Real Interest Rate Parity in Practice: Evidence from Asia-Pacific Economies

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Abstract

This study explores the empirical relationship between real interest rate parity and the interest parity puzzle based on a number of economies in the Asia-Pacific region. In a departure from conventional studies, we build a general theoretical framework for the parity and then examine it using macroeconomic and financial market data for 15 economies in this region. We find that deviations from the parity are basically temperate for most countries, and the real interest rate differentials usually have strong connections with the real exchange rate changes and interest-exchange rate interaction terms, particularly in middle income economies. Furthermore, there are interest parity puzzles for most high income/low inflation economies, but not many where the opposite situation prevails. This implies that the risk factor is a major consideration for investors deciding to engage in a carry trade, and can therefore be used to interpret the puzzle. The income level and inflation rates are crucial in explaining the deviations from the parity under this generalized model. Of particular importance, we confirm that the interaction terms play a non-trivial role in most cases. Finally, the *ex ante* price forecast approaches are critical to realize the parity.

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Keywords: Exchange rate, interest parity puzzle, interest-exchange interaction, real interest rate parity

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1 INTRODUCTION

Real interest rate parity (RIRP) is one of the central issues in international macroeconomics, and is also a fundamental or preliminary preassumption of economic theory (see for example, Frankel, 1979). However, conventional empirical studies have often found the parity to not hold or to give rise to mixed results. In other words, this simple and plain theory has not received a lot of support in the empirical world (see Mark, 1985). In this study we build a general RIRP model and then utilize some macroeconomic and financial market data for the Asia-Pacific region to re-examine the parity and finally determine whether the parity holds or not by mainly depending upon currency risk factors. Specifically, if one currency has relatively higher *ex ante* real returns with lower risk (a low risk premium) than average, these high returns attract international investors to move funds across borders to buy this currency in order to benefit from these excess real returns (Engel, 1996).[1] This cross-border arbitrage causes these high real returns to decline due to the currency's excess supply so as to make the excess returns disappear, with the results that the parity eventually holds. By contrast, if the high real returns are associated with high currency risk, for example exchange rate volatility or inflation risk, the international investors might give up engaging in carry trades because the excess currency returns might be not sufficient to compensate for the risk they are burdened with. If the relatively high real returns compared to the average cannot incentivize the investors to engage in carry trades, then one can no longer expect to see the parity continue to hold due to the absence of arbitrage. The risk premium for investors cannot be observed because no one can read the investors' minds, but it is straight forward to understand the relationship between risk and the risk premium. When one currency has relatively high risk, for example, due to volatile currency values or a high inflation rate, the investor will ask for a higher risk premium. In this study, we classify the income levels or inflation rates to symbolize the different currency risks (see Bansal and Dahlquist, 2000; Frankel and Poonawala, 2010; Engel, 2016).

When the real interest rate in a country is higher than average over a short-time horizon, the investors are expected to move funds to earn higher real returns, so that the high interest rate currency usually gives rise to high real returns. Unfortunately, this theoretical prediction is not presented with much authentication according to the empirical evidence, a characteristic that is referred to as the *interest parity puzzle* (see for example, Backus, Gavazzoni, Telmer and Zin, 2013; Engel, 2016). We utilize the signs of the covariance between the excess returns on foreign deposits and real interest rate differentials to measure the puzzle (see Engel, 2016). In other words, it is a puzzle as the covariance is positive, otherwise it is not a puzzle. That is to say, the puzzle can therefore occur because a country with a high

[1] When investors consider engaging in a carry trade (or not engaging in such a carry trade), they do not have enough information to make the trade, such as that related to price level changes during their trading period. That is, it is necessary to define the trading decision as *ex ante* in theory, but *ex post* in practice. In the literature, the methods used to forecast future price sometimes play a role in the investigation of the parity (see Chang and Su, 2015).

real interest rate is able to attract investors and the associated inflows of money, so that the country's currency appreciates now and depreciates later. If we investigate the covariance between real interest rate differentials and excess returns on foreign short-term deposits, we will find evidence of a negative covariance. Based on the theoretical prediction, the parity (or the puzzle) analyzes the results, such as the uncovered interest rate parity (UIRP), but never considers the risk premium associated with the carry trade (see Backus et al., 2013). A local investor, for example, may deposit one unit of currency at home without any exchange rate risk, but if he/she deposits the same unit of currency in a foreign country, he/she has to face the exchange rate risk. In order to encourage investors to invest in risky assets, there must be a sufficient large risk premium to compensate them for their risk burden. When considering the risk factors, if the foreign currency is relatively less risky, this implies that the real interest rate differential is more attractive for home investors.

The relatively high interest rate drives home investors to sell the home currency in exchange for the foreign currency. As the funds flow from the home to the foreign country, the home currency will depreciate today and the exchange rate will adjust in an opposite direction tomorrow (with a short-term maturity). However, if the foreign currency is not relatively safe, even though the foreign currency has a high interest rate, when thinking about the exchange rate risk, home investors will have no incentive to engage in a carry trade for the high interest revenues. In these kinds of cases, the interest parity puzzle might occur. Hence, the puzzle (the forward premium anomaly) is that the short-maturity deposit in the high interest rate currency is usually risker than a deposit in the home currency, so that the high returns can be understood as the risk-premium needed to compensate for taking the risk to invest overseas. More precisely, the *ex ante* risk premium associated with the exchange rate can be co-moved with the interest rate differentials, and the *ex ante* excess return on short-term foreign deposits should negatively co-vary with the (real) interest rate differentials (see Engel, 2014; 2016).[2] However, the empirical findings often given rise to a positive covariance between excess return and interest rate differentials, particularly in the main developed economies, like the OECD & the G7 (see Bansal and Dahlquist, 2000; Engel, 2014, 2016). To illustrate with an example, over the past few decades, Japan has usually suffered from a low interest rate with a low inflation rate, so that the real interest rates are mostly lower than average. However, the Japanese yen usually maintained a stable currency value (being less risky) compared to other currencies, so that even though other foreign currencies obviously enjoy high real interest rates, the investors in Japan might not have enough of an incentive to move funds from Japan to other countries, like the U.S., to earn higher returns with more risk.[3] Therefore, the safer currency or hedging currency

[2]With regard to the *ex ante* price forecast, we apply three popular price forecasting technical methods, i.e. the random walk (RW) model, the first-order autoregressive (AR) model and the autoregressive moving average (ARMA) model. The *ex post* price model serves as the benchmark (see for example, Nikolsko-Rzhevskyy, 2011).

[3]The Japanese yen has been a typical hedging currency in the foreign exchange (FX) market over recent decades (see Campbell, Medeiros and Viceira, 2010).

might result in the occurrence of the interest parity puzzle at least empirically.

Another problem with the puzzle might arise from the inflation rate risk, because the real interest rate can be decomposed into both a nominal interest rate and inflation rate using Fisher's equation, when one currency enjoys a high real interest rate which might result from either a high nominal interest rate or a low inflation rate, and sometimes both. When one country has an average nominal interest rate with a low inflation rate, which may then result in a high real interest rate, the currency will be characterized by low inflation rate risk. When the foreign currency has a lower inflation rate risk than the home currency, it will be attractive to home investors. That is, the home investors will have an incentive to engage in a carry trade for the *ex ante* excess real returns. If the home currency does not have relatively high risk, investors in the home country may not move their funds in order to avoid the inflation rate risk in their own country, so that we might observe the interest parity puzzle for this currency-pair. If the puzzle applies in relation to one currency relative to another currency, this means that even if the interest differentials are becoming large, the investors will not move their currency to earn excess returns or to avoid the risk mentioned above. That is why the RIRP can no longer always hold without arbitrage. It is the intuitive bridge between the puzzle and the parity.

In conventional international macroeconomic studies, the UIRP always assumes that the interest-exchange rate interaction term is sufficiently small to rule out the RIRP. However, one of the purposes of this study is to examine if the interaction term really plays no role in interpreting the deviations from the parity.[4] If the interaction term is not really small, it will either improve the parity or make the parity worse. That is to say, the interaction term might narrow down or enlarge the deviations from the parity when it is not as small as we thought. The deviation from the parity is converging as the interaction term co-moves together with the real interest rate differentials in the same direction. By contrast, the interaction term can also move in an opposite way to cause a deviation away from the parity. As the real interest rate differentials are quite close to zero, the interaction term is important for the RIRP even if its absolute value is still minuscule. In other words, even if the interaction term is not big enough, however, the role of the term might still not be trivial. In the end, one cannot *ad hoc* neglect the term without figuring out the characteristics of the RIRP.

This study investigates the empirical relationship between the parity and the puzzle using some economies in the Asia-Pacific region (see also Liu, Chang, Su and Jiang, 2013). Differing from the conventional studies in the literature, we build a general framework for the parity and then examine this parity using macroeconomic and financial market data for 15 countries. In order to realize the alternative behaviors of the parity between different economic development stages, all the economies are basically

[4] Deviations from UIRP across countries imply that a unit of currency deposited in one country receives different real returns from depositing the currency in another country. In other words, it is possible for an investor to make more money via a carry trade from one country to another country.

categorized into High and Middle Income countries using the criteria reported by the World Bank. We first examine the characteristics of the deviations from the parity, and then estimate the regression equations for the RIRP (see Engel, 2016). We illustrate the deviations from the parity and explore how the real interest rate differential is interpreted based on certain factors, such as the real exchange rate changes and interest-exchange rate interaction terms. We find that deviations from the parity are not too large for most countries, and the real interest rate differentials are usually strongly linked with the real exchange rate changes and interaction terms, especially in Middle Income economies, but less so in High Income economies. Real exchange rate changes and interaction terms can cause the parity to converge, but in some cases they make the parity worse. We find that the covariance and income per capita (in relation to the United States) move in the same direction, but the covariance and inflation rate do so in the opposite way. That is to say, there are interest parity puzzles for most high income/low inflation economies, but seldom for other countries (see Bansal and Dahlquist, 2000). The results support the view that the risk premium, represented by the income level or inflation rate, for a currency can be used to interpret the interest parity puzzle and the RIRP. Of particular importance, we confirm that the interest-exchange rate interaction terms play a non-trivial role in most cases. Finally, the *ex ante* price forecast approaches, for example, the popular RW, AR or ARMA, are critical to examining the parity.

The rest of this study is organized as follows. The general RIRP model is presented in Section 2. Section 3 discusses the data sources, econometric approaches, and the results. Finally, we conclude.

2 REAL INTEREST RATE PARITY

In this section, we build the RIRP model using several fundamental conditions in macroeconomic or finance theory. Accordingly, the conventional RIRP is basically constructed upon the UIRP, real exchange rate and Fisher's equation. Using these conditions, we can figure out a general form for the parity which is different from the conventional model in the literature.

2.1 Fundamental International Macroeconomic Models

Uncovered Interest Rate Parity. The UIRP is based on the connection between the money market and FX market under the no-arbitrage condition. The return on one unit of currency deposited in the home country (country H) should be equal to the return on a deposit in the foreign country (country F) under the UIRP in equilibrium. Assume that $i_{H\$}$ ($i_{F\$}$) is the short-term nominal interest rate for country H (F), and S is the home currency's ($H\$$) price for one unit of foreign currency ($F\$$). The UIRP then implies that:

$$(1 + i_{H\$,t}) = (1 + i_{F\$,t}) \times \frac{S_{t+1}}{S_t}. \tag{1}$$

If this UIRP holds, this implies that investors are unable to make any extra nominal profits by moving funds from one country to another. Obviously, Eq.(1) can be rewritten by moving items so that $\frac{(1+i_{H\$,t})}{(1+i_{F\$,t})} = 1 + \frac{S_{t+1}-S_t}{S_t}$, and then the equation obtained is as follows:

$$i_{H\$,t} = i_{F\$,t} + (1 + i_{F\$,t}) \times \frac{dS_{t+1}}{S_t}, \tag{2}$$

where we define $\frac{dS_{t+1}}{S_t} \equiv \frac{S_{t+1}-S_t}{S_t}$. Eq.(2) shows that the nominal interest rate in country H is equal to the nominal interest rate in country F with its total nominal exchange rate changes. If this equation does not hold, investors can therefore make extra profits by engaging in a carry trade. The UIRP refers not to the relationship between the short-term nominal interest rate returns for different countries, but to real returns. However, the nominal exchange rate movements in Eq.(2) may change the real relative price (real exchange rate) if relative price levels do not relatively change. In order to connect the nominal exchange rate with the relative price level, we therefore define the real exchange rates as follows.

Real Exchange Rate. According to the literature, we define the real exchange rate as $Q \equiv \frac{S \times P_F}{P_H}$, where P_H (P_F) denotes the aggregate price level in country H (country F). One may take logarithms on both sides of the real exchange rate, and then obtain $\ln Q = \ln S + \ln P_F - \ln P_H$. The deviation from the real exchange rate can therefore be given by:

$$\frac{dQ_{t+1}}{Q_t} = \frac{dS_{t+1}}{S_t} + \frac{dP^e_{F,t}}{P_{F,t}} - \frac{dP^e_{H,t}}{P_{H,t}}, \tag{3}$$

where $\frac{dP^e_{H,t}}{P_{H,t}}$ $(\frac{dP^e_{F,t}}{P_{F,t}})$ denotes the annual home (foreign) expected price changes (expected inflation rates).[5] Of course, the expected price changes can result in *ex ante* real interest rate changes even if the nominal interest rate remains constant.

Fisher's Equation. According to Fisher's equation in macroeconomics, the nominal interest rate can be decomposed by the real interest rate (r_t) and expected inflation ($\frac{dP^e_t}{P_t}$), i.e.:

$$i_t = r_t + \frac{dP^e_t}{P_t},$$

[5] As $\frac{dQ_{t+1}}{Q_t} = 0$, the relative purchasing power parity holds, i.e., $\frac{dS_{t+1}}{S_t} = \frac{dP^e_{H,t}}{P_{H,t}} - \frac{dP^e_{F,t}}{P_{F,t}}$.

where both country H and country F would apply the Fisher's equation.[6] The Fisher's equations for both country H and country F are therefore as follows:

$$\begin{aligned} i_{H\$,t} &= r_{H\$,t} + \frac{dP^e_{H,t}}{P_{H,t}}, \\ i_{F\$,t} &= r_{F\$,t} + \frac{dP^e_{F\$,t}}{P_{F\$,t}}. \end{aligned} \tag{4}$$

By using the three fundamental conditions in the international macroeconomics field, we may construct a general RIRP model.

2.2 Real Interest Rate Parity

In this subsection, we combine all of the parities and definitions above together, and then the RIRP in a general form can be solved using a straightforward model (see MacDonald and Nagayasu, 2000).

Real Interest Rate Parity. From Eqs.(2) and (4), we may obtain:

$$\begin{aligned} i_{H\$,t} - i_{F\$,t} &= r_{H\$,t} - r_{F\$,t} + (\frac{dP^e_{H,t}}{P_{H,t}} - \frac{dP^e_{F,t}}{P_{F,t}}), \\ &= \frac{dS_{t+1}}{S_t} + i_{F\$,t} \times \frac{dS_{t+1}}{S_t}. \end{aligned} \tag{5}$$

According to Eqs.(5) and (3), one can derive the RIRP in a general form as:

$$r^D_t = \frac{dQ_{t+1}}{Q_t} + i_{F\$,t} \times \frac{dS_{t+1}}{S_t}, \tag{6}$$

where $r^D_t \equiv r_{H\$,t} - r_{F\$,t}$ denotes the real interest rate differentials between country H and country F.[7] Eq.(6) is a general form of the RIRP. On the RHS of Eq.(6), the first item is the real exchange rate changes and the second item is the interest-exchange rate interaction term. In this study, we propose to answer the question of whether real exchange rate changes, $\frac{dQ_{t+1}}{Q_t}$, and the interaction term, $i_{F\$,t} \times \frac{dS_{t+1}}{S_t}$, play any roles in interpreting real interest rate differentials, i.e. r^D_t.

According to Eq.(6), one may regress real interest differentials (r^D_t) on real exchange rate changes ($\frac{dQ_{t+1}}{Q_t}$) and the interaction terms ($i_{F\$,t} \times \frac{dS_{t+1}}{S_t}$) to examine the parity. In theory, if the coefficients for

[6] In fact, Fisher's equation can also be built as a more general form as: $\frac{1+i}{1+dP^e/P} = 1 + r$, and the dP^e/P refers to the *ex ante* price changes. Similarly, $i = r + dP^e/P + r \times dP^e/P$. However, the real interest rate is a latent term and *ex ante* price changes are *un*observed, so that we do not symmetrically incorporate the term $(r \times dP^e/P)$ in Fisher's equation into the model.

[7] In the literature, the RIRP usually assumes that the interaction term, $i_{F\$,t} \times \frac{dS_{t+1}}{S_t}$, is small enough to eliminate it from the estimation, for example Engel (2016). Some works even assume that purchasing power parity holds, i.e., $\frac{dQ_{t+1}}{Q_t} = 0$, and therefore we evaluate the RIRP using the item $r^D_t = 0$ only, such as in Wu and Chen (1998) and Chang and Su (2015).

the real exchange rate changes and interaction terms are significantly close to one, the RHS increases (or decreases) in a similar pattern to the LHS. In these circumstances, the parity holds because the two sides move together. However, one may simply examine the parity by using the deviations from the RIRP. The deviations from the real interest rate parity (henceforth, DRIRP) is defined as the difference between the real interest rate differentials and real exchange rate changes and nominal exchange rate changes, namely:

$$\zeta_t \equiv r_t^D - \frac{dQ_{t+1}}{Q_t} - i_{F\$,t} \times \frac{dS_{t+1}}{S_t}. \tag{7}$$

As to whether the RIRP holds or not, one can simply examine the characteristic of the DRIRP process. $\zeta_t = 0$, for example, means of course that the parity strictly holds in theory because the LHS equals the RHS in Eq.(6). Empirically, however, $\zeta_t = 0$ is not possible due to all of them being time series random variables. By contrast, one may analyze the basic scenarios for ζ_t in order to realize how far the parity deviates and how volatile the DRIRP is (see Wu and Chen, 1998; Chang and Su, 2015).

Interest Parity Puzzle. Following Engel (2016) and Nucera (2017), we define the excess return on the foreign deposit ρ_{t+1} in our framework as:[8]

$$\rho_{t+1} = i_{F\$,t} + (1 + i_{F\$,t}) \times \frac{dS_{t+1}}{S_t} - i_{H\$,t}. \tag{8}$$

The interest parity puzzle can be understood using the covariance between $E_t[\sum_{j=0}^{\infty} \rho_{t+j+1}]$ (or $E_t\rho_{t+1}$) and the real interest rate difference $(r_{F\$,t} - r_{H\$,t})$ (see Engel, 2016).

That is to say, we may calculate the covariances between the excess return on foreign deposits and real interest rate difference, and we then illustrate $Cov(E_t\rho_{t+1}, r_{F\$,t} - r_{H\$,t})$.[9] In theory, if the real return on deposits in country F is higher than that in country H, i.e., $r_{F\$,t} - r_{H\$,t} > 0$, the home investors will tend to move funds by selling the home currency to buy foreign currency today in order to deposit money in country F for higher returns. The moving of funds from the home to foreign country for a short-term deposit results in the home currency depreciating now and appreciating shortly, i.e., $\frac{dS_{t+1}}{S_t} < 0$, and the term $i_{F\$,t} - i_{H\$,t}$ is connected with the real return differentials $r_{F\$,t} - r_{H\$,t}$ by Fisher's equation. The carry trade between the home and foreign currency results in $Cov(E_t\rho_{t+1}, r_{F\$,t} - r_{H\$,t}) < 0$.

However, one intuitive question concerns which factor(s) cause the interest parity puzzle. One of the factors referred to in the literature is the risk premium. That is, an investor invests in his/her

[8] In fact, the excess return on foreign deposits in Engel (2016) and Nucera (2017) is a special case of our definition. The excess return on foreign deposits does not incorporate the interest-exchange rate interaction term $i_{F\$,t} \times \frac{dS_{t+1}}{S_t}$.

[9] We calculate not only the current period excess return on the foreign deposits ($E_t\rho_{t+1}$) but the summation of the excess return on the foreign deposits ($E_t[\sum_{j=0}^{\infty} \rho_{t+j+1}]$). For the summation of the excess returns on the foreign deposits we of course have no infinity observation. In the literature, existing studies mostly apply the truncated summation method. However, we use all of the observations to calculate the summation of the excess returns on the foreign deposits.

own currency without exchange rate risk, but when investing in a foreign country faces exchange rate risk so as to require a risk premium. However, a high income country with a low inflation rate usually experiences a more stable currency value, namely low currency risk. In addition, if a foreign currency is usually characterized by low risk, i.e., a low risk premium, an investor's intention to make a carry trade will result in no puzzle, otherwise will result in puzzle. In order to figure out if these factors play some role in the puzzle or not, we illustrate the puzzle with gross domestic product (GDP) per capita and the inflation rate in this study.

Connections between the Parity and the Puzzle. The holding of real interest rate parity is based on the no-arbitrage conditions in financial markets as one currency's real return is higher than that of another. If the investors have to face relatively high exchange rate volatility risk, the high risk discourages the investors from engaging in a carry trade due to the high real returns being insufficient to compensate for the risk premium they face. That is, there are interest parity puzzles between the currencies. Without no-arbitrage conditions across markets, the real interest rates across countries lose their ability to achieve parity. In other words, deviations from the RIRP may stem from the interest parity puzzle in theory, but we need to examine whether the features are based on empirical evidence or not. To be specific, the theory predicts that a country with high income and a low inflation currency usually experiences an interest parity puzzle because the risk posed by these currencies to local investors is usually much lower rather for foreign currencies. If the investors in these low currency risk countries do not intend to move funds across borders to make excess real returns, the arbitrage does not take place. Without arbitrage between markets, one cannot expect the RIRP to hold anymore.

3 DATA SOURCES AND EMPIRICAL RESULTS

3.1 Data Description

We collected data for 15 Asia-Pacific economies, namely, Australia, China, Hong Kong, India, Indonesia, Japan, Malaysia, New Zealand, the Philippines, Singapore, Sri Lanka, S. Korea, Taiwan, Thailand, and Vietnam, with the U.S. serving as the numéraire (country F). The macroeconomic and financial market data were monthly and mainly covered the period from 1986M11 to 2018M1. They were obtained from *DataStream*.[10]

Short-Term Interest Rates & Bilateral Exchange Rates. All of the financial market data were

[10] However, for some countries, in particular in emerging economies, the period covered by the data was usually not as long as for other developed states. More specifically, that for China was from 2002M01, for Hong Kong from 1993M12, for India from 1998M12, for Sri Lanka from 2001M12, for Thailand from 1989M01 and for Vietnam from 2000M02.

those at the end of the period, and were not period averages. Specifically, as for the short-term nominal interest rates, we utilized the money market interest rates as the indicators. However, the interbank offered rates or three-month Treasury bill rates were used instead if the money market rates were not available for some economies. In regard to the nominal exchange rates, we collected bilateral exchange rates for each currency against one unit of the U.S. dollar. In order to figure out the big picture of the RIRP for High and Middle Income economies, we adopted the income level criterion reported by the World Bank in 2017. Based on that criterion, we classified our data according to High Income, Upper-Middle Income and Lower-Middle Income economies (High Income for > US$12,236, Upper-Middle Income for US$3,956-US$12,235, and Lower-Middle Income for US$1,006-US$3,955).[11]

Price Indices & Expected Inflation Rate. We adopted the consumer price index (CPI) as the indicator of the aggregate price level, but the producer price index (PPI) was used instead if the CPI data were not available. The price index data were also collected from *DataStream*. Furthermore, we applied real GDP to measure the weights for virtual high-income country and virtual middle-income country. The weight was calculated based on the share of each country in relation to the total high income and to the total middle (a mix of both Upper-Middle and Lower-Middle) income countries.[12] The base year for the CPI (PPI) and real GDP was 2010.

In order to mimic the *ex ante* price movements the investors faced, we summarize three alternative price movement models in the literature, namely, RW, AR, and ARMA, to *ex ante* forecast the concurrent price movements for which information is not available at time t. We utilize the monthly CPI as the indicator to calculate the *ex ante* expected inflation rate. However, the inflation rate and interest rate are based on annual data. In order to measure the RIRP in the short term (monthly), we divide the annual inflation rates and annual interest rates by 12, namely, $\frac{dP_t^e}{P_t}/12$ and $i_t/12$, and then use the moving average monthly nominal interest rate and monthly *ex ante* expected inflation rate to convert the real interest rate on to a monthly basis.

3.2 Empirical Findings

In this subsection, we first present the descriptive statistics for deviations from the parity, and then show the RIRP regression estimation via single equation and panel regression models with cross-section fixed

[11]Based on this criterion, our High Income countries were Australia, Hong Kong, Japan, New Zealand, Singapore, S. Korea, and Taiwan; the Upper-Middle Income countries were China, Malaysia, and Thailand; and the Lower-Middle Income countries were India, Indonesia, the Philippines, Sri Lanka, and Vietnam according to the given criteria. There were no Low Income economies in our observations. Similar classifications, we also refer to Bansal and Dahlquist (2000) and Frankel and Poonawala (2010).

[12]We do not separately report the results for the virtual Upper-Middle Income country and Lower-Middle Income country, because China empirically dominates the Upper-Middle Income economies so as to make the features of the virtual Upper-Middle Income country are quite close to those of China.

effects. We also perform cross-sectional dependence and heteroskedasticity tests to make sure that the panel regression fits the data well. The time-varying slope coefficients with the confidence intervals of the regressors, i.e., real exchange rate changes and interest-exchange interaction terms, are presented for confirmation. Finally, we calculate the interest parity puzzles under different features and illustrate the puzzles with GDP per capita and the inflation rate.

Deviations from Real Interest Rate Parity. First of all, we report the summary statistics for deviations from the parity using all of the price forecasting approaches, i.e., *ex ante* (RW, AR and ARMA) and *ex post*, in order to understand the basic features of the parity in the Asia-Pacific countries, see Table 1. In theory, as the DRIRP is close to zero and stable, it implies that the real interest rate differentials are moving together with the real exchange rate changes and interest-exchange rate interaction terms (see Wu and Chen, 1998; Chang and Su, 2015). In other words, the RIRP basically holds. The summary statistics for the DRIRPs are described as 4 raw moments of the distribution, i.e., the mean, standard deviation (S.D.), skewness (Skew.) and kurtosis (Kurt.). In general, the means for the DRIRP calculated by *ex ante* price forecasting range from -0.338% (Japan using AR) to 0.538% (the Philippines using AR). Regardless of what kind of *ex ante* price forecasting is used, the means of the DRIRP are mostly close to zero for most countries, and of particular interest, the means of the DRIRP using ARMA are similar to those obtained using *ex post*. The means of the DRIRP for Lower-Middle Income countries are slightly higher than those for High Income and Upper-Middle Income countries. In addition, the S.D.s for Lower-Middle Income countries, which range from 1.046 (Vietnam *ex post*) to 5.430 (Indonesia *ex post*), are much higher than the S.D.s for High Income countries, which range from 0.719 (Hong Kong *ex post*) to 3.6 (S. Korea). The higher S.D.s of the DRIRP implies more volatility of the deviations from the parity. Furthermore, some DRIRPs have a leptokurtic shape due to high kurtosis, such as for S. Korea, Malaysia, Thailand, and Indonesia.

When comparing our results with those for the different price forecasting models, we found that there are considerable difference in the distributions of the deviations from the parity between the *ex ante* price forecasting approaches and the *ex post* method (also seeing Nikolsko-Rzhevskyy, 2011). In other words, the results substantially vary between investors *ex ante* anticipating the DRIRP and *ex post* realized DRIRP when they are making investment decisions. Furthermore, if we examine the DRIRP for the three *ex ante* models, we find that price forecasting using AR is considerably different from the other two approaches (RW and ARMA), particularly in terms of means and S.D.s. The summary statistics for the deviations from the parity for ARMA are very similar to those for *ex post* approaches in most countries. However, this kind of summary statistic cannot clarify all possible sources of deviations from the parity. For example, the simple DRIRP statistics cannot tell what the major sources resulting in the deviations are, either for real exchange rate changes ($\frac{dQ_{t+1}}{Q_t}$) or the interest-exchange rates interaction term ($i_{F\$,t} \times \frac{dS_{t+1}}{S_t}$) in Eq.(7). Do the effects of real exchange rates and the interaction terms offset each other? Are there any possible structural breaks in the processes? Do any interest parity puzzles exist in these real interest rate differentials? In order to answer the questions raised in the RIRP, we now explore the parity by using some alternative approaches as follows.

Real Interest Rate Parity Regressions & Parameter Instability. In the literature, the relationships between interest rates and exchange rates are usually examined using Fama regression (see Engel, 2016). That the RIRP holds in the regression implies that the drift term in the regression should be equal to zero, and the estimated coefficients for the regressors ($\frac{dQ_{t+1}}{Q_t}$ and $i_{F\$,t} \times \frac{dS_{t+1}}{S_t}$) should be significantly positive values in theory.[13] In this study, we symmetrically report the standard regression estimations using the least squares models with/without dummy variables for the Asian Financial Crisis in 1997-1998 and the Great Recession in 2008-2009, and all of the results are placed in Tables 2-3 (see Hass and Van Lelyveld, 2014). In general, most of the estimated coefficients for the constant terms are positive and different from zero at least at the 10% significance level, and there are no big differences among the High, Upper-Middle and Lower-Middle Income economies or among alternative price forecasting approaches. This implies that there is a gap in terms of real interest rates between the home and foreign (the United States) countries even if the real exchange rate changes and interaction terms are not considered. The results indicate that the transaction cost does play a more active role in the parity regression. However, the estimated coefficients of the real exchange rate changes and interest-exchange rate interaction terms do not perform consistently. Some of them are positively significant, some are not negatively significant and some are not significantly different from zero at the 10% level (see Table 2).

Of particular interest, the significant (at least at the 10% level) coefficients of the real exchange rate changes are all positive, other than for Taiwan when using price forecasting based on the *ex ante* approaches. The negatively significant coefficients of the real exchange rate changes imply that the real exchange rate changes cause the RIRP to deviate and make the parity worse. By contrast, the coefficients of the interest-exchange rate interaction terms are statistically significant at least at the 10% level for 29 out of 60 country-pairs for all possible price forecasting approaches. The estimated coefficients of the interest-exchange rate interaction terms range from -38.92 (Vietnam using the *ex post* approach) to 117.2 (China using ARMA). In order to illustrate the basic scenarios of the RIRP regressions for different economic development features, we construct virtual high income and virtual middle income

[13] If the drift term is different from zero, it indicates that there is a gap between the foreign and home country real interest rates in a complete financial market based on a theoretical prediction. However, the transaction costs can give rise to a significant gap in the real interest rate differentials in the empirical estimation because no investors want to engage in a carry trade when the real interest rate differential is less than transaction cost. That coefficients of the regressors are significantly negative means that real interest rates deviate from the parity because the dependent variable is going up as the regressors are going down and *vice versa*.

countries (including Upper-Middle and Lower-Middle) as already mentioned. The estimation results use the terms, High Income and Middle Income, in Tables 2-3, respectively. Of special interest, we find that the coefficient of the interaction term for the virtual high income country, calculated by the weight of real GDP, is negative and significant at the 10% level for the *ex post* case only. On the contrary, that for the virtual middle income country is negatively significant at least at the 10% level for each of the RW, ARMA, and *ex post* approaches (also see Table 2). Roughly speaking, the RIRP basically holds since real exchange rate changes mostly lead to co-movements or insignificant co-movements with real interest rate differentials using *ex ante* price forecasting approaches, particularly for Upper-Middle and Lower-Middle Income economies based on the simple parity regression. Of particular importance, the interest-exchange rate interaction term is not trivial when interpreting the RIRP even if the absolute values of the significant estimated coefficients are usually not big enough in this simple Fama regression. The results are confirmed by using a virtual high income country or virtual middle income country.

However, some might argue that the regional or global financial crisis could play a role when one examines the parity or certain economic behavior (see, for example, Chiang, Jeon and Li, 2007; Choi, Kim and Lee, 2011; Hass and Van Lelyveld, 2014). Accordingly, we re-examine the standard RIRP regression with the financial crises in our observations, namely, the Asian Financial Crisis in 1997-1998 and the Great Recession in 2008-2009. The estimates are reported in Table 3. To sum up, the estimates for the drift, real exchange rate changes, and interaction term are not much different from those for the standard RIRP regression in Table 2. In this estimation of the RIRP with dummy variables, the interaction term is as important as the real exchange rate changes in terms of contributing to the interpretations of the deviations from the parity (see Table 3). In general, both the Asian Financial Crisis and the Great Recession have a substantial influence on the RIRP, regardless of whether in the high income or middle income countries, or when engaging in carry trade using any price forecasting approaches (also see Hass and Van Lelyveld, 2014).[14] To be specific, 36 out of 48 estimates of the Asian Financial Crisis have a significant influence at least at the 10% level, and similarly 39 out of 60 for the Great Recession. There are significant effects of both financial crises in all cases for some economies, such as Australia, Japan, Singapore, S. Korea, India and the Philippines, but no effects of either crisis only for Hong Kong. For some specific countries, such as Taiwan, Malaysia and Thailand, the RIRP was not influenced by the Great Recession, but was really affected by the Asian Financial Crisis 1997-1998. The results are basically confirmed by the estimates for the virtual high income and virtual middle income countries.[15]

Furthermore, we integrate the economy to become high and middle income with all observations to

[14] One will find that some countries have no estimation results during the Asian Financial Crisis (γ_{C1}), such as China, because the observations are only available later than 1998.

[15] The estimates for the Asian Financial Crisis in the virtual middle income country are all insignificant at the 10% significance level, probably due to some countries being absent from the observations, such as China, Sri Lanka and Vietnam.

estimate the RIRP panel regression with cross-section fixed effects in Table 4. First of all, the drift terms in all cases are positive and statistically significant at the 1% level. The results support the findings of the single-equation standard RIRP regression and imply that transaction costs are essential for achieving parity. We find that the estimates of the panel regression of the parity for High Income countries are considerably different from the estimates for the Middle (Upper- & Lower-) Income countries, especially based on the *ex ante* approach. By using the *ex ante* price forecasting approaches, we find that neither the real exchange rate changes nor interaction terms are significantly correlated with the real interest rate differentials for High Income countries. The estimation coefficients for the interaction terms of the panel regression for the parity using *ex ante* price forecasting methods for Middle Income economies are all positively significant at the 1% level (see the 2nd panel in Table 4), but the coefficients for the real exchange rates are ambiguous and not significant at the 10% level. However, the estimates of the panel regression for the parity for the overall sample appear to be dominated by the Middle Income economies, and lead to almost the same conclusions. It can clearly be seen that the interaction terms can significantly improve the RIRP for the Middle Income economies and the overall sample. Roughly speaking, the results estimated by the panel regression using the *ex ante* price forecasting methods basically support the RIRP, especially for the Middle Income countries. In addition, the cross-section dependence is examined using the Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD and the heteroskedasticity is tested using the LR statistic for the overall sample, and the results are then reported in Table 5. The results reject the no cross-section dependence and the assumption that the residuals are homoskedastic. These findings imply that the estimating method is suitable for the panel regression estimations.

In the literature, there are parameter instability problems when one estimates the UIRP or RIRP in international finance (see Molodtsova, Nikolsko-Rzhevskyy and Papell, 2008; Engel, 2016; Ismailov and Rossi, 2018).[16] In order to examine the possible parameter instability, we illustrate the time-varying slope coefficients with 90% confidence intervals for ($\frac{dQ_{t+1}}{Q_t}$, $i_{F\$,t} \times \frac{dS_{t+1}}{S_t}$) in the RIRP panel regressions for High Income countries (see Figure 1) and for Middle Income countries (see Figure 2). In general, there are real instability problems for both the real exchange rate changes ($\frac{dQ_{t+1}}{Q_t}$) and interaction terms ($i_{F\$,t} \times \frac{dS_{t+1}}{S_t}$). Of particular interest, there are hump-shaped slope coefficients for the real exchange rate changes and U-shaped coefficients for the interaction terms for the panel of High Income countries (see Figure 1). The time-varying slope coefficient estimates for the real exchange rate changes and the interaction terms for the High Income economies are close to zero at about period 80 because the windows of the estimates start to cover the Great Recession so that the interest rate dramatically declines to zero in most developed economies. In the specific low interest rate environments, the regressors, either real

[16] We depict the time varying slope coefficients for both regressors, the real exchange rate changes and interaction terms. We illustrate the last 120 moving-average parameters with their confidence intervals (see Engel, 2016). That is, there are 255 observations for the fixed estimation window.

exchange rate changes or interaction terms, are then close to zero, too. There are specific oscillations for the slope coefficients of both the real exchange rate changes and interaction terms for the panel Middle Income countries (see Figure 2). A possible reason for this is that the moving window observation starts to cover the Great Recession so that the time-varying coefficients become more unstable (see Ismailov and Rossi, 2018).[17] In some cases, the time-varying parameters cannot reject the null hypothesis of the slope coefficient being equal to zero because of the 90% confidence intervals covering zero (see Molodtsova et al., 2008). In other words, even if the estimated slope coefficients for the RIRP regressions are statistically significant at the 10% level in Table 4, it is still possible for the time-varying slope coefficients to cover zero in some time periods.

The Interest Parity Puzzle. In order to realize possible connections between the interest parity puzzle and the RIRP, we plot the covariances between the excess returns on foreign deposits and real interest rate differentials for each country, the covariances with real GDP per capita (in relation to the U.S.), and the covariances with average inflation rates (in relation to the U.S.). In addition, we also report the covariances between the summation of excess returns and real interest rate differentials for each country to confirm our results and present them in the Appendix (see Engel, 2016).

To begin with, we illustrate the covariances between the excess returns and real interest rate differentials for each country. Three alternative income levels categorized by the World Bank, i.e., High, Upper-Middle and Lower-Middle, are distinguished using dark, medium and light blue, and the four different price forecasting approaches are similarly depicted in Figure 3. In general, the covariances between the excess returns and real interest rate differentials are positive for most High Income countries, but negative for most Upper-Middle and Lower-Middle Income economies.[18] Interest parity puzzle is found to apply to most High Income economies, but basically there are no puzzles for Middle (Upper-Middle & Lower-Middle) Income economies (see Bansal and Dahlquist, 2000; Engel, 2016).

In order to confirm the results in Figure 3, we calculate the covariance between the summation of the excess returns on foreign deposits and real interest rate differentials, which we report in Table A1 (see Engel, 2016). We find that the interest parity puzzle is quite common in the High Income economies, and there are no puzzles for the Upper-Middle Income and Lower-Middle Income countries except for the Philippines. The findings are similar to the results for the single-period covariance case obtained in Figure 3. The results, based either on the single-period or summed covariances lead us to conclude

[17]One can find that there are drastically different patterns of time-varying coefficients between High and Middle Income economies. High Income economies have problems in relatively lower interest rates, but Middle Income countries experience highly volatile situations after the Great Recession.

[18]One specific outlier is S. Korea, because the covariances are consistently negative for all cases. That is not a puzzle. The possible interpretation for the result is that the Korean won is relatively riskier than the U.S. dollar for local Korean investors. The Korean investors are encouraged to engage in carry trades once an opportunity for U.S. dollar excess returns presents itself.

that there are interest parity puzzles for most High Income economies, but no puzzles for Middle Income countries. This conclusion can shed some light when seeking to interpret why deviations from the parity do not usually converge or why the RIRP does not often hold as the theory predicts. It is because an investor takes currency risk into account when making a carry trade decision. If the investor has to bear relatively high currency risk compared to that for his/her local currency, he/she might not want to move funds across borders even if the foreign currency can generate excess returns. That is to say, the parity puzzle occurs, and the RIRP does not hold because of the absence of arbitrage.

However, some studies claim that the interest parity puzzle is related to certain economic factors, such as income levels, inflation rates, and so on. (see Bansal and Dahlquist, 2000). We therefore present the scatter diagrams of average real GDP per capita (in relation to the U.S.) and covariances between excess returns and real interest rate differentials in the first panel of Figure 4. The scatter diagrams for the average inflation rates (in relation to the U.S.) and the covariances are shown in the second panel of Figure 4. More specifically, that the real GDP per capita in relation to the U.S. equals one implies that the country's income level is the same as that for the U.S. (such as Japan and Australia), and some countries, for example, Taiwan have an income level that is about 35% that of the U.S. (see the first panel of the figure). Similarly, the average inflation rates in relation to the U.S. being equal to one means the same (such as New Zealand and Malaysia), but that for China is slightly negative because of its average inflation rate being negative in the observations (see the second panel of the figure). We place both the average real GDP per capita in relation to the U.S. and the average home inflation to the average for the U.S. on the x-axis to determine whether the income level and inflation are really playing roles in the interest parity puzzle.

It can be found that there is obviously a positive relationship between the covariances and income levels (real GDP per capita), and a definite negative relationship between the covariances and average inflation. That is to say, relatively high income countries usually have high covariances between the excess returns and real interest rate differentials so as to result in the interest parity puzzles. By contrast, relatively high inflation rate countries often have low covariances so that there is no puzzle (see Figure 4). Intuitively, low income or high inflation rate countries usually suffer from currency risk so that the local investors in these countries usually decide to move funds to other low currency risk countries, like the U.S., especially for a currency with positive excess returns. Finally, we conclude that low income or high inflation rate countries usually have low covariances because these countries' investors decide to engage in carry trades for higher returns so that there is no interest parity puzzle. The main interpretation is that these investors usually have a low *risk premium* when engaging in a carry trade (see Figure 4). The results support the findings obtained by Bansal and Dahlquist (2000).

4 CONCLUDING REMARKS

The study explores the RIRP and the interest parity puzzle by using several popular price forecasting methods based on the data collected from Asia-Pacific economies. Differing from the existing studies, we build a general form of the RIRP model, and then examine the parity by using some alternative empirical data. All of the economies are categorized according to High, Upper-Middle and Lower-Middle Income countries. First of all, we report the preliminary summary statistics for the deviation from the parity, and find that there are different features between developed and developing economies. The deviations from the parity are not too significant for most countries based on the summary statistics of the DRIRP, and the real interest rate differentials usually have strong connections with the real exchange rate changes and the interaction terms for the Upper-Middle and Lower-Middle Income economies. We find that the distribution of the DRIRPs for some middle income countries are clearly platykurtic. The price forecasting methods, either *ex ante* or *ex post*, also play a key role in the parity, and the results of the ARMA model are similar to the results using the *ex post* approach. Of particular importance, we find that the puzzle occurs in high income/low inflation economies. In other words, income and inflation levels play crucial roles in explaining the RIRP in a very general form. Finally, we confirm that the interest-exchange interaction term plays a non-trivial role in most cases.

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Table 1: Summary statistics for deviations from the real interest rate parity

	Ex ante															
	RW				AR				ARMA				*Ex post*			
Economy	Mean	S.D.	Skew.	Kurt.	Mean	S.D.	Skew.	Kurt.	Mean	S.D.	Skew.	Kurt.	Mean	S.D.	Skew.	Kurt.
High Income																
Australia	0.321	2.660	-0.940	4.906	0.225	2.736	-0.948	5.026	0.193	2.735	-0.953	5.049	0.324	2.658	-0.944	4.937
Hong Kong	-0.013	0.777	0.110	5.167	0.103	0.777	0.123	5.178	-0.009	0.777	0.114	5.154	-0.007	0.719	0.099	5.108
Japan	-0.063	2.723	0.319	0.931	-0.338	2.723	0.318	0.929	-0.057	2.722	0.318	0.928	-0.054	2.717	0.314	0.912
New Zealand	0.397	3.430	-0.531	2.279	0.419	3.430	-0.530	2.277	0.403	3.429	-0.526	2.260	0.403	3.428	-0.526	2.251
Singapore	0.060	1.713	-0.256	3.080	0.273	1.713	-0.250	3.076	0.062	1.714	-0.255	3.074	0.063	1.702	-0.260	3.167
S. Korea	0.274	3.600	-2.394	26.11	0.171	3.600	-2.395	26.10	0.274	3.599	-2.399	26.11	0.272	3.599	-2.432	26.55
Taiwan	0.119	1.615	-0.082	1.342	0.480	1.613	-0.087	1.338	0.123	1.614	-0.081	1.341	0.124	1.573	-0.089	1.490
Upper-Middle Income																
China	0.345	0.788	-0.346	0.754	0.368	0.788	-0.344	0.755	0.343	0.789	-0.346	0.744	0.344	0.754	-0.358	0.891
Malaysia	-0.029	2.473	1.002	25.86	0.032	2.474	1.004	25.83	-0.027	2.473	0.996	25.81	-0.026	2.468	0.967	25.77
Thailand	0.112	2.709	-0.468	24.38	-0.004	2.709	-0.468	24.37	0.114	2.709	-0.477	24.35	0.112	2.703	-0.488	24.54
Lower-Middle Income																
India	0.333	1.677	-0.335	2.001	0.176	1.677	-0.341	2.010	0.316	1.678	-0.346	2.019	0.317	1.667	-0.384	2.109
Indonesia	0.149	5.371	-2.699	37.98	0.254	5.370	-2.709	37.97	0.184	5.365	-2.791	38.62	0.183	5.430	-2.975	40.81
Philippines	0.264	2.344	-0.961	5.769	0.538	2.344	-0.961	5.767	0.257	2.344	-0.967	5.781	0.251	2.333	-0.998	5.871
Sri Lanka	0.463	1.596	0.210	3.426	0.231	1.597	0.218	3.455	0.454	1.593	0.221	3.484	0.445	1.540	0.165	3.767
Vietnam	0.306	1.088	-1.224	9.381	0.469	1.091	-1.201	9.070	0.308	1.075	-1.356	10.04	0.307	1.046	-1.606	11.55

[1] S.D. refers to the standard deviation, Skew. is skewness and Kurt. is kurtosis.

[2] High, Upper-Middle and Lower-Middle Income are categorized based on the criteria reported by the World Bank in 2017.

Table 2: Standard real interest rate parity regression

Economy	RW			AR			ARMA			*Ex post*		
	γ_0	γ_Q	γ_{iS}	γ_0	γ_Q	γ_{iS}	γ_0	γ_Q	γ_{iS}	γ_0	γ_Q	γ_{iS}
High Income												
Australia	$0.159^‡$	0.004	$-3.782^‡$	$0.195^‡$	0.005	$-4.000^‡$	$0.162^‡$	0.005	$-3.910^‡$	$0.162^‡$	0.005	$-3.684^‡$
	(0.00)	(0.18)	(0.01)	(0.00)	(0.16)	(0.01)	(0.00)	(0.15)	(0.01)	(0.00)	(0.14)	(0.01)
Hong Kong	-0.009	$0.074^‡$	-19.91	$0.107^‡$	$0.074^‡$	-20.54	-0.005	$0.074^‡$	-20.34	-0.003	$0.157^‡$	-47.51
	(0.59)	(0.00)	(0.80)	(0.00)	(0.00)	(0.79)	(0.77)	(0.00)	(0.79)	(0.87)	(0.00)	(0.54)
Japan	0.014	-0.004	-1.955	$-0.261^‡$	-0.004	-1.958	$0.020^†$	-0.003	-2.027	$0.022^‡$	0.000	-2.629^*
	(0.11)	(0.50)	(0.21)	(0.00)	(0.51)	(0.21)	(0.02)	(0.55)	(0.19)	(0.01)	(0.94)	(0.09)
New Zealand	$0.290^‡$	-0.00	-3.769^*	$0.312^‡$	-0.000	$-3.751^‡$	$0.296^‡$	0.001	-4.168^*	$0.296^‡$	0.002	$-4.530^†$
	(0.00)	(0.96)	(0.09)	(0.00)	(0.96)	(0.09)	(0.00)	(0.89)	(0.07)	(0.00)	(0.77)	(0.05)
Singapore	-0.008	0.008	-2.495	$0.206^‡$	0.007	-1.783	-0.006	0.008	-2.645	-0.005	$0.021^‡$	$-4.902^†$
	(0.34)	(0.22)	(0.27)	(0.00)	(0.29)	(0.43)	(0.48)	(0.21)	(0.47)	(0.53)	(0.00)	(0.04)
S. Korea	$0.226^‡$	-0.004	$4.164^†$	$0.123^‡$	-0.004	$4.153^†$	$0.226^‡$	-0.004	$4.134^†$	$0.224^‡$	-0.001	2.698
	(0.00)	(0.45)	(0.02)	(0.00)	(0.45)	(0.02)	(0.00)	(0.49)	(0.02)	(0.00)	(0.93)	(0.12)
Taiwan	$0.142^‡$	$-0.027^‡$	$10.79^‡$	$0.503^‡$	$-0.028^‡$	$11.58^‡$	$0.146^‡$	$-0.027^‡$	$10.77^‡$	$0.143^‡$	$0.022^‡$	-0.025
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.99)
High[a]	$0.053^‡$	-0.006	-1.726	$-0.120^‡$	-0.005	-1.714	$0.058^‡$	-0.005	-1.839	$0.060^‡$	-0.000	-2.633^*
	(0.00)	(0.33)	(0.27)	(0.00)	(0.37)	(0.29)	(0.00)	(0.39)	(0.25)	(0.00)	(0.96)	(0.09)
Upper-Middle Income												
China	$0.396^‡$	0.050^*	$116.4^‡$	$0.419^‡$	0.050^*	$116.0^‡$	$0.394^‡$	0.051^*	$117.2^‡$	$0.387^‡$	$0.106^‡$	$92.38^‡$
	(0.00)	(0.07)	(0.00)	(0.00)	(0.07)	(0.00)	(0.00)	(0.07)	(0.00)	(0.00)	(0.00)	(0.00)
Malaysia	$0.068^‡$	-0.003	1.519	$0.129^‡$	-0.003	1.453	$0.070^‡$	-0.003	1.515	$0.070^‡$	0.003	0.100
	(0.00)	(0.68)	(0.42)	(0.00)	(0.70)	(0.45)	(0.00)	(0.69)	(0.43)	(0.00)	(0.61)	(0.96)
Thailand	$0.113^‡$	-0.010	$6.648^†$	-0.003	-0.010	$6.840^‡$	$0.115^‡$	-0.009	6.314^*	$0.115^‡$	0.008	2.308
	(0.00)	(0.44)	(0.05)	(0.83)	(0.42)	(0.04)	(0.00)	(0.50)	(0.06)	(0.00)	(0.54)	(0.48)
Lower-Middle Income												
India	$0.186^‡$	$0.024^†$	-5.084	0.028^*	$0.024^†$	-4.640	$0.168^‡$	$0.024^†$	-4.734	$0.171^‡$	$0.032^‡$	-7.090
	(0.00)	(0.03)	(0.51)	(0.09)	(0.04)	(0.55)	(0.00)	(0.04)	(0.55)	(0.00)	(0.01)	(0.38)
Indonesia	0.057	-0.018	$8.986^‡$	$0.161^‡$	-0.018	$9.239^‡$	$0.096^‡$	-0.008	$7.087^†$	$0.119^‡$	0.202	-2.747
	(0.11)	(0.21)	(0.00)	(0.00)	(0.21)	(0.00)	(0.01)	(0.58)	(0.03)	(0.00)	(0.17)	(0.39)
Philippines	$0.212^‡$	-0.003	2.976	$0.486^‡$	-0.004	3.397	$0.205^‡$	-0.003	2.877	$0.205^‡$	0.016	-1.752
	(0.00)	(0.82)	(0.42)	(0.00)	(0.74)	(0.36)	(0.00)	(0.84)	(0.44)	(0.00)	(0.23)	(0.64)
Sri Lanka	$0.239^‡$	$0.037^‡$	-23.98^*	0.005	$0.034^†$	-21.28	$0.231^‡$	$0.040^‡$	-24.50^*	$0.234^‡$	$0.078^‡$	$-38.92^‡$
	(0.00)	(0.01)	(0.10)	(0.81)	(0.02)	(0.13)	(0.00)	(0.01)	(0.09)	(0.00)	(0.00)	(0.01)
Vietnam	$0.156^‡$	$0.047^‡$	2.999	$0.324^‡$	$0.050^‡$	-17.46	$0.161^‡$	$0.062^‡$	3.912	$0.165^‡$	$0.090^‡$	-2.530
	(0.00)	(0.01)	(0.91)	(0.00)	(0.01)	(0.50)	(0.00)	(0.00)	(0.88)	(0.00)	(0.00)	(0.92)
Middle[a]	$0.169^‡$	$0.066^‡$	-8.412^*	$0.179^‡$	$0.064^‡$	-7.563	$0.172^‡$	$0.070^‡$	-9.049^*	$0.176^‡$	$0.101^‡$	$-18.61^‡$
	(0.00)	(0.00)	(0.09)	(0.00)	(0.00)	(0.11)	(0.00)	(0.00)	(0.06)	(0.00)	(0.00)	(0.00)

[1] [a] refers to the weighted average for High Income and Middle (mixed up Upper-Middle and Lower-Middle) Income countries. The weights for the High (or Middle) Income are calculated using the shares of one country's real GDP to the whole group's real GDP.

[3] ‡, †, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Numbers in parentheses are p-values.

[3] The RIRP regression is: $r_t^D = \gamma_0 + \gamma_Q \frac{dQ_t}{Q_t} + \gamma_{iS}(i_{F\$} \times \frac{dS_t}{S_t})$.

Table 3: Real interest rate parity regression with dummy variables

Economy	RW					AR					ARMA					*Ex post*				
	γ_0	γ_{C1}	γ_{C2}	γ_Q	γ_{iS}	γ_0	γ_{C1}	γ_{C2}	γ_Q	γ_{iS}	γ_0	γ_{C1}	γ_{C2}	γ_Q	γ_{iS}	γ_0	γ_{C1}	γ_{C2}	γ_Q	γ_{iS}
High Income																				
Australia	0.159‡	-0.093‡	0.088‡	0.005	-3.097†	0.195‡	-0.103‡	0.095‡	0.005	-3.235†	0.162‡	-0.086‡	0.083‡	0.005	-3.275†	0.162‡	-0.083‡	0.080‡	0.005	-3.069†
	(0.00)	(0.00)	(0.00)	(0.14)	(0.02)	(0.00)	(0.00)	(0.00)	(0.12)	(0.02)	(0.00)	(0.00)	(0.00)	(0.11)	(0.02)	(0.00)	(0.00)	(0.00)	(0.11)	(0.02)
Hong Kong	-0.001	-0.049	-0.047	0.074‡	-22.01	0.115‡	-0.051	-0.047	0.075‡	-22.63	0.003	-0.050	-0.047	0.075‡	-22.45	0.005	-0.052	-0.044	0.157‡	-49.46
	(0.96)	(0.41)	(0.43)	(0.00)	(0.78)	(0.00)	(0.39)	(0.43)	(0.00)	(0.77)	(0.86)	(0.40)	(0.43)	(0.00)	(0.77)	(0.77)	(0.39)	(0.46)	(0.00)	(0.53)
Japan	0.029‡	-0.309‡	0.079‡	-0.003	-1.761	-0.246‡	-0.313‡	0.081‡	-0.003	-1.767	0.035‡	-0.312‡	0.080†	-0.003	-1.830	0.037‡	-0.316‡	0.088‡	0.001	-2.459*
	(0.00)	(0.00)	(0.01)	(0.49)	(0.21)	(0.00)	(0.00)	(0.01)	(0.51)	(0.20)	(0.00)	(0.00)	(0.01)	(0.56)	(0.19)	(0.00)	(0.00)	(0.01)	(0.85)	(0.07)
New Zealand	0.296‡	0.035	-0.119*	-0.000	-3.841*	0.317‡	0.032	-0.112*	-0.000	-3.817*	0.301‡	0.048	-0.124*	0.001	-4.276*	0.301‡	0.053	-0.127*	0.002	-4.651†
	(0.00)	(0.60)	(0.07)	(0.96)	(0.08)	(0.00)	(0.62)	(0.09)	(0.96)	(0.08)	(0.00)	(0.48)	(0.07)	(0.89)	(0.06)	(0.00)	(0.44)	(0.06)	(0.77)	(0.04)
Singapore	-0.004	0.083‡	-0.136‡	0.007	-2.733	0.208‡	0.077‡	-0.124‡	0.006	-2.018	-0.002	0.081†	-0.137‡	0.007	-2.868	-0.002	0.087‡	-0.142‡	0.019‡	-5.161†
	(0.59)	(0.01)	(0.00)	(0.30)	(0.21)	(0.00)	(0.01)	(0.00)	(0.38)	(0.36)	(0.79)	(0.01)	(0.00)	(0.30)	(0.19)	(0.83)	(0.01)	(0.00)	(0.00)	(0.02)
S. Korea	0.219‡	0.253‡	-0.133‡	-0.003	3.059*	0.116‡	0.252‡	-0.136‡	-0.003	3.047*	0.219‡	0.246‡	-0.137‡	-0.002	3.049*	0.218‡	0.245‡	-0.142‡	0.001	1.613
	(0.00)	(0.00)	(0.01)	(0.65)	(0.07)	(0.00)	(0.00)	(0.01)	(0.66)	(0.08)	(0.00)	(0.00)	(0.01)	(0.70)	(0.07)	(0.00)	(0.00)	(0.00)	(0.80)	(0.33)
Taiwan	0.134‡	0.126‡	-0.000	-0.027‡	9.667‡	0.495‡	0.124‡	0.011	-0.028‡	10.47‡	0.138‡	0.124‡	-0.001	-0.027‡	9.658‡	0.135‡	0.125‡	0.001	0.022‡	-1.141
	(0.00)	(0.00)	(0.99)	(0.00)	(0.00)	(0.00)	(0.00)	(0.75)	(0.00)	(0.00)	(0.00)	(0.00)	(0.98)	(0.00)	(0.00)	(0.00)	(0.00)	(0.97)	(0.00)	(0.65)
High^{a}	0.063‡	-0.200‡	0.053†	-0.005	-1.324	-0.111‡	-0.213‡	0.073‡	-0.005	-1.362	0.068‡	-0.202‡	0.052†	-0.005	-1.428	0.069‡	-0.205‡	0.056†	0.000	-2.233
	(0.00)	(0.00)	(0.04)	(0.33)	(0.36)	(0.00)	(0.00)	(0.01)	(0.39)	(0.53)	(0.00)	(0.00)	(0.05)	(0.39)	(0.33)	(0.00)	(0.00)	(0.03)	(0.98)	(0.12)
Upper-Middle Income																				
China	0.367‡	-	0.265‡	0.043*	130.84‡	0.391‡	-	0.266‡	0.043*	130.4‡	0.346‡	-	0.278‡	0.045*	132.3‡	0.357‡	-	0.278‡	0.100‡	107.5‡
	(0.00)		(0.00)	(0.10)	(0.00)	(0.00)		(0.00)	(0.10)	(0.00)	(0.00)		(0.00)	(0.10)	(0.00)	(0.00)		(0.00)	(0.00)	(0.00)
Malaysia	0.061‡	0.072*	0.032	-0.002	0.922	0.122‡	0.070*	0.042	-0.002	0.869	0.064‡	0.067*	0.030	-0.002	0.956	0.065‡	0.061	0.025	0.004	-0.409
	(0.00)	(0.06)	(0.38)	(0.75)	(0.63)	(0.00)	(0.07)	(0.27)	(0.76)	(0.66)	(0.00)	(0.08)	(0.42)	(0.75)	(0.62)	(0.00)	(0.10)	(0.49)	(0.56)	(0.83)
Thailand	0.090‡	0.338‡	0.010	-0.004	4.075	-0.025*	0.339‡	0.000	-0.005	4.251	0.093‡	0.330‡	0.011	-0.003	3.800	0.093‡	0.323‡	0.010	0.013	-0.154
	(0.00)	(0.00)	(0.85)	(0.72)	(0.20)	(0.09)	(0.00)	(1.00)	(0.69)	(0.19)	(0.00)	(0.00)	(0.84)	(0.78)	(0.23)	(0.00)	(0.00)	(0.85)	(0.29)	(0.96)
Lower-Middle Income																				
India	0.207‡	-0.843‡	-0.168‡	0.024†	-1.915	0.049‡	-0.831‡	-0.169‡	0.024†	-1.453	0.190‡	-0.845‡	-0.181‡	0.024†	-1.315	0.196‡	-0.709‡	-0.212‡	0.032‡	-3.081
	(0.00)	(0.00)	(0.00)	(0.03)	(0.80)	(0.00)	(0.00)	(0.00)	(0.03)	(0.85)	(0.00)	(0.00)	(0.00)	(0.03)	(0.86)	(0.00)	(0.00)	(0.00)	(0.00)	(0.69)
Indonesia	0.059	0.239*	-0.220	-0.013	7.507†	0.168‡	0.243	-0.293†	-0.013	7.715†	0.106‡	0.182	-0.288†	-0.005	5.932*	0.128‡	0.201	-0.294†	0.025	-4.020
	(0.11)	(0.10)	(0.12)	(0.37)	(0.02)	(0.00)	(0.10)	(0.04)	(0.36)	(0.02)	(0.01)	(0.23)	(0.05)	(0.76)	(0.07)	(0.00)	(0.19)	(0.05)	(0.11)	(0.23)
Philippines	0.209‡	0.248‡	-0.164‡	0.001	0.496	0.484‡	0.245‡	-0.170‡	0.000	0.924	0.204‡	0.239‡	-0.175‡	0.002	0.437	0.204‡	0.236‡	-0.184‡	0.021	-4.192
	(0.00)	(0.00)	(0.01)	(0.91)	(0.89)	(0.00)	(0.00)	(0.01)	(0.99)	(0.80)	(0.00)	(0.00)	(0.01)	(0.90)	(0.91)	(0.00)	(0.00)	(0.01)	(0.12)	(0.26)
Sri Lanka	0.241‡	-	-0.015	0.037‡	-24.14*	0.008	-	-0.024	0.034†	-21.53	0.233‡	-	-0.020	0.040‡	-24.72*	0.238‡	-	-0.027	0.078‡	-39.21‡
	(0.00)		(0.82)	(0.01)	(0.10)	(0.73)		(0.71)	(0.02)	(0.13)	(0.00)		(0.76)	(0.01)	(0.09)	(0.00)		(0.68)	(0.00)	(0.01)
Vietnam	0.177‡	-	-0.200‡	0.042†	3.146	0.344‡	-	-0.187‡	0.045†	-17.32	0.185‡	-	-0.232‡	0.057‡	4.082	0.190‡	-	-0.239‡	0.084‡	-2.355
	(0.00)		(0.00)	(0.02)	(0.90)	(0.00)		(0.00)	(0.01)	(0.49)	(0.00)		(0.00)	(0.00)	(0.88)	(0.00)		(0.00)	(0.00)	(0.93)
Middle^{a}	0.158‡	-0.055	0.202‡	0.062‡	-6.201	0.170‡	-0.049	0.187‡	0.060‡	-5.556	0.163‡	-0.063	0.196‡	0.065‡	-6.641	0.167‡	-0.060	0.191‡	0.096‡	-16.32‡
	(0.00)	(0.23)	(0.00)	(0.00)	(0.21)	(0.00)	(0.26)	(0.00)	(0.00)	(0.25)	(0.00)	(0.16)	(0.00)	(0.00)	(0.17)	(0.00)	(0.18)	(0.00)	(0.00)	(0.00)

[1] See Notes to Table 2.

[2] The RIRP regression with dummy variables: $r_t^D = \gamma_0 + \gamma_{C1} Crisis\texttt{97-8}_t + \gamma_{C2} Crisis\texttt{08-9}_t + \gamma_Q \frac{dQ_t}{Q_t} + \gamma_{iS}(i_{F\$} \times \frac{dS_t}{S_t})$ where $Crisis\texttt{97-8}_t = 1$, for the years 1997-1998, 0 otherwise; $Crisis\texttt{08-9}_t = 1$, for the years 2008-2009, 0 otherwise (see, for example, Chiang et al., 2007; Choi et al., 2011; Hass and Van Lelyveld, 2014).

Table 4: Panel real interest rate parity regression

	Ex ante			
Model	RW	AR	ARMA	*Ex post*
High Income				
γ_0	0.119‡	0.170‡	0.123‡	0.124‡
	(0.00)	(0.00)	(0.00)	(0.00)
γ_Q	-0.000	-0.000	0.000	0.008‡
	(0.90)	(0.86)	(0.92)	(0.00)
γ_{iS}	-0.347	-0.270	-0.501	-2.397‡
	(0.67)	(0.74)	(0.55)	(0.00)
$\bar{R}^2$	0.206	0.507	0.202	0.198
# of economies	7	7	7	7
Observations	2,479	2,479	2,479	2,479
Middle Income				
γ_0	0.154‡	0.190‡	0.158‡	0.162‡
	(0.00)	(0.00)	(0.00)	(0.00)
γ_Q	-0.001	-0.025	0.004	0.028‡
	(0.78)	(0.68)	(0.49)	(0.00)
γ_{iS}	5.079‡	5.340‡	4.014‡	-4.171‡
	(0.00)	(0.00)	(0.00)	(0.00)
$\bar{R}^2$	0.07	0.20	0.06	0.05
# of economies	8	8	8	8
Observations	2,307	2,307	2,307	2,307
Whole Sample				
γ_0	0.136‡	0.180‡	0.140‡	0.142‡
	(0.00)	(0.00)	(0.00)	(0.00)
γ_Q	-0.002	-0.003	0.000	0.016‡
	(0.40)	(0.33)	(0.93)	(0.00)
γ_{iS}	3.581‡	3.759‡	3.027‡	-2.453‡
	(0.00)	(0.00)	(0.00)	(0.00)
$\bar{R}^2$	0.11	0.31	0.10	0.10
# of economies	15	15	15	15
Observations	4,786	4,786	4,786	4,786

[1] The cross-section fixed effects are included in the estimation. The Middle Income economies are mixed up with Upper-Middle and Lower-Middle together.

[2] ‡, †, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Numbers in parentheses are p-values.

[3] The panel RIRP regression is: $r_t^D = \gamma_0 + \gamma_Q \frac{dQ_t}{Q_t} + \gamma_{iS}(i_{F\$} \times \frac{dS_t}{S_t})$.

Table 5: Cross-section dependence and heteroskedasticity tests

	Ex ante			
Test	RW	AR	ARMA	*Ex post*
Breusch-Pagan LM	3,511.6‡	3,542.4‡	3,539.3‡	3,712.0‡
	(0.00)	(0.00)	(0.00)	(0.00)
Pesaran scaled LM	235.1‡	237.2‡	237.0‡	248.9‡
	(0.00)	(0.00)	(0.00)	(0.00)
Pesaran CD	42.75‡	43.22‡	43.10‡	44.53‡
	(0.00)	(0.00)	(0.00)	(0.00)
LR stat.	1,760.9‡	1,719.3‡	1,848.2‡	1,879.3‡
	(0.00)	(0.00)	(0.00)	(0.00)

[1] ‡ denotes statistical significance at the 1% level. Numbers in parentheses are p-values.

[2] Null: No cross-section dependence (correlation) in the residuals. LR stat. is for the cross-section heteroskedasticity LR test. Null: The residuals are homoskedastic.

[3] The tests are for the whole sample only.

Figure 1: Slope coefficients and 90% confidence intervals of the panel RIRP regressions for High Income countries

Figure 2: Slope coefficients and 90% confidence intervals of the panel RIRP regressions for Middle Income countries

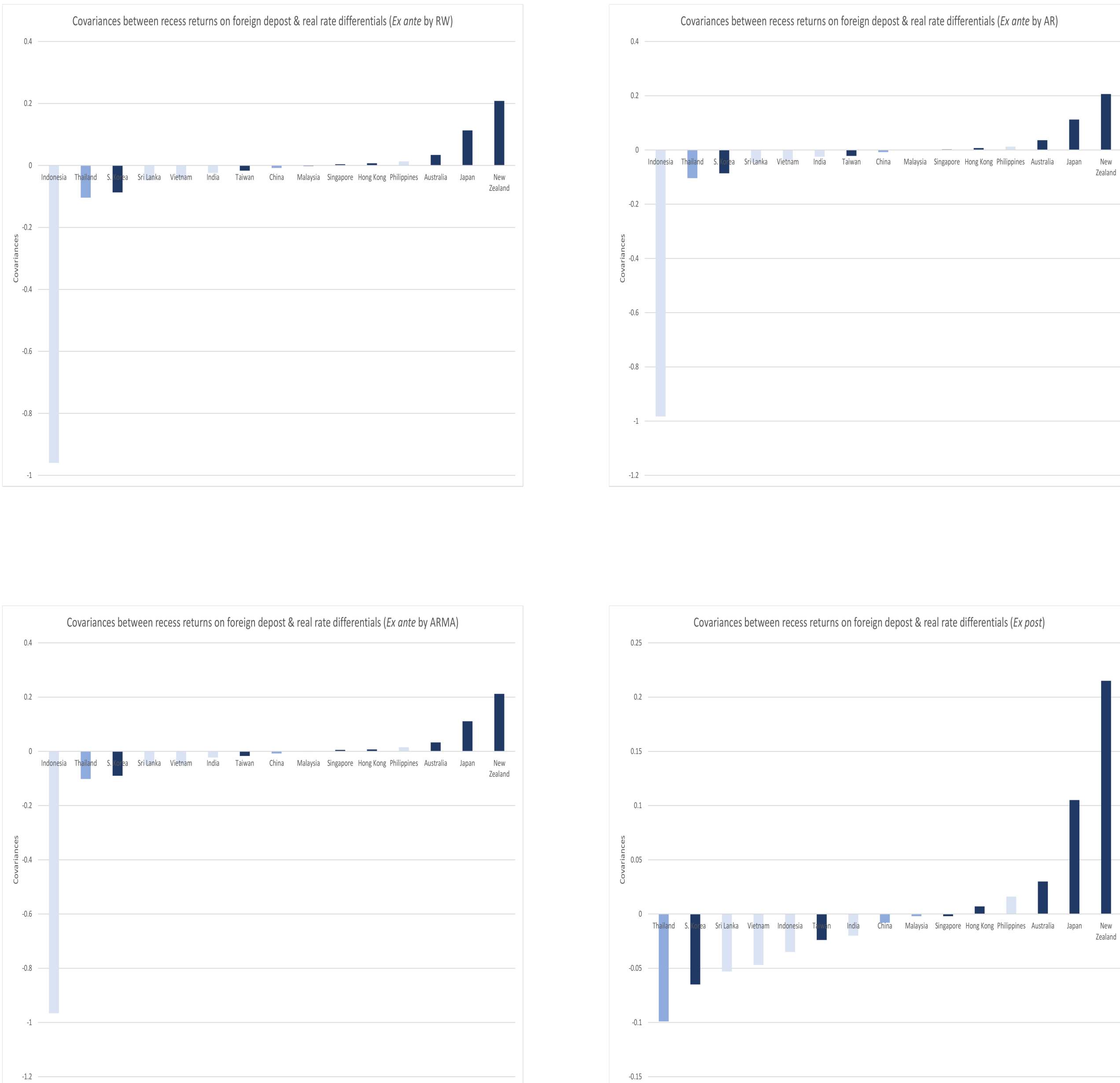
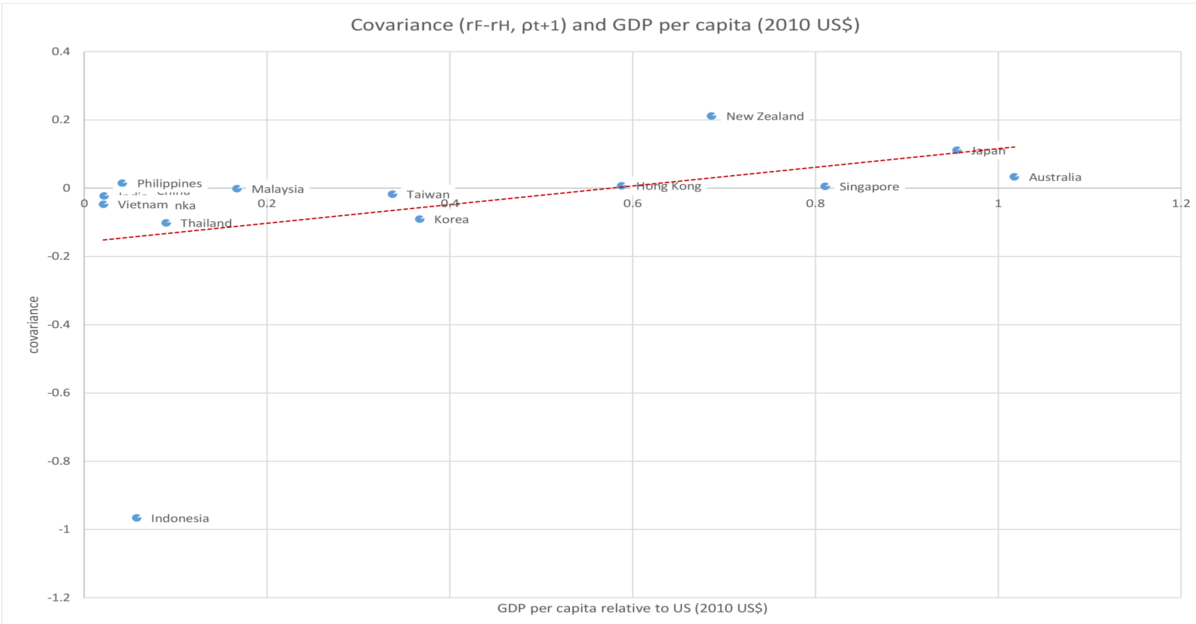


Figure 3: Covariances between excess returns & real interest rate differentials

Notes: High Income countries in dark blue; Upper-Middle Income in medium blue; Lower-Middle in light blue.



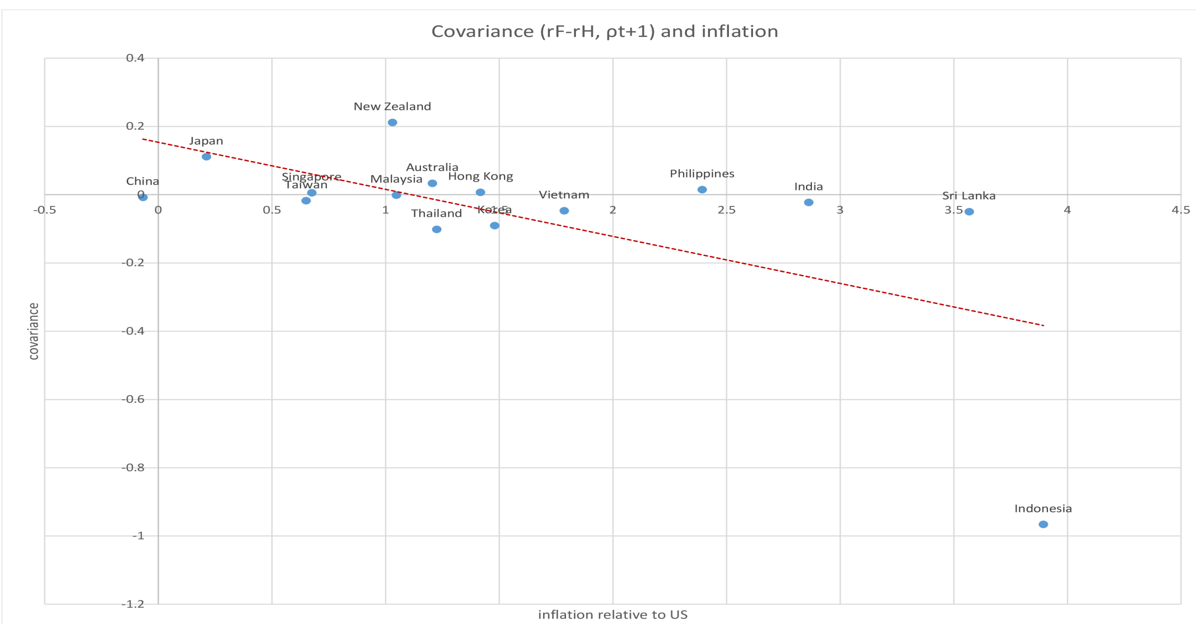


Figure 4: Covariances between excess returns & real interest rate differentials with 1) Average real GDP per capita (2010 US$) in relation to U.S. GDP per capita; 2) Average inflation in relation to U.S. inflation

Notes: We illustrate the figures with price forecasting by ARMA method only.

A APPENDIX

Table A1: Covariance between the summation of excess returns and real interest rate differentials ($cov[E_t \sum_{j=0}^{\infty} \rho_{t+j+1}, r_{US,t} - r_{H,t}]$)

	Ex ante			
Economy	RW	AR	ARMA	*Ex post*
High Income				
Australia	-1.388	-1.656	-1.366	-1.349
Hong Kong	-0.298	-0.297	-0.299	-0.324
Japan	**0.076**	**0.111**	**0.077**	**0.059**
New Zealand	**2.754**	**2.514**	**2.748**	**2.827**
Singapore	**0.601**	**0.493**	**0.607**	**0.666**
S. Korea	**0.776**	**0.833**	**0.772**	**0.731**
Taiwan	-0.449	-0.467	-0.453	-0.374
Upper-Middle Income				
China	-3.550	-3.587	-3.609	-3.662
Malaysia	-0.557	-0.454	-0.577	-0.595
Thailand	-1.659	-1.695	-1.654	-1.641
Lower-Middle Income				
India	-0.750	-0.561	-0.531	-0.351
Indonesia	-3.312	-4.827	-5.398	-6.011
Philippines	**0.719**	**0.813**	**0.759**	**0.616**
Sri Lanka	-4.324	-3.701	-4.233	-4.507
Vietnam	-0.453	-1.569	-0.184	-0.144

[1] $E_t(\sum_{j=0}^{\infty} \rho_{t+j+1})$ refers to the summations of excess returns on foreign deposits ρ_{t+j+1} from the present time to infinity.

[2] Of course, we have no data extended to infinity, so as to utilize all of the available observations to calculate the summations.