Special Feature A

The Exchange Rate as an Instrument of Monetary Policy

by Ilian Mihov[1]

Introduction

Understanding the properties of alternative monetary policy rules and designing rules which maximise social welfare are important objectives, both from a policy point of view and from an analytical perspective. Following the seminal paper by Taylor (1993), research has focused on studying the properties of interest rate rules, with the majority of papers analysing theoretical or empirical models of closed economies. The celebrated Taylor rule prescribes that the monetary authority adjusts interest rates in response to deviations in inflation from a pre-specified implicit or explicit inflation target and to fluctuations in the output gap. Taylor's work has generated a large body of literature which has extended the policy rule by including additional variables, implementing different estimation techniques to determine the reactions of central banks to key macroeconomic variables, and building theoretical models to study the properties of these rules. Galí (2008) provides a useful overview.

In small open economies, however, the exchange rate is an important element of the transmission process of monetary policy (Svensson, 2000) and central banks in these economies generally prefer to keep it under tight control. The economic literature has incorporated these perspectives on exchange rate movements in two ways. First, a large number of papers evaluate the costs and benefits of fixed exchange rates (including Friedman, 1953; and Flood & Rose, 1995).[2] A second approach to incorporating the exchange rate into discussions of optimal monetary policy is by augmenting a closed-economy Taylor rule with an exchange rate variable. For example, De Paoli (2009) derives an optimal monetary policy rule within a dynamic stochastic general equilibrium (DSGE) model and shows that by putting some weight on real exchange rate fluctuations, a central bank can achieve improvements in social welfare.

In discussing how monetary authorities deal with exchange rates, research has focused on "corner solutions": either the currency rate is fixed by the central bank or government, or it is flexible and determined by market forces. In the latter case, the exchange rate does not enter the policy reaction function. In Mihov and Santacreu (2013), we evaluate the properties of an alternative class of policy rules which use the exchange rate as an instrument of monetary policy.[3] The exchange

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[2] The classic debate on fixed versus flexible exchange rate regimes is still ongoing, as indicated by several recent papers evaluating the costs and benefits within full-fledged microfounded dynamic stochastic general equilibrium (DSGE) models (e.g. Schmitt-Grohé and Uribe, 2011).

[3] This paper will also be released as an *MAS Staff Paper* on the MAS website at a later date. (URL http://www.mas.gov.sg/About-MAS/Monographs-and-information-papers/Staff-Papers.aspx)

rate is adjusted by the central bank in a manner similar to the use of interest rates as an operating instrument. We build a model in which the rate of currency appreciation is determined as a reaction to the rate of inflation and the output gap. Our goal is to establish whether there are economic structures for which the use of this exchange rate-based rule delivers higher social welfare compared to policies based on interest rate rules.

These considerations are most relevant for Singapore, a small open economy which conducts an exchange rate-based monetary policy. Accordingly, this Special Feature illustrates the results of the model and how it is consistent with the Singapore experience. It also offers a new test of the uncovered interest parity (UIP) hypothesis for Singapore. Before discussing the model, I will briefly examine the framework and formulation of monetary policy in Singapore.

Monetary Policy in Singapore and the "Basket, Band, Crawl" System

Unlike most central banks, the Monetary Authority of Singapore (MAS) does not rely on the overnight interest rate or any monetary aggregate as an instrument to implement its monetary policy. Since 1981, the operating instrument has been the exchange rate. Khor *et al.* (2007), McCallum (2007), and MAS (2012) offer detailed descriptions of the policy regime in Singapore. Many authors see Williamson (1998, 2001) as providing the analytical foundations of this system, since he proposed an intermediate exchange rate system in the form of an adjustable crawling peg with a band. The system is also referred to as BBC (basket, band, crawl) as the currency can be pegged against a basket of currencies in order to minimise misalignment with major trading partners. The crux of Williamson's argument is that the crawl or the level of the exchange rate must be adjusted to reflect differences in inflation and productivity trends between the domestic and foreign economies. In other words, the exchange rate must move over time towards its equilibrium value.

There can be little doubt that having the exchange rate aligned with the fundamentals is a valuable goal in the long run. In Mihov and Santacreu (2013), however, we argue that MAS goes beyond a simple adjustment towards equilibrium and uses the exchange rate to stabilise the business cycle. At the cyclical frequencies, the central bank reacts to changes in inflation and the output gap. As Parrado (2004) and McCallum (2007) show in standard reaction function estimations, the rate of inflation and the output gap have significant explanatory power for the appreciation of the Singapore dollar, while deviations of the exchange rate from equilibrium make only a marginal contribution.

To establish whether the exchange rate is indeed reacting to deviations of the inflation rate from an implicit (constant) target and to the magnitude of the output gap, I estimate the following reaction function:

$$\Delta e_t = \alpha + \beta E_{t-1}(\pi_{t+1} - \pi^T) + \gamma E_{t-1}(y_{t+1} - \bar{y}_{t+1}) + \rho \Delta e_{t-1} + \varepsilon_t \quad (1)$$

This is a forward-looking reaction function, originally proposed as an interest rate rule by Clarida *et al*. (2000) for a closed economy, in which the annualised rate of currency appreciation depends on the expected inflation for the next quarter, the expected deviation of output from potential (as a percentage of potential), and the lagged rate of appreciation. As explained in MAS (2012), there are two channels through which the rest of the world affects inflation in Singapore:

"First, … a stronger exchange rate makes imports cheaper and directly lowers domestic prices … The second underlying source of inflation in Singapore comes from the rising prices of domestic factor inputs ... which are influenced by external demand. Appreciating the exchange rate leads to lower demand for Singapore's exports." (MAS, 2012, pp. 38–39)

The formulation of the reaction function is consistent with this statement—inflation enters directly, while the output gap enters because it provides additional explanatory power for cost pressures, and thus, future inflation.

Using quarterly data from Q1 1981 to Q4 2012, I estimate this reaction function by using four lags of inflation and the output gap to instrument for the future values of these variables. The exchange rate is the nominal effective exchange rate from the IMF, and an increase in the rate implies appreciation of the Singapore dollar *vis-à-vis* the currencies of its trading partners.

The results from estimating regression (1) by instrumental variables are reported in Table 1.[4] Although there are some differences with Parrado (2004), Khor *et al.* (2007) and McCallum (2007), they can be attributed to the different sample periods, specifications and data frequencies. Irrespective of the specification, however, the key finding reported in all three papers and in this regression is that the Singapore dollar appreciates when expected inflation increases or when the output gap widens.

Both the empirical evidence, as well as communications from MAS, provide support for the notion that the central bank reacts to macroeconomic conditions at business cycle frequencies. Furthermore, according to standard policy objectives such as economic growth, stable inflation and low currency volatility, this policy has been quite successful over the past 30 years. Yet, it is still not clear whether the success of the central bank is due to the exchange rate policy rule or to other factors. For example, an important question is whether other countries should adopt a rule whereby the exchange rate is adjusted on a continuous basis as a reaction to the actual or expected level of inflation and the output gap. To understand the benefits of this rule relative to a standard interest rate rule, we need the discipline of a model with optimising agents, market clearing, and other features that are characteristic of recent advances in monetary policy analysis.

Table 1
MAS Reaction Function, Q1 1981–Q4 2012

Constant (α)	**Inflation** (β)	**Output gap** (γ)	**Lagged appreciation** (ρ)
−0.379	0.288**	0.276**	0.744***
(0.291)	(0.120)	(0.130)	(0.052)

Note: Robust standard errors in parentheses. Estimation by instrumental variables with four lags of inflation, and four lags of the output gap used to instrument for future inflation and future output gap.
** Statistically significant at the 5% level.
*** Statistically significant at the 1% level.

4 The first-stage regressions produced very high F-statistics, suggesting that the second-stage regression does not suffer from the problem of weak instruments.

A Dynamic Stochastic General Equilibrium Model with an Exchange Rate Rule

Understanding the costs and benefits of an exchange rate policy rule within a fully specified model is no trivial task. If the model features a UIP condition, then interest rate and exchange rate rules ought to generate equivalent outcomes.[5] Therefore, the new model can only provide interesting dynamics if it features some failure of UIP. Indeed, Alvarez *et al.* (2007) have argued forcefully that a key part of the impact of monetary policy on the economy goes through the conditional variances of macroeconomic variables rather than their conditional means. In terms of the UIP condition, the paper implies that a proper derivation of the interest parity condition generates a time-varying risk premium. Among recent papers on time-varying risk premiums, Verdelhan (2010) has shown how consumption models with external habit formation can generate countercyclical risk premiums that match key stylised facts quite successfully.

In Mihov and Santacreu (2013), we build a relatively standard New Keynesian small open economy model following Galí and Monacelli (2005). We analyse the performance of the model under two different policy rules: a standard Taylor rule in which the monetary authority sets interest rates, and an alternative monetary rule in which the authority sets the rate of appreciation or depreciation of the nominal exchange rate. We show that if UIP holds under certain parameterisations and assumptions, these rules are equivalent and generate identical responses to exogenous shocks, lead to the same time series properties of aggregate variables, and point to the same optimal monetary policy rule with regard to coefficients on the deviations of inflation and the output gap, and changes in exchange rates. The intuition is straightforward: there is a one-to-one correspondence between the interest rate and the rate of change in the nominal exchange rate if UIP holds, which allows us to replicate the Taylor rule by appropriately changing the exchange rate.

The interesting dynamics occur when we build into the model external consumption habit formation, following Campbell and Cochrane (1999), Verdelhan (2010), and De Paoli and Søndergaard (2009). Habit-based behaviour implies that if households experience a decline in consumption which brings them closer to the baseline, the drop in utility is much larger than in models without habit formation. This in turn generates time-varying risk aversion and changes households' behaviour over the business cycle. Such models have been used to explain the "forward premium" puzzle i.e. the failure of UIP in empirical studies. The essence of the argument is that a time-varying risk premium creates a wedge between interest rate differentials and the expected appreciation or depreciation of the exchange rate:

$$r_t - r_t^* = E_t \Delta e_{t+1} + RP_t \qquad (2)$$

The last term is derived from the model and it depends on the volatility of the exchange rate as well as the covariance between the appreciation of the currency and the change in the consumption growth path.[6]

5 There is a subtle point here. If an interest rate rule maximises social welfare, then the UIP states that the central bank can replicate the outcome by changing the exchange rate today and committing to future appreciation/depreciation of the currency. Implicit in this statement is that the central bank adjusts the money supply to ensure that the path is consistent with equilibrium. Similarly, an exchange rate rule can be replicated with an interest rate rule only if the central bank commits to the appropriate money supply path. While UIP determines the rate of appreciation (or the appropriate interest rate differential), it does not pin down the level of the exchange rate.

6 To be more precise, the covariance is between the appreciation of the currency and the logarithm of the stochastic discount factor. The latter is the log difference of the marginal utility of consumption tomorrow and the marginal utility of consumption today.

We calibrate and solve the model through numerical approximation techniques. The parameter values used to evaluate the dynamics implied by the two monetary rules are taken from Chow *et al.* (2011) and Khor *et al.* (2007), which were estimated using Singapore data. In addition, the calibrated degree of openness reflects Singapore's high level of trade intensity. After the model is calibrated, it is customary to examine what happens to the volatility of various macroeconomic variables under alternative rules or assumptions of the model. Table 2 presents the results for the Taylor rule and the exchange rate rule (ERR) under the assumptions of habit and no habit formation for households.

The results in Table 2 indicate that for a relatively open economy such as Singapore, the exchange rate rule reduces volatility quite substantially for both inflation and output. The reduction in volatility is quite small in the models without habit, but quite substantial in the models with external habit. For the latter, both output and inflation are five times less volatile in economies following an exchange rate rule compared to economies operating with a Taylor rule.[7]

Because the model is non-linear and involves higher-order terms, the mechanisms at work are relatively complicated. The basic intuition, however, is as follows: Habit formation introduces time-varying risk aversion. In good times, risk aversion declines sharply, while in bad times, it increases. To see its impact on the dynamics, let us suppose that there is a positive productivity shock in the economy. Output increases but due to rigidities in the economy, it does not reach the potential level immediately and the output gap remains negative for several periods (prices are adjusting slowly and for some producers they are set too high relative to the optimal level).

Under the Taylor rule, the central bank lowers interest rates since the output gap is negative. Lower interest rates generate a sharp depreciation of the currency with expected future appreciation (standard interest parity result). In models with habit formation, however, consumers also experience a reduction in their risk aversion, which leads to a further increase in consumption. This amplifies the initial reaction of output and also raises the demand for foreign goods, which in turn depreciates the currency even more. Prices of foreign goods increase even if the domestic price level falls. Depending on the openness of the economy, CPI may go up or down. For a highly open economy, the CPI may become quite volatile due to the overshooting of the exchange rate. Notice that the depreciation of the currency also increases the foreign demand for domestic goods, which exacerbates the initial output reaction.

Table 2
Volatility of Key Macroeconomic Variables

Variable	No Habit		With Habit	
	Taylor	ERR	Taylor	ERR
Output	0.0936	0.0873	0.5055	0.0983
Interest rate	0.0478	0.0455	0.1878	0.1725
Δe_t	0.0595	0.0590	0.2514	0.2229
Inflation	0.1033	0.0524	0.4142	0.0853
Terms of trade	0.0566	0.0277	0.4389	0.0708

Note: The model is expressed in logs, so the volatility can be interpreted in percentages.

7 These results have to be interpreted with caution as we continue to work on refining the calibration exercise. Based on the parameter values used to derive the results in Table 2, the volatility with habit under the Taylor rule is somewhat excessive. Currently we use the parameters for the Taylor rule as reported in Chow *et al*. (2011), but our future work will clarify whether we can improve the fit by modifying this reaction function.

With the exchange rate rule, the currency still needs to depreciate because of the negative output gap but the central bank—depending on the desired smoothness of the exchange rate—can implement a gradual depreciation. This will make the prices of foreign goods less volatile and therefore, foreign demand will increase less, leading to lower volatility of CPI and output.

The degree of openness will play a crucial role in terms of which rule performs better. In our calibration, even a 40% imports-to-GDP ratio results in significant benefits for the exchange rate rule. Clearly, Singapore's import intensity is well beyond this level.

Does UIP Hold for Singapore?

A substantial body of literature starting with Fama (1984) shows that UIP fails for a large set of countries and time periods. Lewis (1995) reviews the early literature, while Chinn (2012) offers an overview of the work since the mid-1980s. The fact that our model encompasses a failure of the interest parity condition is not only theoretically interesting, but also seems to be empirically relevant to studying macroeconomic dynamics for open economies. If time-varying risk premiums are indeed important and the exchange rate rule reduces these premiums, then it must be the case that UIP does not fail so badly for the Singapore dollar, compared to other currencies. Indeed, Khor *et al*. (2007) report that various studies of the interest parity condition find no failure of the basic condition for Singapore.

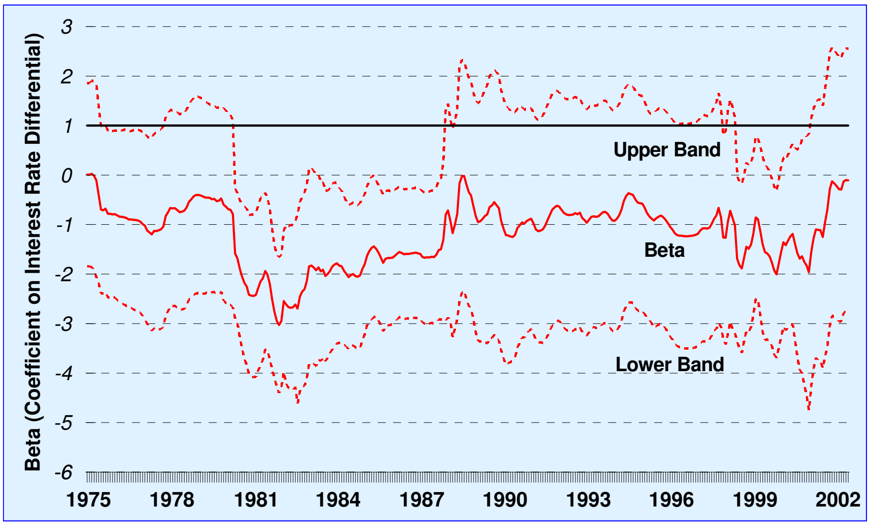
To investigate the link between interest rates and exchange rate depreciation, I estimate a sequence of rolling regressions using monthly data for the three-month S$ interbank offer rate, the three-month US$ interbank offer rate, and the S$/US$ exchange rate. The specification is as follows:

$$\Delta e_{t+1} = \alpha + \beta \left\{ log(1+r_t^{SGD}) - log(1+r_t^{USD}) \right\} + \varepsilon_t \qquad (3)$$

The two nominal interest rates are defined above. The nominal exchange rate is defined as the amount of S$ necessary to buy one unit of US$ (an increase in e_t implies an appreciation of the US$). The rolling regressions are estimated over a 10-year moving window. Chart 1 plots the coefficient on the interest rate differential, which under the null hypothesis must be equal to one.

As is common in such regressions, the estimated coefficient, β, is negative, indicating a bias in favour of US$-denominated securities. Interestingly, from the late 1980s, the coefficient becomes insignificantly different from one, as indicated by the 95% confidence bands. The exception is the period of the Asian Financial Crisis, roughly from the beginning of 1998 to the end of 2000. Of course, this only provides indirect evidence in support of a model where the interest parity condition holds due to a specific exchange rate rule. Nonetheless, the result is consistent with McCallum (1994), Anker (1999), and Backus *et al.* (2010), who all argue that deviations from UIP are due to the behaviour of monetary policy.

Chart 1
Rolling UIP Regressions (10-year Window)



The Zero Interest Rate Bound

In the past few years, the economic environment has brought an unexpected challenge to the exchange rate rule, stemming from the well-known zero lower bound on nominal interest rates. This minimum bound created a problem for economies that use the interest rate as an instrument of monetary policy, forcing them to switch to quantitative easing once interest rates reached zero.

For an economy operating with an exchange rate rule, the challenge is slightly different. Suppose the anchor currency is the US$ and interest rates in the US are zero. Further suppose that in the domestic economy, inflation increases and the central bank is forced to let the currency appreciate. If the currency is expected to appreciate slowly over time, the interest rate in the domestic economy must fall below the foreign rate (i.e. below zero) in order to preclude arbitrage opportunities. Otherwise, if interest rates are zero in both the domestic and foreign economies, and the domestic currency appreciates, there will be an arbitrage opportunity.

Interest rates cannot go below zero (at least not for a sustained period of time), so arbitrage is indeed possible. But arbitrage also implies that capital inflows increase, which in turn generates an increase in liquidity and higher inflationary pressures. These pressures call for a stronger appreciation, thereby increasing the attractiveness of investing in the domestic currency and ultimately creating an unstable dynamic. It is not clear how this explosive path will be resolved. Of course, if the global economy goes into recession, the pressure for appreciation will be reduced due to lower external demand. Alternatively, if the US starts to grow rapidly and the Fed raises interest rates, then the interest parity condition will be re-established because of higher foreign rates. If there is no external adjustment, however, the monetary authority may have to adjust its rule to take into account the zero lower bound.

One way that this challenge has been addressed in the case of Singapore is to make use of targeted macroprudential measures, as a complement to the exchange rate-based policy, to ensure financial stability and the alignment of asset price increases with economic fundamentals. The general conclusion is that with the zero lower bound in play, central banks need to resort to an additional instrument to complement monetary policy, in order to ensure macro-financial stability.

Sum-up

The use of the exchange rate as an instrument of monetary policy was pioneered by MAS and has supported Singapore's economic growth while ensuring low inflation since its implementation in 1981. Certainly, credit for this achievement also goes to other dimensions of economic policy. Nevertheless, this article has shown how a theoretical model based on optimising behaviour of households and producers and calibrated to the Singapore economy is able to generate powerful conclusions about the desirability of the exchange rate as an instrument of monetary policy.

More generally, Mihov and Santacreu (2013) show that in a standard microfounded monetary model, relatively open economies can generate an improvement in social welfare by adopting the exchange rate rule. The improvement comes from a reduction in the volatility of key macroeconomic variables such as inflation and output, especially when households exhibit habit formation behaviour.

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