Responding to exchange rates in a globalised world

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Abstract

How should monetary policy respond to nominal exchange rates? How does this change as economies become increasingly globalised? In this paper, we address these questions for Asia, focusing on structural changes that may influence the optimal policy response to exchange rates. We also summarise some new results based on an analytical model outlined in Devereux and Yetman (2014b) designed to address these issues. We show that sterilised intervention can be a potent tool that offers policymakers an additional degree of freedom in maximising global welfare. We illustrate how the gains to sterilised intervention can be sensitive to various aspects of goods and financial market structure. When financial internationalisation is high, the gains to sterilised intervention fall. And at the limit of perfect financial integration, the gains from sterilised intervention are entirely eliminated. Unsterilised intervention may also have a role to play, and may continue to work even in cases where sterilised intervention is rendered ineffective.

Many central banks in Asia have actively used sterilised foreign exchange intervention as a policy tool for smoothing exchange rate movements. This is a policy that appears to have served the region well. But, over time, structural changes in the region, including increased goods market integration, declining exchange rate pass-through and ongoing internationalisation of financial markets are likely to reduce the efficacy of sterilised intervention. More generally, these structural changes may call into question the appropriate role of exchange rates in monetary policy setting in the region.

Keywords: globalisation; foreign exchange intervention; exchange rate pass-through.

JEL classification: E58, F62.

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Introduction

How should central banks respond to exchange rate changes? Across the Asia-Pacific region we see a wide variety of responses. For example, in Australia and New Zealand, the exchange rate is allowed to float relatively freely and the central banks hold low levels of foreign exchange reserves. At the other extreme, Hong Kong SAR enjoys a de facto fixed exchange rate due to its currency board mechanism, and domestic monetary policy is effectively subordinated to maintaining a stable external value of the currency relative to the US dollar. But for most of the other economies in the region, monetary authorities appear to lean against changes in the exchange rate using foreign exchange intervention. Further, as we will see, this intervention appears to have been effectively sterilised: significant growth in foreign currency assets on the balance sheets of central banks has not coincided with any corresponding change in domestic currency in circulation, or a loss of domestic inflation control.

There is a considerable literature that addresses the role of stabilising exchange rates in an optimal monetary policy framework.[2] For example, Taylor (2001) reviews the literature on including the exchange rate in monetary policy reaction functions and finds that this can result in only modest improvements (or even a deterioration) in terms of output and inflation outcomes in standard small open economy macro models. Garcia et al (2011) argue that a central bank response to exchange rates may be desirable, especially in financially vulnerable economies. Sutherland (2005) shows that the optimal variance of exchange rates depends on a variety of factors, including the degree of pass-through, the size and openness of the economy, the elasticity of labour supply and the volatility of foreign producer prices.

Engel (2011) argues that, in a model with currency misalignments, monetary policy should respond to those misalignments. Currency misalignments cause inefficient outcomes because home and foreign households pay different prices for the same goods. Responding to exchange rates can then play a role in reducing the cost of that distortion. Corsetti and Pesenti (2005) argue that using monetary policy to reduce exchange rate volatility may be welfare-enhancing, even if it leads to increased output gap volatility. This is because risk-averse foreign exporters are likely to reduce average mark-ups in response to decreased exchange rate volatility. And Devereux (2004) demonstrates that, in a world with nominal rigidities, perhaps due to incomplete international financial markets, then, even if a flexible nominal exchange rate would serve as a perfect shock absorber, fixed exchange rates may be preferable. Effectively, flexible exchange rates can lead to inefficient output responses to demand shocks in that output may be too stable.

Returning to Asia, working to stabilise the external value of the currency appears to have served many economies in the region well. In this paper, we question whether that is likely to continue to be the case in future. First, we provide evidence that many central banks in the region have actively used sterilised intervention. Second, we discuss various structural changes that are occurring in the region that may affect the benefits of stabilising exchange rates, or the costs of the tools required to achieve that policy end. Third, we summarise some results from a

[2] See Mussa et al (2000) for a summary of the various factors that may influence the optimal choice of exchange rate regime.

recent paper (Devereux and Yetman, 2014b) that we have developed to address these issues. Finally, we conclude.

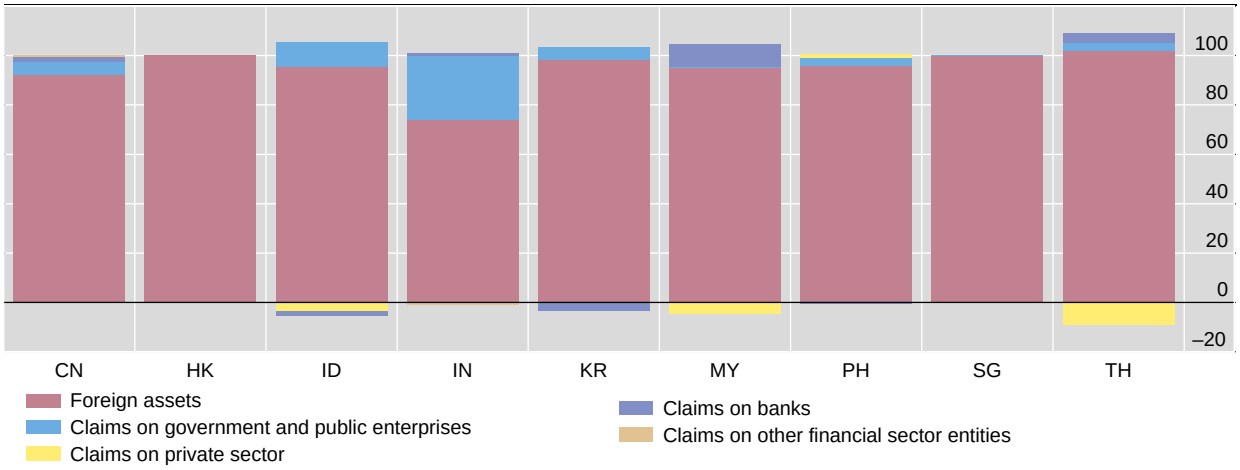
How have central banks in Asia responded to exchange rates?

In many Asian economies, a common response to exchange rate fluctuations has been foreign exchange intervention, intended to smooth the path of exchange rates. In some cases, the policy response to exchange rates has been found to exceed the response to either inflation or the output gap (Mohanty and Klau, 2004). In a recent paper, Filardo et al (2011) provide a summary of how emerging market economy central banks respond to exchange rates and report that central banks managed the value of their currencies more actively in the aftermath of the international financial crisis than before.

Perhaps the most important policy tool used to stabilise exchange rates in Asia has been direct intervention in foreign exchange markets. One consequence of this is the massive expansion of foreign exchange reserves on central bank balance sheets in the region. The overall size of the central bank balance sheet has increased dramatically over the past decade, and lies at around 100% of GDP in the case of Hong Kong SAR and Singapore, and more than 30% of GDP in China, Korea, Malaysia, the Philippines and Thailand. Changes in foreign exchange reserves account for nearly all of the change in the size of the overall central bank balance sheet for these economies (Graph 1).

Change in composition of central bank assets in emerging Asia, 2002–12

As a percentage of change in total assets — Graph 1



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

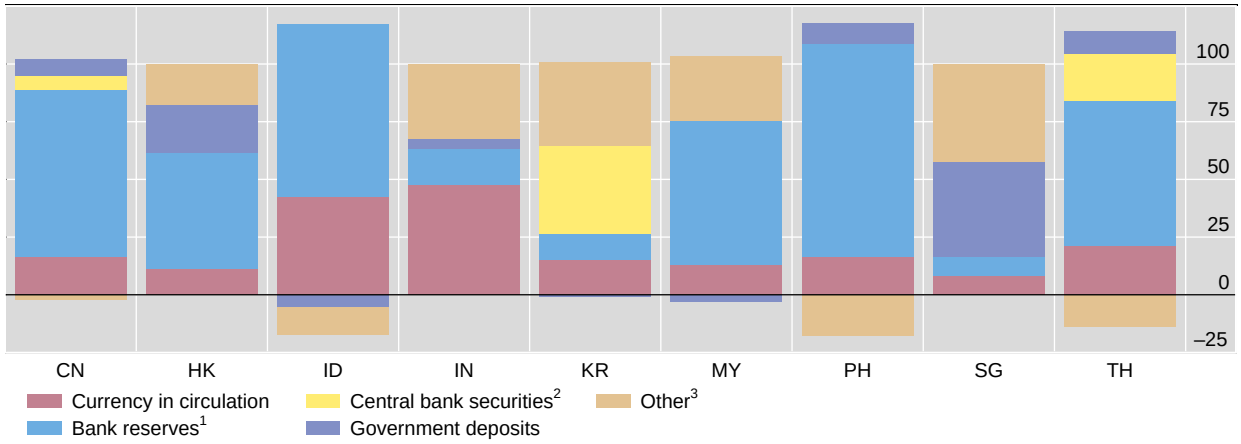
Source: IMF *International Financial Statistics*.

The accumulation of foreign exchange reserves must be financed in some way. We can determine how this takes place by looking at the other side of the balance sheet, to see the corresponding changes in liabilities that coincide with the asset growth. As shown in Graph 2, only a small portion of the increase in foreign

exchange reserves has been financed via an increase in the amount of currency in circulation. Instead, increased required reserves and the issuance of sterilisation instruments have been used to effectively sterilise the effects of the increase in foreign exchange reserves, allowing policymakers to maintain domestic monetary control.[3] Hence, despite the large increases in the size of the balance sheet, there appears to have been no loss of domestic monetary policy control. Indeed, the period since the Asian financial crisis may be accurately described as a period of relatively high and stable growth and low inflation for the region as a whole.

Change in composition of central bank liabilities in emerging Asia, 2002–12

As a percentage of change in total liabilities — Graph 2



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

[1] Reserves and deposits of banks. [2] Central bank bonds and securities. [3] Including other liabilities (foreign liabilities, loans and other net items) and equity capital.

Source: IMF, *International Financial Statistics*.

Going forward, one possibility would be for policymakers to continue with past practice, and lean against any ongoing exchange rate pressures with foreign exchange intervention. However, there are reasons to believe that this may be becoming a less attractive policy option. First, the already large holdings of foreign exchange reserves are very costly to the central banks in the region, and are only likely to become more so as they grow larger, as would occur if appreciation pressures remain dominant.

Table 1 offers a simple illustration of the possible costs of large reserves, under the simplifying assumption that all reserves are held in short-term US treasury bills and are financed (or, equivalently, sterilised) via the sale of short-term sterilisation bills with an interest cost equal to the domestic deposit rate.[4]

One component of this is carrying (or sterilisation) costs. Typically, domestic interest rates in Asia are higher than the yields central banks earn on their reserves. The difference between these two is a loss to the central bank, and may be as much

[3] See the discussion in Filardo and Yetman (2012).

[4] See also the discussion in Cook and Yetman (2012).

as 1.2% of GDP per year for some economies. Another, potentially much larger, cost could result from an appreciation in the domestic currency. For illustrative purposes, the table considers a 10% appreciation against the basket of currencies that reserves are held in and indicates that the mark-to-market losses as a percentage of GDP for the central banks in the region would be considerable. As a comparison, the table also displays central bank equity, which is available to absorb central bank losses, again as a percentage of GDP, and illustrates that this is low relative to potential losses in many cases. While a central bank can in principle continue to operate with low, or even negative, capital, this is unlikely to be desirable in the long run. More importantly, any loss on the central bank's balance sheet that results from excessive foreign exchange reserves may be viewed as a loss in welfare to society.

Estimates of sterilisation costs and valuation losses from domestic currency appreciation

As of December 2012 Table 1

	FX reserves (USD billions)	Deposit rate (%)	Central bank equity[1, 2]	100% sterilisation cost[1, 3]	Valuation loss for a 10% appreciation of domestic currency (%)[1]
AU	44.94	3.17	0.13	0.10	0.29
CN	3331.12	3.78	0.04	1.11	4.04
HK	317.23	0.40	31.17	–0.31	12.30
IN	270.59	8.74	0.07	0.73	1.39
ID	106.04[4]	4.92	2.02	0.64[4]	1.18[4]
JP	1227.15	0.28	0.00	0.05	2.05
KR	323.21	2.89	0.88	0.90[4]	2.81
MY	137.75	3.21	0.01	1.22	4.48
NZ	17.58	2.64	1.30	0.39	1.05
PH	73.48	0.83	0.55	0.89	3.05
SG	259.09	0.31	20.49	–0.12	9.67
TH	173.33	2.93	2.61	0.98	4.60

[1] As a percentage of nominal GDP. [2] Capital and reserves for AU and NZ; provisions and other liabilities for SG; net worth or own capital for others. [3] Assumes entire FX reserve is invested in one- to three-year US government bonds and the funding rate is the domestic deposit rate. [4] As of September 2012.

Sources: IMF, *International Financial Statistics*; Bloomberg; Datastream; BIS calculations.

The second reason to reconsider the historical response to exchange rates is that the region is undergoing structural change. As a result, policy measures that were effective in the past may become less so in future. In the next section we will outline the nature of some of these structural changes, before we discuss some results from a model that we have developed to analyse their effect on monetary policy.

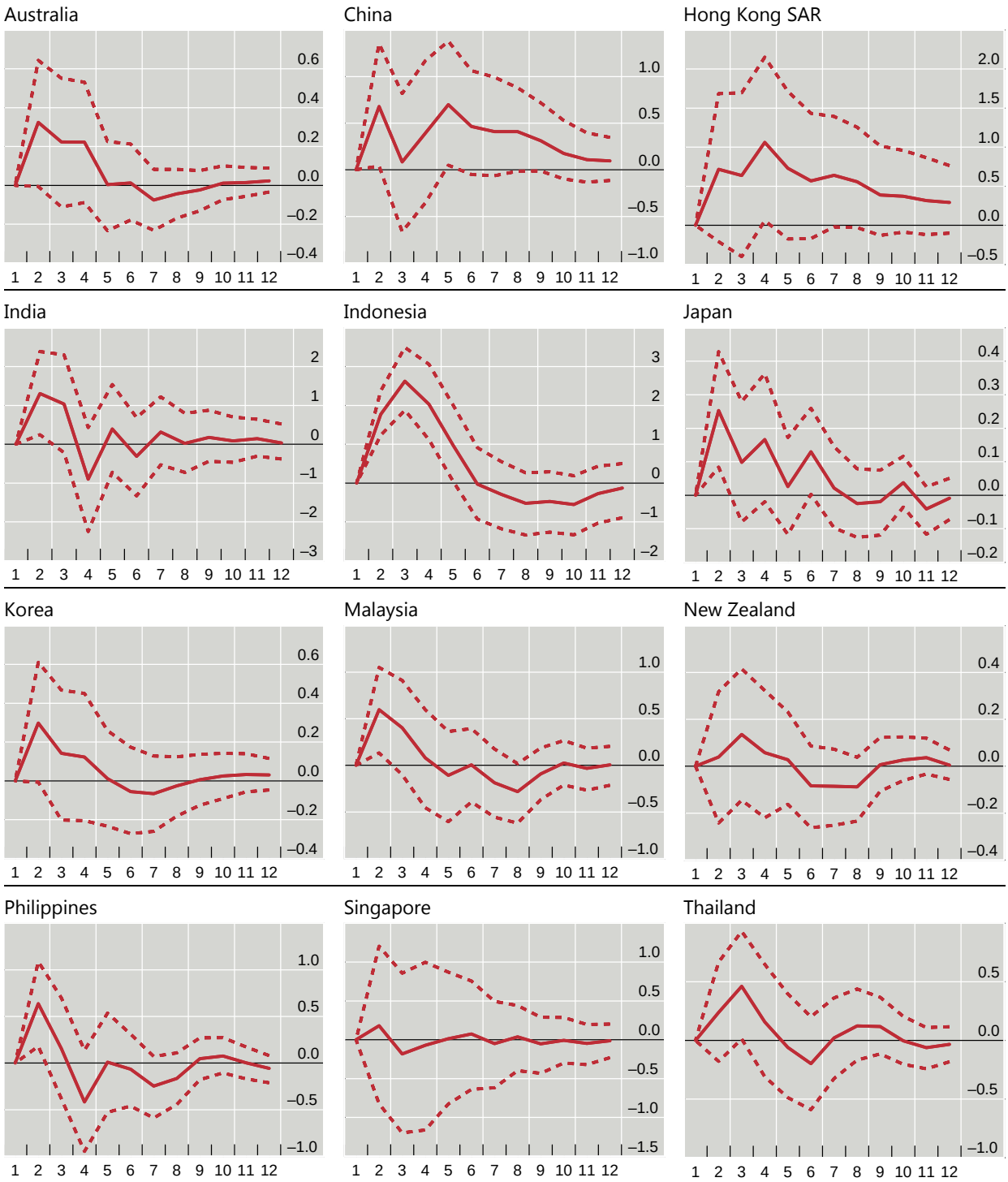
The evolution of emerging Asian economies

Recent decades have witnessed a wide range of changes in the structure of Asian economies. Four factors are of particular relevance to the traditional desire by central banks in the region to stabilise nominal exchange rates.

Impulse response of CPI inflation to NEER shock

10% depreciation

Graph 3



Vertical axis in per cent. Dashed lines display 80% confidence bands.

Source: Authors' estimates.

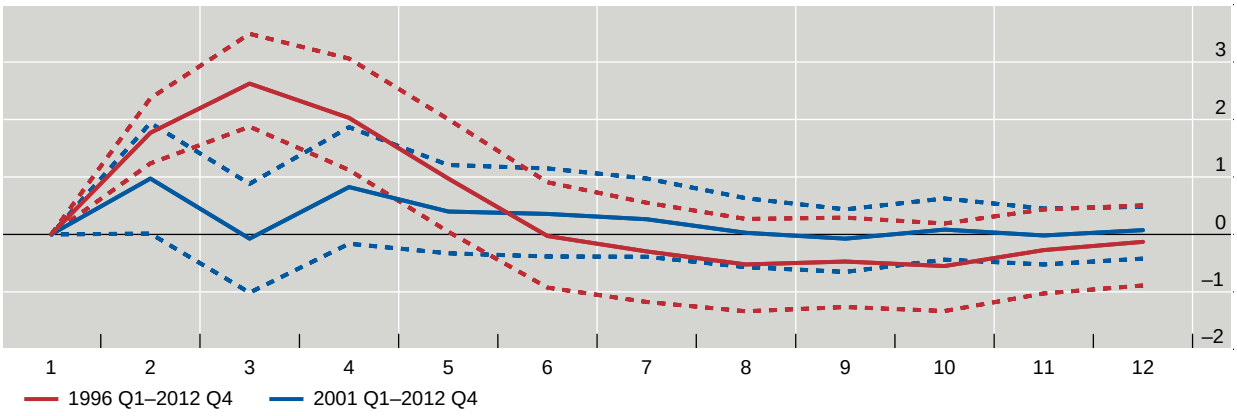
First, exchange rate pass-through to inflation appears to now be low. We provide evidence for this in Graph 3. We estimate a simple vector autoregression,

economy by economy, on quarterly data, consisting of real GDP growth, inflation, the change in the policy rate and the change in the nominal effective change rate, in that order.[5] We also include four seasonal dummies and three lags. The model is identified by orthogonalising the reduced-form errors by means of a Choleski decomposition of the variance-covariance matrix. We then compute the impulse response of inflation, in per cent, to a 10% depreciation shock to the nominal effective exchange rate. We use Monte Carlo methods and plot, in the graph, the median projection along with the 10th and 90th percentiles (as confidence bands), for the longest period for which all our data are available.[6]

The results suggest that exchange rate pass-through for many economies in Asia-Pacific has been low for some time. The point-estimate of the peak increase in inflation following a 10% depreciation in the nominal effective exchange rate is 0.7% or lower for most economies. The only exceptions are Hong Kong SAR (1.1%), China (1.3%) and Indonesia (2.6%). However, the relatively high rate of pass-through in Indonesia is driven entirely by observations around the time of the Asian financial crisis. If we instead start the data sample in 2001, the peak increase in inflation drops to 1.0% (Graph 4).

Exchange rate pass-through in Indonesia

Response of CPI inflation to a 10% depreciation shock to the NEER; different sample periods — Graph 4



Source: Authors' estimates.

We are not the first to question the received wisdom that exchange rate pass-through remains much higher in emerging market economies than in advanced economies. Brun-Aguerre et al (2012), for example, find that short-run pass-through in emerging market economies is low and close to that for advanced economies.[7]

[5] Our variables are defined as the quarter-on-quarter change in the log of the level for real GDP, the CPI and the nominal effective exchange rate, and the change in the level for the policy rate.

[6] Sample periods vary between 1994Q1–2012Q4 (Australia, China, Hong Kong SAR, Japan, Korea, Malaysia, Philippines, Thailand), 1994Q1–2012Q3 (New Zealand, Singapore), 1996Q1–2012Q4 (Indonesia) and 1996Q2–2012Q3 (India).

[7] See, also, Ca'Zorzi (2007) and Mihaljek and Klau (2008).

The literature offers a number of possible explanations for declining exchange rate pass-through that are likely to apply in the Asian context. For example, improved inflation control, leading to declines in both the level and volatility of inflation, is associated empirically with lower levels of exchange rate pass-through, as prices become more sticky (Devereux and Yetman 2010; Choudry and Hakura, 2006; Gagnon and Ihrig, 2004).[8] For Asian economies with a history of high inflation, the improvement in inflation outturns has been substantial. Average inflation in China and Indonesia, for instance, declined by almost one half from 1993–2002 to 2003–12. Hong Kong SAR, Korea, Malaysia, the Philippines and Thailand have also seen substantial, although smaller, declines in inflation between these same two periods.[9]

Changes in the composition of import bundles are also likely to play an important role in the decline in pass-through. The elasticities of pass-through for manufactured goods and food products are generally lower than for commodities and energy, as Campa and Goldberg (2005) argue. Choi and Cook (2013) provide industry-level evidence that suggests that increased concentration on final goods trade helps to explain low exchange rate pass-through in Asia. Wealth increases in the region may have seen changes in import patterns towards goods that typically exhibit low levels of pass-through.

The upshot of declining pass-through is that the effectiveness of exchange rate control as a policy lever may be declining, for two reasons. First, declining pass-through implies a weakening link between exchange rate stability and inflation stability. To the extent that exchange rate movements are a source of macroeconomic volatility, then, less exchange rate pass-through reduces the domestic macroeconomic benefits from stabilising the exchange rate. And second, where exchange rates are actively used as a tool for domestic business cycle management to offset other shocks, if domestic prices fail to adjust, there will be little expenditure-switching in response to exchange rate changes, as Devereux and Engel (2003) discuss. Adjusting the exchange rate in response to shocks in a low pass-through environment will have smaller effects on the demand for domestically produced goods than in a high pass-through environment.

A second changing dynamic that may influence the role of the exchange rate is the ongoing integration of goods markets. Graph 5 illustrates the growth in trade volumes over time. One consequence of this is that consumption bundles are becoming increasingly similar across economies over time. As we will see, the mechanics of international risk-sharing depend in part on the degree to which consumption bundles overlap between economies.

A third characteristic that may be important for the policy trade-offs that central banks face between exchange rate stability and inflation control is the

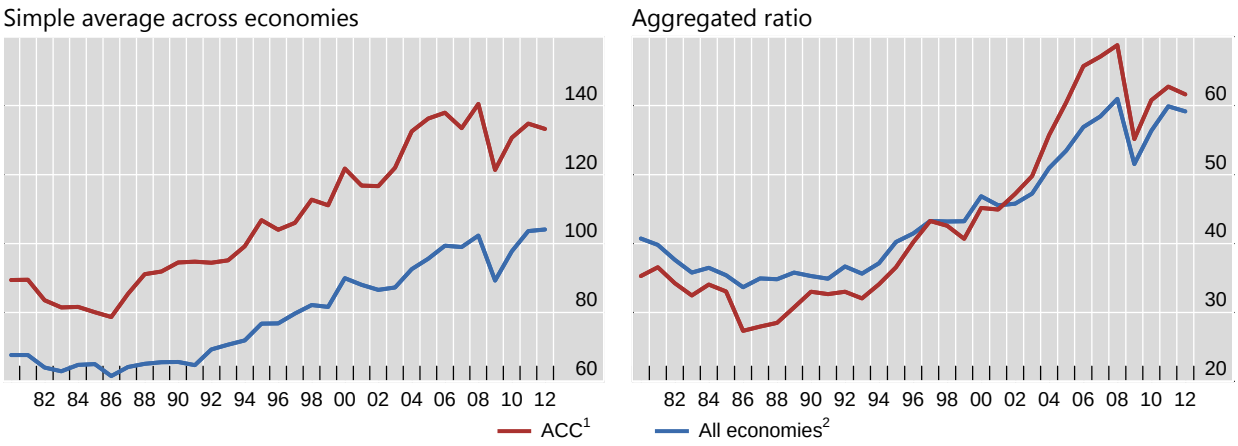
[8] Care should be taken in giving a decline in pass-through a structural interpretation, however. Improved inflation outcomes are likely to present as evidence of declining pass-through regardless of any underlying structural changes. This is because, the more stable inflation is, the less correlated inflation will tend to be with any potential explanatory variables, including exchange rates, as Parsley and Popper (1998) argue. Similarly, Reyes (2007) argues that successful currency intervention to smooth exchange rate changes may result in the appearance of reduced pass-through, even if pricing behaviour is unchanged.

[9] A related potential cause of declining pass-through is less volatile exchange rates. Brun-Aguerre et al (2012) find that pass-through is higher in response to large exchange rate shocks than small ones.

increasing degree of financial internationalisation. One simple metric of this is gross investment positions as a share of GDP, given in Graphs 6A and 6B. Without question, these have grown dramatically in recent years, in spite of a noticeable correction at the time of the international financial crisis. Further, in the latest available data, gross international positions as a share of GDP are at all-time highs for most regional economies.

Trade integration

Imports and exports of goods and services as a percentage of GDP — Graph 5

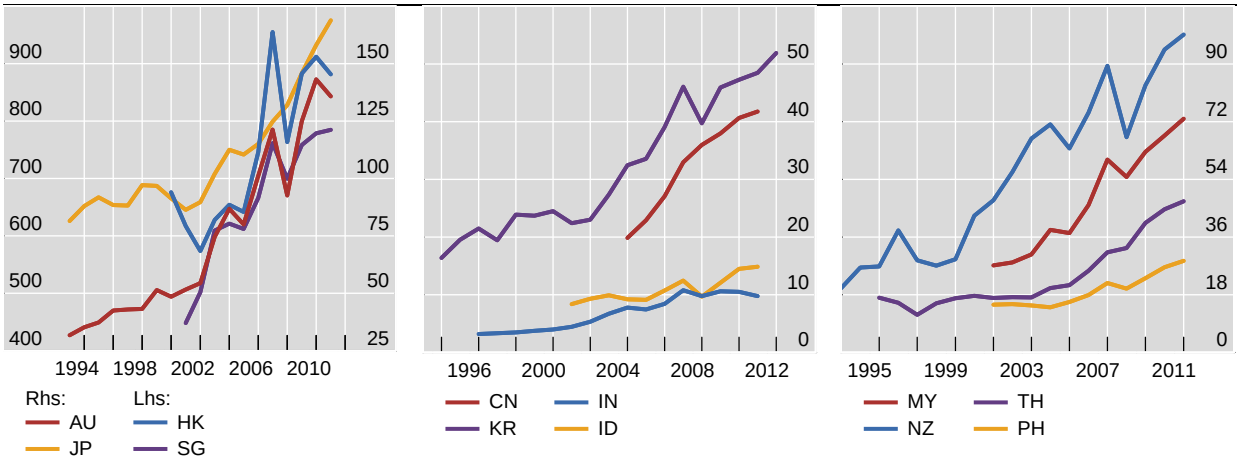


[1] BIS Asian Consultative Council: Australia, China, Hong Kong SAR, India, Indonesia, Japan, Korea, Malaysia, New Zealand, Philippines, Singapore and Thailand. [2] Aggregation of 50 major economies.

Source: IMF, *World Economic Outlook*, April 2013.

International investment position

Gross assets as a percentage of GDP at PPP exchange rate — Graph 6A



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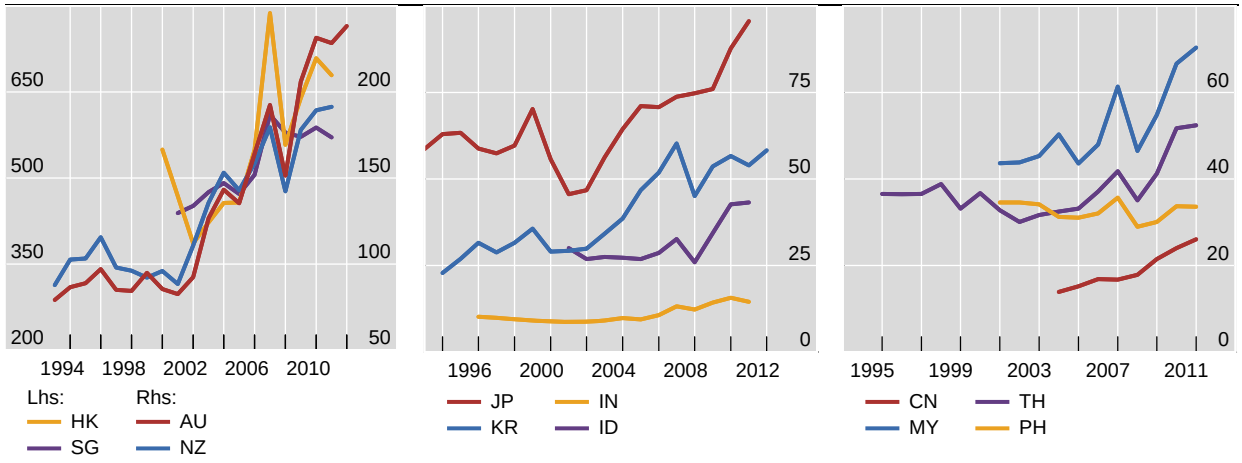
Source: IMF *International Financial Statistics*; IMF *World Economic Outlook*; CEIC.

The international links between banking systems globally, based on BIS data and illustrated in Graph 7, tell a similar story. The size of the circles is proportional to total cross-border positions of banks in a given geographical area, and the thickness of the lines proportional to the cross-border positions between regions where at least one of the counterparties is a bank. "Asia-Pac" refers to China, Chinese Taipei, India, Indonesia, Korea, Malaysia, Pakistan, the Philippines and Thailand. "Asia FC" consists of Hong Kong SAR, Macau SAR and Singapore.

International investment position

Gross liabilities as a percentage of GDP at PPP exchange rate — Graph 6B



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Source: IMF *International Financial Statistics*; IMF *World Economic Outlook*; CEIC.

The Asia-Pacific region has seen a substantial increase in the size of cross-border positions over time. And while there was a pull-back in the aftermath of the international financial crisis, as with gross investment positions, the strength of current links involving banks are at, or near, all-time highs.

Devereux and Sutherland (2008) examine whether increased international asset positions in themselves influence optimal monetary policy. After all, when international positions are large, exchange rate movements may have considerable wealth effects. However, they show that when large asset positions are the result of efficient portfolio choices, so that the increase in asset positions represents an increase in international risk-sharing, movements in the exchange rates are an important ingredient in ensuring the optimal sharing of risk. Then large international positions per se do not support the need for exchange rate stability.

More generally, however, our graphical evidence is suggestive that the economies in emerging Asia are increasingly internationalised and integrated into global financial markets. One practical implication of this is that the scope for policymakers' use of sterilised foreign exchange intervention to stabilise exchange rate movements may be becoming more limited. Indeed, in the limit, if financial markets are fully integrated and asset markets are complete, the implications of the policy trilemma are likely to become stark.

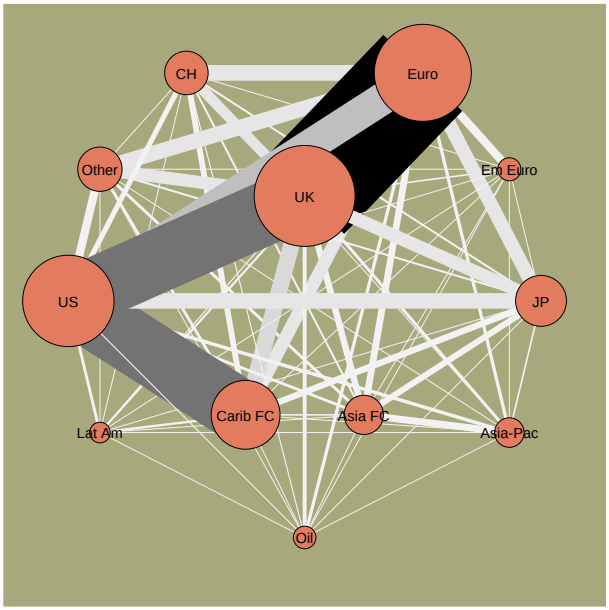
While such a stylised model of efficient markets and full risk-sharing is unlikely to match reality, the underlying principle of reduced effectiveness of foreign

exchange intervention as financial internationalisation increases is likely to be a practical constraint on policymakers' actions. Effectively, central bankers may still be able to influence exchange rates as financial internationalisation increases, but not without having to sacrifice some degree of domestic monetary control. In practical terms, as we will later model, increased financial openness reduces the possibility of sterilised intervention – where the exchange rate can be controlled without changing domestic interest rates – while leaving open the possibility of unsterilised intervention.

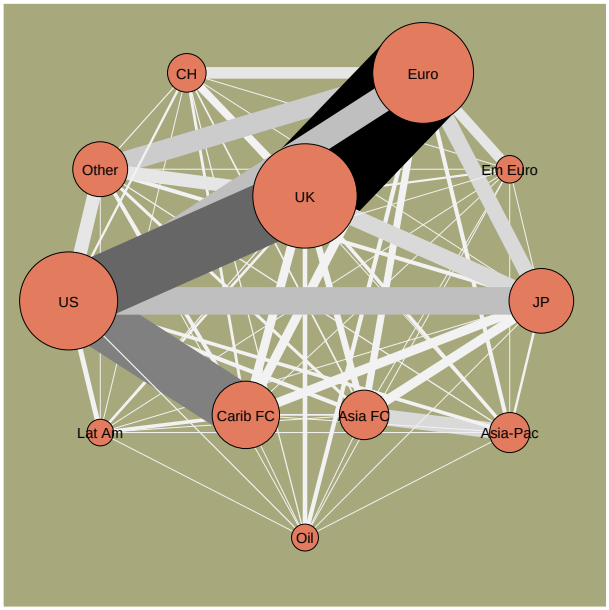
Stock linkages in the international banking system

Graph 7

Q2 2007[1]



Q3 2012[1]



Asia FC = Asian financial centres (Hong Kong SAR, Macao SAR and Singapore); Asia-Pac = China, Chinese Taipei, India, Indonesia, Korea, Malaysia, Pakistan, Philippines and Thailand; Carib FC = Caribbean financial centres (Aruba, Bahamas, Bermuda, Cayman Islands, Curaçao and Panama); CH = Switzerland; Em Euro = emerging Europe (Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia, Turkey and Ukraine); Euro = euro area member states excluding Cyprus, Malta, Slovakia and Slovenia; JP = Japan; Lat Am = Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela; Oil = OPEC member states plus Russia; Other = Australia, Canada, Denmark, New Zealand, Norway and Sweden; UK = United Kingdom; US = United States.

See I Fender and P McGuire, "Bank structure, funding risk and the transmission of shocks across countries: concepts and measurement", *BIS Quarterly Review*, September 2010, pp 63–79.

[1] The size of each circle is proportional to the stock of cross-border claims and liabilities of reporting banks located in that geographical region. Some regions include non-reporting economies. The thickness of a line between regions A and B is proportional to the sum of claims of banks in A on all residents of B, liabilities of banks in A to non-banks in B, claims of banks in B on all residents of A, and liabilities of banks in B to non-banks in A. Note that the two panels are not perfectly comparable due to the addition of Malaysia, Indonesia and South Africa to the sample between the two dates.

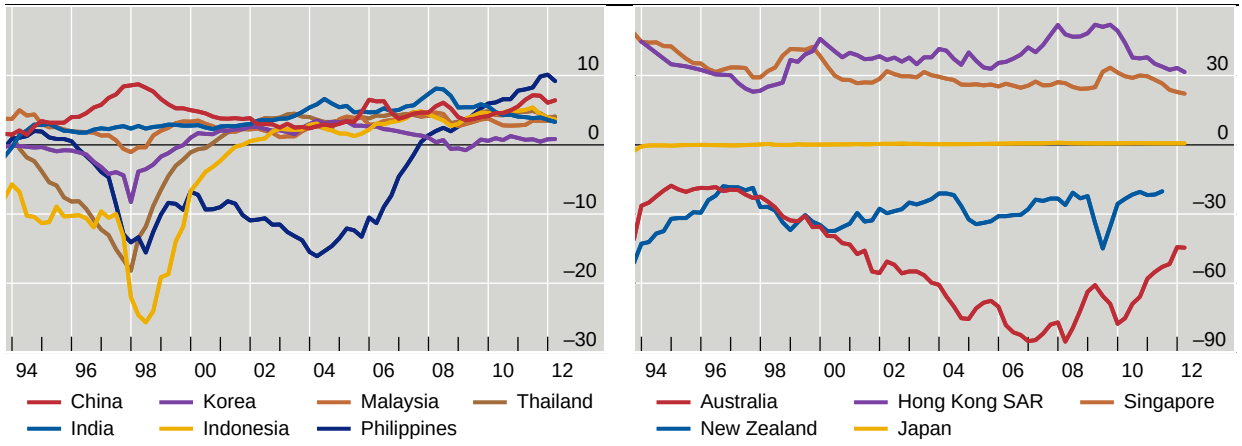
Sources: BIS locational banking statistics by residence; authors' calculations. © Pajek.

This leads us to a final important factor that is likely to weigh heavily on the minds of policymakers in emerging Asia when considering the need to stabilise exchange rates. That is the interaction between exchange rate stability and financial stability. Central to this concern is the degree of mismatch on private sector balance sheets. Suppose that the growing gross international financial positions displayed in Graph 6B represent banks and corporations borrowing heavily in foreign currencies to finance domestic spending rather than efficient international risk-sharing, for example. Then any significant depreciation of the domestic currency may threaten the solvency of firms and banks and, ultimately, the stability of the financial system.

This currency mismatch was a central element explaining the propagation and severity of the Asian financial crisis of 1997–99.[10]

There are a variety of possible measures of currency mismatch. We present one specific measure in Graph 8, based on Goldstein and Turner (2004). It is constructed as the product of two variables: the foreign currency share of total debt and net foreign currency assets vis-à-vis non-residents.

Aggregate effective currency mismatch (AECM)[1] Graph 8



[1] The AECM is the product of the economy's net foreign currency asset position (as a percentage of GDP) and the "mismatch ratio", ie the foreign currency share of aggregate debt relative to export (or imports)/GDP ratio. Hence an economy with a net foreign currency liability position has a negative AECM; the larger this is in absolute magnitude, the greater the effective currency mismatch.

Sources: IMF, *International Financial Statistics*; Datastream; national data; BIS locational banking statistics; BIS international debt securities statistics; BIS domestic debt securities statistics; Goldstein and Turner (2004).

From the graph, there is a strong correlation between the degree to which economies were affected by the Asian financial crisis and the size of the AECM measure in 1997. More recently, the degree of currency mismatch has changed dramatically. With the exceptions of Australia and New Zealand, all the regional economies represented here have had positive measures of currency mismatch for at least the last two years, indicating that exchange rate depreciation would increase the overall net worth of these economies in domestic currency terms, while an appreciation would reduce it, in sharp contrast to earlier periods.

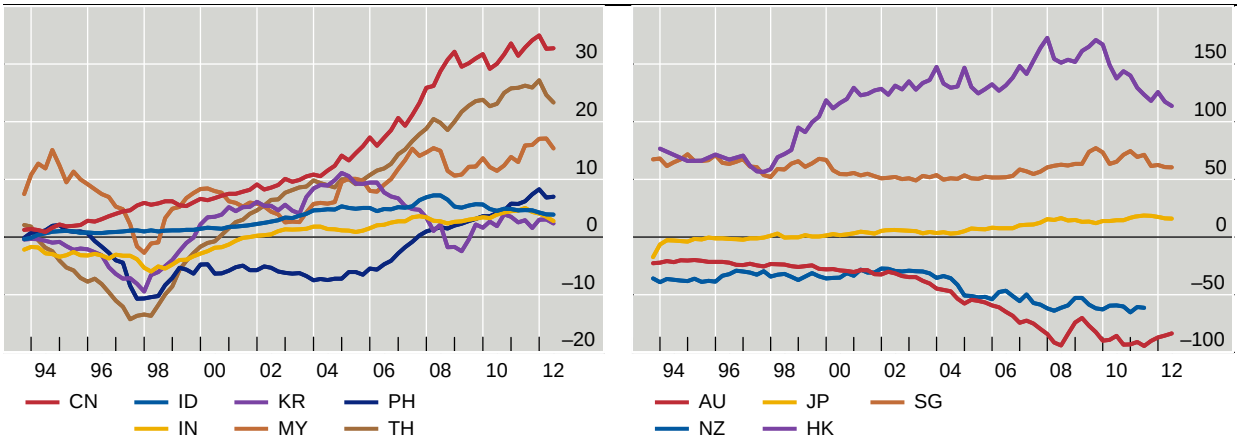
Graphs 9 and 10 represent the main components of the AECM, the net foreign currency asset position and the foreign currency share of aggregate debt, separately. These tell a consistent story. Whereas many economies had considerable net negative asset positions in 1997, they are generally positive and trending up today (Graph 9). Thus the implications of exchange rate movements for financial stability are likely to be less severe than in the past. Given the large (gross and net) stock of foreign assets owned by domestic residents, any sudden rush for the exits from assets denominated in domestic currencies are more likely to be met with inflows as domestic residents repatriate their wealth. This offsetting dynamic was generally not present in the past, and may reduce the macroeconomic fallout from a sudden stop, as well as the need to increase policy rates during a crisis in order to

[10] For related discussion, see Calvo (2002).

support the domestic currency. Meanwhile, the foreign currency share of debt has been steady or declining in most regional economies (Graph 10).

Net foreign currency assets

As a percentage of GDP at PPP exchange rate — Graph 9



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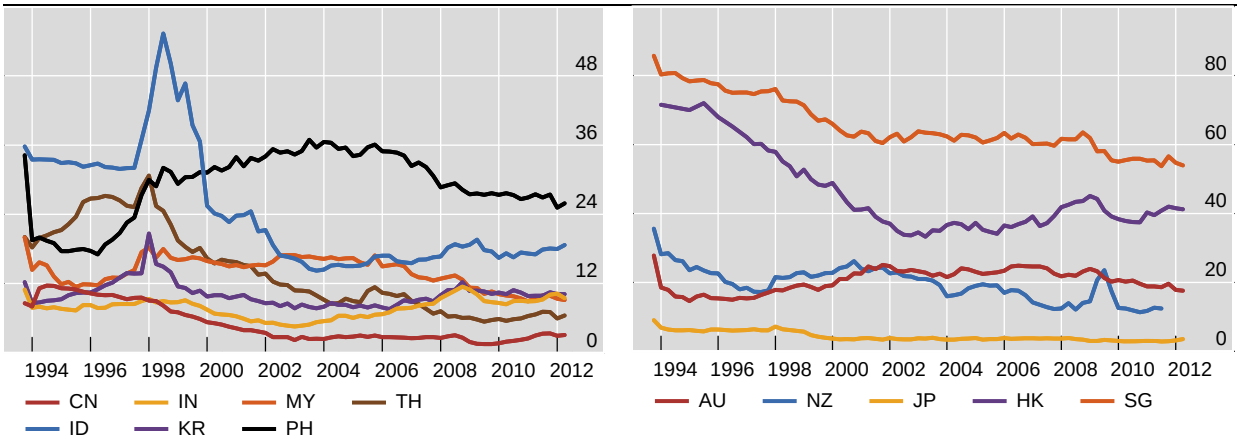
Sources: IMF, *International Financial Statistics*; BIS locational banking statistics; BIS international debt securities statistics; BIS domestic debt securities statistics.

Foreign currency share of total debt outstanding

In per cent — Graph 10



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Sources: IMF, *International Financial Statistics*; BIS locational banking statistics; BIS international debt securities statistics; BIS domestic debt securities statistics.

One contributing factor to this decline in currency mismatch is the continued development of domestic financial markets. For example, local currency bond markets have grown consistently in emerging Asian economies in recent years,

though in some cases from a low base. Domestic borrowers can increasingly find sources of funding without taking on currency risk.[11]

Taking all our arguments together, there is increasing evidence that most of the historical motivations for what have lain at the heart of the so-called "fear of floating" (Calvo and Reinhart, 2002), or the reluctance of policymakers to allow nominal exchange rate flexibility, have declined. Improved inflation performance, indicating increased policy credibility, declining currency mismatch, decreased exchange rate pass-through and ongoing internationalisation, may now allow for a reassessment of the importance of exchange rate stability in achieving monetary policy goals.

In the next section we summarise some analytical results from a model we have developed to address some of these issues.

A summary of model results

We now summarise the key results of Devereux and Yetman (2014b), which we developed to analyse the effect of certain structural changes on the optimal monetary policy response to exchange rates. The model is based on a standard two-country New Keynesian DSGE framework, with a mixture of producer currency pricing and local currency pricing and some degree of home bias.[12] We add one new element to the model. We allow for varying degrees of financial market integration via the following equation:

$$\left[\left(\frac{C_t^{-\sigma}}{C_t^{*-\sigma}}\right)\left(\frac{S_t P_t^*}{P_t}\right)\right]^{\lambda}\left[\frac{\overline{P}_t Y_t - \Delta(FR_t)}{P_t C_t}\right]^{1-\lambda} = 1. \qquad (1)$$

Here, C is consumption, P is the price level, S is the nominal exchange rate (defined as number of units of domestic currency per unit of foreign currency so that an increase is a domestic currency depreciation), σ is the inverse of the elasticity of inter-temporal substitution, Y is total domestic production, $\overline{P}$ is the price index for domestically produced goods, FR is the total stock of foreign exchange reserves, measured in domestic currency, and an asterisk (*) indicates a variable for the foreign economy.

The beauty of this equation is that a single parameter, λ, captures the degree of financial integration. For $\lambda = 1$, we have the standard condition for fully integrated financial markets and perfect risk-sharing. On the other hand, for $\lambda = 0$, we have the equivalent condition for economies that trade with each other but have completely closed financial markets (with the exception of changes in foreign exchange reserves). And for $0 < \lambda < 1$, we can examine intermediate cases in a

[11] Aghion et al (2009) report empirical evidence that exchange rate volatility results in negative growth outcomes in economies with low levels of financial development. In contrast, for financially advanced economies, they find no relationship.

[12] The model is also similar to Engel (2011, 2013a and 2013b).

simple, tractable framework.[13] Further, this equation embodies the trilemma. Clearly, given condition (1), with full risk-sharing ($\lambda = 1$), changes in the stock of foreign exchange reserves will have no effect on the exchange rate nor on the real economy, since foreign exchange reserves only enter via the second square-bracketed term on the left-hand side of the equation.

We combine condition (1) with a standard New Keynesian open-economy model where we can vary the degree of home bias in consumption (to capture the level of goods market integration) and the degree of local currency versus producer currency pricing (to capture the degree of short-run exchange rate pass-through).

We also allow the policymaker to respond to exchange rate changes in two ways. First, we assume that interest rates respond to the change in the nominal exchange rate in the home country, in addition to CPI inflation. One may think of this as being a form of unsterilised foreign exchange intervention, since interest rates are affected by policy actions intended to influence exchange rates.

Second, we allow policymakers to intervene directly in foreign exchange markets by adjusting foreign exchange reserves in response to changes in the nominal exchange rate. This will directly affect the solution to equation (1) above. One may think of foreign exchange intervention of this nature as a form of sterilised intervention, as interest rates are not directly affected by such policy actions that influence the exchange rate.

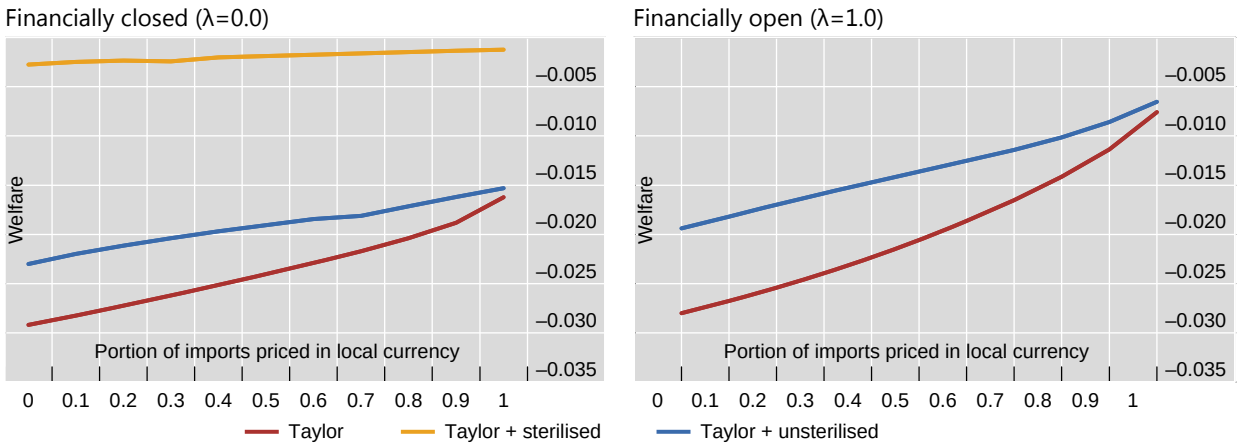
We then evaluate the welfare effects of following different monetary policy rules based on a second-order approximation to the welfare function, in the spirit of Woodford (2003). As in Engel (2011), this welfare function depends on the output gaps (that is, output relative to where it would be if prices were flexible), inflation rates and exchange rate misalignment. One important element of our approach is that we abstract away from strategic considerations to focus on the cooperative optimal policy that maximises global welfare. Thus we do not take into account any advantages that an undervalued exchange rate might offer due to "beggar-thy-neighbour" effects.

We compute the maximum achievable level of global welfare under four different assumptions about how monetary policy is set. First, monetary policy is characterised by a simple Taylor-type rule, where interest rates in both countries respond linearly to domestic CPI inflation (labelled "Taylor" in the graphs that follow). Second, monetary policy is characterised by a Taylor-type rule, but where interest rates in the home country also respond linearly to the change in the nominal exchange rate ("Taylor + unsterilised"). Third, monetary policy is characterised by a Taylor-type rule in both countries, but the home country monetary authority can also make use of sterilised intervention in foreign exchange markets, where the change in foreign exchange reserves is a linear function of the change in the nominal exchange rate in log terms ("Taylor + sterilised"). Finally, we also compute the optimal Ramsey outcome, where the responses of interest rates in both countries, and the change in foreign exchange reserves in the home country, are chosen optimally so as to maximise global welfare. This is used as a benchmark to compare the other policy solutions against.

[13] Devereux and Yetman (2014a) show that this condition can be derived based on a tax on the financial returns from investing in foreign assets which takes the form $(1+t_t) = \left(PC_t / (\overline{PY}_t - \Delta(FR_t))\right)^{(1-\lambda)/\lambda}$.

Graph 11 illustrates the effectiveness of different policy rules at achieving optimal welfare in response to productivity shocks. The horizontal axis is the proportion of imports that are priced in the local currency, δ. The left-hand panel is under financial autarky ($\lambda = 0$), and the right-hand panel with complete financial internationalisation ($\lambda = 1$). In-between levels of financial internationalisation are qualitatively similar to the autarky case. All welfare levels are relative to the Ramsey outcome.[14]

Welfare effects of productivity shocks — Graph 11



Source: Authors' calculations.

Perhaps the most important result here is that, with less-than-complete financial internationalisation, a combination of sterilised intervention and following a simple Taylor rule where the coefficient is chosen optimally comes closest to achieving the optimal Ramsey outcome (ie welfare is close to zero). However, there is little substitutability between sterilised and unsterilised intervention. This is because, with unsterilised intervention, any improvement in outcomes is the result of a trade-off: a single policy instrument (interest rates) is being used to respond to an additional variable. In welfare terms, that trade-off is barely worth making: the paths of all nominal and real variables are little changed whether the central bank responds only to inflation or to both inflation and exchange rate changes optimally. In contrast, unsterilised intervention represents an additional policy tool that does not compromise the effectiveness of interest rates in responding to other variables.

In general terms, monetary policy and exchange rate control can be effective in our model for two reasons. First, they can help to alleviate the effects of nominal rigidities. Second, they can enhance international risk-sharing. Here, interest rates can be used to substantially reduce the effects of nominal rigidities. Meanwhile, for $\lambda < 1$, sterilised intervention can be used as a separate instrument to increase international risk-sharing by partially mimicking the effects of asset allocations that would result under complete markets.

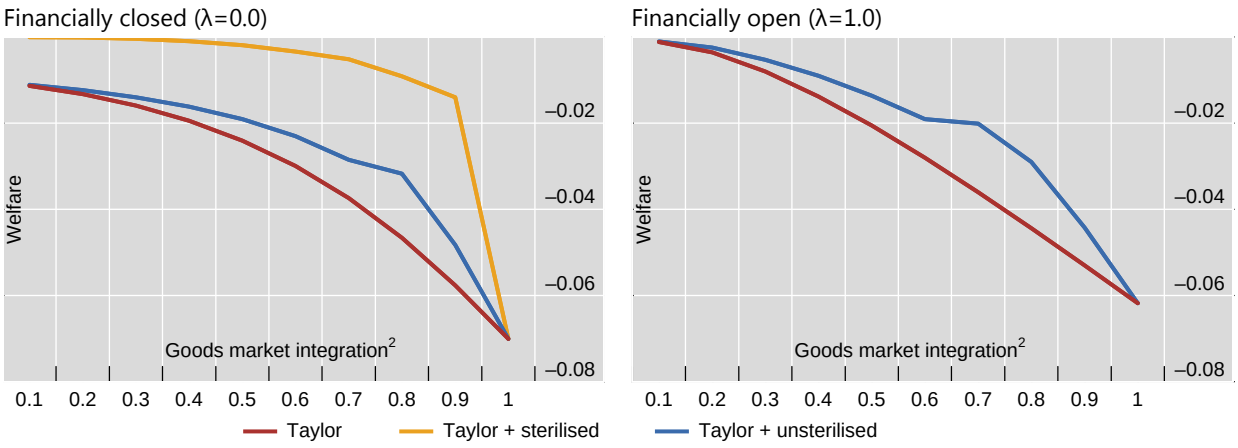
[14] That is, if a policy achieves the same level of welfare as the Ramsey policy, it would be indicated by zero.

In a world of complete financial internationalisation, sterilised intervention is no longer effective. Instead, the only avenue for policymakers seeking to influence the exchange rate is unsterilised intervention. And when policymakers cannot use sterilised intervention as a secondary policy tool, they cannot get as close to the Ramsey outcome, *conditional* on the level of financial internationalisation.

Graph 12 repeats the same exercise but with the degree of short-run exchange rate pass-through fixed such that half of imports are priced in the producer currency, and half in the local currency. Instead, the degree of goods market integration is varied from almost closed (on the left of the horizontal axis) to no home bias in consumption (on the right). All welfare measures are again relative to those under the Ramsey policy. Note that the levels of welfare across different values of goods market integration are not directly comparable, since the degree of home bias is a preference parameter. Instead, the purpose of the exercise is to focus on the relative performance of the different policy measures at given levels of goods market integration.

Welfare effects of productivity shocks

Mixture of local and producer currency pricing[1] Graph 12



[1] Half of all import varieties are assumed to be priced in the local currency and half in the producer currency. [2] Goods market integration is defined as $2\text{-}\upsilon$.

Source: Authors' calculations.

With high levels of home bias, sterilised intervention, if feasible, is an especially potent tool for achieving close to the first-best outcome. Without sterilised intervention, a positive domestic productivity shock would cause the domestic currency and terms of trade to depreciate, distorting consumption decisions. The appropriate use of sterilised intervention can be used to prevent this.

The effectiveness of sterilised (and unsterilised) intervention in response to productivity shocks relies on some degree of home bias. In the limit of no home bias in consumption, at the extreme right of the panels in the above graph, provided the monetary policy response to inflation is optimal, there are no gains to intervening in foreign exchange markets in response to productivity shocks. (This is independent of the degree of exchange rate pass-through and financial internationalisation). The optimal response to inflation via the Taylor rule is sufficient to fully stabilise inflation and, when consumers in both countries have

identical preferences over both home and foreign goods, this also fully stabilises the nominal exchange rate. Given that inflation and the exchange rate are fully stabilised, and therefore deviations from the law of one price are fully eliminated, the welfare costs of nominal rigidities are entirely eliminated. More generally, if goods markets are not fully integrated, then even if inflation in both countries is stabilised, the price of imported goods will tend to behave differently from the price of domestically produced goods, and the exchange rate will vary in response to productivity shocks. In that case, sterilised intervention can be effective.

One interesting outcome across all our results is the relative unimportance of the degree of financial internationalisation. Visually, for all levels of $\lambda < 1$, the graphs look similar to the financially closed ($\lambda = 0$) case presented in the left-hand panels of the graphs above. As λ increases, provided it remains below 1.0, there is little impact on the achievable level of welfare. But once we move to a world of perfect financial internationalisation, then, by construction, sterilised intervention no longer plays a role.

One limitation in this interpretation of our results is that we do not capture the potential costs of volatile reserves in our model, discussed in Section 2. As the level of financial internationalisation increases, but remains incomplete, central banks are able to achieve almost the same outcome with ever increasing foreign exchange intervention. But this implies that the volatility of foreign exchange reserves is increasing in the level of financial internationalisation.

Clearly policymakers would ascribe a negative welfare impact to highly volatile foreign exchange reserves. While explicitly modelling the cost of volatile reserves is beyond the scope of the current paper, we address this issue by adding an additional term to the welfare function of $(fr_t - fr_{t-1})^2$, where fr_t is the log of foreign exchange reserves, with a weight of negative one. In Graph 13 we present analogous results to those presented previously in Graph 11 for a range of levels of financial internationalisation, but incorporating this negative welfare effect of foreign reserves volatility. This has the intuitive effect of lowering the gains available from pursuing sterilised intervention, such that unsterilised intervention dominates sterilised intervention long before the economies are fully financially internationalised.

Conclusions

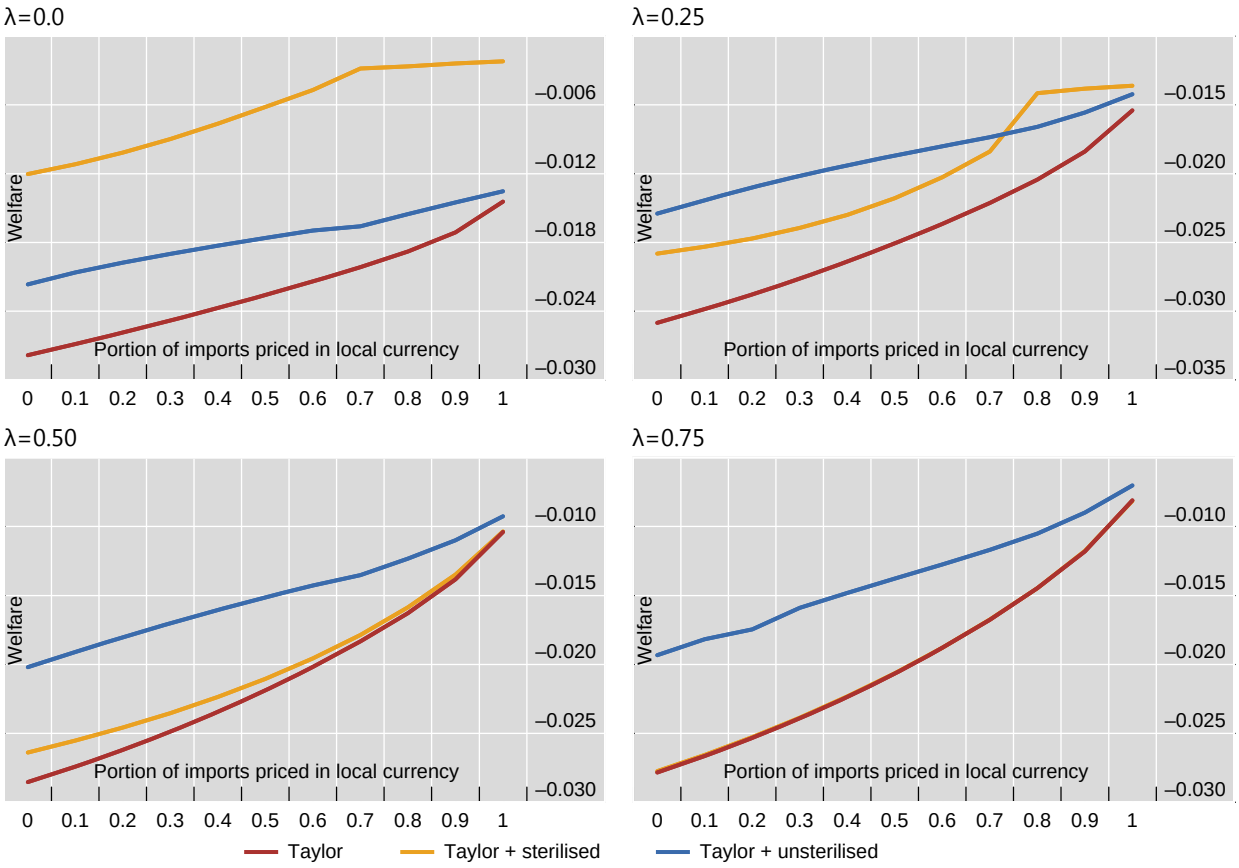
In this paper we have examined how monetary policy should respond to nominal exchange rate changes. We have shown how the optimal response to exchange rates depends on the degree of financial internationalisation, goods market integration and exchange rate pass-through. Sterilised intervention can be a potent tool that offers policymakers an additional degree of freedom in maximising global welfare. The potential welfare benefits from sterilised intervention are largest when exchange rate pass-through is high and when international goods markets are poorly integrated.

However, as the international policy trilemma implies, there are limitations to the use of sterilised intervention. As financial internationalisation increases, achieving a given degree of exchange rate stability requires ever increasing changes in foreign exchange reserves. Taking into account that volatile reserves are likely to

be costly, increased financial internationalisation reduces the role for sterilised intervention. And in the case of fully integrated international financial markets, sterilised intervention has no influence on exchange rates at all.

Where sterilised intervention is no longer a desirable policy tool, unsterilised intervention may have a role to play. However, the potential welfare gains from the optimal use of unsterilised intervention in our model are relatively small. With unsterilised intervention, a single policy instrument (interest rates) is being used to respond to an additional variable (exchange rates), compromising its response to inflation for most plausible parameters. In contrast, unsterilised intervention represents an additional policy tool that does not impinge on the optimal response of interest rates to other variables.

Welfare effects of productivity shocks with costly reserves volatility — Graph 13



Source: Authors' calculations.

Most central banks in Asia have actively used sterilised foreign exchange intervention as a policy tool to smooth exchange rate movements over time. In our model, the use of sterilised intervention represents good policy from a welfare point of view when goods markets and financial markets are not well integrated internationally and exchange rate pass-through is high. But these characteristics are changing in the region. By most metrics, the degree of exchange rate pass-through has fallen. The combination of developing domestic financial markets, and declining barriers to international capital flows, has seen increased financial internationalisation. And goods markets have become more integrated as consumer preferences across countries have moved closer together.

The effect of these changes is to reduce the benefits of stabilising exchange rates with sterilised foreign exchange intervention in our model. And, given the limited effectiveness of unsterilised intervention, our model results imply that the role of exchange rate movements in the optimal setting of monetary policy is decreasing across the region.

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