A Simple Model of Monetary Policy with Sterilised Intervention in an Emerging Market Economy

by

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(Version: October 2010)

Abstract

In this paper, I solve for the optimal monetary policy reaction function with sterilised intervention given the central bank's objectives and the structural characteristics of a stylised emerging market economy. In a departure from previous work that deals with estimating the reaction function when there is intervention and sterilisation, I assume the interest rate as the primary monetary policy instrument in a simple model of Keynesian style elements. This interest rate targeting set up keeps in line with the monetary policy framework now prevalent in many emerging market economies. At the same time, in contrast to more recent work on modelling monetary policy, I give attention to the effects of different types of sterilisation methods, and (re)introduce a role for broad money as a factor affecting inflation to illustrate the effects of sterilised intervention. The resulting monetary policy reaction function shows how the policy interest rate behaves given various exogenous factors. It highlights the difficulties that arise with incomplete broad money sterilisation and illustrates situations where the need for additional policy instruments becomes particularly important.

Keywords: monetary policy, exchange rate, foreign exchange intervention, money, sterilisation, emerging markets, inflation targeting

JEL Codes: E52, F31, F33, F41

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Introduction

Many emerging market economies attempt to simultaneously manage exchange rates and maintain domestic monetary control. The experiences of many countries have come under the scrutiny of academics in recent years amidst large and volatile capital flows and the growing size of current account imbalances taking centre stage.

In a small open economy, the exchange rate is important for two key reasons. One, from the monetary policy perspective, abrupt and persistent movements in the exchange rate can have adverse repercussions for inflation when pass-through is high, and output, via the tradables sector. Two, exchange rate policy also matters for financial stability in countries susceptible to sudden reversals of large capital inflows and in which foreign exchange markets are relatively thin. In either case, the monetary policy response (typically by way of a short term policy interest rate) to the exchange rate may depend on whether the central bank can use other instruments. As Mohanty and Klau (2004) note "These can include not only the conventional types such as foreign exchange intervention but also less conventional ones such as temporary capital controls, debt swaps and exchange rate-linked instruments to stabilise exchange rate expectations".

Foreign exchange intervention is fairly common among emerging market economies, and this can be approximated from changes in international reserves. Based on the 21 countries that currently make up the membership of the Morgan Stanley Capital International (MSCI) index for emerging market economies[1], 14 have adopted the inflation targeting framework, with most having done so post 1998. Ho and McCauley (2003) note that the majority of inflation targeting emerging market economies had intervened at least once in the foreign exchange market since adopting the inflation targeting framework.

On one hand, while thin markets provide a reason to intervene to avoid excessive exchange rate volatility, on the other, they also allow for effective foreign exchange intervention in emerging markets as the central bank is a large player in the market for its own currency (Engel, 2009). Thus, intervention, with effective sterilisation – successfully insulating domestic liquidity and maintaining policy independence, offers the possibility of

[1]Source: http://www.mscibarra.com/products/indices/tools/index_country_membership/emerging_markets.html. The website was last accessed on 8 June 2010.

separating exchange rate policy from monetary policy, as well as the possibility of using the exchange rate as an additional policy instrument.

There is a gap in the literature in terms of analysing sterilisation and incorporating sterilised intervention into monetary policy reaction functions, especially where present reality is concerned. Empirical studies (including those based on theoretical models) that attempt to assess the extent and effectiveness of sterilisation tend to assume the central bank's net domestic assets (NDA) as the monetary policy instrument. These include older studies such as Argy and Kouri (1974), Herring and Marston (1977) and Obstfeld (1983) which were reflective of conditions prevailing at the time, and newer studies such as Brissimis et al. (2002) which attempt a historical study of Germany over 1979-1992, and Ouyang et al. (2007) which though dealing with a more recent sample period (1990-2005), and eight Asian countries, also assume NDA as the policy instrument. Studies that focus on more recent developments ought to consider more carefully the monetary policy frameworks of countries under focus and the fact that most central banks now operate through a short term interest rate.

The focus of studies also tends to be on the narrow definition of sterilisation, comparing base money changes against changes in central bank net foreign assets (NFA), as opposed to the broad definition of sterilisation which compares broad money changes against changes in NFA. Sterilising broad money in fact has different implications for financial variables than sterilising base money. Mohanty and Turner (2006) suggest that the type of instruments used, and the sector from which liquidity is absorbed – whether non-bank private agents or banks, determine the completeness of sterilisation. Although the authors do not make an explicit note nor calculate broad sterilisation coefficients, these two factors influence the relative impact of NFA on broad money. Further, as Argy and Murray (1985) note: "there is surprisingly little, if any literature concerned with the effects of sterilisation per se, on financial variables".

Estimation of Taylor type monetary policy rules meanwhile, while cognisant of the shift to interest rate targeting (the interest rate as policy instrument) and have as model set up, the New Keynesian style approach, focus on whether central banks react to exchange rate changes or misalignments with the policy interest rate. However, as Engel (2009) states "there is very little analysis of sterilized intervention in the new Keynesian framework". In particular, most studies pertaining to emerging market economies seek to assess whether central banks have an additional objective in managing the exchange rate, beside inflation and output stabilisation. Mohanty and Klau (2004) for instance find a strong response of interest rates to persistent exchange rate shocks in Asian and Latin American economies over 1995-2002.

With these gaps in mind, in this paper I attempt to bring together the elements of interest rate targeting, and intervention and sterilisation using a simple theoretical model, analysing the effects and issues associated with sterilised intervention. I solve for the optimal monetary policy reaction function given the central bank's objectives and the structural characteristics of the economy. I give attention to the effects of different types of sterilisation methods, and (re)introduce a role for money as a factor affecting inflation to illustrate the effects of sterilised intervention. The resulting monetary policy reaction function shows how the policy interest rate behaves given various exogenous factors.

The Model

(1) Central Bank Loss Minimisation Function

I assume that the representative central bank focuses on inflation and output stabilisation[2] as its monetary policy objectives. The exchange rate is important for the achievement of these goals, and this is reflected in aggregate supply and demand. This, however, does not require that exchange rate stability be specified explicitly in the central bank's loss minimisation function though there are instances where countries have price stability and currency stability as separate monetary policy objectives (Ortiz, 2009). A financial stability mandate could be seen to present a case for having exchange rate stability as a separate objective, and a more likely scenario in which possible policy conflicts may arise. Minimising interest rate volatility is also sometimes considered a financial stability objective (often translating into an interest rate smoothing term in simple rules). From a monetary policy perspective, however, and to maintain the simplicity and generality of the model's exposition, the central bank's loss minimisation function is written as follows:

$$\text{Min } L_t = \frac{1}{2}\left[(\pi_t - \pi_t^T)^2 + \alpha(Y_t - Y_t^p)^2\right] \quad (1.1)$$

where π_t = inflation rate, π_t^T = inflation target, Y_t = actual output, Y_t^p = potential output, α = parameter that reflects weight central bank places on output stabilisation relative to inflation stabilisation.

The central bank seeks to minimise inflation and output growth deviations around a target inflation rate and potential output respectively. Restating the output objective in terms of the output gap, the loss minimisation function can be simplified to:

$$\text{Min } L_t = \frac{1}{2}\left[(\pi_t - \pi_t^T)^2 + \alpha(y_{g,t})^2\right] \quad (1.2)$$

where $y_{g,t}$ = domestic output gap (actual output less potential output)

[2] Based on legislation and extra-statutory elements, Ortiz (2009) finds that for 33 out of 45 central banks (across industrial and emerging market economies) price stability is usually the dominant monetary policy objective. In most cases it is a singular objective or is superior to other macroeconomic objectives specified in the law (general welfare, general economic health, growth and development). Nevertheless, the author highlights scenarios where there could be potential conflicts, in particular, seemingly equal ranked price and real economic objectives (e.g. the US), and when the objective of currency stability is not equivalent to price stability (i.e. both are specified as objectives). The author also notes that in a 2006 sample of 36 central banks, 64% had a single quantifiable price stability objective, 11% had an exchange rate target, 6% had multiple targets, while 17% had no explicit target or a monitoring range.

The central bank seeks to minimise the loss function, by manoeuvring the instruments at its disposal subject to several constraints that characterise the economy. It is assumed that the central bank operates primarily through an interest rate. The following sub-sections detail the structural equations for the economy and the derivation of the reaction function.

(2) Inflation (open economy aggregate supply/Phillips curve) [3]

The inflation equation is defined as follows:

$$\pi_t = \beta_1\pi_{t-1} + (1-\beta_1)\left(\Delta e_t + \pi_t^f\right) + \beta_2 y_{g,t} + u_{\pi t} \quad (2.1)$$

$(\beta_1 + (1-\beta_1) = 1;\ \beta_2 > 0)$

where e_t = nominal effective exchange rate; π_t^f = foreign inflation; $u_{\pi t}$ =cost push shocks

Equation (2.1) relates current inflation to lagged inflation, the output gap (actual output less potential output, defined as a percentage change), change in the log of the nominal effective exchange rate, e (with an increase indicating depreciation), foreign inflation, and exogenous "cost-push" disturbances, u. Long run homogeneity (long run Phillips curve verticality) is imposed, that is, the right-hand side coefficients in the equation, with the exception of the coefficient on the output gap, sum to one.

(3) Aggregate demand/IS curve

Aggregate demand is represented by the following output gap equation:

$$y_{g,t} = \gamma_1 y_{g,t-1} - \gamma_2(i_t - E_t\pi_{t+1} - r_t^*) + \gamma_3(q_t - q_t^*) + u_{yt} \quad (3.1)$$

$(0 < \gamma_1 < 1;\ \gamma_2 > 0; \gamma_3 > 0)$

i_t = central bank policy interest rate, nominal
r_t^* = natural real interest rate
q_t = real effective exchange rate (an increase reflects depreciation)
q_t^* = equilibrium real effective exchange rate
u_{yt} = demand shocks

[3] Strictly speaking the equation presented is not a typical New Keynesian or hybrid New Keynesian equation as there is no forward looking element. $E_t\pi_{t+1}$ is currently excluded to make model solving more tractable but its inclusion will be part of work to refine the model. Empirical evidence does, nevertheless, point to the backward looking element playing an important role in the inflation process.

The output gap depends negatively on the difference between the real short term interest rate and the natural real interest rate, and positively on the lagged output gap, and the depreciation in the real effective exchange rate, relative to its equilibrium level.

(4) Balance of payments, exchange rate and intervention

I make the simplifying assumption that any accumulation of net foreign assets by the domestic economy is due solely to the central bank. Net inflows through the capital and financial accounts, ΔNK_t, reflect non-resident demand for domestic assets and do not encompass any transactions by domestic residents[4]. Essentially, domestic residents do not invest abroad. The change in the central bank's net foreign assets ($\Delta NFA_{cb,t}$) is the sum of the current account surplus, CA_t, and ΔNK_t.

$$\Delta NFA_{cb,t} = CA_t + \Delta NK_t \tag{4.1}$$

The current account surplus is made up of the trade surplus and net investment income (receipts less expenditure) as in (4.2) below. For simplicity, compensation to employees and transfers are excluded. Given that the accumulation of net foreign assets is due solely to the central bank, $i_t^{f,iv} NFA_{cb,t-1}$ reflects inflows due to investment income earned by the central bank ($i_t^{f,iv}$ being the foreign interest rate on investments abroad). Net investment income should actually be net off interest paid on foreign holdings of domestic assets ($-i_t^{d,iv} NK_{t-1}$, with $i_t^{d,iv}$ being the domestic interest rate paid on non-residents' investments domestically) but for simplification purposes, I omit this term or consider it subsumed under ΔNK_t, without material consequences for the analysis.

$$CA_t = TB_t + i_t^{f,iv} NFA_{cb,t-1} \tag{4.2}$$

From (4.1) and (4.2):

$$\Delta NFA_{cb,t} = TB_t + i_t^{f,iv} NFA_{cb,t-1} + \Delta NK_t \tag{4.3}$$

$$\Delta NFA_{cb,t} - i_t^{f,iv} NFA_{T,t-1} = TB_t + \Delta NK_t \tag{4.4}$$

[4] Essentially, when there is no intervention, CA and ΔNK balance out, without changes to banking institutions net foreign assets or liabilities.

This gives an expression for central bank foreign exchange intervention:

$$\Delta NFA_{cbi,t} = TB_t + \Delta NK_t \quad (4.5)$$

where $\Delta NFA_{cbi,t} = \Delta NFA_{cb,t} - i_t^{f,iv} NFA_{T,t-1}$, represents central bank intervention.

Based on (4.5) above, central bank intervention is driven by the trade surplus and capital inflows. The trade surplus, as a ratio to nominal gross domestic product (NGDP), in (4.6) below is determined by an exogenous component and increases with a depreciation in the real effective exchange rate relative to the equilibrium exchange rate[5]. Net capital inflows as a ratio to NGDP, meanwhile, depends imperfectly on the interest rate parity condition as described in (4.7) below, where c represents the degree of international asset substitutability. Further, $u_{nk,t}$ represents shocks to risk premium. If c=0, domestic and foreign assets are perfect substitutes and capital is perfectly mobile. If $c \neq 0$, deviations from the uncovered interest parity would not lead to infinite capital flows. Here it is assumed that $0 < c < \infty$[6].

$$\frac{TB_t}{NGDP_t} = \bar{t} + \theta(q_t - q_t^*) \quad (4.6)$$

$$\frac{\Delta NK_t}{NGDP_t} = \left({}^{1}/_{c} \right)\left\{\left[(e_t - E_t e_{t+1}) + (i_t - i_t^f)\right]\right\} + u_{nk,t} \quad (4.7)$$

$\bar{t}$ = exogenous trade surplus
e_t = current nominal exchange rate (increase reflects depreciation)
$E_t e_{t+1}$ = current expectation of the exchange rate at time t+1
i_t^f = foreign interest rate
$NGDP_t$ = nominal GDP

It is generally accepted that a random walk forecast of the exchange rate tends to outperform other models in out of sample forecasting, and thus one can assume that $E_t e_{t+1} = e_t$. Incorporating this assumption into (4.7) would eliminate the term $(e_t - E_t e_{t+1})$. Nevertheless, empirical evidence on the random walk hypothesis, where emerging markets are concerned, is mixed (see for instance Azad (2009)). Results are sensitive to the methodology employed, the sample period and the data series. Rejection of the random walk hypothesis, however, is not inconsistent with active foreign exchange intervention. As such, an alternative assumption is to have the expected nominal exchange rate change as function of the extent of perceived real exchange rate misalignment. That is, $(e_t - E_t e_{t+1}) = \varphi(q_t - q_t^*)$. The expectation of a nominal exchange rate appreciation in the next period is a

[5] The Marshall-Lerner condition is assumed to hold without inertia.
[6] The discussion on international asset substitutability follows Brissimis et al. (2002).

function of the perceived[7] real exchange rate undervaluation in the current period. Using this assumption, (4.7) can be written as:

$$\frac{\Delta NK_t}{NGDP_t} = \left(\,^1/_c\right)\left\{\left[\varphi(q_t - q_t^*) + (i_t - i_t^f)\right]\right\} + u_{nk,t} \tag{4.7b}$$

Expressing the elements of (4.5) as a ratio to NGDP and then substituting (4.6) and (4.7b) into (4.5) yields the following:

$$\frac{1}{NGDP_t}\left(\Delta NFA_{cbi,t}\right) = \frac{1}{NGDP_t}\left(TB_t + \Delta NK_t\right) \tag{4.8}$$

$$\frac{\Delta NFA_{cbi,t}}{NGDP_t} = \bar{t} + \theta(q_t - q_t^*) + \left(\,^1/_c\right)\left\{\left[\varphi(q_t - q_t^*) + (i_t - i_t^f)\right]\right\} + u_{nk,t} \tag{4.9}$$

Rearranging (4.9) gives:

$$\frac{\Delta NFA_{cbi,t}}{NGDP_t} = \bar{t} + \left(\theta + \frac{\varphi}{c}\right)(q_t - q_t^*) + \left(\,^1/_c\right)\left(i_t - i_t^f\right) + u_{nk,t} \tag{4.10}$$

In (4.10), the amount of central bank intervention, as a ratio to nominal GDP, is determined by exogenous trade flows, the real exchange rate disequilibrium which matters for exchange rate sensitive trade flows (reflected by the coefficient θ) and as well as capital flows (reflected by the coefficient φ), the interest rate differential which influences capital flows, and capital flow shocks $u_{nk,t}$. The higher is the international asset substitutability (lower c), the higher are capital flows and consequent intervention.

(5) The role of money in aggregate demand and supply

This section deals with the question as to whether there should be a role for money in the model, particularly when sterilised intervention is a policy option for central banks. As evident in (2) and (3) above, money does not figure explicitly as a variable in the inflation and output gap equations that tend to typify current models of monetary policy. Existing literature dealing with sterilised intervention, meanwhile, have tended to assume a direct relationship between money and inflation. As mentioned in the introduction, the models in

[7] I subsequently assume perceived = actual for ease of exposition, but clearly this need not be the case, and the difference would influence the complexity of the resulting monetary policy reaction function.

these studies, however, do not adequately reflect the current state of policy-making[8]. Leaving aside the issue of sterilised intervention for a moment, there has been quite substantial debate on whether money is still relevant. Rudebusch and Svensson (2002) write, "As a general characterization, central bankers typically hold the view that movements in the monetary aggregates play no role in the direct quarter-by-quarter determination of either output or prices; however a sizeable fraction also concedes that money may have some value as an indicator of economic developments". Woodford (2008), while arguing that there is no need to assign money a particularly prominent role a la the European Central Bank (ECB)'s "monetary analysis" pillar, nevertheless concedes that there is no a priori reason to exclude monetary variables from the set of indicators that are taken into account in a central bank's information set. The following are three views in support of the relevance of money:

(i) The long run link between money and inflation

Both the Swiss National Bank (SNB) and the European Central Bank (ECB) place importance on money in determining inflation at the long run horizon. The SNB makes a distinction between two groups of indicator variables – on the one hand, a range of short to medium term indicators, including inflation itself; and on the other hand, monetary indicators, mostly relevant at a longer horizon (Trichet, 2007). This is similar to the ECB's two-pillar strategy – economic analysis and monetary analysis.

Gerlach (2003, 2004) provides an empirical interpretation of the ECB's two pillar monetary policy strategy, with a non-structural augmentation to the standard Phillips curve. The monetary analysis pillar captured by trend monetary growth accounts for changes in steady state inflation by influencing inflation expectations while the economic analysis pillar captured by the output gap accounts for short run movements in inflation around the steady state rate[9]. Gerlach's empirical work suggests that M3 growth contains information about future inflation in the Euro Area that is not already embedded in the current inflation rate. Gerlach nevertheless views

[8] The studies present models where a monetary aggregate is still the operating or intermediate target of monetary policy. For instance, Brissimis et al. (2002) posit the following money-inflation relationship:
$\Delta p_t = \mu_1(\Delta NFA_t + \Delta NDA_t) + \mu_2 \Delta p_{t-1}$, with ΔNDA_t as the monetary policy instrument.

[9] Gerlach (2003) links low frequency inflation to low frequency money growth in the estimation of the two-pillar Phillips curve while Gerlach (2004) links expected inflation to trend money growth. Beck and Wieland (2007), meanwhile propose the following estimation: $\pi_t = \varphi_1 \mu_t^f + \varphi_2 \pi_{t-1} + \varphi_3 (y_t - y_t^*) + \epsilon_{\pi,t}$, where the first term on the right hand side of the equation is filtered money growth.

the results as neither suggesting M3 as the best indicator of inflation nor that a separate pillar for monetary growth is required.

Nelson (2008) in a critique of Woodford (2008), also alludes to the long run importance of money for the determination of steady state inflation, clarifying the definition of "long run" as the economic conditions prevailing after prices have fully adjusted to monetary policy actions; the state of the economy prevailing after any inertia in nominal prices and wages has passed. The short run/long run distinction has important implications for the central bank to affect interest rates. Open market operations affect nominal and real interest rates only with nominal price rigidity. In the long run prices move by the same percentage as the nominal money stock. "A change in the money supply cannot alter the real interest rate: it can only influence nominal rates by changing inflationary expectations"[10]. As such, an understanding of how a central bank's actions determine long run inflation expectations when the real interest rate cannot be controlled is needed, and this is where steady state money growth matters. The central bank's open market operations continue in the long run to affect nominal money growth. Thus, the steady state money demand (based on the quantity theory of money), delivered by a specified quantity of open market operations, provides a guide for hitting the desired inflation rate.

(ii) Measurement error

Beck and Wieland (2008) highlight that while potential output cannot be assessed with any certainty, research with Keynesian style models has nevertheless emphasised the importance of the output gap. They develop a justification for including money in the policy reaction (interest rate) rule by allowing for imperfect knowledge regarding unobservable variables such as potential output and the equilibrium interest rate. Through simulations based on US and Germany in the 1970s, the authors show that the misperceptions about potential output, which cause a bias in policy setting, make the long run relationship between money growth and inflation quite apparent, based on filtered measures of inflation and money growth. Essentially, the increase in average money growth and inflation is due to the same

[10] Ritter and Silber (1983, page 431), as quoted by Nelson.

source - persistent central bank misperceptions about potential output. "Cross-checking"[11] and changing the interest rate in response to sustained deviations of long run money growth helps the central bank overcome the bias.

(iii) Money as a proxy for yields on financial assets

Meltzer (1999) finds and Nelson (2000) reaffirms that real base money growth matters for economic growth (in the US and the UK respectively) for a given level of the short term real interest rate. This has to do with there being many real interest rates and asset prices that are relevant for economic activity and the real short term interest rate is an inadequate stand in for these yields. Meltzer (1995) asserts that changing base money and at the same time changing the stock of securities have different effects on the interest rate and asset price level. In an interest rate targeting framework, money supply changes to meet money demand. However, in equilibrium asset prices also change, which affects spending and output. Thus, "control of the interest rate does not avoid portfolio or output market responses and may amplify these responses", when the money and asset markets are interrelated. A key element in these mechanics is the supply of assets.

King (2002) notes "most finance theory is based on the assumption that equilibrium yields on assets, including risk premia, are independent of the quantities of the supplies of different assets. Hence the search for a better model of the monetary transmission mechanism is, in part, a search for evidence of supply effects on financial asset yields. That is why the view that money matters, over and above interest rates, is intimately bound up with a question of whether the supplies of different assets affect yields, and hence whether the composition of government debt affects both money and real economic behaviour".

A related argument is that money matters for the effectiveness of monetary policy at zero interest rates. King (2002) provides a succinct explanation of the hypothesis. "...if the demand for money is satiated at a finite level as interest rates

[11] The cross-checking interest rate rule consists of two elements: $i_t = i_t^{K/NK} + i_t^{CC}$, the first term on the right-hand side of the equation reflecting the optimal interest-rate policy conditional on the preferred Keynesian-style model and gap estimates and the second term reflecting the occasional adjustment in interest-rate levels due to cross-checking, that shows a shift in filtered money growth trends.

tend to zero, then the creation of money beyond that point would be translated into a demand for other assets and higher incomes. ...changes in household portfolios lead to changes in relative yields on different financial and real assets, and hence on asset prices and, in turn, real spending. Despite interest rates remaining at zero, monetary policy, in this world, can influence nominal spending and incomes".

From the above, the long run link between money and inflation and measurement error in key variables provide general reasons to include money in the aggregate supply-aggregate demand set up, notwithstanding short term money demand (velocity) instability. The third reason, money as a proxy for information on monetary conditions not summarised by the short-term interest rate, however, appears to be particular relevant in emerging economies that experience large external inflows and which carry out sterilisation, both of which affect the demand for and supply of financial assets and hence their yields (I discuss this in section 6(ii)a). Consequently, given the above, the inflation/Phillips Curve (2.1) is augmented to capture the role of money with a term representing money growth as follows:

$$\pi_t = \beta_1\pi_{t-1} + \beta_2\left(\Delta e_t + \pi_t^f\right) + (1-\beta_1-\beta_2)\Delta m_t + \beta_3 y_{g,t} + u_{\pi t} \qquad (5.1)$$

$\Delta m_t =$ percentage change in broad money

Long run homogeneity is assumed: $\beta_1 + \beta_2 + (1-\beta_1-\beta_2) = 1$

With intervention, inflation is less affected by the direct exchange rate channel in (5.1) as Δe_t is controlled. Nevertheless, the central bank would still need to be concerned about money growth affecting inflation and in particular the effects of its intervention and sterilisation operations. A situation of excess money growth coupled with resistance to appreciation pressure could prove particularly detrimental for inflation.

Conceptually, in terms of determinants, the change in broad money, ΔM, is made up of the change in net foreign assets and the change in net domestic assets (which encompasses credit growth). A simplification seen in Section (4) was that any accumulation of foreign assets is solely due to the central bank. I take this simplification further in the following sections, by assuming that the central bank's foreign exchange intervention is the only factor driving money growth. Essentially, I exclude the credit growth element.

(6) Monetary policy reaction function

I have thus far framed the discussion in the context of a monetary policy framework with an interest rate as the main policy instrument. Ho (2008) provides support for such an assumption for this model of a stylised emerging market economy though there are a few exceptions among the countries that enter the MSCI index for emerging market economies. The author finds, in a study of monetary operating frameworks in 17 countries as of March 2007, that most central banks express their official monetary policy stance in terms of an interest rate, for example, a central bank facility/operation rate, or a target for a market rate[12]. At the same time, the day-to-day operating objective of central banks has focused more on stabilising some measure(s) of short-term interest rate, less on targeting quantities (such as reserve money). With regards to the nature of instruments, there has been reduced use of direct controls, and more use of indirect instruments based on market mechanisms and incentives.

The monetary policy reaction function is derived by minimising (1.2) with respect to the policy instrument, i_t, subject to the constraints described in sections (2) to (5).

I explore three cases. First I leave money as exogenous and derive the monetary policy reaction function, as the baseline case. Then I consider the case of the monetary policy reaction function with intervention, in scenarios of complete and incomplete sterilisation.

[12] The survey includes the following Asian emerging market economies: China, Hong Kong, India, Indonesia, Korea, Malaysia, the Philippines, Taiwan, Thailand and Singapore. Ho notes that China represents a special case in terms of interest rates as policy rates: its formal policy rates are, unlike the others, not directly related to the money market but are instead the reference rates for 1-year bank lending and deposits. Further, in China and Taiwan, the formal operating target is still a quantity target (excess reserves and reserve money respectively, with Taiwan having an M2 growth target range). China's not yet fully functioning interest rate transmission channel and persistent excess liquidity make attention to quantity objectives a high priority. Ho also highlights that not all central banks express their policy stance with an interest rate. "Central banks running exchange rate based regimes with no capital controls obviously cannot independently set policy interest rates. The currency board regimes of Hong Kong and Macao are typically identified by their respective spot exchange rate anchors. Their domestic money market interest rates are endogenously determined by the forces of capital flows. Under Singapore's unique regime, the Monetary Authority expresses its policy stance with a qualitative statement about the centre, width and gradient of its target band for the Singapore dollar nominal effective exchange rate (NEER). Although the Singaporean regime allows much more flexibility than the single anchor regimes of Hong Kong and Macao, the high degree of capital mobility means that the Singapore dollar interest rate level is still broadly endogenous."

(i) Monetary policy reaction function with exogenous money

A reduced form of the inflation equation, (5.1), is derived, by substituting (3.1), the output gap equation into (5.1):

$$\pi_t = \beta_1\pi_{t-1} + \beta_2\left(\Delta e_t + \pi_t^f\right) + (1-\beta_1-\beta_2)\Delta m_t + \beta_3\gamma_1 y_{g,t-1} - \beta_3\gamma_2 i_t + \beta_3\gamma_2 E_t\pi_{t+1} + \beta_3\gamma_2 r_t^* + \beta_3\gamma_3(q_t - q_t^*) + \beta_3 u_{yt} + u_{\pi t} \quad (6.1)$$

Then

$$L_t = \frac{1}{2}\left[(\pi_t - \pi_t^T)^2 + \alpha(y_{g,t})^2\right]$$

$$L_t = \frac{1}{2}\Big[(\beta_1\pi_{t-1} + \beta_2\left(\Delta e_t + \pi_t^f\right) + (1-\beta_1-\beta_2)\Delta m_t + \beta_3\gamma_1 y_{g,t-1} - \beta_3\gamma_2 i_t + \beta_3\gamma_2 E_t\pi_{t+1} + \beta_3\gamma_2 r_t^* + \beta_3\gamma_3(q_t - q_t^*) + \beta_3 u_{yt} + u_{\pi t} - \pi_t^T)^2 + \alpha(\gamma_1 y_{g,t-1} - \gamma_2(i_t - E_t\pi_{t+1} - r_t^*) + \gamma_3(q_t - q_t^*) + u_{yt})^2\Big] \quad (6.2)$$

The loss function is minimised with respect to i_t:

$$\frac{\partial L}{\partial i_t} = 0$$

$$\left[\beta_1\pi_{t-1} + \beta_2\left(\Delta e_t + \pi_t^f\right) + (1-\beta_1-\beta_2)\Delta m_t + \beta_3\gamma_1 y_{g,t-1} - \beta_3\gamma_2 i_t + \beta_3\gamma_2 E_t\pi_{t+1} + \beta_3\gamma_2 r_t^* + \beta_3\gamma_3(q_t - q_t^*) + \beta_3 u_{yt} + u_{\pi t} - \pi_t^T\right](-\beta_3\gamma_2) + \alpha\left[\gamma_1 y_{g,t-1} - \gamma_2(i_t - E_t\pi_{t+1} - r_t^*) + \gamma_3(q_t - q_t^*) + u_{yt}\right](-\gamma_2) = 0 \quad (6.3)$$

Solving for i_t:

$$i_t = \frac{\beta_3}{\gamma_2({\beta_3}^2 + \alpha)}\left[\beta_1\pi_{t-1} + \beta_2\left(\Delta e_t + \pi_t^f\right) + (1 - \beta_1 - \beta_2)\Delta m_t + u_{\pi t} - \pi_t^T\right] + \frac{1}{\gamma_2({\beta_3}^2 + \alpha)}\left[\gamma_1\left({\beta_3}^2 + \alpha\right)y_{g,t-1} + \gamma_2\left({\beta_3}^2 + \alpha\right)E_t\pi_{t+1} + \gamma_2\left({\beta_3}^2 + \alpha\right)r_t^* + \gamma_3\left({\beta_3}^2 + \alpha\right)(q_t - q_t^*) + \left({\beta_3}^2 + \alpha\right)u_{yt}\right] \tag{6.4}$$

Simplifying (6.4) yields:

$$i_t = \frac{\beta_3}{\gamma_2({\beta_3}^2 + \alpha)}\left[\beta_1\pi_{t-1} + \beta_2\left(\Delta e_t + \pi_t^f\right) + (1 - \beta_1 - \beta_2)\Delta m_t + u_{\pi t} - \pi_t^T\right] + \frac{\gamma_1}{\gamma_2}y_{g,t-1} + E_t\pi_{t+1} + r_t^* + \frac{\gamma_3}{\gamma_2}(q_t - q_t^*) + \frac{1}{\gamma_2}u_{yt} \tag{6.5}$$

Equation (6.5) is the solution for the optimal interest rate policy in terms of various exogenous factors that determine inflation and the output gap. Faster money growth raises the inflation rate and thus requires a higher policy rate. Assuming that changes in money arise only from changes in $\Delta NFA_{cbi,t}$, then with no intervention, Δm_t=0 in (6.5). This is effectively a floating exchange rate regime. The exchange rate nevertheless still matters for interest rate policy decisions as the nominal exchange rate affects inflation directly Δe_t, (an increase (depreciation) leading to a rise inflation, and triggering an increase in the policy rate) and the real effective exchange rate affects the output gap. A positive deviation of the real effective exchange rate from equilibrium, $(q_t - q_t^*) > 0$ signals undervaluation and widens the output gap leading to a rise in the policy interest rate.

Higher lagged inflation, π_{t-1}, a rise in foreign inflation, π_t^f, and positive cost push shocks, $u_{\pi t}$, directly lead to higher inflation and a higher policy interest rate. A lower inflation target π_t^T requires a higher policy interest rate.

Higher lagged output gap, $y_{g,t-1,}$ higher expected inflation, $E_t\pi_{t+1}$(which lowers the real interest rate) and a rise in the natural rate of interest, r_t^* (which signals a wider gap against the actual real short term interest rate and hence an easing of policy) lead to a higher output gap, $y_{g,t}$ which requires a higher policy interest rate.

As set forth in (1.1), the parameter α reflects the weight the central bank places on output stabilisation relative to inflation stabilisation. From (6.5), it can be observed that as this parameter increases in size, the smaller are the coefficients on the factors affecting inflation directly.

Finally, in a floating exchange rate regime, it appears that the interest rate policy decision is independent of the foreign interest rate (given the specification of the inflation and output gap equations).

(ii) Monetary policy reaction function with intervention and sterilisation

In this section I consider how the optimal monetary policy reaction function would look like with intervention, with complete sterilisation as well as with less than complete sterilisation. In order to do this, I first clarify how intervention and sterilisation affect broad money and define complete sterilisation. I do this with the aid of a portfolio balance model of the monetary sector and this is discussed in the following subsection.

(a) Money, portfolio balance and sterilisation

The goal of sterilisation is to insulate domestic liquidity from foreign exchange intervention and maintain monetary policy independence. Under a floating exchange rate regime, large current account and capital account inflows lead to an exchange rate appreciation which offsets some of the inflationary risk associated with increased money and leads to some adjustment in inflows. In a fixed or closely managed exchange rate regime, the inflation risk and build up in domestic liquidity have to be managed in other ways, including through effective sterilisation.

With an interest rate target, base money and the central bank's NDA, which encompasses its monetary operations, become endogenous with the amount supplied depending on the demand for these balances given the central bank's mandate to maintain a specific short term interest rate level. The central bank conducts monetary operations (injecting or withdrawing liquidity) depending on the factors affecting liquidity, including foreign exchange intervention.

The notion of complete sterilisation depends on two factors – the monetary policy framework and the nature of instruments used. First, since in an interest rate targeting framework any amount of money is supplied to meet demand, incomplete sterilisation is possible even if it does not reflect an inability to "control" liquidity. Disyatat (2008) states: the liquidity impact of foreign exchange intervention in the money market is much the same as any other autonomous factor affecting liquidity and thus must be offset by the central bank to hold interest rates steady. I would refine this statement by clarifying that the extent to which any of the factors affecting liquidity are offset depend on the private sector's demand to hold money balances.

Second, the type of instruments used and the sector from which liquidity is absorbed, whether non-bank private agents or banks, have different effects on balance sheets and broad money. The effect is much less obvious in base money. Since broad money is a multiple of base money through the reserve-deposit and currency deposit ratios, what is observed is a fluctuation in the multiplier. Crucially, depending on how broad money is affected, this has an effect on the yields of financial assets, which affects monetary conditions even if the short term policy interest rate is unchanged. This can be illustrated with a simple asset portfolio model of the financial sector in the domestic economy as follows. The model considers if sterilising different types of flows –current account and capital account flows and using different sterilisation methods have different effects.

There are three financial assets available to the domestic non-bank private sector- domestic money, domestic bonds and equity[13]. The sum of these three assets is assumed to comprise total gross financial wealth[14]. For consistency with the discussion in Section (4), it is assumed that no foreign assets are held:

$$W = M + b^d + e^d \qquad (6.6)$$

Equity within the domestic economy is held by the domestic non-bank private sector and non-residents:

$$e^{td} = e^d + fe^d \qquad (6.7)$$

[13] It is assumed at this juncture that Ricardian equivalence does not hold, and holdings of Government bonds are considered as wealth, without implied future tax liabilities.

[14] At this point, I have kept the model to the basics, and have not shown the demand equations for each asset, for example, as in Argy and Murray (1985). This is an improvement to the paper which I will consider going forward, as it will also make observations about the impact on returns on financial assets more explicit.

Domestic bonds outside of the central banks' holdings are held by the domestic non-bank private sector, domestic banking institutions and non-residents:

$$b^{td} = b^d + bb^d + fb^d \tag{6.8}$$

W = wealth
M = domestic broad money
b^d = domestic bonds held by the domestic non bank private sector
e^{td} = total domestic equity
e^d = domestic equity held by the domestic non bank private sector
fe^d = foreign holdings of domestic equity
b^{td} = total domestic bonds
bb^d = domestic bonds held by banks
fb^d = foreign holdings of domestic bonds

To illustrate the effect of sterilisation, I assume a fixed exchange rate regime, so that the central bank intervenes in the full amount of current account and capital account inflows. Complete sterilisation would entail completely offsetting the impact of the resulting increase in the central bank's net foreign assets on broad money.

Consider as the first case, a rise in wealth due to a current account surplus. If the domestic non-bank private sector chooses to hold all this rise in wealth as money, $\Delta M = \Delta W$, there would be no impact on bond yields and stock prices (as demand for these assets are unchanged), If the central bank attempts to sterilise any amount of the increase in broad money, the return on domestic bonds (the supply of which has increased via the central bank's operations) must rise in order to induce residents to switch from money to bond holdings. If the central bank wants to avoid a rise in bond yields, arising from its operations, then it would allow broad money to increase, and not sterilise. It is important to note however, that under an interest rate targeting framework, the central bank still would absorb the resulting net domestic liquidity increase among banks (arising from the central bank's intervention operations) through its open market operations (using repos, the issuance of new securities or direct money market money borrowing) to the extent that is required to keep the short term interest rate target stable – thus increasing the money multiplier. The excess domestic liquidity absorbed from banks could, however, have an impact on monetary conditions if banks lower their retail interest rates. Additionally the pass through from the policy rate to banks' retail rates might be weakened.

If the exporters desire for a portion of the wealth arising from the current account surplus to be held in both bonds and equity, there would be downward pressure on bond yields and upward pressure on equity prices (assuming supply of these assets, b^{td} and e^{td} is unchanged). Broad money still increases as the purchase of the other two assets from other domestic residents transfers money to the sellers of these assets (in (6.6), $b^d + e^d$ is uchanged while M increases). In this scenario, the central bank, by partially sterilising the increase in broad money, can avoid the downward pressure on bond yields by supplying bonds as a sterilisation instrument. Monetary conditions are still looser, however, as stock prices are higher. If the central bank fully sterilised the increase in broad money, then there would be an increase in bond yields while stock prices are still higher – the net impact on monetary conditions is ambiguous.

Consider next a situation where there are non-resident inflows which are invested in existing assets (purchased from residents), and that these flows are only invested either in bonds and equity, but not deposits. M increases in (6.6) while e^d and b^d fall in (6.7) and (6.8). In (6.8), b^d falls, while fb^d increases. The increase in demand by non-residents for an existing pool of assets raises stock prices and pushes bond yields down. The central bank can avoid the fall in bond yields through the issuance of new securities, with non-residents taking up the securities. If non-residents chose only to invest in bonds, and the central bank fully met this demand, then there would be the following effects:

- In (6.6), there would be no change to any of the components of W.
- In (6.8), b^{td} increases with a rise in fb^d, while $b^d + bb^d$ is unchanged. The increased demand for bonds is met through the central bank increasing supply. (It is assumed that the increased supply of assets is perfectly substitutable for the type of assets (bonds) that non-residents actually demand).

From the above, several observations can be made in summary. Effectively, the non-bank private sector's demand for money, the choice of sterilisation instruments and the sector from which the central bank absorbs liquidity has an effect on the yields on financial assets and banks' excess domestic liquidity.

- The central bank can conduct sterilisation such that base money growth is limited, or sterilise broad money and limit the impact of an influx of liquidity on the yields of financial assets and banks' excess liquidity.

- Absorbing the net increase in domestic liquidity from banks as part of operations to keep the short term policy interest rate target stable does not offset the increase in M driven by inflows, or the impact on bond yields and stock prices. Monetary and financial conditions are still looser, with lower bond yields, higher stock prices and possibly lower retail interest rates among banking institutions due to excess liquidity.
- Absorbing liquidity or sterilising inflows at the source (exporters and non-residents) by increasing the supply of instruments to meet demand, offsets the downward pressure on bond yields, limits the increase in M and the build up of excess liquidity among banks.
- Attempting to sterilise at the source, by inducing the non-bank private sector to hold more bonds (and less money) than it wants to would lead to higher bond yields.

Based on the above, for the next stage of analysis, I make the assumption that there is a desire on the part of exporters and non-residents to channel trade inflows and capital account inflows respectively into bonds. As such, a complete sterilisation of these inflows by supplying the sought after assets offsets its impact on M and alleviates the downward pressure on bond yields, and at the same time does not cause a rise in yields.

I now consider the impact of intervention, and sterilisation on broad money in the wider context of the model presented in this paper. Any change in broad money, M, is assumed to arise from the central bank's foreign exchange intervention operations, $\mathrm{NFA}_{\mathrm{cbi,t}}$. Then I can write $\Delta \mathrm{m}_{\mathrm{t}}$ which appears in (5.1) as:

$$\Delta \mathrm{m}_{\mathrm{t}} = \mathrm{k}\Delta \mathrm{nfa}_{\mathrm{cbi,t}} \qquad (6.9)$$

$\Delta \mathrm{m}_{\mathrm{t}}$ and $\Delta \mathrm{nfa}_{\mathrm{cbi,t}}$ are percentage changes with $\mathrm{k} = \frac{\mathrm{NFA}_{\mathrm{cbi,t-1}}}{\mathrm{M}_{\mathrm{t-1}}}$.

Equivalently, $$\frac{\Delta \mathrm{M}_{\mathrm{t}}}{\mathrm{M}_{\mathrm{t-1}}} = \frac{\Delta \mathrm{NFA}_{\mathrm{cbi,t}}}{\mathrm{M}_{\mathrm{t-1}}} \qquad (6.10)$$

Then, substituting (4.10) into (6.10) gives[15]:

$$\frac{\Delta M_t}{M_{t-1}} = \frac{NGDP_t}{M_{t-1}}\left(\bar{t} + \left(\theta + \frac{\varphi}{c}\right)(q_t - q_t^*) + \left(\,{}^{1}\!/_{c}\right)(i_t - i_t^f) + u_{nk,t}\right) \quad (6.11)$$

I next define s, as the sterilisation coefficient. When s=1, complete sterilisation occurs, and thus the central bank's intervention operations has no impact on broad money.

$$\frac{\Delta M_t}{M_{t-1}} = \frac{(1-s)\Delta NFA_{cbi,t}}{M_{t-1}} \quad (6.12)$$

$$\frac{\Delta M_t}{M_{t-1}} = \frac{(1-s)NGDP_t}{M_{t-1}}\left(\bar{t} + \left(\theta + \frac{\varphi}{c}\right)(q_t - q_t^*) + \left(\,{}^{1}\!/_{c}\right)(i_t - i_t^f) + u_{nk,t}\right) \quad (6.13)$$

Setting $v = \frac{NGDP_t}{M_{t-1}}$,

$$\frac{\Delta M_t}{M_{t-1}} = v(1-s)\left(\bar{t} + \left(\theta + \frac{\varphi}{c}\right)(q_t - q_t^*) + \left(\,{}^{1}\!/_{c}\right)(i_t - i_t^f) + u_{nk,t}\right) \quad (6.14)$$

From (6.14), if the central bank is concerned about incomplete sterilisation (s<1), then it would have to consider the impact of the interest rate differential and possible exchange rate disequilibrium (particularly if it is a fixed exchange rate regime) on capital flows. It would have to take into account the effect of capital inflows on its interest rate setting decision (depending on the level of c). Reducing its degree of intervention and increasing uncertainty about the direction of the exchange rate could alleviate some of the pressure of capital inflows and hence the weight of it on the interest rate decision. The central bank would also be concerned about the inflationary/overheating consequences of large trade inflows driven by an undervalued exchange rate.

I next solve for the monetary policy reaction functions under two cases – with complete sterilisation of trade and capital inflows and less than complete sterilisation of these inflows.

[15] Note $\frac{\Delta M_t}{M_{t-1}} x \frac{NGDP_t}{NGDP_t} = \frac{\Delta NFA_{cbi,t}}{NGDP_t} x \frac{NGDP_t}{M_{t-1}}$

(b) Monetary policy reaction function with complete sterilisation

To derive the reduced form inflation equation with endogenous money, I first substitute Δm_t with $\frac{\Delta M_t}{M_{t-1}} = \frac{(1-s)\Delta NFA_{cbi,t}}{M_{t-1}}$, into (6.1):

$$\pi_t = \beta_1 \pi_{t-1} + \beta_2(\Delta e_t + \pi_t^f) + (1-\beta_1-\beta_2)\left[\frac{(1-s)\Delta NFA_{cbi,t}}{M_{t-1}}\right] + \beta_3\gamma_1 y_{g,t-1} - \beta_3\gamma_2 i_t + \beta_3\gamma_2 E_t\pi_{t+1} + \beta_3\gamma_2 r_t^* + \beta_3\gamma_3(q_t - q_t^*) + \beta_3 u_{yt} + u_{\pi t} \tag{6.15}$$

Following the same method of solving the loss minimisation problem as earlier, a similar monetary policy reaction function is derived:

$$i_t = \frac{\beta_3}{\gamma_2({\beta_3}^2+\alpha)}\left[\beta_1\pi_{t-1} + \beta_2(\Delta e_t + \pi_t^f) + (1-\beta_1-\beta_2)\left[\frac{(1-s)\Delta NFA_{cbi,t}}{M_{t-1}}\right] + u_{\pi t} - \pi_t^T\right] + \frac{\gamma_1}{\gamma_2}y_{g,t-1} + E_t\pi_{t+1} + r_t^* + \frac{\gamma_3}{\gamma_2}(q_t - q_t^*) + \frac{1}{\gamma_2}u_{yt} \tag{6.16}$$

If sterilisation was complete (s=1), (6.16) would be similar to (6.5) with $\Delta m_t = 0$. The policy interest rate would also be independent of the foreign interest rate. The difference would be that in (6.16), Δe_t would be smaller than in (6.5), as the central bank intervenes to limit nominal exchange rate volatility. In a fixed exchange rate regime, $\Delta e_t = 0$, shutting down the direct channel of exchange rate effect on inflation. However, the effect of the deviation of the real effective exchange rate from its equilibrium level, $(q_t - q_t^*)$, remains. In particular, in a fixed exchange rate regime, q_t remains relatively stable at a particular level, which arguably makes the exchange rate more susceptible to disequilibrium and possibly having a greater effect on the output gap than in (6.5). In addition, if for instance, q_t was at an appreciated level relative to q_t^* that is, $(q_t - q_t^*) < 0$, while based on the reaction function, this would entail a lower policy interest rate, at the same time it would lead to capital outflows. The central bank can support the particular level of the exchange rate with intervention without having to raise interest rates, but risks running down its international reserves.

(c) Monetary policy reaction function with incomplete sterilisation

If sterilisation of trade and capital inflows was incomplete, then the policy interest rate would need to rise. To consider the case of incomplete sterilisation more closely, I substitute for the determinants of $\Delta NFA_{cbi,t}$ following (6.14), into (6.15):

$$\pi_t = \beta_1\pi_{t-1} + \beta_2(\Delta e_t + \pi_t^f) + (1-\beta_1-\beta_2)\left[v(1-s)\left(\bar{t} + \left(\theta + \frac{\varphi}{c}\right)(q_t - q_t^*) + (1/c)(i_t - i_t^f) + u_{nk,t}\right)\right] + \beta_3\gamma_1 y_{g,t-1} - \beta_3\gamma_2 i_t + \beta_3\gamma_2 E_t\pi_{t+1} + \beta_3\gamma_2 r_t^* + \beta_3\gamma_3(q_t - q_t^*) + \beta_3 u_{yt} + u_{\pi t}$$

$$\pi_t = \beta_1\pi_{t-1} + \beta_2(\Delta e_t + \pi_t^f) - \left(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right) i_t + \beta_3\gamma_1 y_{g,t-1} + \beta_3\gamma_2 E_t\pi_{t+1} + \beta_3\gamma_2 r_t^* + (1-\beta_1-\beta_2)v(1-s)\bar{t} - (1-\beta_1-\beta_2)\frac{v(1-s)}{c} i_t^f + \left[\beta_3\gamma_2 + (1-\beta_1-\beta_2)v(1-s)\left(\theta + \frac{\varphi}{c}\right)\right](q_t - q_t^*) + (1-\beta_1-\beta_2)v(1-s)u_{nk,t} + \beta_3 u_{yt} + u_{\pi t} \quad (6.17)$$

Compared with (6.1) and (6.15) respectively (the no intervention and full sterilisation cases), in (6.17), the effect of the policy interest rate on inflation is now partly muted. The effect is more moderate the smaller is c. At the same time, the foreign interest rate now matters, and its effect is stronger the smaller is c. The smaller is c, for a shock to foreign interest rate and perceived real exchange disequilibrium, the stronger is the effect on inflation from capital inflows. Trade and capital flows, through unsterilised money, affect inflation.

Substituting (6.17) and (3.1) into the loss function:

$$L_t = \frac{1}{2}\left[(\pi_t - \pi_t^T)^2 + \alpha(y_{g,t})^2\right]$$

$$L_t = \frac{1}{2}\Bigg[\Big(\beta_1\pi_{t-1} + \beta_2(\Delta e_t + \pi_t^f) - \Big(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\Big) i_t + \beta_3\gamma_1 y_{g,t-1} + \beta_3\gamma_2 E_t\pi_{t+1} + \beta_3\gamma_2 r_t^* + (1-\beta_1-\beta_2)v(1-s)\bar{t} - (1-\beta_1-\beta_2) - (1-\beta_1-\beta_2)\frac{v(1-s)}{c} i_t^f + \Big[\beta_3\gamma_2 + (1-\beta_1-\beta_2)v(1-s)\Big(\theta + \frac{\varphi}{C}\Big)\Big](q_t - q_t^*) + (1-\beta_1-\beta_2)v(1-s)u_{nk,t} + \beta_3 u_{yt} + u_{\pi t} - \pi_t^T\Big)^2 + \alpha(\gamma_1 y_{g,t-1} - \gamma_2(i_t - E_t\pi_{t+1} - r_t^*) + \gamma_3(q_t - q_t^*) + u_{yt})^2\Bigg] \quad (6.18)$$

Minimising the loss function with respect to i_t:

$$\frac{\partial L}{\partial i_t} = 0$$

$$\frac{\partial L}{\partial i_t} = \Big[\Big(\beta_1\pi_{t-1} + \beta_2(\Delta e_t + \pi_t^f) - \Big(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\Big) i_t + \beta_3\gamma_1 y_{g,t-1} + \beta_3\gamma_2 E_t\pi_{t+1} + \beta_3\gamma_2 r_t^* + (1-\beta_1-\beta_2)v(1-s)\bar{t} - (1-\beta_1-\beta_2)\frac{v(1-s)}{c} i_t^f + \Big[\beta_3\gamma_2 + (1-\beta_1-\beta_2)v(1-s)\Big(\theta + \frac{\varphi}{C}\Big)\Big](q_t - q_t^*) + (1-\beta_1-\beta_2)v(1-s)u_{nk,t} + \beta_3 u_{yt} + u_{\pi t} - \pi_t^T - \pi_t^T\Big]\Big(-\Big(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\Big)\Big) + \big[\alpha(\gamma_1 y_{g,t-1} - \gamma_2(i_t - E_t\pi_{t+1} - r_t^*) + \gamma_3(q_t - q_t^*) + u_{yt})\big](-\gamma_2) = 0 \quad (6.19)$$

Solving for i_t:

$$i_t = \frac{1}{\left(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right)^2 + \alpha\gamma_2{}^2}\Bigg\{\left(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right)\Big[\beta_1\pi_{t-1} + \beta_2(\Delta e_t + \pi_t^f) + (1-\beta_1-\beta_2)v(1-s)\bar{t} - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}i_t^f\Big]$$
$$+\left[\left(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right)\beta_3\gamma_1 + \alpha\gamma_1\gamma_2\right]y_{g,t-1}$$
$$+\left[\left(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right)\beta_3\gamma_2 + \alpha\gamma_2{}^2\right]E_t\pi_{t+1}$$
$$+\left[\left(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right)\beta_3\gamma_2 + \alpha\gamma_2{}^2\right]r_t^*$$
$$+\left[\left(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right)(1-\beta_1-\beta_2)v(1-s)\left(\theta + \frac{\varphi}{C}\right) + \alpha\gamma_3\gamma_2\right](q_t - q_t^*) - \left(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right)\pi_t^T$$
$$+\left(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right)\left[(1-\beta_1-\beta_2)v(1-s)u_{nk,t} + u_{\pi t}\right]$$
$$+\left[\left(\beta_3\gamma_2 - (1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right)\beta_3 + \alpha\gamma_2\right]u_{yt}\Bigg\} \quad (6.20)$$

If sterilisation is incomplete (s<1), as in (6.20), three new terms appear in the monetary policy reaction function which affect the policy interest rate in different ways. These are $\bar{t}$ (exogenous trade flows), $u_{nk,t}$ (capital flows shocks) and the foreign interest rate i_t^f. The incomplete sterilisation of trade inflows and positive capital flows shocks, as discussed in subsection 6 ii(a), imply looser monetary and financial conditions (stronger money growth, lower bond yields and higher stock prices; excess liquidity among banking institutions potentially leading to a reduction in retail interest rates) and that the policy interest rate should be higher than it is. The foreign interest rate complicates monetary policy independence, particularly when c is small, that is, when the degree of international asset substitutability is high. A lower foreign interest rate triggers capital inflows, which if incompletely sterilised, entails a higher policy interest rate. If c approaches infinity (very low/limited international asset substitutability), then the interest rate differential would not induce capital inflows and it would not matter for the policy interest rate.

As long as $\left(1-\beta_1-\beta_2\right)\frac{v(1-s)}{c}>0$ (essentially when s<1), the coefficients on the output gap determinants $(y_{g,t-1}; E_t\pi_{t+1}; r_t^*; (q_t - q_t^*); u_{yt})$, that is the responses to demand driven shocks, are larger compared to the no intervention (6.5) and complete sterilisation (6.16) scenarios. The policy interest rate needs to respond more strongly as its effect on inflation is partly muted with the incomplete sterilisation of trade and capital inflows, which drive $\Delta NFA_{cbi,t}$ and hence Δm_t. The stronger money growth also drives a wedge between the policy interest rate and the yields on financial assets.

Meanwhile, the coefficients on $\pi_{t-1}, \Delta e_t, \pi_t^f, \pi_t^T$ and $u_{\pi t}$, that is the responses to inflation inertia, external and cost push/supply shocks, could be higher or lower in the incomplete sterilisation scenario compared to the cases of no intervention and complete sterilisation. The relative strength of the responses depends on the sensitivity of current inflation to the policy interest rate $\beta_3\gamma_2-(1-\beta_1-\beta_2)\frac{v(1-s)}{c}$, as well as the weight placed on output gap stabilisation, α. That is, comparing (6.20) against (6.5) and (6.16), if $\beta_3\gamma_2-(1-\beta_1-\beta_2)\frac{v(1-s)}{c}<\sqrt{\alpha}\gamma_2$, or rearranging to give $(\beta_3-\sqrt{\alpha})\gamma_2<(1-\beta_1-\beta_2)\frac{v(1-s)}{c}$, then $\frac{\beta_3\gamma_2}{\gamma_2{}^2(\beta_3{}^2+\alpha)}>\frac{\beta_3\gamma_2-(1-\beta_1-\beta_2)\frac{v(1-s)}{c}}{\left(\beta_3\gamma_2-(1-\beta_1-\beta_2)\frac{v(1-s)}{c}\right)^2+\alpha\gamma_2{}^2}$, and the policy interest rate response would be weaker in the case of incomplete sterilisation. More specifically, this occurs if (i) the sensitivity of current inflation to the policy interest rate $(\beta_3\gamma_2)$, which works through the output gap, is low, (ii) the weight on output stabilisation is high, (iii) the sensitivity of inflation to $\Delta NFA_{cbi,t}$ or Δm_t is high $((1-\beta_1-\beta_2))$[16], and (iv) capital mobility is high (c is low). Intuitively this makes sense. When there are external or cost push inflation shocks[17], which do not have a particularly strong effect on inflation, and a large policy interest rate change is required to effect a change in inflation, the central bank would do better by reacting less when it cannot fully sterilise compared to the situations where it does not intervene, or can carry out full sterilisation. This is particularly so when inflation is sensitive to incompletely

[16] Equivalently, the sensitivity of current inflation to lagged inflation β_1, and the nominal exchange rate change and foreign inflation (β_2) is low.
[17] As opposed to demand driven shocks to inflation.

sterilised money growth, which in turn is influenced by highly mobile capital flows sensitive to the interest rate differential.

Conclusion

The model presented shows the differences in the optimal monetary policy reaction function when the central bank does not intervene, and intervenes but either completely sterilises or only partially sterilises. It offers a fresh perspective by combining the elements of intervention and sterilisation within a monetary policy framework where the primary monetary policy instrument is the short term interest rate. This is consistent with actual practice among central banks, where monetary or liquidity operations are conducted to keep the operating target for this policy rate unchanged as long as the policy stance is unchanged.

With foreign exchange intervention, exchange rate volatility is reduced and there is less need for the central bank to adjust its policy interest rate in response to the effects of nominal exchange rate changes. At the same time however, the central bank still has to be concerned with the possibility of real effective exchange rate disequilibrium.

In the context of interest rate targeting, sterilisation to offset the effects of intervention is typically carried out to the extent necessary to keep the target for the policy rate at the desired level, using mainly market based instruments. The extent of sterilisation thus varies over time and with underlying economic conditions. Absorption of liquidity is of a “voluntary” nature as opposed to forced. The nature of sterilisation – the instruments used and the sector from which liquidity is absorbed, however, has implications for broad money growth and wider monetary and financial conditions, and therefore, the relative accommodativeness of policy. With complete sterilisation of trade and capital inflows (defined as offsetting the impact on broad money), the central bank is able to maintain monetary independence. Pressures are asymmetric, however, in the sense that preventing currency depreciation (rather than limiting currency appreciation) runs the risk of running down reserves, and thus raising interest rates may be an inevitable option (if the central bank does not consider alternative measures such as capital account restrictions) if a peg were to be maintained.

Incomplete sterilisation reduces monetary policy independence and effectiveness. Though the policy interest rate is unchanged, incomplete sterilisation affects broad money and wider monetary and financial conditions (such as yields on financial assets and banking institutions' liquidity positions). Incompletely sterilised trade and capital inflows lead to looser monetary conditions – stronger money growth and the development of a wedge between the short-term policy interest rate and other yields. Consequently the policy interest rate needs to be higher than it is (compared with the no intervention and complete sterilisation scenarios), particularly where demand shocks are concerned. At the same time an increase in the policy interest rate triggers another round of capital inflows, as the interest rate differential against the foreign interest rate widens. A change in the way the central bank manages its exchange rate and recourse to additional policy instruments and options become more critical in the incomplete sterilisation scenario.

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