Exchange rates, expected returns and risk: what can we learn from Asia-Pacific currencies?

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Abstract

This paper employs a risk-augmented asset price model of the exchange rate to compare the risk and return characteristics of a range of Asia-Pacific USD currency pairs. The Asia-Pacific currencies include a full range of exchange rate regimes, so provide a broad perspective of exchange rate behaviour. The results suggest that more managed exchange rates are associated with higher variance of the relative "bond premium" (the difference between observed interest rates and the underlying risk-free rate), lower variance of the "currency premium" (currency-specific premia and/or long-run fundamentals), and a slightly higher degree of risk-sharing. The results point to a role for risk and risk sharing in monetary policy trilemma trade-offs.

Keywords: exchange rate, asset price, currency risk, monetary policy trilemma, Asia-Pacific

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1. Introduction

Exchange rate behaviour is important for our understanding of cross-border financial linkages. In theory, uncovered interest parity (UIP) links exchange rates and relative interest returns. UIP is a workhorse in models used to assess optimal monetary policy in open economies. In a modern open-economy model, that parity condition also defines the monetary policy trade-offs between interest rate management and exchange rate management, akin to the trilemma trade-offs of Mundell (1983).[2] However, the standard empirical test of UIP fails systematically across currency pairs and across time periods.[3]

The standard test of UIP treats risk as exogenous because short-term interest rates are assumed to be risk-free. In practice, even highly rated government bills or central bank rates, can reflect a considerable "specialness premium" (Krishnamurthy and Vissing-Jorgensen (2012)), and any interest rate with a maturity greater than zero reflects a term premium, and from the foreign investor's point of view, currency revaluation risk (Lustig and Verdelhan (2007)). Munro (2014) derives a structural asset price model with risk adjustments, and shows, analytically, that the exchange rate and relative returns reflect common premia. Those common premia can severely bias the estimated exchange rate-interest rate relationship, if not accounted for.

This paper uses that structural framework to compare the risk and return properties of Asia-Pacific exchange rates and interest returns. The currencies examined in Munro (2013) were advanced country floating exchange rate currencies. Here that sample is extended to include six additional Asian currencies: the Hong Kong dollar (HKD), the Korean won (KRW), the Malaysian ringgit (MYR), the Philippine peso (PHP), the Singapore dollar (SGD) and the Thai baht (THB). The wider sample includes emerging market currencies, and is considerably more diverse in terms of exchange rate regimes. It includes more actively managed exchange rates, and the HKD provides a useful boundary case of a fixed exchange rate system (see Table 1).

The results for the additional Asian currencies both confirm the earlier results and provide a new perspective. As in Munro (2014),[4] a structural decomposition implies that, if risk is not accounted for, the estimated relationship between exchange rates and relative returns is severely biased. That bias is estimated to be even more severe for the more managed Asian exchange rate regimes.

The additional Asian currencies also provide a new perspective. The volatility of the relative bond premium – the spread between relative interest rate payoffs and relative risk-free interest rates, that is the source of reduced-form estimation bias, is larger for the additional Asian currencies. However, there appears to be a trade-off.

[2] In a financially open economy, we can either control the exchange rate or have independent monetary policy, but not both. See Obstfeld et al (2005) for an empirical overview.

[3] See Bilson (1981) and Fama (1984). For literature reviews, see Engel (2013), Engel (2012), Engel (1996), and Flood and Rose (1996).

[4] Munro 2014) examines eight advanced-country USD exchange rates: he Australian dollar (AUD), the Canadian dollar (CAD), the Swiss franc (CHF), the euro (EUR), the British pound (GBP) the Japanese yen (JPY), the New Zealand dollar (NZD) and the Swedish krona (SEK).

Larger bond premium volatility tends to be associated with lower volatility of the "currency premium" – an exchange rate premium that includes measures of risk and long-run exchange rate fundamentals, and with slightly greater risk-sharing. Those trade-offs are related to the IMF de facto classification of exchange rate arrangements (Habermeier et al (2009)), and are correlated with the reserves to GDP – an indicator of foreign exchange market intervention capacity. Those correlations suggest a role for risk and risk-sharing in trilemma trade-offs.

The model used in the paper is derived in Munro (2014), and builds on Engel and West (2010) and Lustig and Verdelhan (2007). The model is a structural two-equation, partial equilibrium model. The first equation is Engel and West (2010)'s asset price equation, augmented with explicit risk adjustments. The second expresses the difference between home and foreign interest payoffs in terms of risk adjustments, following Lustig and Verdelhan (2007). By accounting explicitly for risk, the structural model reveals an estimation bias problem in the reduced-form relationship between exchange rates and relative interest returns. The idea that the exchange rate risk premium is correlated with expected returns goes back at least to Fama (1984).

Burnside (2012) and Sarno et al (2012) show that measures of risk that help to price equities or bonds are not helpful in pricing exchange rates. Furthermore, non-traditional measures of risk that help to price exchange rates are unhelpful in pricing equity and bond markets. The unobserved bond and currency premia derived from the structural model are consistent with that empirical regularity.

This paper also relates to the literature on the monetary policy trilemma, or "impossible trinity". The trilemma (Mundell (1983)) is based on the Mundell-Fleming model,[5] which is inconsistent with UIP because it does not account for expectations (Wren-Lewis (2013), Dornbusch (1976a)), and does not account for risk. Both are central to the model employed here. In a modern, open-economy model, interest parity implies trade-offs similar to those in Mundell's trilemma (Obstfeld et al (2005)). In a financially open economy, taking the expected foreign interest rate path as given, policymakers can control either the domestic interest rate or the exchange rate, but not both. Arbitrage in vast foreign exchange markets and fixed-income markets determines the other. Therefore, policymakers face a trade-off between interest rate stabilisation and exchange rate stabilisation.

Monetary policy trade-offs are also affected by expectations about future interest rates and by risk. Central banks typically control the overnight interest rate, while the exchange rate reflects the entire expected future paths of home and foreign interest rates. Monetary policy influences expectations about the future interest rate path, but that influence is constrained by the economic outlook (Bernanke (2013)), and payoffs further into the future also reflect increasing risk premia. The results here link monetary policy trade-offs to risk and risk sharing.

Empirical assessments of the trilemma support the idea that additional exchange rate management reduces interest rate independence (for example, Obstfeld et al (2005) and Aizenman et al (2010)). The results here suggest that some Asian countries have achieved, to varying degrees, lower exchange rate variance through additional exchange rate management, and have given up a corresponding

[5] See Fleming (1962) and Mundell (1962).

degree of interest rate control. That is, countries are not necessarily limited to the "corners" of the trilemma (Klein and Shambaugh (2013)). The results imply that the trade-off between exchange rate stabilisation and interest rate stabilisation is mainly a trade-off between the risk premium components of interest rates and the exchange rate.

The next section describes the risk-augmented asset price model of the exchange rate employed in this paper. Section 3 describes the empirical approach used. Section 4 presents the structural decompositions and relates the results to exchange rate regimes. Section 5 concludes.

2. The asset price model of the exchange rate

The asset price model used for the empirical analysis is derived in Munro (2014). It is a partial-equilibrium, structural asset price model based on two equations. The first equation is an exchange rate asset price equation, as in Engel and West (2010). It expresses the log of the real exchange rate, q_t (the value of the foreign currency in terms of home currency), as its expected long-run equilibrium value, $E_t\overline{q}_t$, net of the sum of expected relative real interest returns, R_t, and the sum of expected excess returns to holding foreign currency:[6]

$$q_t = -R_t - \Lambda_t + E_t\overline{q}_t \tag{1}$$

where, the sum of expected future relative interest payoffs $R_t = E_t\sum_{k=0}^{\infty} r_{t+k}^{d}$ is an undiscounted sum of future home-foreign short-term interest differentials, r_t^d. The "level" excess return, $\Lambda_t = E_t\sum_{k=0}^{\infty}\lambda_{t+k}$, is the sum of expected one-period excess returns to holding foreign currency $\lambda_t \equiv E_t(q_{t+1}) - q_t - r_t^d$. The expected long-run equilibrium exchange rate $E_t\overline{q}_t$ reflects factors such as the terms of trade and relative productivity (Benigno and Thoenissen (2003)).

Abstracting from risk, if the home interest rate is expected to rise relative to the foreign rate, the no-arbitrage condition (UIP) requires an immediate appreciation of the home currency (Dornbusch (1976b)) so that it can depreciate over the period of relatively high home returns. The initial appreciation eliminates all future excess returns, while the subsequent depreciation offsets the higher interest payoffs, period by period, so there is no excess return to holding the home or foreign asset.

The short-term interest rate is often assumed to be risk-free. Government bills or central bank rates are often assumed to be risk-free because their credit default risk and liquidity risk are relatively low. However, government bills reflect different sovereign ratings and can reflect "specialness" premia associated with investment

[6] This asset price form of the UIP condition has been examined in real terms (Engel and West (2010)) and in nominal terms (Engel and West (2010), Nason and Rogers (2008) and Kano (2014)). It is derived from the home investor's Euler equations for home bonds and foreign bonds.

mandates and collateral value (Krishnamurthy and Vissing-Jorgensen (2012)). Interest rates with a maturity greater than zero also reflect interest rate risk and term premia, and from the foreign investor's point of view, currency revaluation risk (Lustig and Verdelhan (2007)).

Lustig and Verdelhan (2007) show that the observed short-term home-foreign interest differential, r_t^d , can be expressed as:

$$r_t^d = (r_t^f - r_t^{*f}) - [cov_t(m_{t+1}, r_t) - cov_t(m_{t+1}^*, r_t^*)] \tag{2}$$

where the unobserved home risk-free interest rate, r_t^f , is defined by the home investor's willingness to give up a unit of consumption today to consume $(1 + r_t^f)$ units of consumption next period.[7] Similarly, r_t^{*f} is the unobserved foreign risk-free rate, defined by the foreign investor's consumption discount factor. m_t is the log of the stochastic discount factor M_t defined by:

$$M_{t+1} = E_t \beta U'_{C,t+1} / U'_{C,t} = \frac{1}{1+r_t^f}$$

where, β is the subjective discount factor and $U'_{c,t}$ is the marginal utility of consumption.

The covariance terms in (2) are consumption risk adjustments. They increase yields on bonds that perform poorly in bad times, and reduce the yields on bonds that perform well in bad times, such as those denominated in reserve currencies. Lustig and Verdelhan show that, with complete risk-sharing (risk-free rates are equal and the interest differential reflects only risk premia), the second covariance term includes exchange rate revaluation risk. Empirically, they also show that high interest currencies depreciate, on average, when consumption growth is low.

The second equation in the structural asset price model is a forward-looking version of equation (2). It expresses expected relative interest returns, R_t, as the difference between expected home and foreign risk-free rates and a "bond premium" Λ_t^R that reflects consumption risk adjustments:

$$R_t = R_t^f - \Lambda_t^R \tag{3}$$

where $R_t^f = E_t \sum_{j=1}^{N} (r_{t+j-1}^f - r_{t+j-1}^{f*})$ and $\Lambda_t^R = E_t \sum_{j=1}^{N} \lambda_{t+j-1}^R$.

Interpreting Λ_t in terms of consumption risk-adjustments, Munro (2014) shows that equation (1) can be written as:

$$q_t = -R_t - \Lambda_t^R - \Lambda_t^{FX} \tag{4}$$

7 Depending on the formulation of the utility function, the risk-free rate is lower when people save more because they are patient, are averse to varying consumption across time (inter-temporal substitution), are averse to varying consumption across states (risk aversion) or if consumption growth is expected to be volatile (precautionary savings). See Cochrane (2001).

where $\Lambda_t^{FX} = \Lambda_t - \Lambda_t^R - E_t\overline{q}_t$ reflects a currency-specific premium, that reflects incomplete risk-sharing, and long-run fundamentals, such as relative productivity and the terms of trade. Despite the role of fundamentals, for convenience, here, we will refer to Λ_t^{FX} as the "currency premium".

Expected interest returns, R_t and the exchange rate excess return, Λ_t reflect common risk premia. If we assume that returns are risk-free, and estimate equation (4):[8]

$$\Delta q_t = -\alpha \Delta R_t \underbrace{-\Delta\Lambda_t + (E_{t+1}\overline{q}_t - E_t q_t)}_{\text{unobservables, } \varepsilon_{t+1}} \tag{5}$$

then our estimate of the parameter, α, will be biased:

$$\hat{\alpha} = \alpha + \frac{cov(-\Delta R_t, \varepsilon_{t+1})}{var(\Delta R_t)}$$

In the limit of complete risk-sharing,[9] consumption is perfectly correlated across countries, home and foreign risk-free rates are equal, and $m_t = m_t^*$. In that case, the risk-free interest rate differential is zero, and we should expect to estimate $\hat{\alpha} = 1 + \frac{cov_t(\Lambda_t^R, -\Lambda_t^R)}{var(\Lambda_t^R)} = 0$. In the complete risk-sharing case, there is complete disconnect in the reduced-form relationship between expected short-term interest returns and changes in exchange rates. There is also disconnect between measures of risk that price domestic asset markets and measures of risk that price the exchange rate (Sarno et al (2012), Burnside (2012)).

3. Empirical approach

3.1 Structural decomposition

To compare the risk and return characteristics of Asia-Pacific currencies, I first estimate the reduced-form relationship between exchange rates and expected returns (equation 5). Then I estimate the structural model defined by equations (3) and (4). The structural model decomposes the exchange rate and relative returns into three unobserved components – expected relative risk-free returns, R_t^f, the bond premium, Λ_t^R and the currency premium, Λ_t^{FX}, using q_t and R_t as observables.[10]

8 Engel and West (2007) examine the unconditional correlation between q_t and R_t in differences to ensure stationarity.

9 Complete risk-sharing is rejected in empirical studies (Backus and Smith (1993)). Kose et al (2003) find that, on average, consumption did not become more correlated across countries in the 1990s, despite financial integration.

10 Another potential empirical approach is instrumental variables. For example, the residual of equation (5) can be used as an instrument for the bond premium in equation (3). Thanks to Hugo Vega for suggesting this.

The variables q_t, R_t and $\Lambda_t = (q_t - R_t)$ test as integrated for most currency pairs (Table 2). Therefore, the model is estimated in differences.[11]

$$\Delta q_t = -\Delta R_t - \Delta\Lambda_t^R - \Delta\Lambda_t^{FX} \tag{6}$$

$$\Delta R = \Delta R_t^f - \Delta\Lambda_t^R \tag{7}$$

Intuitively, variation in q_t and R_t is attributed to three unobserved components: negative co-movement between q_t and R_t is attributed to R_t^f; other variation in R_t is attributed to the bond premium, Λ_t^R; and other exchange rate fluctuations are attributed to the currency premium Λ_t^{FX}.

The implied bias in the reduced-form equation (5) is the ratio of the variance of changes in the bond premium to the variance of ΔR_t. Since variances must be positive, the parameter, α, will be biased downwards from its risk-free value of one, consistent with the weak unconditional correlation between Δq_t and ΔR_t in Engel and West (2010) and Table 3.

Applying this framework to a broad set of currencies, including emerging market currencies and more managed exchange rate regimes, allows us to compare, across currency regimes, the properties of the unobserved components, R_t^f, Λ_t^R and Λ_t^{FX}, from the structural decomposition,.

3.2 Forecasts of real interest rate returns

To estimate the model (6) and (7) we need measures of q_t and R_t. Real exchange rates are constructed as nominal rates times relative consumer prices. For R_t, we need a forecast of future relative interest returns.[12]

The interest rate swap market provides a useful market-based measure of expected future short-term (Libor or equivalent) nominal returns. The swap rate is the rate the market is willing to pay (receive) in exchange for floating-rate interest payments (receipts). When participants agree on a fixed rate, it should provide a good forecast of future floating rate payments. The risk component of swap rates is generally low compared to bonds of the same maturity. No principal is exchanged, collateral may be posted against out-of-the-money positions, and the counterparties are often similarly rated banks (see Duffie and Singleton (1997)). However, they still reflect other premia such as term premia, interest rate risk and currency revaluation risk.

[11] Estimating in differences should also make estimates less sensitive to structural change. See Munro (2014) for robustness.

[12] Engel and West (2005, 2010) forecast future economic fundamentals, such as relative interest payoffs using AR(1) and VAR(2) models.

The N-period interest-rate swap provides a forecast of the discounted sum of future short-term nominal floating Libor interest rates:

$$(1+i_t^{PV})^N = E_t \prod_{k=1}^{N} \beta^k (1+i_{t+k-1})$$

taking logs,

$$Ni_t^{PV} \approx E_t \sum_{k=1}^{N} \beta^k i_{t+k}$$

These discounted, 10-year forecasts not quite the infinite, undiscounted sum we would like, but it is a market-based forecast of short-term interest returns over a long horizon, based on transacted prices.[13] Zero-coupon swaps would provide an undiscounted forecast of future short-term rates, but are not readily available for the additional six currencies.[14]

Expected relative real returns, R_t, are defined as expected relative nominal returns net of expected relative inflation:

$$\begin{aligned} R_t &= \sum_{k=0}^{119} (i_{t+k} - i_{t+k}^*) - E_t \sum_{k=1}^{120} (\pi_{t+k} - \pi_{t+k}^*) \\ &\approx 120(i_t^{sw10} - i_t^{*sw10}) - \frac{(\rho_\pi)^2(1-\rho_\pi^{120})}{1-\rho_\pi}(\pi_{t-1} - \pi_{t-1}^*) \end{aligned} \tag{8}$$

where home and foreign 10-year nominal swap rates i_t^{sw10} and i_t^{*sw10} (% per month) are multiplied by 120 months to proxy a 120 month sum of returns. The expected 10-year sum of future relative inflation is proxied by an N-period AR1 forecast, based on observed $t-1$ inflation.[15] The AR(1) coefficient for inflation is estimated jointly with other parameters.

3.3 Estimation, data and prior distributions

The model is estimated for the original eight US dollar (USD) currency pairs examined in Munro (2014), and six additional Asian USD currency pairs (see Table 1). For each USD currency pair, the model is estimated using demeaned observed data for the CPI-based real exchange rate, q_t, the 10-year swap

13 Those forecasts are the basis for a vast volume of transactions: the Bank for International Settlements (2013) reports that the notional amount of interest rate swaps outstanding globally in December 2012 was $490 trillion.

14 The Euler equations for home and foreign bonds, from which UIP is derived, are discounted sums. The relative price is undiscounted. Plain vanilla swap rates are highly correlated with zero coupon swaps, so plain vanilla swaps should provide a good proxy for movements in expected returns in our framework that relies on sign restrictions. Munro (2014) shows the results using zero-coupon and plain-vanilla swaps to be qualitatively similar. Kano (2014) argues that the appropriate discount rate is well below one.

15 Break-even inflation rates, derived from inflation-indexed bonds, might provide a better measure of expected inflation. In practice, inflation-indexed bonds are only systematically issued in a few jurisdictions, markets are often not very liquid and data samples are short.

differential, and relative annual CPI inflation $(\pi_t^{12} - \pi_t^{12*})$. The "home" currency is always the USD. The start date of the sample is limited by the available period for swap data on Bloomberg. The end of the sample is March 2014. Exchange rate and interest rate data are end-month. Data sources are shown in Appendix A.

The real exchange rates and forecasts of relative returns, R_t, are shown in Graph 1a for the original eight currencies and Graph 1b for the six additional Asian currencies. Descriptive statistics for q_t, R_t and Λ_t are shown in Table 3.

The model is estimated using Bayesian techniques.[16] In a first step, the mode of the posterior distribution is estimated by maximising the posterior function, that combines the prior information on the parameters with the likelihood of the data. In a second step, the Metropolis-Hastings algorithm is used to sample the posterior space and build the posterior distributions. The posterior distributions are from a Metropolis-Hastings chain, of which the first third is discarded. Acceptance rates are about 30%. Convergence is established using chi-squared statistics comparing the means of the beginning and end of the retained section of the Markov chain (Geweke (1992)). Dispersed priors restrict shock variances to be positive (Table 4).

For estimation, the full model also includes an expression for the forecast of expected real returns R_t (equation 8), accounting identities that relate levels and differences, and an AR(1) process for the evolution of annual inflation $(\pi_t^{12} - \pi_t^{12*})$.

4. Results

4.1 Posterior estimates

Table 4 reports the reduced-form estimates (top panel) and the structural estimates (bottom panel) for the 14 currency pairs. The posterior estimates of the parameters and shock standard deviations are well identified in the sense that the posterior distributions are distinct from the prior distributions as shown in Graph 2.

The estimates of α in equation (5) suggest a weak relationship between exchange rates and expected returns. The parameter α is consistently estimated to be well below one, consistent with the correlations reported in Engel and West (2010). The average estimate of α for the six additional Asian currencies (HKD, KRW, MYR, PHP, SGD and THB) is near zero. That is low compared a theoretical value of one,[17] and lower than the average reduced-form estimate of 0.44 for the original eight currency pairs.[18] How can we understand the weaker estimates for the

[16] See An and Schorfheide (2007) for a description of this methodology. The estimation is implemented in Dynare (Adjemian et al (2011)).

[17] The theoretical value for α may be greater than unity because we ignore interest rate differentials beyond 10-years and because we use a discounted sum of expected returns by using plain vanilla swaps rather than zero coupon swaps.

[18] This is higher than the 0.35 baseline estimate reported in Munro (2014) because the explanatory variable, R_t, is a smaller, discounted sum constructed from plain vanilla swaps rather than zero coupon swaps.

additional Asian currencies? While capital controls may play a role for some currencies, for others, such as the HKD, capital markets are very open.

From the perspective of the structural model (equations 6 and 7), the reduced-form estimate of α, is biased downward from one if observed interest returns are not risk-free. The downward bias is increasing in the volatility of the bond premium and falling in the volatility of R_t (bias $= -var(\Delta\Lambda_t^R)/var(\Delta R_t)$). The structural decomposition attributes the low reduced-form estimates to two factors. The main factor is the variance of the bond premium. The average standard deviation of changes in the bond premium for the six additional Asian currencies, at 2.9% is about double the average 1.4% for the original eight currency pairs.

The second factor that contributes to low reduced-form estimates is the variance of changes in relative risk-free returns. The average standard deviation of relative risk-free returns is slightly smaller for the additional Asian currencies, at 0.9%, compared to 1.2% for the eight original currency pairs. The lower variance of relative risk-free returns increases the reduced-form estimation bias by reducing the variance of R_t, the denominator in the bias equation.

The estimated volatility of relative risk-free returns is particularly low for the HKD and CAD, helping to explain the low reduced-form estimates of α for those currencies. The low variance of relative risk-free returns is interesting in terms of the higher implied degree of risk-sharing. As countries become more financially integrated, we expect consumption growth to be increasingly correlated, so that risk-free rates, defined by consumption discount factors, converge. The low estimated volatility of relative risk-free returns for the CAD and HKD relative to the USD suggest that the degree of financial market completeness increases with a common currency (Hong Kong SAR) or with a high degree of economic integration (Canada).

Together, the higher degree of risk-sharing (lower variance of the relative risk-free returns) and the larger relative bond premium imply severely biased estimates of α for the six additional Asian currencies. The implied reduced-form estimation bias is shown in the right hand column in the bottom section of Table 4. For the additional Asian currencies, the reduced-form estimation bias implied by the structural model averages –0.92, compared to –0.58 for the original eight currency pairs.

4.2 Variance decomposition

When observed interest rates are assumed to be risk-free, all of the variance of relative returns is attributed to relative risk-free rates (Table 5 top panel, last two columns). When risk is accounted for, the relative bond premium accounts for 55% of the variance in expected relative returns, on average (Table 5 bottom panel). For the additional six Asian currencies, the relative bond premium accounts for an average 88% of the variance of changes in expected relative returns.

When risk is accounted for, risk-free returns account for a considerably higher share of exchange rate variance. Relative risk-free returns account for an average 19% of exchange rate variance, compared to 5% in the reduced-form equation (Table 5, first three columns). For the additional six Asian countries, relative risk-free returns account for an average 24% of exchange rate variance, compared to 4% in the reduced-form equation. The contribution of relative risk-free returns to exchange rate variance is highest for the HKD at nearly 50%. Overall, even though UIP is assumed to hold in the structural decomposition, movements in the currency premium (risk and changes in expected long-run fundamentals) account for about three quarters of exchange rate variance, on average.

4.3 Unobserved components and exchange rate regimes

While the estimated bond premium volatility tends to be higher for the additional Asian currencies, there appears to be a trade-off. The volatility of the currency premium for those currencies (except the Korean won) is correspondingly smaller, and the volatility of relative risk-free returns is slightly smaller. Graph 3 illustrates those trade-offs.

In Graph 3, the currencies are ordered according to the ratio of the currency premium volatility to bond premium volatility. That ordering loosely groups the currencies according to IMF de facto exchange rate regimes.[19] At the right, the Hong Kong dollar (currency board, dark colour) has the highest currency premium to bond premium variance. The currencies classified as partly managed (medium colour) tend to lie towards the right. Currencies that are classified in the most freely floating category (lighter colour) over the whole 2000–12 period (see Table 1) tend toward the left, and have smaller relative bond premium volatility relative to currency premium volatility.

Another potential indicator of the exchange rate regime is the ratio of foreign currency reserves to GDP. The reserves to GDP ratio is an indicator of foreign exchange market intervention capacity. For more managed currencies a substantial stock of reserves is required to credibly stabilise exchange rates in the event of downward pressure on the currency. For countries with floating exchange rates, there is less reason to incur the carry cost of holding a large stock of reserves. Reserves tend to be expensive to hold because the tendency of reserve currencies to appreciate in bad times, when the marginal utility of consumption rises, lowers the yield on reserve currencies (Lustig and Verdelhan (2007)).

Graph 4 plots the standard deviations of the risk and risk-free components against reserves/GDP. For these 14 currencies, countries with greater foreign exchange market intervention capacity tend to have more volatile bond premia and less volatile currency premia. For the latter, the slope coefficient of -1.8% is significant to the 1% level. The slope coefficient for the bond premium is a little smaller in magnitude at 1.2%. It is not significant, unless the PHP outlier is removed, in which case, the slope coefficient is little changed, but is significant to the 1% level and the R^2 statistic increases from 0.12 to 0.57.

The standard deviation of innovations in relative risk-free rates declines slightly with reserves/GDP. The slope coefficient, at -0.40%, is relatively small and is significant to the 5% level. If the CAD is excluded, on the basis that close geography and trade integration might play a role in that case, the slope coefficient is still relatively small at -0.47, and is significant to the 1% level.

[19] There is no perfect measure of exchange rate regime and popular measures of regime are not highly correlated. See Klein and Shambaugh (2010) for a summary of the literature.

4.4 The trilemma and trade-offs

For a financially open economy, Mundell's trilemma is usually stated as a trade-off between capital mobility, a stable exchange rate, and the ability to conduct an independent monetary policy (Graph 5, top panel). Of those three, we can only achieve two. Mundell's monetary policy trilemma is based on the Mundell-Fleming model.[20] However, that model is inconsistent with UIP, because it abstracts from expectations (Wren-Lewis (2013), Dornbusch (1976a)), and abstracts from risk. Both are central to the model used here.

In a modern open-economy model, monetary policy trade-offs, akin to those of Mundell, can be stated simply in terms of interest parity (Obstfeld et al (2005)). As illustrated in the centre panel of Graph 5, with an open financial account, arbitrage is active and UIP links the exchange rate with expected relative returns. Taking the expected path of the foreign interest rate as given, the home policymaker can either stabilise the exchange rate or control the home interest rate path, but not both. Arbitrage in vast foreign exchange and fixed income markets pins down the other. When the trilemma is framed in terms of arbitrage, independent monetary policy has been replaced with stabilisation of the domestic interest rate path.[21]

The trade-off is not so simple when we consider expectations about future interest rates and risk, which also matter for the exchange rate. Central banks typically control an overnight interest rate, while the exchange rate reflects the entire expected future paths of home and foreign interest rates. The influence of short-term rates on longer-term rates, through the expectations hypothesis, is constrained by economic conditions (Bernanke (2013)).[22] Moreover, term premia are increasingly important for less certain payoffs further into the future.

The trade-off between volatility of the bond premium, the currency premium and, to a lesser extent, risk-free returns, and the correlation of those trade-offs with measures of the exchange rate regime (Graphs 3 and 4), suggest a role for risk and risk sharing in understanding monetary policy trade-offs (Graph 5, bottom panel). Exchange rate stabilisation is associated with lower currency premium variance, but with higher relative bond premium variance. That is, observed interest rates are further from the underlying risk-free rate.

The idea that the currency premium is less volatile in a managed exchange rate regime makes sense. If foreign exchange market intervention achieves the purpose of stabilising the exchange rate relative to the base country, then the less volatile exchange rate translates into a smaller currency premium. The larger "currency

20 See Mundell (1962) and Fleming (1962).

21 This formulation of the trilemma is helpful in understanding Singapore's monetary system. The objective of the Monetary Authority of Singapore is stated in terms of an inflation target, suggesting independent monetary policy, but is achieved through an intermediate exchange rate target with foreign exchange market intervention as the primary instrument. For a financially open economy, that combination appears to contradict Mundell's trilemma. While a managed exchange rate implies giving up control over the home interest rate path, there is no reason that the exchange rate target cannot be varied as a function of home inflation. In the Singaporean case, imports account for a large share of the CPI basket, so the exchange rate has a strong effect on inflation.

22 Future interest rates may be influenced through unconventional policies such as forward guidance and bond purchases. In addition, prudential policies may influence the supply/demand for credit.

premium" in floating exchange rate currencies may also reflect more variable long-run fundamentals that affect the choice of the exchange rate regime, ex ante.

Conversely, in floating exchange rate countries, monetary policy appears to stabilise the bond premium – the distance between observed interest rates and the underlying risk-free rate. That is consistent with the idea that optimal monetary policy, in a floating exchange rate regime, sets interest rates close to the underlying risk-free rate (Woodford (2003), Broadbent (2014)).

Asian countries appear to have achieved a varied degree of additional exchange rate management but to have given up a corresponding degree of interest rate control. That result supports the idea that countries may not be limited to "corner" solutions of the trilemma (Klein and Shambaugh (2013)).

4.5 Derived risk premia, capital flows and the VIX index

Through the lens of the risk-augmented asset price model, we have interpreted Λ_t^R as a bond premium and Λ_t^{FX} as a currency premium plus long-run fundamentals. However, we cannot rule out a role for the supply and demand effects of cross-border capital flows. Empirically, cross-currency flows are large and volatile,[23] so may have significant short-term effects on prices,[24] and reflect a variety of factors including, risk, portfolio shifts, "carry trade", safe-haven flows and central bank intervention.

Cerutti et al (2014) and Rey (2013) link the VIX index[25] to the global financial cycle and cross-border flows. Table 6 shows correlations between changes in the VIX index and changes in the exchange rates and the unobserved components. When the VIX index rises, non-reserve currencies depreciate (first column). Through the lens of the risk-adjusted model, non-reserve currencies depreciate because their currency premium rises relative to the USD.[26]

For some currencies, the foreign bond premium also rises relative to the USD when VIX rises, but that effect is generally weaker, is less consistent across currency pairs, and has little effect on the currency – only risk-adjusted returns matter for the exchange rate.

In practice, risk premia and capital flows are often closely related. Empirically, stress events are often associated with large capital flows. Uncertainty or a rise in

[23] For advanced countries, gross current account credits and debits typically account for less than 1% of foreign exchange market turnover reported in the BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity.

[24] Evans and Lyons (2002, 2006) show that flows through foreign currency markets have strong explanatory power for exchange rate movements.

[25] The VIX index is the implied volatility of the S&P 500 equity index.

[26] Changes in VIX tend to be dominated by periods of elevated uncertainty and safe haven flows. Speculative positioning in the International Money Market (IMM) of the Chicago Merchantile Exchange is perhaps more indicative of cross-border capital flows in normal times. In contrast to the correlations for changes in VIX, Munro (2014) shows that, when IMM positioning in a currency increases relative to the USD, that currency appreciates because the foreign bond premium falls and foreign risk-free returns rise relative to US risk-free returns. Those correlations do not inform on causality. IMM positioning is not reported for the additional Asian currencies.

risk may generate safe haven flows, or a retreat from risky assets; and expectation of flows in/out of asset markets, in turn, affect the risk of holding assets in those markets. In principle, assets can be repriced without actual flows (Fama (1965)), so a lasting role for flows implies some sort of limit to capital free arbitrage (Shleifer and Vishny (1997)).

5. Conclusions

This paper examined the risk and return properties of exchange rates and expected relative interest returns, for a diverse group of currencies, including nine Asia Pacific currencies. Extending the analysis of Munro (2014) to include six additional Asian currencies both confirms the original results and provide a new perspective.

When risk is not accounted for, the relationship between exchange rates and expected returns is estimated to be weak, and even weaker for the additional six Asian USD currency pairs. That weaker reduced-form relationship for more managed currencies can be understood in terms of a larger wedge between the underlying risk-free rate and the observed interest rate. That wedge – the bond premium – is a source of reduced-form estimation bias. When risk is accounted for, relative risk-free returns account for about 20% of exchange rate variance, on average, compared to about 5% when interest rates are assumed to be risk-free. Overall, even when UIP holds, the bulk of exchange rate variation is attributed to currency-specific premia, linked to incomplete risk sharing, and to short-term changes in expected long-run fundamentals.

The additional Asian currencies provide a new perspective. There appears to be a trade-off between bond premium volatility and volatility of the currency premium or fundamentals. That trade-off is significantly related to measures of the exchange rate regime. Countries with more managed exchange rates have more volatile bond premia and correspondingly less volatile currency premia or long-run fundamentals. To a lesser extent, more managed currencies' risk-free rates move more closely with US risk-free rates. Asia-Pacific currencies span a full range of exchange rate regimes and risk premium trade-offs. The paper supports the idea that countries are not limited to the corners of the trilemma, and points to a role for risk and risk-sharing in monetary policy trilemma trade-offs.

IMF de facto exchange rate classification 2000–12

Table 1

	2000	2002	2004	2006	2008	2010	2012
Additional six Asian currencies							
HKD	CB	CB	CB	CB	CB	CB	CB
MYR	P	P	P	MF	MF	MF	MF
SGD	MF	MF	MF	MF	MF	MF	MF
THB	FF	MF	MF	MF	MF	F	F
PHP	FF	FF	FF	FF	FF	F	F
KRW	FF	FF	FF	FF	FF	F	F
Original currency pairs							
CHF	FF	FF	FF	FF	FF	FF	MF
AUD	FF	FF	FF	FF	FF	FF	FF
CAD	FF	FF	FF	FF	FF	FF	FF
EUR	FF	FF	FF	FF	FF	FF	FF
GBP	FF	FF	FF	FF	FF	FF	FF
JPY	FF	FF	FF	FF	FF	FF	FF
NZD	FF	FF	FF	FF	FF	FF	FF
SEK	FF	FF	FF	FF	FF	FF	FF

Source: International Monetary Fund, Annual Report, various issues. The IMF classification system was revised in 2009 (see https://www.imf.org/external/pubs/cat/longres.aspx?sk=23311.0.).

Note: CB=currency board, P=other pegged arrangement, MF=managed float, F=floating with some intervention, FF=freely floating. HKD=Hong Kong dollar, MYR=Malaysian ringgit, SGD=Singapore dollar, THB=Thai baht, PHP=Phillipine peso, KRW=Korean won, AUD=Australian dollar, CAD=Canadian dollar, CHF=Swiss franc, EUR=euro, GBP=Bristish pound, JPY=Japanese yen, NZD=New Zealand dollar, SEK=Swedish krona. All currencies are measured against the US dollar.

Unit root tests

Table 2

	Real exchange rate, q_t			Forecast returns, R_t			$\Lambda_t = -(q_t + R_t)$		
	Statistic	lag		statistic	lag		statistic	lag	
				Levels					
AUD	–2.8	0	*	–2.0	0		–2.1	0	
CAD	–2.6	0		–2.2	0		–2.0	0	
CHF	–3.5	0	***	–2.3	0		–2.3	0	
EUR	–2.2	0		–2.2	0		–2.2	0	
GBP	–2.9	0	*	–2.3	0		–2.4	0	
JPY	–2.1	0		–2.6	0		–2.8	0	*
NZD	–3.9	0	***	–2.3	0		–2.1	0	
SEK	–2.8	0	*	–2.0	0		–2.2	0	
KRW	–2.5	2		–2.4	0		–2.3	0	
HKD	–3.3	0	**	–1.5	1		–3.8	0	***
SGD	–2.5	0		–2.6	0		–3.5	0	***
MYR	–3.4	0	**	–2.0	0		–3.0	0	**
PHP	–3.1	0	**	–3.4	0	**	–3.0	0	**
THB	–3.4	0	**	–3.6	0	***	–3.3	0	**
				Differences					
AUD	–14.8	0	***	–15.4	0	***	–15.5	0	***
CAD	–16.7	0	***	–15.7	0	***	–16.4	0	***
CHF	–16.0	0	***	–13.4	1	***	–16.0	0	***
EUR	–13.9	0	***	–14.9	0	***	–13.5	0	***
GBP	–15.0	0	***	–13.6	1	***	–15.4	0	***
JPY	–15.5	0	***	–14.5	1	***	–17.0	0	***
NZD	–6.6	2	***	–13.1	1	***	–15.2	0	***
SEK	–15.3	0	***	–15.6	0	***	–15.8	0	***
KRW	–13.1	0	***	–12.9	1	***	–12.8	0	***
HKD	–13.2	0	***	–15.1	0	***	–15.4	0	***
SGD	–15.4	0	***	–13.9	0	***	–14.5	0	***
MYR	–11.4	0	***	–12.1	0	***	–10.1	1	***
PHP	–13.1	0	***	–13.7	0	***	–13.9	0	***
THB	–11.6	0	***	–14.6	0	***	–15.1	0	***

Notes: Dickey and Fuller (1979) test using the Schwarz/Bayesian Information Criterion to select lag length. Maximum lag of 2. *** indicates significance at the 1% level; ** indicates significance at the 5% level; * indicates significance at the 10% level. See Table 1 for abbreviations.

Estimated standard deviations and correlations of q, R, and Λ

Table 3

		Levels						Differences				
		q	R		Λ			q	R		Λ	
AUD	q	22.16	–0.79	***	–0.96	***	Δq	3.58	–0.32	***	–0.89	***
	R		7.74		0.58	***	ΔR		1.62		–0.14	**
	Λ				16.74		$\Delta\Lambda$				3.43	
CAD	q	14.22	–0.05		–0.94	***	Δq	2.42	–0.05		–0.88	***
	R		4.90		–0.28	***	ΔR		1.27		–0.43	***
	Λ				14.79		$\Delta\Lambda$				2.68	
CHF	q	14.34	–0.58	***	–0.91	***	Δq	3.21	–0.21	***	–0.84	***
	R		6.02		0.19	***	ΔR		1.84		–0.35	***
	Λ				11.91		$\Delta\Lambda$				3.34	
EUR	q	14.94	–0.38	***	–0.94	***	Δq	3.16	–0.31	***	–0.87	***
	R		5.06		0.04		ΔR		1.60		–0.20	***
	Λ				13.84		$\Delta\Lambda$				3.07	
GBP	q	7.88	–0.27	***	–0.82	***	Δq	2.38	–0.24	***	–0.77	***
	R		4.77		–0.33	***	ΔR		1.68		–0.43	***
	Λ				8.04		$\Delta\Lambda$				2.57	
JPY	q	14.17	–0.13	**	–0.82	***	Δq	3.18	–0.19	***	–0.78	***
	R		9.14		–0.46	***	ΔR		2.24		–0.47	***
	Λ				15.86		$\Delta\Lambda$				3.53	
NZD	q	21.50	–0.59	***	–0.98	***	Δq	3.83	–0.29	***	–0.88	***
	R		5.04		0.41	***	ΔR		1.87		–0.21	***
	Λ				18.95		$\Delta\Lambda$				3.75	
SEK	q	13.24	–0.51	***	–0.75	***	Δq	3.30	–0.25	***	–0.84	***
	R		8.93		–0.19	***	ΔR		1.91		–0.32	***
	Λ				11.59		$\Delta\Lambda$				3.38	
KRW	q	17.69	0.29	***	–0.97	***	Δq	3.57	0.06		–0.84	***
	R		5.39		–0.53	***	ΔR		2.43		–0.59	***
	Λ				19.94		$\Delta\Lambda$				4.44	
HKD	q	11.81	–0.75	***	–0.75	***	Δq	0.84	–0.12	*	–0.22	***
	R		7.88		0.12	**	ΔR		2.46		–0.94	***
	Λ				7.88		$\Delta\Lambda$				2.50	
SGD	q	12.76	–0.57	***	–0.87	***	Δq	1.95	–0.12	*	–0.59	***
	R		6.37		0.08		ΔR		2.29		–0.73	***
	Λ				10.55		$\Delta\Lambda$				2.82	
MYR	q	8.56	–0.65	***	–0.54	***	Δq	1.84	0.05		–0.68	***
	R		7.51		–0.29	***	ΔR		2.08		–0.76	***
	Λ				6.82		$\Delta\Lambda$				2.85	
PHP	q	16.99	0.84	***	–0.94	***	Δq	2.05	0.44	***	–0.67	***
	R		25.52		–0.97	***	ΔR		5.65		–0.96	***
	Λ				40.85		$\Delta\Lambda$				6.81	
THB	q	15.16	–0.24	***	–0.92	***	Δq	1.82	–0.02		–0.52	***
	R		5.89		–0.15	**	ΔR		2.86		–0.84	***
	Λ				14.89		$\Delta\Lambda$				3.36	
averages	q	14.67	–0.31		–0.87		Δq	2.65	–0.11		–0.73	
	R		7.87		–0.13		ΔR		2.27		–0.53	
	Λ				15.19		$\Delta\Lambda$				3.47	

Notes: Following Table 1 in Engel and West (2010), diagonal elements are standard deviations; off-diagonal elements are correlations. Expected relative returns, R_t , is the 10-year interest rate swap differential, net of an AR(1) relative inflation forecast. $\Lambda_t \equiv -(q_t + R_t)$.

*** indicates significance to the 1% level; ** to the 5% level, and * to the 10% level. See Table 1 for abbreviations.

Prior and posterior estimates

(Forecasts of expected returns from plain-vanilla interest rate swaps) Table 4

	α	σ^{R^f}	σ^{Λ^R}	$\sigma^{\Lambda^{FX}}$	ρ^{π}	σ^{π}	$\hat{\alpha}$ Bias
Distribution	N	γ^{-1}	γ^{-1}	γ^{-1}	β	γ^{-1}	
Prior mean	1	0.020	0.020	0.020	0.8	0.0003	$\frac{var(\Delta\Lambda_t^R)}{var(\Delta R_t)}$
Prior stdev	0.5	0.50	0.50	0.50	0.1	0.0050	
Reduced form model (Risk treated as exogenous $\Lambda^R = 0$)							
AUD	0.71	0.016	–	0.034	0.88	0.00048	
CAD	0.12	0.013	–	0.024	0.89	0.00029	
CHF	0.40	0.019	–	0.031	0.89	0.00028	
EUR	0.64	0.016	–	0.030	0.89	0.00030	
GBP	0.35	0.017	–	0.023	0.93	0.00033	
JPY	0.27	0.022	–	0.031	0.92	0.00037	
NZD	0.61	0.019	–	0.037	0.87	0.00045	
SEK	0.42	0.019	–	0.032	0.91	0.00035	
KRW	–0.08	0.024	–	0.036	0.87	0.00044	
HKD	0.04	0.025	–	0.009	0.92	0.00073	
SGD	0.10	0.023	–	0.019	0.91	0.00051	
MYR	–0.03	0.021	–	0.019	0.85	0.00055	
PHP	–0.16	0.056	–	0.019	0.91	0.00061	
THB	0.01	0.029	–	0.018	0.87	0.00046	
Avg. Orig8	0.44	0.018	–	0.030	0.90	0.00036	
Avg.Asian6	–0.02	0.030	–	0.020	0.89	0.00055	
Structural decomposition							
AUD	1	0.013	0.011	0.033	0.89	0.00048	–0.42
CAD	1	0.008	0.011	0.024	0.89	0.00028	–0.70
CHF	1	0.012	0.014	0.030	0.89	0.00029	–0.59
EUR	1	0.012	0.011	0.029	0.89	0.00030	–0.45
GBP	1	0.011	0.014	0.022	0.93	0.00033	–0.65
JPY	1	0.012	0.019	0.029	0.92	0.00037	–0.72
NZD	1	0.014	0.013	0.036	0.87	0.00045	–0.48
SEK	1	0.013	0.015	0.031	0.91	0.00035	–0.59
KRW	1	0.010	0.023	0.035	0.87	0.00044	–0.87
HKD	1	0.006	0.024	0.007	0.92	0.00073	–0.94
SGD	1	0.010	0.021	0.017	0.91	0.00051	–0.84
MYR	1	0.009	0.020	0.017	0.85	0.00055	–0.90
PHP	1	0.009	0.058	0.019	0.91	0.00062	–1.05
THB	1	0.010	0.027	0.016	0.87	0.00046	–0.91
Avg.Orig.8	1	0.012	0.014	0.029	0.90	0.00036	–0.58
Avg.Asian6	1	0.009	0.029	0.019	0.89	0.00055	–0.92

Notes: The posterior mode is the maximum of posterior distribution. The standard asset price model is subject to the restriction $\alpha > 0$ and Bayesian priors. α is the exchange rate response to expected interest returns. $\rho\pi$ is the AR(1) coefficient for relative inflation. σ_{R^f} , σ_R , σ_{FX} and σ_π are the standard deviations of the innovations in risk-free relative returns, the bond premium, the currency premium and of relative inflation respectively. See Table 1 for abbreviations.

Unconditional variance decomposition

Table 5

variable →	Exchange rate			Expected returns	
innovation →	relative risk-free returns	common bond premium	idiosyncratic currency premium	relative risk-free returns	common bond premium
	Reduced-form model (Risk treated as exogenous $\Lambda^R = 0$)				
AUD	10.59	–	89.41	100	–
CAD	0.44	–	99.56	100	–
CHF	5.20	–	94.80	100	–
EUR	10.66	–	89.34	100	–
GBP	6.09	–	93.91	100	–
JPY	3.55	–	96.45	100	–
NZD	8.72	–	91.28	100	–
SEK	6.10	–	93.90	100	–
KRW	0.29	–	99.71	100	–
HKD	1.42	–	98.58	100	–
SGD	1.39	–	98.61	100	–
MYR	0.09	–	99.91	100	–
PHP	18.29	–	81.71	100	–
THB	0.04	–	99.96	100	–
Average	5.21	–	94.80	100	–
	Structural decomposition				
AUD	13.43	–	86.57	60.50	39.50
CAD	10.21	–	89.79	35.27	64.73
CHF	14.42	–	85.58	42.49	57.51
EUR	15.84	–	84.16	56.93	43.07
GBP	20.16	–	79.84	38.61	61.39
JPY	15.24	–	84.76	30.39	69.61
NZD	13.19	–	86.81	53.35	46.65
SEK	15.38	–	84.62	43.37	56.63
KRW	8.13	–	91.87	17.15	82.85
HKD	46.87	–	53.13	6.58	93.42
SGD	25.22	–	74.78	18.61	81.39
MYR	21.52	–	78.48	17.52	82.48
PHP	16.73	–	83.27	2.20	97.80
THB	27.69	–	72.31	11.75	88.25
Average	18.86	–	81.14	31.05	68.95

Note: for this random walk model, the unconditional variance decomposition and forecast error variance decomposition are identical. See Table 1 for abbreviations.

Correlations of innovations with changes in VIX

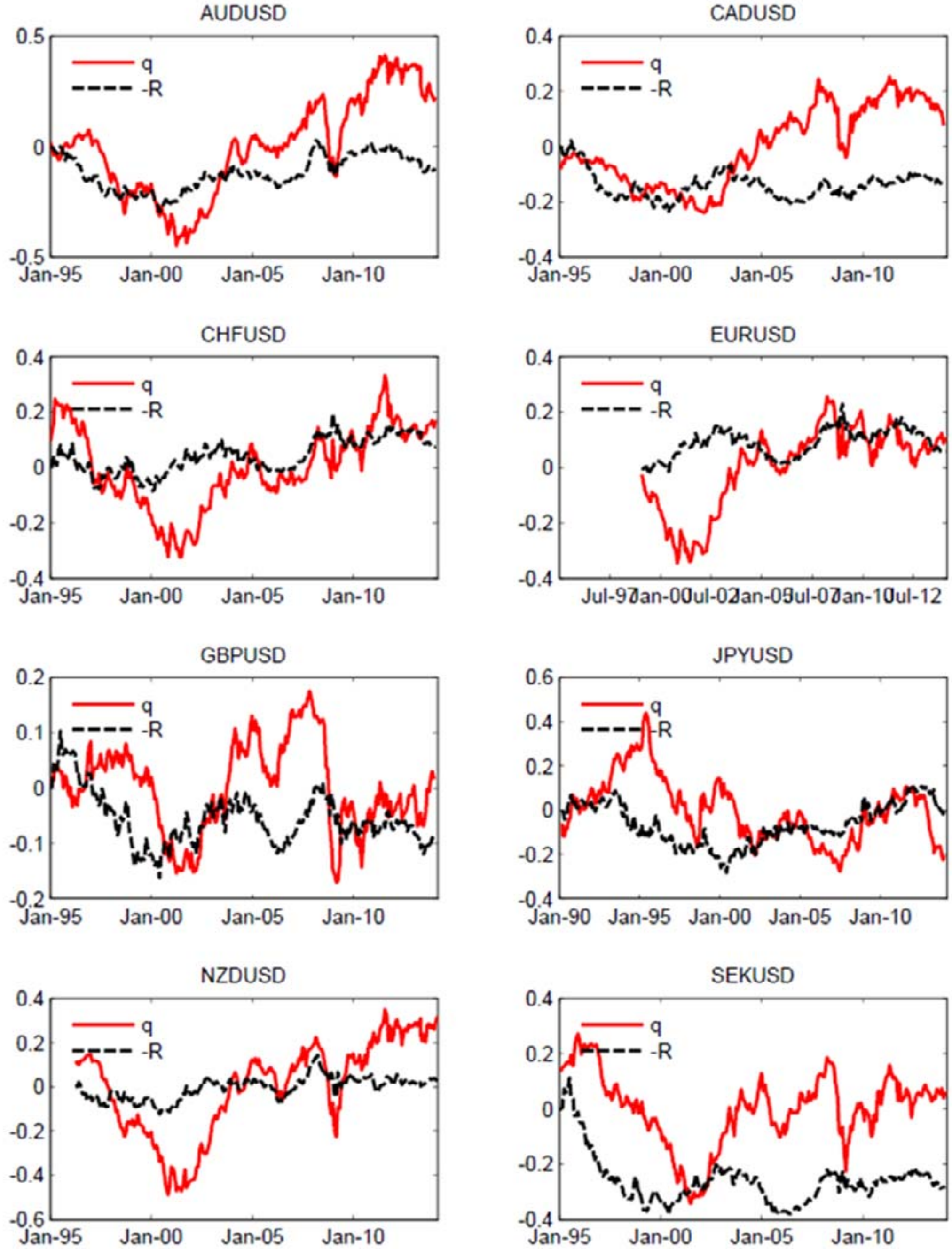
Table 6

	Δq_t		ΔR_t^f		$\Delta\Lambda^R$		$\Delta\Lambda^{FX}$	
AUD	–0.50	***	0.09		0.17		0.53	***
CAD	–0.43	***	0.07		0.18		0.45	***
CHF	–0.13	**	0.01		0.07		0.14	**
EUR	–0.36	***	0.10		0.11		0.37	***
GBP	–0.06		–0.04		0.10		0.08	
JPY	0.06		–0.06		0.03		–0.05	
NZD	–0.39	***	0.04		0.18		0.43	***
SEK	–0.32	***	0.12	*	0.07	*	0.33	***
KRW	–0.41	***	0.14	*	0.14	*	0.42	***
HKD	–0.09		0.07		0.08		0.10	
SGD	–0.32	***	0.25	***	0.04	***	0.32	***
MYR	–0.42	***	0.26	***	0.19	***	0.43	***
PHP	–0.27	***	0.19	***	0.31	***	0.28	***
THB	–0.23	***	0.12		0.19		0.25	***
average	–0.28		0.10		0.13		0.29	
Reserve currencies: CHF, EUR, GBP, JPY, HKD	–0.11		0.02		0.08		0.13	
Other currencies	–0.37		0.14		0.16		0.38	

The VIX index is the implied volatility of S&P 500 options, and is commonly used as a measure of risk aversion. A rise in the exchange rate is a depreciation of the USD. Relative risk-free returns are US minus foreign. A rise in VIX is correlated with appreciation of the USD relative to non-reserve currencies because the foreign currency premium rises. For some currencies, the "bond premium" also rises significantly, but that result is less consistent across currencies and weaker, except for the PHP and THB. *** indicates significance to the 1% level; ** indicates significance to the 5% level, * indicates significance to the 10% level. See Table 1 for abbreviations.

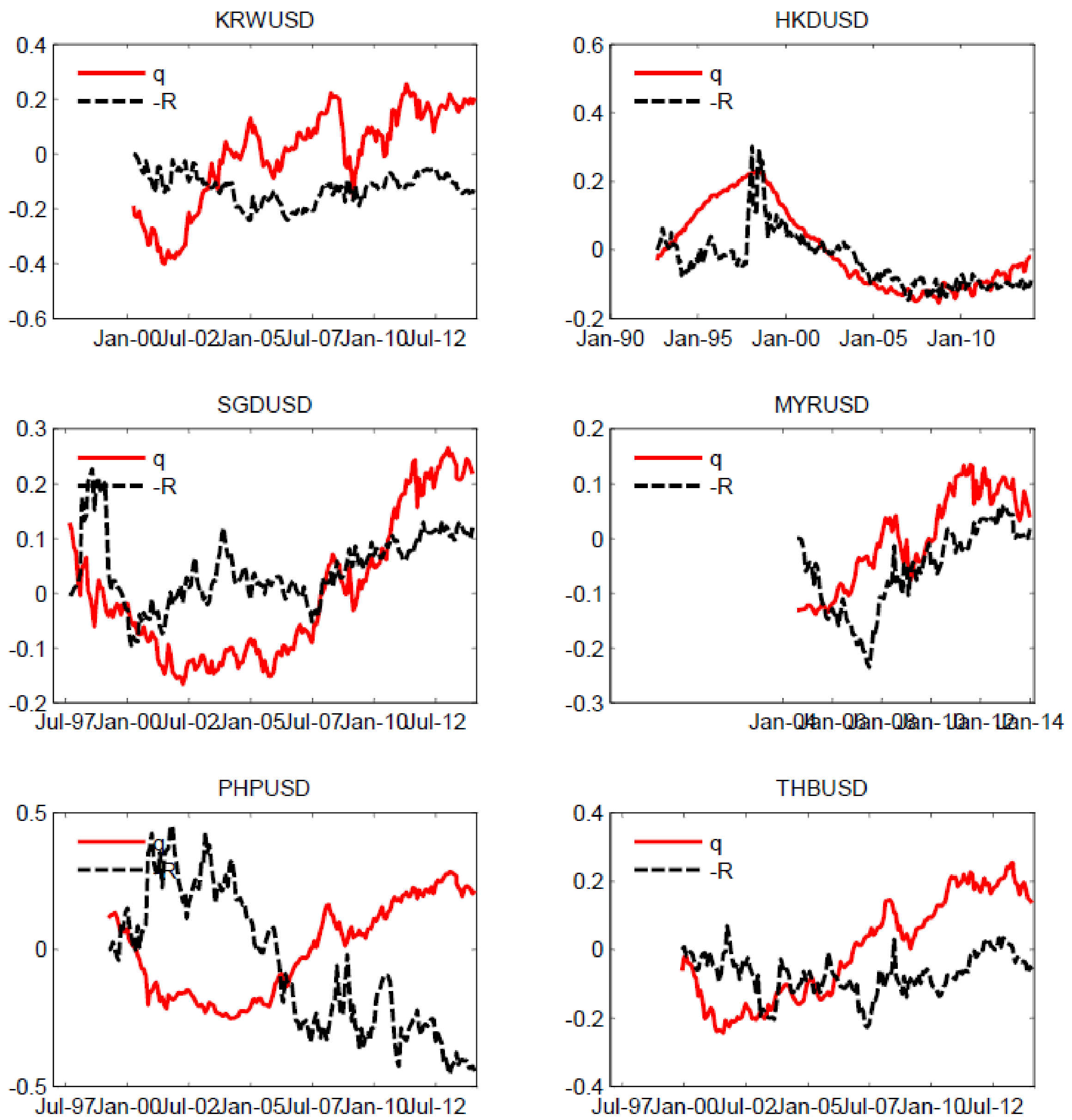
Real exchange rates and forecast sums of future relative returns

Graph 1a



Real exchange rates (q_t , red lines) are % deviation from sample mean. Dashed black lines show expected relative returns ($-R_t$) constructed as 120 times the 10-year nominal swap differential (monthly rate), net of an AR(1) forecast of the relative inflation paths.

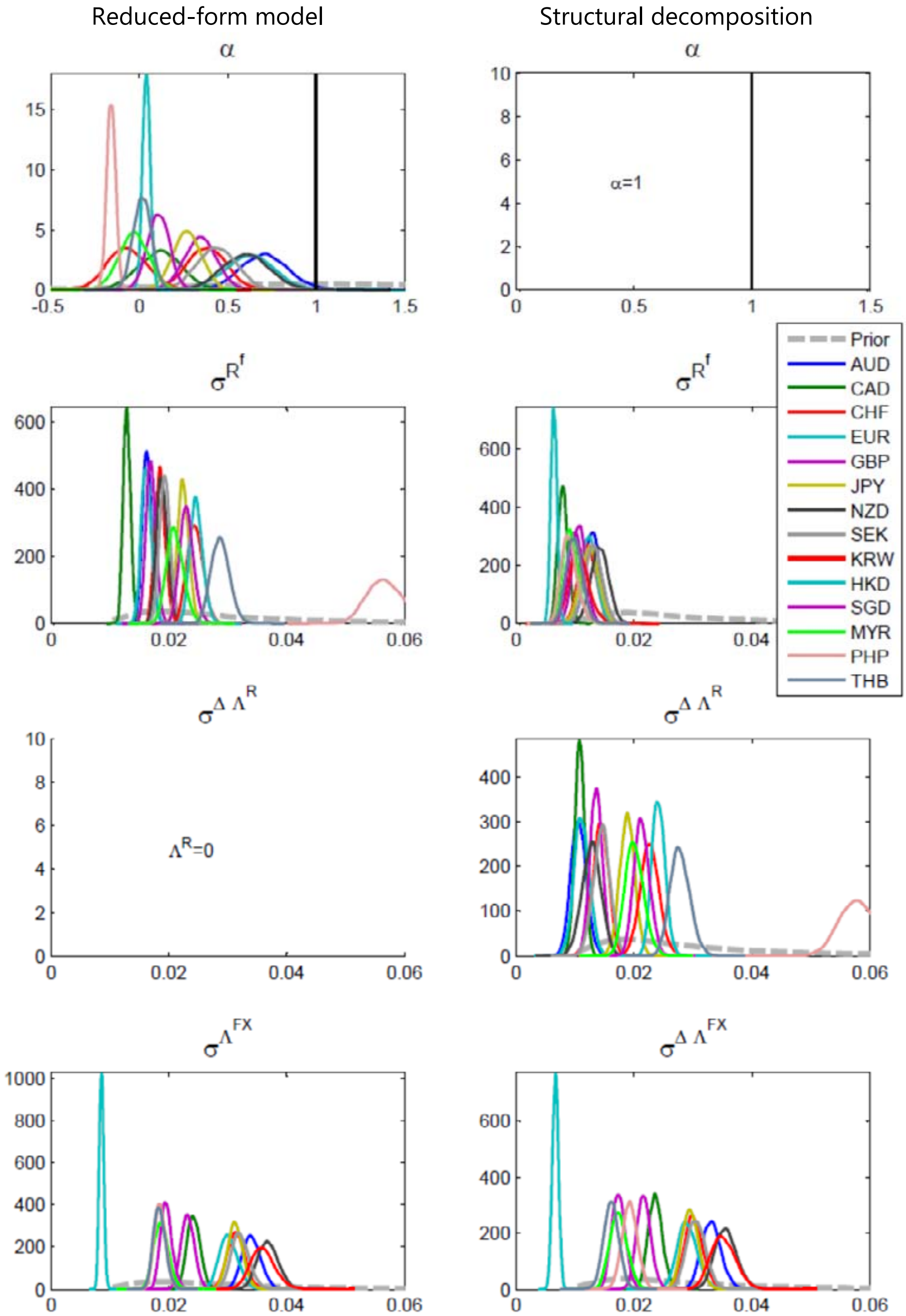
Real exchange rates and forecast sums of future relative returns	Graph 1b



Notes: Real exchange rates (Δq_t , red lines) are % deviation from sample mean. Dashed black lines show expected relative returns ($-\Delta R_t$) constructed as 120 times the 10-year nominal swap differential (monthly rate), net of an AR(1) forecast of the relative inflation paths. See Table 1 for abbreviations.

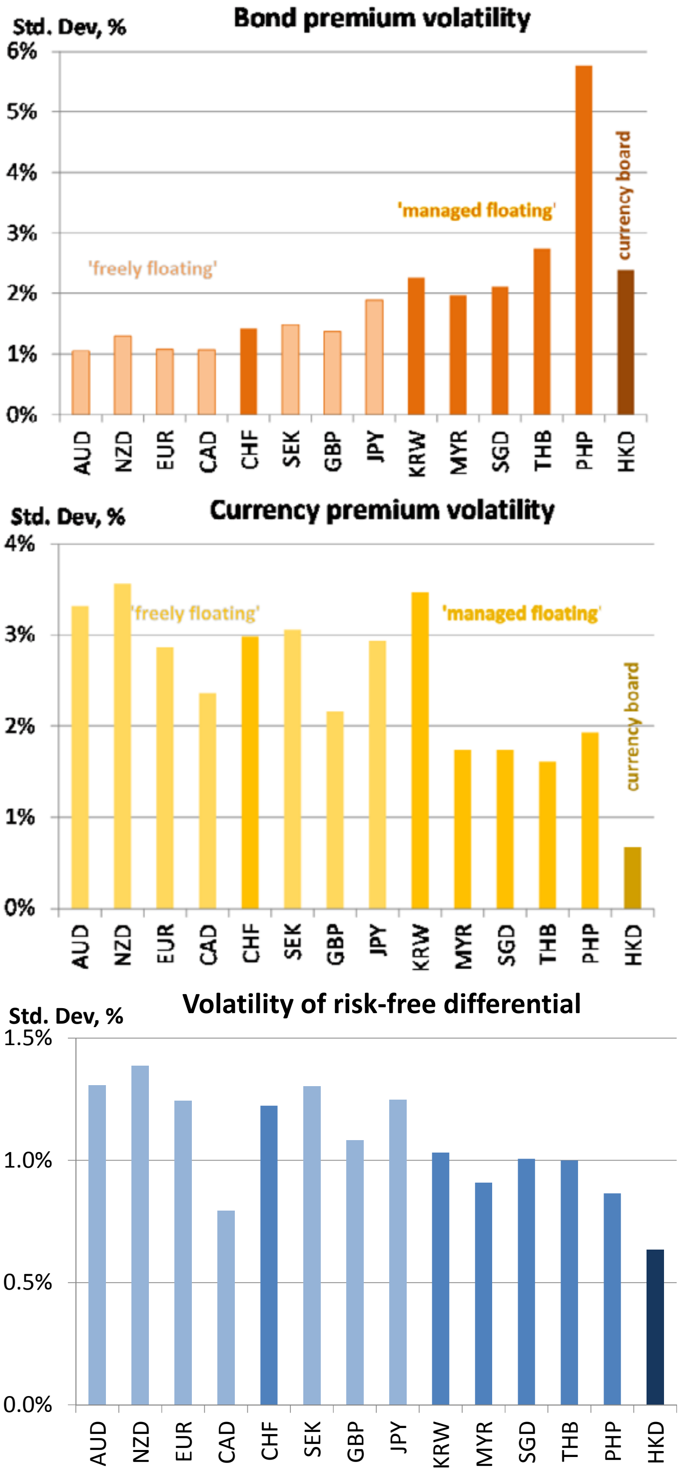
Prior and posterior densities:

(expected returns constructed from plain-vanilla interest rate swaps) Graph 2



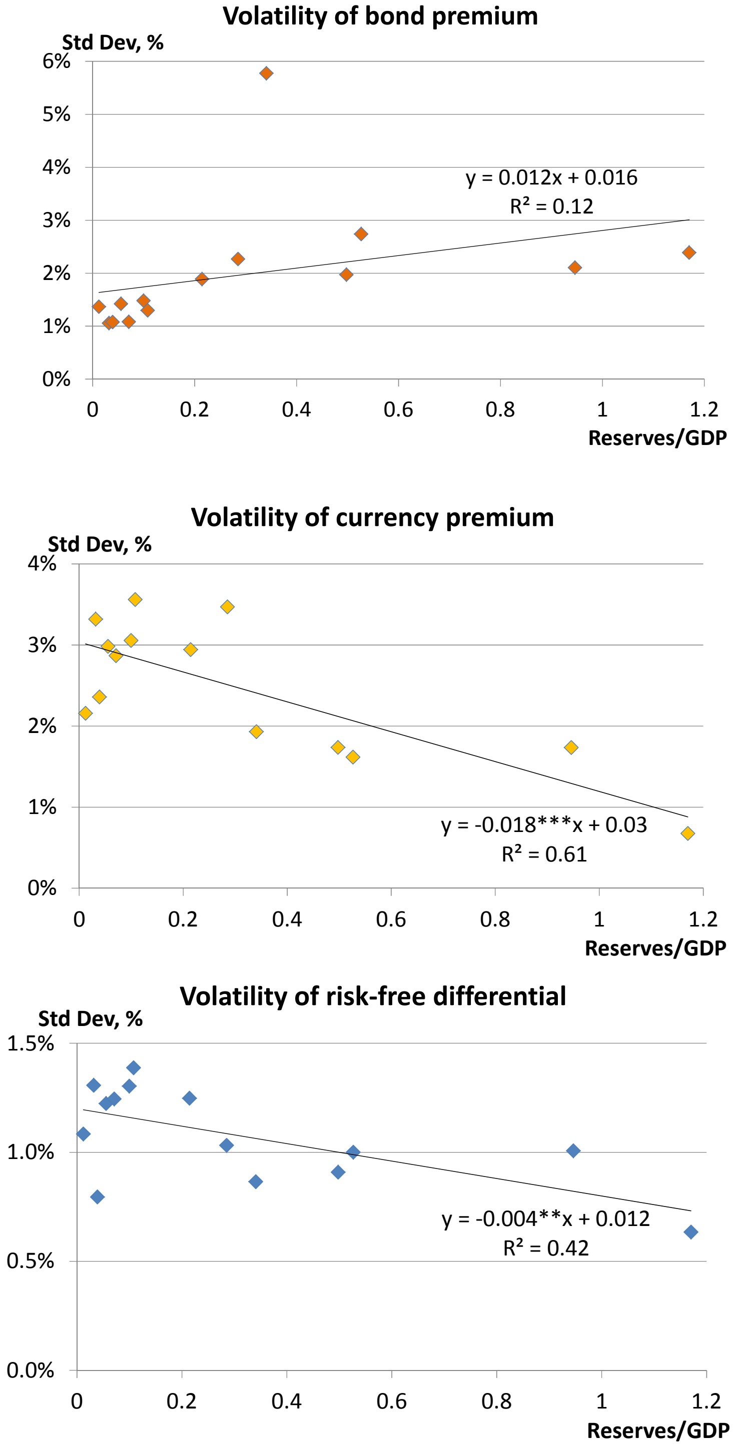
Notes: The posterior mode is the maximum of posterior distribution. The standard asset price model is subject to the restriction $\alpha > 0$ and Bayesian priors. α is the exchange rate response to expected interest returns. σ_{R^f}, σ_R, σ_{FX} and σ_π are the standard deviations of the innovations in risk-free relative returns, the bond premium, the currency premium and of relative inflation respectively. See Table 1 for abbreviations.

Can the exchange rate regime explain the risk-premium trade-off? Graph 3



Notes: See Table 1 for IMF de facto exchange rate regime over 2000–12. In these graphs, currencies are ordered by the ratio of currency premium variance to bond premium variance. The fixed exchange rate (HKD) is shown in a darker colour; currencies classified in the most freely floating category in all years, are shown in a lighter colour. More managed currencies generally have larger `bond premium' variance and smaller "currency premium" variance.

Intervention capacity and trade-off between bond premium, currency premium and relative risk-free returns. Graph 4

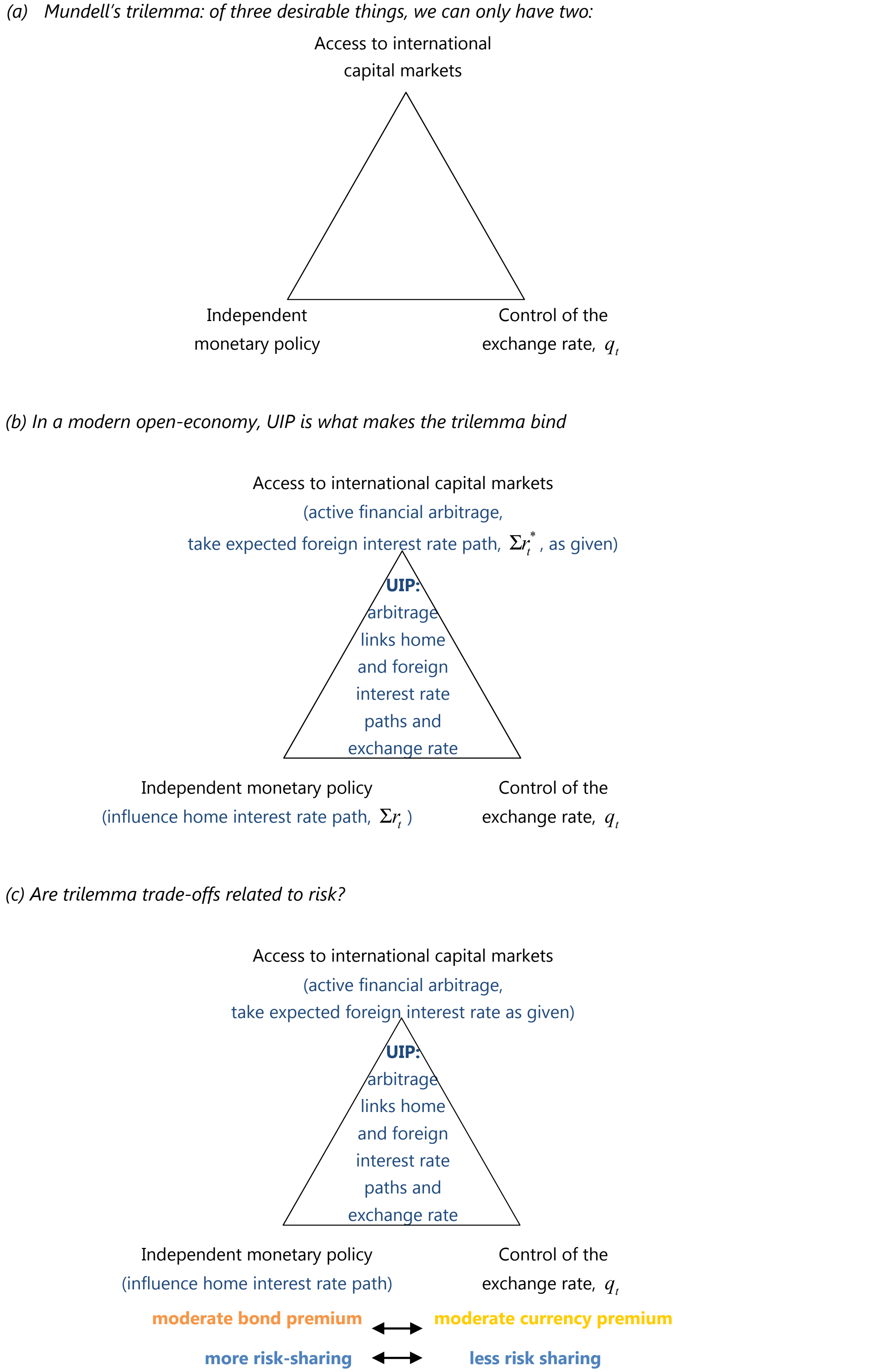


Notes: These graphs plot foreign exchange reserves/GDP – a measure of intervention capacity – against the variances of the unobserved components from the risk-augmented model. Reserves are a proxy for the exchange rate regime. The trade-off between bond premium variance and currency premium variance appears is related to the exchange rate regime. In particular, intervention capacity appears to be associated with a lower currency premium.

Source: Reserves/GDP (December 2011) from IMF, *International Financial Statistics*.

The monetary policy trilemma in a modern macroeconomic model

Graph 5



A Data appendix

Exchange rates and nominal interest rates are end-month rates. Real exchange rates are measured ex post. The inflation component of real interest rates is forecast on the basis of distributed lag equations. CPI data are assumed to be released within a month. Nominal 30-day interest rates, zero coupon swap rates and spot exchange rates are end-month rates from Bloomberg:

Bloomberg codes — Table A.1

	30-day interest rate	10-year interest rate swap	10-year zero coupon swap	exchange rate
AUD	ADBB1M Curncy	ADSW10 Curncy	I00110yIndex	AUD Curncy
CAD	CD001M Curncy	CDSW10 Curncy	I00710YIndex	CAD Curncy
CHF	SF001M Curncy	SFSW10 Curncy	I05710yIndex	CHF Curncy
EUR	EU001M Curncy	EUSa10 Curncy	I05310YIndex	EUR Curncy
GBP	BP001M Curncy	BPSW10 Curncy	I05510YIndex	GBP Curncy
JPY	JY001M Curncy	JYSW10 Curncy	I05610YIndex	JPY Curncy
NZD	NDBB1M Curncy	NDSW10 Curncy	I04910yIndex	NZD Curncy
SEK	STIBOR1M Index	SKSW10 Curncy	I08710yIndex	SEK Curncy
USD	US0001M Index	USSW10 Curncy	I05210YIndex	1
HKD	HIHD01M Index	HKSW10 Curncy	-	HKD Curncy
MYR	KLIB1M Index	MYSW10 Curncy	-	MYR Curncy
KRW	KRBo1M Curncy	KRSWo10 Curncy	-	KRW Curncy
PHP	PHSWND1M Index	PHSWo10 Curncy	-	PHP Curncy
SGD	SORF1M Index	SGSW10 Curncy	-	SGD Curncy
THB	TBFR1M Index	THSWo10 Curncy	-	THB Curncy

Nominal 30-day interest rates are Libor rates or a local equivalent rate where the local benchmark rate is more heavily traded (eg Australia and New Zealand bank bill rates). Ten year swap rates are available from February 1990 for JPY/USD, March 1992 for the HKD, December 1994 for AUD, CAD, CHF, GBP, and SEK, March 1996 for the NZD, August 1997 for the SGD, January 1999 the euro, March 1999 for the PHP, Nov 1999 for the THB, March 2000 for the KRW, and July 2004 for the MYR. The sample ends in March 2014. Consumer price indices and import and export price indices are from the IMF, *International Financial Statistics*. For Australia and New Zealand, quarterly price indices are interpolated so that observed inflation is the same for the three months between quarterly inflation data (there is no inflation news between data releases).

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