pol} is the policy rate.[13] For each individual bank *j* in market *m* we estimate the OLS regression:

$$R_t^j = \alpha_0 + \beta_j R_t^m + \eta_j^Y dyc_t + \varepsilon_t,$$

where dyc is the first difference of the yield curve and R_t^m is the return (i.e. log first difference) on a market index. We estimate this regression for the 50 banks using data from the beginning of 2005 to the end of 2009.

A standard notion is that bank assets tend to be of longer maturity than their liabilities (see English, 2002). Thus, a steeper yield curve will tend to improve the balance sheets of the bank. However, this is not the case in emerging Asia. Table 10 shows that the average level of η_j^Y is negative for each country indicating that, on average, banking stocks do worse than the broader market when the yield curve steepens. In addition, we find that the coefficient η_j^Y is negative and significant at the 5% level in 10 of the 50 banks. A number of explanations might account for this. First, Asian banks tend to issue floating rate mortgages (see Zhu, 2006) indicating more short-term interest sensitive asset income. Second, Asian banks raise a high level of their funds from customer deposits (see Mohanty and Turner, 2010). If costs

[13] For the Philippines, 10 year sovereign yield this series ends on June 22, 2007. Beginning in July, we substitute a 10 year government yield also from Datastream.

of deposits are primarily non-interest related, then, a drop in interest rates might have a negative impact on balance sheets.

Table 10

Bank equity exposure

2005 – 2009

Exposure to:	**Yield curve** η_j^Y	**VIX** φ_j^V
Indonesia	-1.263	
Korea	-3.784	-0.97
Malaysia	-1.121	-1.07
Philippines	-0.170	-0.34
Thailand	-1.056	0.20
Total	-1.40	-0.98

In Table 11, column 1 we report the results of a regression of the exposure to yield curve risk on some bank level determinants (along with country dummies). We find that large banks have relatively more negative yield curve exposure. We might expect this to be positive, since large banks may be more able to use derivative instruments to eliminate interest rate risk. However, given the central importance of commercial banks in emerging markets, large banks may play a role as a counter-party for other players in swap markets. We also see that banks that are funded in large part through non-core liabilities have relatively less negative exposure to a steepening of the yield curve. Since the costs of funds raised in money markets are primarily interest rate-related, such banks might tend to benefit the most from a reduction in market interest rates relative to long-term rates.

To check the robustness of these results to the specifics of different countries, we re-estimate the regression in column 1 dropping each of the countries in turn. We find that when we drop the Philippines, the coefficient on bank size is significant only at the 10% level; when we drop banks from Korea, the coefficient is not significant at the 10% level. However, even in this latter case the coefficient is similar to the estimate in the total sample. Regardless of which country is dropped, the coefficient on *NonCore* is negative and significant at the 5% level.

To test whether central bank balance sheets affect the relationship between risk determinants and yield curve exposure, we include some interaction terms between the measure of non-monetary liabilities relative to GDP and the risk determinants (columns 2 and 3). We find no evidence that yield curve risk is impacted by the level of sterilised reserves, suggesting that the market does not perceive banks to be more risky in countries where there is a large stock of sterilised reserves.

Table 11

Explaining bank exposure to the yield curve, η_j^Y

	(1)	(2)	(3)
Size	-0.339**	0.191	-0.373**
	(0.152)	(0.582)	(0.170)
NonCore	8.593***	8.008***	14.986
	(2.023)	(2.215)	(10.297)
*NML*Size*		-2.855	
		(3.123)	
*NML*NonCore*			-27.009
			(41.136)
Adj. R^2	0.386	0.385	0.375
N	50	50	50

Heteroskedasticity consistent standard errors report in parenthesis. ***, **, * signify significance at the 1%, 5%, 10% level respectively.

4.5 Market risk

We also use equity prices to examine whether the acquisition of non-sterilised reserves modifies exposure to market risk. First, we examine exposure to a generalised level of market volatility, as measured by the VIX (following Milesi-Ferretti and Tille, 2010), an implied options volatility measure from the Chicago Board Options Exchange. For each individual bank *j* in market *m* we estimate the OLS regression:

$$R_t^j = \alpha_0 + \beta_j R_t^m + \varphi_j^V dvix_t + \varepsilon_t,$$

where R_t^j is the log first difference of the equity price of bank *j*; R_t^m is the log first difference of a broad market index for market *m*; and $dvix_t$ is the first difference of the VIX index. The regression is estimated over the period 2005-2009. We find that for most of the Asian countries in the sample, negative exposure to market volatility is apparent. Table 10 above reports the average estimate of φ_j^V (scaled by 1000). We see that in Indonesia, Korea and Thailand this estimate is near -1, while it is closer to zero in Malaysia and positive in the Philippines. We find that in 12 out of 50 cases the coefficient estimate is negative and significant at the 5% level (most of these cases are concentrated in Korea and Thailand) indicating banking systems that are more exposed to international volatility than the stock market as a whole.

We also assess the bank-level determinants of exposure to international volatility, focusing on bank size and holdings of investment securities, as follows:

1. *Size*: The logarithm of total bank assets (AT from S & P Global Compustat) in US dollar terms converted from local currency using end of period exchange rate from the IMF *IFS*;
2. *Securities/Assets:* The ratio of total investment securities (IST) to total assets (AT) from S&P Global Compustat measured in 2007.

Table 12, column 1 reports the results of a regression of the estimate of relative volatility exposure, φ_j^V, on these determinants. We find that large banks face relatively large negative exposure to international volatility. Given that large banks will tend to have relatively large international positions, this may not be surprising. Possibly more surprisingly, we find that banks with large holdings of investment securities have less negative responses to an increase in market volatility. This may indicate that bank holdings of investment securities are concentrated in relatively lower risk areas. One interpretation is that holdings of sterilisation bonds in emerging Asian banks reduce overall risk exposure.

Table 12

Explaining bank exposure to the VIX, φ_j^V

	(1)	**(2)**	**(3)**
Size	-0.278*	-0.789	-0.360**
	(0.150)	(0.574)	(0.151)
Securities/Assets	4.820**	5.607*	18.056**
	(2.301)	(2.564)	(7.049)
*NML*Size*		2.717	
		(3.370)	
*NML*Securities/Assets*			-65.658*
			(36.551)
Adj. R^2	0.111	0.113	0.146
N	50	50	50

Heteroskedasticity consistent standard errors report in parenthesis. ***, **, * signify significance at the 1%, 5%, 10% level respectively.

To test whether central bank balance sheets make any significant difference to risk exposures, we report results from regressions which include an interaction term between central banks holdings of non-monetary liabilities relative to GDP and the determinants of risk in Table 12. We do not find significant evidence that heavy central bank holdings of sterilised reserves limit the exposure to the VIX index. However, we do find a significant association (at the 10% level) between sterilised reserves and the relationship between securities holdings and volatility exposure. We find that in economies with high levels of sterilised reserves, banks with large securities portfolios have relatively less positive exposure to the VIX than in countries with relatively smaller holdings. Perhaps this is because banks which hold securities in countries with high sterilised reserves tend to hold relatively safe sterilisation bonds, rather than more risky investments with returns that are highly correlated with the VIX. Thus the accumulation of sterilised reserves may reduce banks exposure to market risk.

4.6 Moral hazard risk

One source of increased risk for banks might result if banks are forced to finance their large holdings of sterilisation bills through international money markets. In practise, this may not be a major concern since most banks in the region are funded primarily from a broad deposit base. However, in the most financially developed economies, such as Korea, banks have the

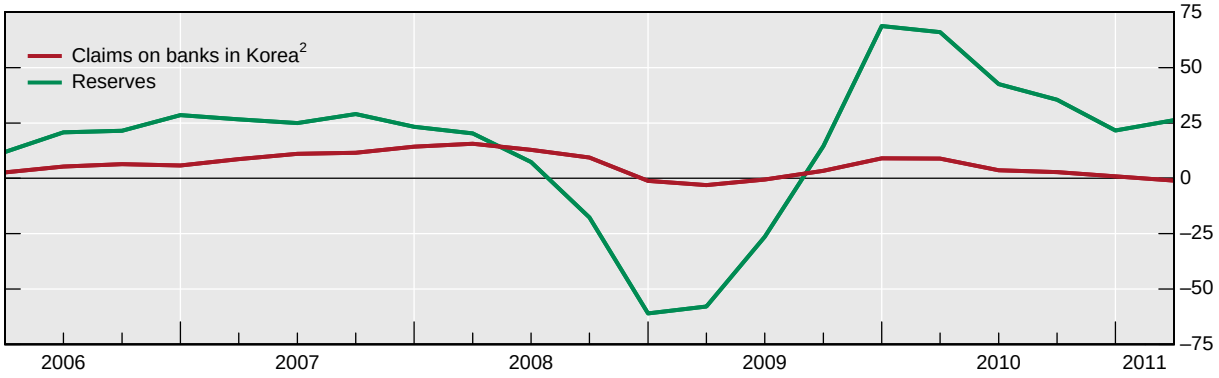
ability to access wholesale markets. There may be increased risks for those economies in which banks' foreign currency exposure and sterilised intervention are highly correlated, as would occur if the banking system's marginal funding comes from accessing international markets. The net effect of these transactions for the banks would be to increase their foreign currency liabilities and their domestic currency assets (sterilisation bills).

We can assess this risk for Korea, an economy in which domestic banks borrow in international markets, by comparing changes in non-won claims on Korean banks, using BIS locational banking statistics, with changes in reserves. As Graph 10 shows, there is some co-movement between the two series, but it is far from complete. Thus either banks' marginal funding does not come from international markets, intervention is not fully sterilised, sterilisation instruments are substantially sold to others besides domestic banks or some combination of these factors holds for Korea.

Graph 10

Korean foreign reserves and claims on Korean banks[1]

In billions of US dollars



[1] Year-over-year changes. [2] Unconsolidated claims on banks resident in South Korea which may include interoffice positions.

Sources: IMF IFS; BIS locational banking statistics.

5. The effect of large reserves on the central bank and monetary policy

We now outline some of the risks of foreign exchange reserves accumulation for the central bank and the conduct of monetary policy.

5.1 Central bank balance sheet risk

As argued in Calvo (1991) and Filardo and Grenville (2011), sterilised intervention, especially based on the issuance of sterilisation bills, is typically costly for two reasons. First, sterilisation bills typically pay a higher interest rate (since they are in domestic currency) than the return on foreign reserves (which may be largely in USD instruments). Second, this effect has been compounded historically by an even larger cost in terms of currency appreciation – a "carry trade" effect.

Table 13 offers estimates of sterilisation costs and the valuation losses from a 10% appreciation of the domestic currency. Note that while sterilisation costs tend to be small, at

least as a percent of GDP, it is in some cases of the same order of magnitude as central bank equity and total central bank revenues.[14] Further, sterilisation costs are small relative to the mark-to-market valuation losses from even a moderate appreciation of the domestic currency. One risk is that these costs reduce the effective independence of the central bank, due to the need for recapitalisation by the government.

Table 13

Estimates of sterilisation costs and valuation losses from domestic currency appreciation

	As of December 2010		Central bank equity[1,2]	Central bank revenues[1,2]	100 % Sterilisation cost[1,3]	Valuation loss for a 10% appreciation of domestic currency (%)[1]
	FX reserves (USD bn)	Short-term rate (%)				
China	2,667	3.1			0.6	4.6
Hong Kong SAR	266	0.3	34.2	6.9	(1.0)	11.8
India	272	6.7			0.7	1.8
Indonesia	83	0.2	1.7	0.5	0.7	1.1
Korea	290	2.8	0.6	1.9	0.8	3.0
Malaysia	99	3.0	7.1	1.4	0.7	4.2
Philippines	46	0.7	3.2	1.1	0.5	2.4
Singapore	215	0.3	10.9	-3.1	(0.6)	9.8
Thailand	159	1.9	-0.9	0.7	0.0	4.8

[1] As a percentage of nominal GDP. [2] 2009 annual report total equity and revenue figures reported by respective central banks. [3] Assumes entire FX reserve is invested in 1–3 year US government bonds and the funding rate is the domestic deposit rate.

Sources: IMF; Bloomberg; Datastream; BIS calculations.

A related possibility is that the risk of valuation losses from currency appreciation may encourage policymakers to resist currency appreciation with foreign exchange intervention even more strongly. However, if the prospects of eventual appreciation remain, and capital flows are sufficiently elastic to these prospects, the end result would be even larger losses from the eventual appreciation.

5.2 Incomplete sterilisation risk

A standard argument in open economy macroeconomics is that exchange rate stability, capital mobility and domestic monetary control are not all simultaneously achievable (Mundell 1963 is a classic reference). We now consider evidence of a loss of domestic monetary control in emerging Asia, a region that appears to be reasonably open to capital and where targeting exchange rates via large scale foreign exchange intervention is

[14] See, also, Table 4 in Mohanty and Turner (2005). Zhang (2010) argues that the cost of China's sterilisation to-date has been more than covered by income earned from reserves.

common. Equivalently, we are examining whether the expansionary effects of reserve accumulation on the domestic economies in emerging Asia have been fully sterilised.

Correlations suggesting deterioration in domestic monetary control due to foreign exchange intervention in emerging Asia are easy to find. For a number of regional economies, higher foreign exchange reserves as a percent of GDP are significantly correlated with higher consumer price inflation[15] (China, Hong Kong, Korea and Malaysia; see Graph 11); higher broad money as a percent of GDP (China, Hong Kong, India, Indonesia, Korea, Philippines and Singapore; see Graph 12) and greater credit to the private sector as a percent of GDP (China, India and Korea; see Graph 13).[16] Curiously for Indonesia, Malaysia and Thailand the final correlation is reversed: credit to the private sector appears to decline as reserves increase.

Much of the reserves accumulation has been sterilised, specifically to avoid increasing the monetary base. However, even if the monetary base is stable, it is possible that sterilisation is incomplete. For example, if sterilisation bills and money are near substitutes, then increased bank holdings of sterilisation bills may not offset the expansionary effects of foreign exchange intervention. Or in an economy in which banks have ready access to wholesale funding, banks may offset the need to hold sterilisation bills by increased wholesale funding so that credit growth remains expansionary despite sterilisation.

To explore the effects of sterilised intervention on the economies of emerging Asia further, we follow Moreno (1996) and Takagi and Esaka (2001) in considering vector auto-regressions on a subset of the economies in our sample for which the monetary policy regime over the 1999-2010 period has been relatively stable, namely Indonesia, Korea, the Philippines and Thailand.[17] Using available monthly data from the post Asian Financial Crisis period, defined as January 1999 to August 2010, we estimate a vector auto-regression in the vector X_t where $X_t = \left[cpi_t, i_t^{MM}, m2_t, s_t, nm_t \right]$ and cpi_t is the natural logarithm of the domestic consumer price index, i_t^{MM} is the domestic money market interest rate, $m2_t$ is the logarithm of broad money, M2, s_t is the logarithm of the spot exchange rate defined as the number of units of domestic currency per US dollar and nm_t is the level of non-monetary liabilities measured in domestic currency, our proxy for sterilised intervention. For each economy we estimate a vector auto-regression with six lags.

Impulse responses are identified using the Choleski decomposition. The ordering of the variables reflects the view that prices are sticky in the short run but inflation impacts monetary policy responses; these in turn contribute to broad money, and all three variables influence exchange rates. The crucial identification assumption in our estimation in the ordering of s_t and nm_t. If sterilised intervention is used to offset exchange rate shocks, then these two series are likely to co-move at high frequencies. To be conservative, we identify all

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[15] Statistical significance at the 5% level based on country-specific regressions on quarterly data. Regressions for the region as a whole, incorporating country fixed effects, also indicate statistically significant relationships between reserves as a percent of GDP and both higher inflation and higher broad money. For Singapore, the 1-month interbank offered rate is used as a proxy for the policy rate. Full results are available from the authors.

[16] Filardo and Grenville (2011) note that emerging Asian economies that have seen large run-ups in credit as a share of GDP in the region were typically those with relatively poorly developed credit markets, who were therefore starting from a low base in terms of credit availability.

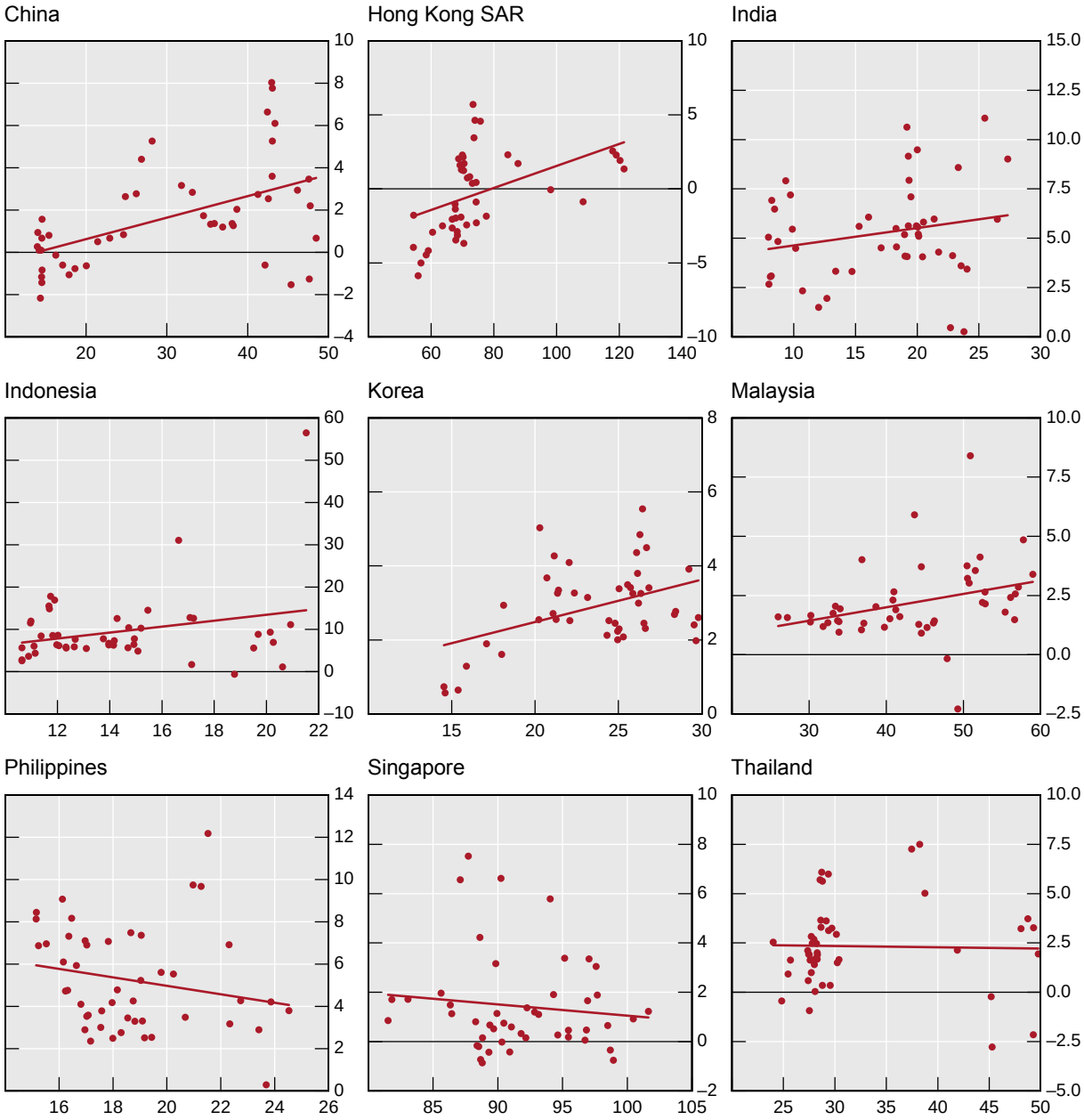
[17] Malaysia is excluded because it switched from a fixed exchange rate to a flexible exchange rate in 2005, leaving too short a sample for our analysis.

short-term co-movement between the two series as the endogenous response of sterilised reserves to exchange rate shocks. By contrast, *exogenous* shocks to non-monetary liabilities are identified as having no contemporaneous effect on exchange rates.

Graph 11

Inflation and reserves as percentage of GDP[1]

In per cent



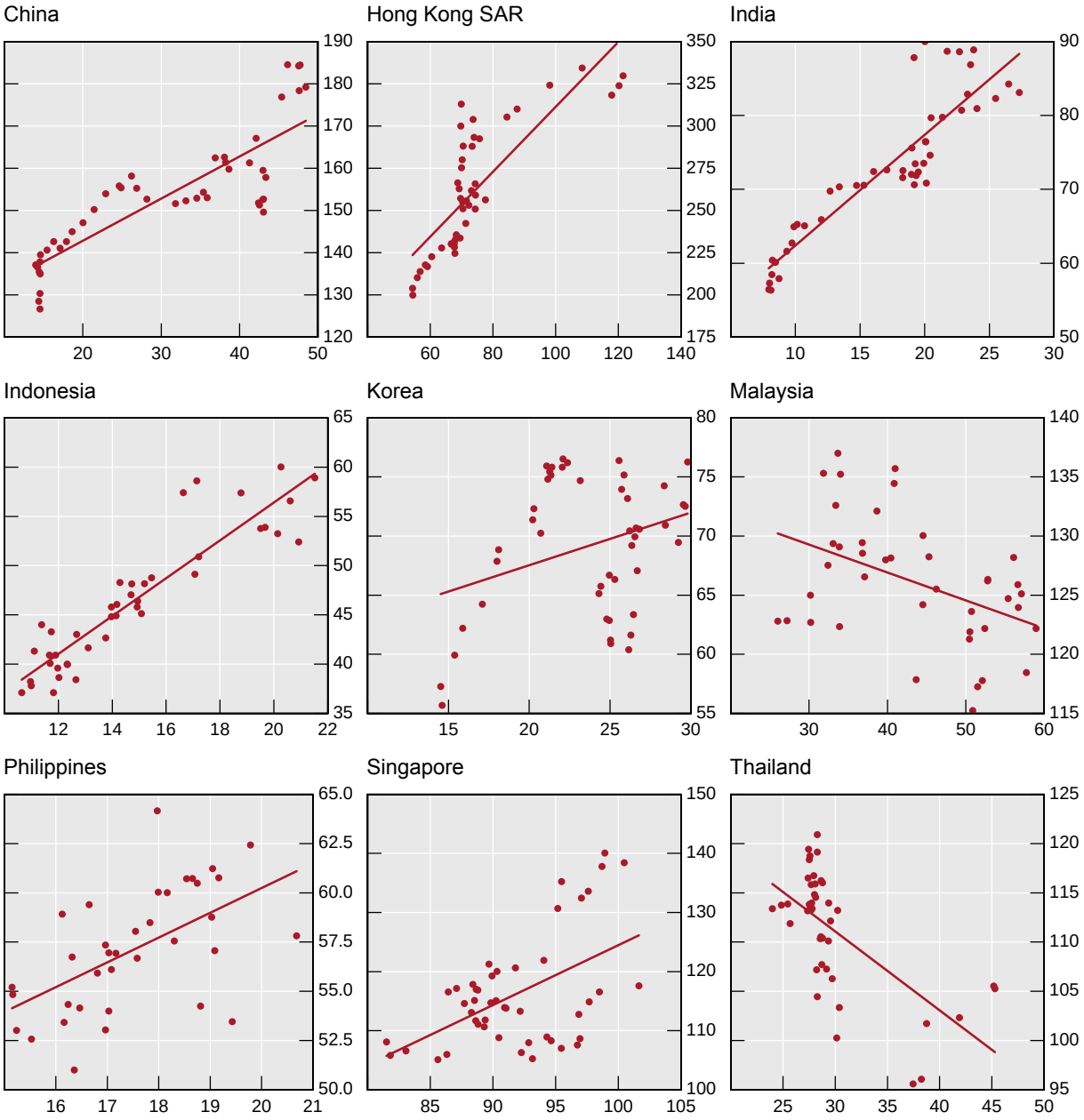
[1] Horizontal axis: foreign exchange reserves as percentage of GDP; vertical axis: year-on-year change on producer prices index for India; year-on-year change of CPI for others.

Sources: IMF *IFS*; national data.

Graph 12

Broad money and reserves as percentage of GDP[1]

In per cent



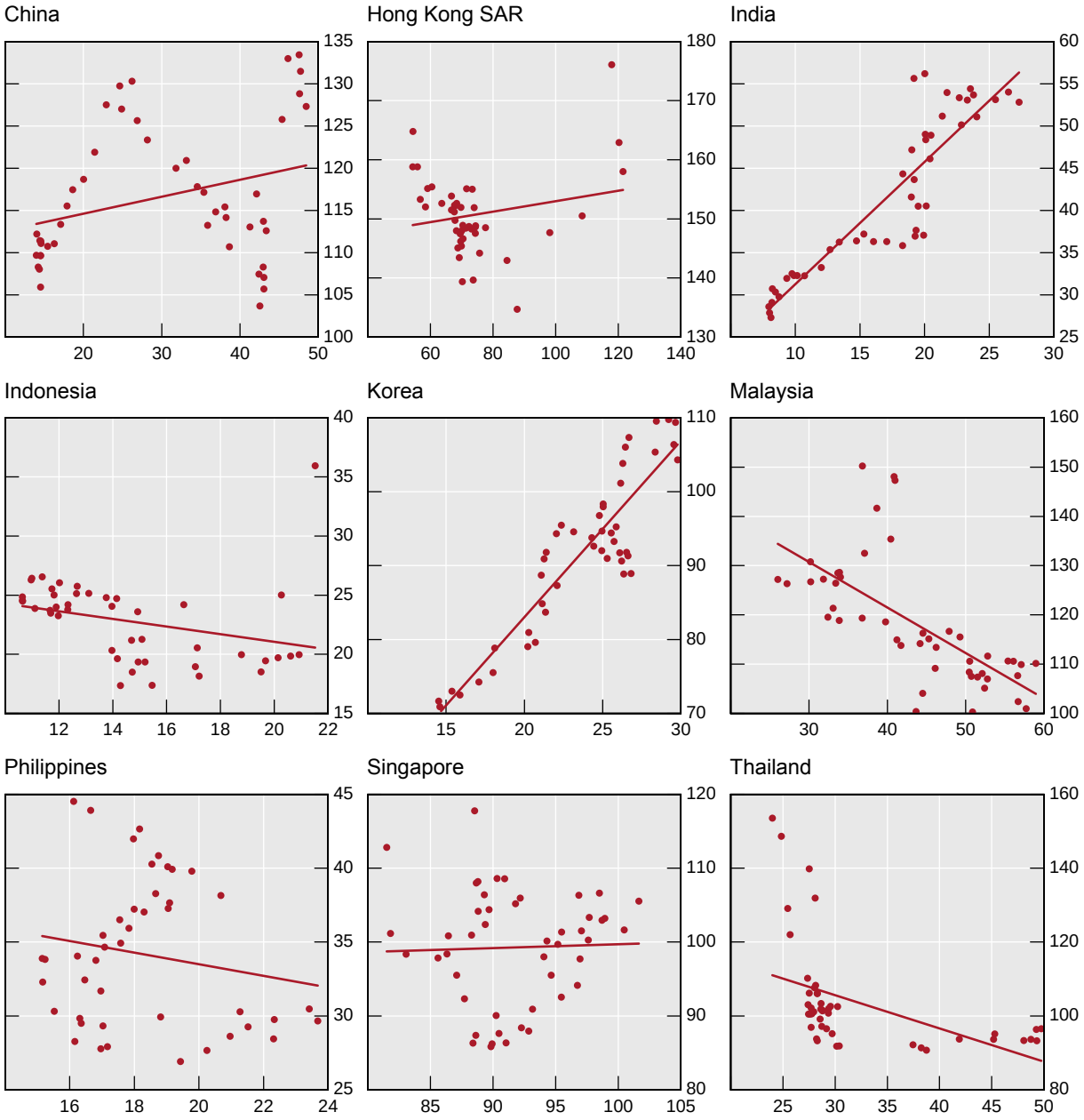
[1] Horizontal axis: foreign exchange reserves as percentage of GDP; vertical axis: money plus quasi money as percentage of GDP.

Source: IMF *IFS*.

Graph 13

Credit and reserves as percentage of GDP[1]

In per cent

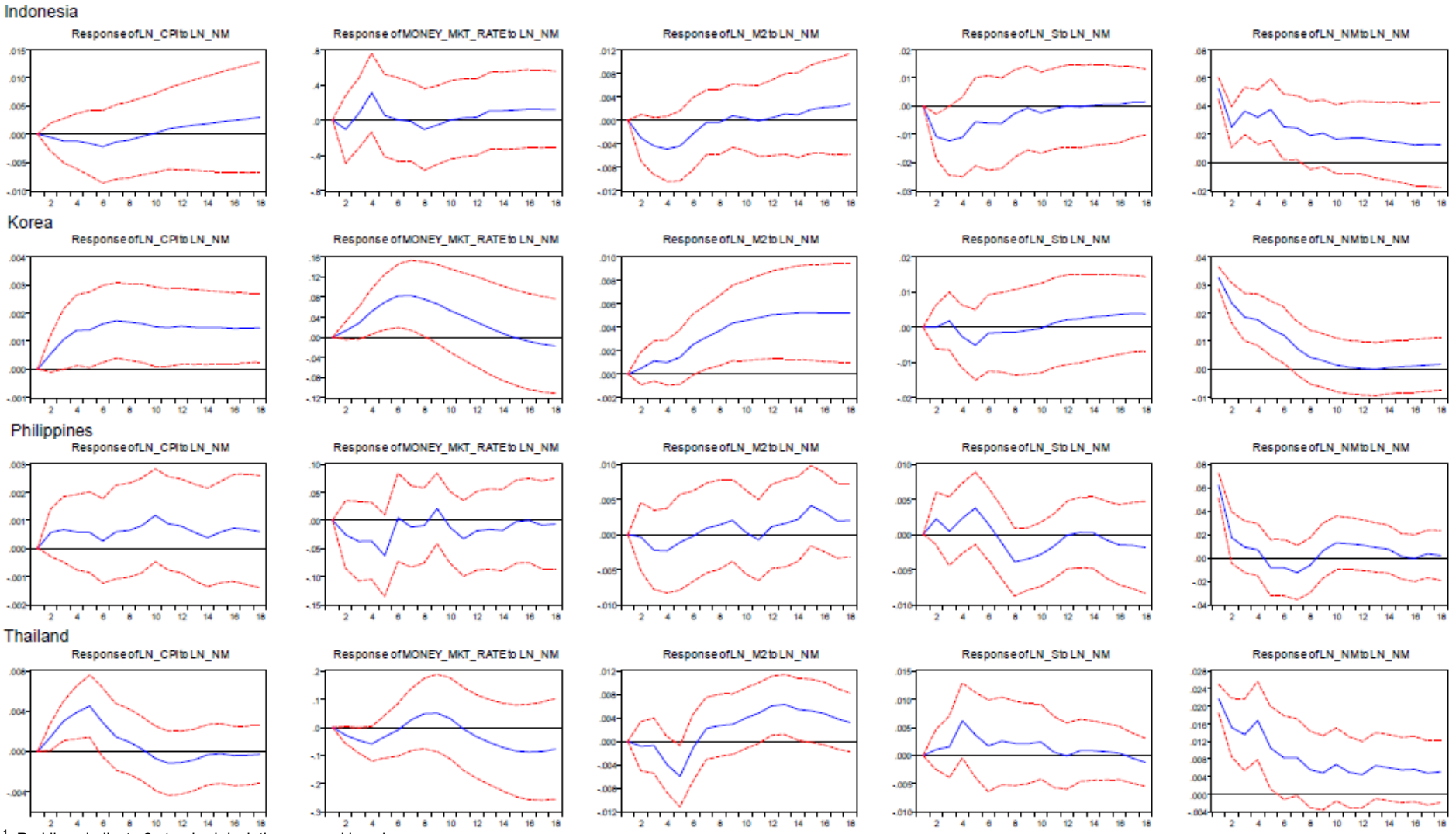


[1] Horizontal axis: foreign exchange reserves as percentage of GDP; vertical axis: credit to private sector as percentage of GDP.

Source: IMF *IFS*.

Graph 14

Impulse responses from vector auto-regression[1]



[1] Red lines indicate 2-standard deviations around impulse responses

Graph 14 illustrates the estimated impact of a one-standard deviation shock to non-monetary liabilities, our proxy for sterilised intervention, on key nominal variables for each economy. For Indonesia and the Philippines the estimated effects of the shock are small, except for an exchange rate appreciation – almost immediate in the case of Indonesia and lagged in the case of the Philippines. For Korea there are significant and persistent increases in consumer prices and broad money, and policy rates also rise, perhaps reflecting the monetary policy response to higher inflation, while the net effect on exchange rates is more muted. Finally, for Thailand, short-lived price increases and exchange rate depreciations follow the shock, while broad money contracts in the short term, but expands over longer horizons.

Overall, the VAR evidence is mixed. For Korea and Thailand, the two economies in the sample with relatively well developed financial markets, "sterilised" intervention does not appear to be fully sterilised, although quantitatively the inflationary effects of sterilised intervention are relatively small: a one-standard deviation increase in sterilised reserves, equivalent to between 2% and 5%, leads to a maximum increase in prices of less than 0.5%. Further, we see in all countries a limited impact of sterilised reserves on exchange rates themselves. Note, however, that the vector auto-regression evidence is based on relationships between the variables over the last 10 years, a period over which reserves grew rapidly. It is possible that risks posed by sterilised intervention have grown steadily worse as reserves have increased, in which case the estimates presented here may understate the true underlying risks.

Together, the results in this section provide some evidence that a number of central banks may have failed to fully sterilise the expansionary effects of reserves accumulation on the domestic economy, implying a growing risk of a loss of effective monetary policy control if the recent rapid accumulation of reserves were to continue. This risk is most clearly visible for China, Hong Kong, India and Korea.

5.3 Policy credibility risk

A lack of domestic monetary control could in principle occur via a number of different channels. For example, a large stock of sterilised foreign exchange reserves may result in reluctance on the part of the central bank to tighten policy in the face of inflationary pressures, since the costs of sterilising reserves are increasing in the spread between local and foreign interest rates. This channel would imply that monetary policy will tend to be relatively expansionary when reserves are larger. There is some evidence of this: in China, Hong Kong, India, Korea and Malaysia there is a significant correlation between higher foreign exchange reserves as a percent of GDP and lower real policy rates- see Graph 15.

To more formally assess the implications of reserves for the conduct of monetary policy, we consider regressions of the form:

$$\Delta YC_{it} = \beta_0 + \beta_{1t}\Delta i_{it} + \beta_{2t}\Delta i_{it}\left(\frac{\text{Reserves}}{GDP}\right)_{it} + \varepsilon_{it}$$

on monthly data where YC is the yield spread between 2 and 10 year government bonds and i is the policy rate.[18] The interactive term between policy rates and reserves as a percent of

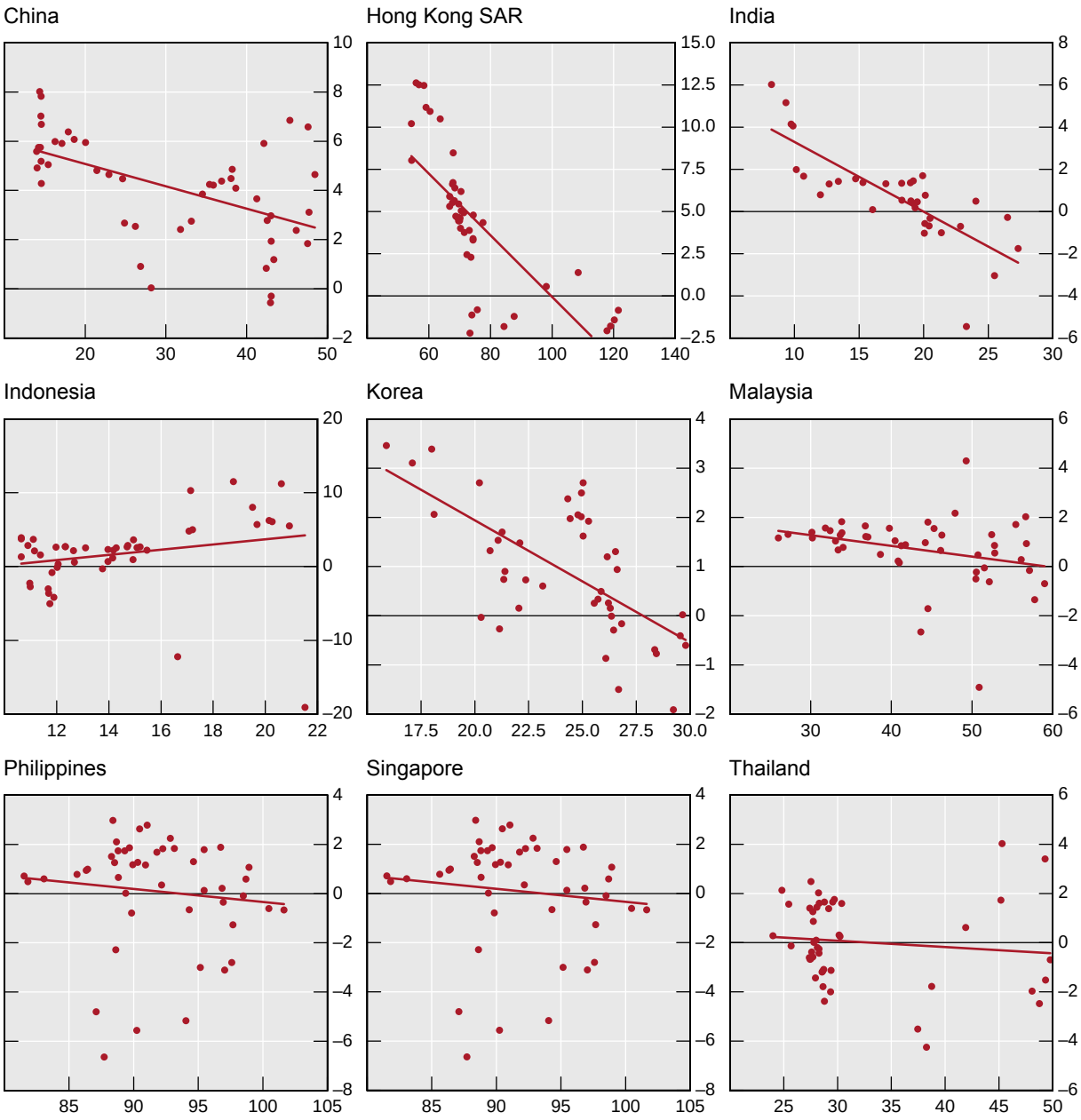
[18] The policy rates are 1-year lending rate (CN), Bank Indonesia rate (ID), 1-day reverse repo rate (IN), overnight call rate target (KR), overnight policy rate (MY), overnight reverse repo rate (PH) and 14-day repo rate (TH). For HK and SG the discount window base rate and 1-month interbank offered rate are used as proxies for the policy rate respectively. The one-year rate is used to construct *YC* for MY and PH starting in July 2007 due to data availability. GDP data is interpolated to monthly frequency to construct a measure of (Reserves/GDP).

GDP allows us to assess changes in the relationship between policy rates and the yield curve.

Graph 15

Real policy rate and reserves as percentage of GDP[1]

In per cent



[1] Horizontal axis: foreign exchange reserves as percentage of GDP; vertical axis: real policy rate which is the policy target rate or its proxy minus the 12-month change in the CPI. For China, one-year lending rate; for Hong Kong, base rate; for Indonesia, one-month SBI rate; for India, reverse repo rate; for Korea, overnight call rate; for Malaysia, overnight policy rate; for Philippines, overnight reserve repo rate; for Singapore, 3-month interbank offered rate; for Thailand, 14-day repo rate before 17 January 2007; overnight repo thereafter.

Sources: Bloomberg; IMF *IFS*.

Table 14 presents the results for a number of different specifications: with and without year fixed effects, and including or excluding data from the period of the international financial crisis. The results indicate that an increase in the policy rate tends to decrease the term spread, consistent with a drop in longer term inflationary expectations. However, this effect is smaller the greater are foreign exchange reserves as a share of GDP.

Table 14

Transmission mechanism

Term spread is the dependent variable

Period	(1) 2001-2010	(2) 2001-2007, 2010	(3) 2001-2010	(4) 2001-2007, 2010
Policy rate	-2.43**	-2.43**	-1.19***	-1.13**
	(0.93)	(0.97)	(0.32)	(0.34)
(Policy rate) x (Reserves)	0.027**	0.028**	0.011**	0.013*
	(0.012)	(0.013)	(0.004)	(0.007)
Economy fixed effects	Y	Y	Y	Y
Year fixed effects	N	Y	N	Y
Obs.	927	927	711	711

Standard errors in brackets. ***, **, * indicates significance at 1%, 5%, 10% level respectively.

There are at least three possible explanations for this phenomenon. First, given the potential loss of domestic monetary control as reserves grow (see sections 5.1 and 5.2), an increase in policy rates may not be perceived as having the same anti-inflationary effects for an economy with large reserves. Second, given that monetary policy tightening is likely to result in capital losses for central banks with large reserves due to exchange rate appreciation, the credibility of any anti-inflationary stance may be compromised. Thus a rise in policy rates may be less likely to bring down inflationary expectations and long-term interest rates, so that any narrowing of the term spread is reduced. Third, given that the balance sheets of financial institutions are likely to be distorted by large-scale holdings of sterilisation instruments, banks may effectively hold a large stock of secondary reserves. Thus the supply of credit may be less responsive to short term rates as more foreign exchange reserves are accumulated.

Regardless of the mechanism, one conclusion is clear. The monetary policy transmission mechanism appears to vary with the size of sterilised foreign exchange reserves. Hence a substantial built-up of reserves requires a recalibration of monetary policy to reflect the changed macroeconomic environment.

6. Conclusions

Reserves in emerging Asia have grown dramatically over the past decade. Many of these reserves have been sterilised, via the issuance of non-monetary liabilities by the central banks in the region, with the sterilisation instruments being held primarily by domestic banks. We have used aggregate and bank-level data to explore some of the potential costs and benefits of such policies. We do find some evidence of benefits precisely where they might be intended: the performance of emerging market banking systems during an external crisis. During the East Asian crisis of 1997 and 1998, banks with foreign currency financing faced large losses in value and high likelihood of default (see Chue and Cook, 2008). The desire to avoid this financial damage may drive foreign reserves accumulation. Further, we find evidence that holdings of excess foreign reserves mitigated the financial losses of banks during the financial crisis of 2008. Foreign exchange reserves appear to play little role mitigating risk in more normal times.

We also document some of the costs of reserves accumulation. The holding of a large stock of foreign exchange reserves may negatively impact on the long-run prospects for the economy, even if the inflationary effects of the reserves are fully sterilised. In the presence of financial imperfections such as leverage constraints, a distorted central bank balance sheet (holding too much or too little of some asset) also distorts the private sector's balance sheet in a mirroring manner that can in theory have either positive or negative welfare effects (see Curdia and Woodford, 2011). We provide evidence that the accumulation of excessive levels of reserves has had negative effects on bank lending and investment. There is a concentration of sterilisation instruments, used to finance the accumulation of foreign exchange reserves, in economies with limited financial markets. This may have reduced the level of domestic investment, thereby contributing to global imbalances.

Finally, we examine the effect of reserves on central banks and monetary policy and find evidence that sterilisation appears to be incomplete in some cases, with reserves accumulation leading to higher levels of broad money, inflation and credit.

Appendix 1:
central bank balance sheet data

China: foreign liabilities are from the CEIC database. Total liabilities are the sum of reserve money plus foreign liabilities plus bonds plus deposits of government plus other liabilities. Total assets are the sum of total liabilities plus net worth. Domestic liabilities are total liabilities minus foreign liabilities. The monetary base is reserve money.

Hong Kong: total assets, liabilities, and foreign liabilities are from the HKMA Monetary Bulletin. The monetary base is the sum of notes and coins, certificates of indebtedness and clearing balances.

India: total assets are from the CEIC database. Total liabilities are the sum of deposits at the Banking Department plus other liabilities of the Banking Department plus notes in circulation plus notes held in the Banking Department. Foreign liabilities are from the IMF's IFS. The monetary base is reserve money from the IMF's IFS.

Indonesia: total assets are from the CEIC database. Total liabilities are reserve money plus central government accounts plus other liabilities plus foreign liabilities. The monetary base is reserve money. Domestic liabilities are total liabilities minus liabilities to non-residents from IMF's IFS.

Korea: total assets, total liabilities and domestic liabilities are all from the CEIC database. The monetary base is the sum of notes and coins issued and reserve deposits of deposit money banks. Non-monetary liabilities are the difference between domestic liabilities and the monetary base.

Malaysia: total assets are from the CEIC database. Total liabilities are currency in circulation plus deposits plus Bank Negara bills/bonds plus allocation of SDR plus other liabilities. The monetary base is currency in circulation plus deposits of commercial banks, finance companies and merchant banks. Domestic liabilities are total liabilities minus liabilities to non-residents from the IMF's IFS.

Philippines: total assets are from the CEIC database. Total liabilities are total assets minus net worth. The monetary base is currency issued plus deposits: banks and other financial institutions. Domestic liabilities are total liabilities minus liabilities to non-residents from the IMF's IFS.

Singapore: total assets and liabilities are annual data from the CEIC database. Foreign liabilities are foreign liabilities from the IMF's IFS. Monetary base is reserve money from the IMF's IFS.

Thailand: total assets and liabilities are from the CEIC database. The monetary base is banknotes in circulation plus deposits of other depository corporations. Domestic liabilities are total liabilities minus liabilities to non- residents from the IMF's IFS.

Appendix 2:
data definitions for regressions

1. *Loan to Asset Ratio* For each bank, the ratio of Loans/Claims/Advances - Customers- Total (LCUACU) to Total Assets (AT).
2. *Real Loans:* For each bank, Loans/Claims/Advances - Customers- Total (LCUACU) deflated by the CPI (Source: IMF *IFS*).
3. *Real Assets:* For each bank, Total Assets (AT) deflated by the CPI.
4. *Loan to Deposit Ratio* For each bank, the ratio of Loans/Claims/Advances - Customers- Total (LCUACU) to Deposits-Total-Customer (DPTC).
5. *Liquidity/Asset Ratio* For each bank, the ratio of the sum of Cash (CH) plus Investment Securities-Total (IST) to Total Assets (AT).
6. *Reserves* End of Period Foreign Assets (from central bank balance sheets, various) converted into Billions of US dollars using the end of year exchange rate (IMF *IFS*).
7. *Size* For each bank, the natural log of foreign assets converted into billions of US dollars using the end of year exchange rate.
8. *Capitalisation* For each bank, the ratio of Total Assets (AT) less Total Liabilities (LT) to Total Assets.
9. *Non-monetary liabilities/GDP:* Non-monetary liabilities are computed as total liabilities less the monetary base and foreign liabilities. GDP is nominal GDP from IMF *IFS*. For each three year period, we take an average of the end of year level for the first two years.
10. *Real GDP Growth:* the log first difference of annual constant price GDP from the World Bank's World Development Indicators. For each three year period, we take an average of growth in each of the three years.
11. *Capitalisation* for each bank is the ratio of net worth to total assets from S&P Global Compustat. For each three year period, we take an average of the end of year level for the first two years.
12. *Size* is the logarithm of bank total assets in USD calculated using an end of year exchange rate from IMF *IFS*. For each three year period, we take an average of the end of year level for the first two years.

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