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Foreign exchange market efficiency under recent crises: Asia-Pacific focus[☆]

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A B S T R A C T

The Asia-Pacific region's currency markets are generally efficient *within-country* when tested using the Johansen (1991, 1995) cointegration technique whereas market efficiency fails to hold when tested using Fama's (1984) conventional regression. Using the Pilbeam and Olmo (2011) model, we reconcile these conflicting findings. The Pilbeam and Olmo (2011) model confirms *within-country* market efficiency. It further confirms that free-float currency markets are more resilient than managed-float currency markets among 12 Asia-Pacific economies. From the *across-country* perspective, the foreign exchange markets are mostly efficient and the results show that the 1997–1998 Asian financial crisis was a more disturbing event than the 2008–2009 global financial crisis in the region.

1. Introduction

In a period of slightly over one decade, the global financial community has witnessed two of the most devastating financial crises in modern history. Shortly after recovering from the 1997–1998 Asian financial crisis (AFC), the U.S. subprime mortgage sector collapsed. The world was struck by the

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unprecedented losses disclosed by the U.S. banking sector in 2008 and 2009 and, as a result, numerous U.S. and European financial institutions were adversely impacted by the 2008–2009 global financial crisis (GFC).

We investigate the Asia-Pacific foreign currency markets because they were greatly impacted by the AFC and the volatility of these currencies increased tremendously during the GFC. Melvin and Taylor (2009) provide detailed accounts of GFC to illustrate its unforeseen impact on volatility and liquidity in the global currency market. The Asia-Pacific currencies are generally perceived to be more susceptible to financial crisis and speculative attacks. The main objective of this paper is to examine market efficiency of these currencies during the periods surrounding the crises, with the focus on both AFC and GFC as the key events.

A few studies have examined market efficiency of Asian currencies (Jeon and Seo, 2003; Kan and Andreosso-O'Callaghan, 2007). However, these studies focus on the impact of AFC (not GFC) in the region's currency markets given their study periods. Our overall conclusion is that the AFC was a more disturbing event than the GFC in the Asia-Pacific region as stronger evidence of inefficiency is observed during the AFC than the GFC.

To draw this conclusion, we have examined foreign currency market efficiency from *within*- and *across-country* perspectives. The Asia-Pacific foreign currency markets are generally efficient *within-country* when tested using the Johansen (1991, 1995) cointegration technique whereas market efficiency fails to hold when tested using Fama's (1984) conventional regression built on the forward unbiasedness hypothesis. The presence of the forward premium puzzle is not unique to the Asia-Pacific region under this conventional approach. Rather, global currency markets (both developed and developing) show that the forward premium is not only biased but also wrong (Bilson, 1981; Fama, 1984; Froot and Thaler, 1990; Baillie and Bollerslev, 1989, 2000; Bansal and Dahlquist, 2000; Sarno, 2005; Gilmore and Hayashi, 2008; Frankel and Poonawala, 2010). The failure of Fama's regression results in supporting market efficiency is not unexpected in view of a number of more recent alternative explanations for the inadequacy of forward unbiasedness in assessing market efficiency [the adverse selection problem by traders (Burnside et al., 2009); improper treatment of different volatilities between forward and spot rates (Pilbeam and Olmo, 2011); perpetual learning by agents (Chakraborty and Evans, 2008); the different orders of integration of the variables in Fama's regressions (Baillie and Bollerslev, 2000); volatility regimes (Clarida et al., 2009); more easily identifiable trends of depreciation of emerging market currencies (Frankel and Poonawala, 2010)].

While various alternative explanations have merits in understanding the forward premium puzzle, our study is limited in scope to using the Pilbeam and Olmo (2011) model when we reconcile the conflicting findings for *within-country* market efficiency under the two different approaches. Pilbeam and Olmo (2011) conclude that the forward discount puzzle is a statistical phenomenon after they examine four major currencies (Swiss franc; Japanese yen; Euro; and Pound sterling) in their model framework.[1] The availability of Asia-Pacific currency data allows us to apply the Pilbeam and Olmo model to the Asia-Pacific currency markets to generalize their findings. Our study is the first which confirms Pilbeam and Olmo's (2011) findings in the Asia-Pacific currency markets. We find that Asia-Pacific currency markets are consistent with *within-country* market efficiency when re-examined using the Pilbeam and Olmo model. We further confirm that free-float currency markets are more resilient than the managed-float currency markets among 12 Asia-Pacific countries.

The availability of Asia-Pacific currency data allows us to make an additional major contribution to the literature. In an insightful study, Bansal and Dahlquist (2000) observe that the forward premium puzzle characterized by the negative correlation between expected exchange rates and interest-rate differentials is not a pervasive phenomenon. It is rather confined to high GNP per capita economies. They report that country attributes, such as income level, inflation rates, and inflation uncertainty, are important in explaining the cross-sectional dispersion in the risk premium. In this study, we introduce

[1] Interested readers may refer to Pilbeam and Olmo (2011) for a technical discussion on the superiority of their suggested models over the conventional Fama regression.

another important attribute which measures the degree of foreign exchange market regulation. This attribute is proxied by the existence of offshore non-deliverable currency forwards (NDFs). The NDF markets were developed after the AFC outside the jurisdiction of countries with varying degrees of foreign exchange convertibility restrictions because the access to onshore forward markets was limited to non-resident investors (Tsuyuguchi and Wooldridge, 2008). Asian monetary authorities regard the NDF markets with suspicion because of their concern about cross-border spillovers and speculative activities even though NDFs are useful for hedging currency risk exposure (Ma et al., 2004). Naturally, the presence of NDF markets implies a less-liberalized regulatory regime whereas its absence indicates a liberalized regime. We find that the degree of market liberalization is another important attribute in explaining the existence of forward bias puzzle. This finding is informative because our study period goes beyond Bansal and Dahlquist's (2000) study period of 1976–1998 and covers additional Asia-Pacific currencies.

From the *across-country* perspective, the foreign exchange markets are generally efficient when tested using the bivariate cointegration methods for the whole period with the exception of crisis subperiods. Comparing the crisis periods, the bivariate cointegration test results show that there are more currency pairs that display the sign of inefficiency during the AFC more than GFC. In the AFC subperiod, most of the cointegrated currency pairs are Thai baht crosses.

2. Data and subperiods

We use 12 Asia-Pacific currencies obtained from the *Datastream* for this study. The currencies chosen are: Australian dollar (AUD); Chinese yuan (CNY); Japanese yen (JPY); Korean won (KRW); Indonesian rupiah (IDR); Indian rupee (INR); Malaysian ringgit (MYR); New Zealand dollar (NZD); Philippine peso (PHP); Singaporean dollar (SGD); Thai baht (THB) and Taiwan dollar (TWD). Daily spot and one-month forward exchange rates are collected for the period from January 1, 1997 to June 30, 2010 with a total observation of 3521 spot and forward exchange rates with some exceptions.[2] The US dollar (USD) is used as the numéraire currency. The descriptive statistics of the related countries are provided in Table 1.

For the overall period, only three of the 12 currencies have appreciated against the US dollar. They are Australian dollar, Chinese yuan, and Japanese yen. Singaporean dollar is largely unchanged while the rest have weakened relative to the US dollar since 1997. In terms of one-month changes against the US dollar, the Indonesian rupiah registers the widest range of fluctuations among the 12 currencies. Not surprisingly, the Chinese yuan displays the narrowest range. As indicated in column 9 of Table 1, half of the countries are characterized as high-income and the other half as middle-income economies. About two-thirds of the countries have their currencies traded in the NDF markets as shown in the last column. The main reason for these currencies to be traded on the NDF market is due to their varying degrees of restriction on capital flows. Therefore we use the existence of NDF market as a proxy for less-liberalized regulatory regime of foreign exchange while we consider its absence to imply the opposite.

To highlight the impact of two recent financial crises on the Asia-Pacific currency markets, we partition the whole period, January 1, 1997–June 30, 2010, into six subperiods:

(i) the pre-AFC subperiod (January 1, 1997–June 30, 1997);
(ii) the AFC subperiod (July 1, 1997–December 31, 1998);
(iii) the post-AFC subperiod (January 1, 1999–July 20, 2005);
(iv) the pre-GFC subperiod (July 21, 2005–December 31, 2007);
(v) the GFC subperiod (January 1, 2008–December 31, 2009); and
(vi) the post-GFC subperiod (January 1, 2010–June 30, 2010).

[2] The study period for Chinese yuan starts only after July 22, 2005 when the fixed exchange rate regime was abandoned. Meanwhile the study period for Malaysian ringgit is interrupted by the fixed peg period which runs from September 1, 1998 to July 21, 2005. The forward exchange rates for INR and KRW become available from October 27, 1997 and February 11, 2002, respectively.

Table 1

Descriptive statistics of the exchange rates series. We have chosen 12 Asia-Pacific currencies as our focus. All the currencies are quoted against the UD dollar. The period covered is from January 1, 1997 to June 30, 2010 for most of the exchange rate series. Chinese yuan (CNY) exchange rate series commences from July 22, 2005 after the abandonment of a fixed exchange rate regime. Meanwhile the forward exchange rate series of Indian rupee (INR) and Korean won (KRW) are only available from October 27, 1997 and February 11, 2002, respectively. The column on the income category denotes the income level of the respective countries as of 2009 which are available from the World Bank database. H and M denote 'high-income' and 'middle-income'. There are equal numbers of high and medium income economies in our sample. The last column indicates whether or not these currencies are traded on the non-deliverable forward (NDF) markets. The main reason for a currency to be traded in the NDF market is due to its restricted nature (e.g. non-tradeable outside of the home country). Hence, we use the existence of NDF market as a proxy for a less-liberalized FX regime while we consider its absence to imply the opposite.

	Mean spot rate	Spot range		Mean forward rate	1-month mean spot changes (%)	1-month spot changes range (%)		Income category	Existence of NDF
		Highest	Lowest			Highest	Lowest		
Australia	1.4422	2.0866	1.0216	1.4445	−0.0552	32.73	−11.80	H	N
China	8.0994	8.7129	6.7817	7.6948	−0.1541	0.86	−5.13	M	Y
India	44.16	51.97	35.69	44.92	0.8487	8.99	−7.22	M	Y
Indonesia	8450	15,500	2361	8490	0.1635	92.79	−47.36	M	Y
Japan	112.84	147.27	86.36	112.51	−0.1616	10.22	−16.86	H	N
Korea	1130	1960	844	1101	0.2245	61.89	−20.05	H	Y
Malaysia	3.6084	4.6852	2.4715	3.6673	0.1697	24.56	−25.58	M	Y
New Zealand	1.6940	2.5481	1.2237	1.6979	0.0101	22.98	−16.15	H	N
Philippines	46.30	56.46	26.28	46.52	0.3547	25.96	−13.37	M	Y
Singapore	1.6177	1.8540	1.3480	1.6162	−0.0031	9.33	−9.44	H	N
Thailand	37.73	56.00	22.70	38.03	0.1468	29.21	−26.07	M	Y
Taiwan	32.52	35.22	27.31	32.51	0.1004	10.13	−6.15	H	Y

This partition of the whole period is also graphically illustrated in Table 2. The subperiod analyses are useful in assessing and contrasting immediate impacts of the two crises. The beginning of the fourth subperiod coincides with the shift in the foreign exchange regimes in China and Malaysia, which will allow us to assess how market efficiency has been affected by this shift.[3] The post-AFC subperiod may be characterized for currency appreciation in the Asia-Pacific region because virtually all the currencies experienced significant appreciation in this period. It would be also interesting to observe how market efficiency has been affected by this pattern of currency appreciation.

3. Theoretical framework, empirical methodologies and results

Efficient markets hypothesis (EMH) takes its modern root from Fama (1970) and his subsequent studies (1991, 1998). These three papers are now known as the "Trilogy of EMH". Fama has ingeniously shown and argued that the markets are efficient and the security prices are always, albeit not continuously, reflecting all available information. Even though the main focus of Fama's "Trilogy of EMH" is the capital markets, we can easily extend the theory and argument to the foreign exchange markets.

In the context of the foreign exchange markets, the uncovered interest-rate parity (UIP) is used as the benchmark efficiency theory. The UIP is a core theory in international finance which stipulated that the returns in an asset of similar risk profile should yield the same returns when calculated under a common currency. Therefore, the changes between two currencies should equal to the corresponding interest-rate differential. The testing of the UIP is also known as the testing of a risk-neutral EMH (Chinn, 2006). Sarno (2005) provides an insightful review of the recent developments in the foreign exchange market efficiency. We subscribe to this same theoretical framework in our paper.

Along with the above theories, the foreign exchange markets efficiency can be viewed from *within-country* and *across-country* perspectives. Foreign exchange market is efficient *within-country* if the forward exchange rates served as unbiased predictor of future spot exchange rates. If the forward rate fails as unbiased predictor, a profit opportunity is available and hence excess returns are possible.[4] Meanwhile, in an *across-country* efficient market, one country's spot exchange rates should not be predictable with another country's spot exchange rates. The presence of cointegration among a series of different countries' spot exchange rates violates this tenet of market efficiency (Baillie and Bollerslev, 1989). For example, Kan and Andreosso-O'Callaghan, 2007 argue that cointegration represents the existence of a long-run relationship among these currencies and therefore any departure from this relationship can be used to forecast future movement of a country's spot exchange rates. Theoretically, the *within-country* efficiency emphasises on the rational expectation of market participants in an efficient market whereas the *across-country* efficiency looks at whether the tenet of no predictability in an efficient market is obeyed. A brief discussion of market efficiency requirements is summarized in Table 3.

3.1. Within-country *market efficiency*

We use the Johansen (1991, 1995) cointegration model and Fama's (1984) conventional regressions to investigate *within-country* market efficiency in each of the six subperiods. We rely on the Pilbeam and Olmo (2011) approach to reconcile mixed results of *within-country* market efficiency under the two popular methods. The Johansen cointegration tests (both bivariate and multivariate) are also used for *across-country* market efficiency.

[3] In a major robustness test reported in Section 3.3, we regroup our six subsample periods into three distinct periods under one single model by treating all the non-crisis subsample periods as one single group of non-crisis sample and leave AFC and GFC as two distinct subperiods. This regrouping is to address the concern about the small number of observations in some subperiods.

[4] We thank an anonymous referee who points out that a potential profit opportunity is not exactly the same as arbitrage opportunity.

Table 2
Summary of subperiods.

Classification	Time Interval	Description
Whole period	1 Jan 1997–30 Jun 2010	The overall period covers two major financial crises in modern history. It covers a sample of 3521 spot and forward exchange rates, respectively.
Pre-AFC subperiod	1 Jan 1997–30 June 1997	This is the period which precedes the full-blown Asian financial crisis. However, some instability and turbulences in the financial markets were already evidenced.
AFC subperiod	1 Jul 1997–31 Dec 1998	This is the period which covers the full-blown turmoil of the Asian financial crisis. Local currencies depreciated substantially during this period as a result of speculative attacks and capital flights.
Post-AFC subperiod	1 Jan 1999–20 Jul 2005	This period signifies the return of market stability after some of the affected nations accepted the IMF's aids while some others subscribed to unorthodox measure.
Pre-GFC subperiod	21 Jul 2005–31 Dec 2007	The beginning of this period is to coincide with the major shift in the FX regime in China and Malaysia. The Asian currencies experienced a period of appreciation following this episode.
GFC subperiod	1 Jan 2008–31 Dec 2009	This period covers the collapse of the US subprime mortgage markets and liquidity squeeze. Volatility in the FX market was as high as the Asian financial crisis period.
Post-GFC subperiod	1 Jan 2010–30 Jun 2010	This period witnesses the implementation of some unconventional measures to tackle the global financial crisis. The financial markets were still highly uncertain.
Graphical representation		

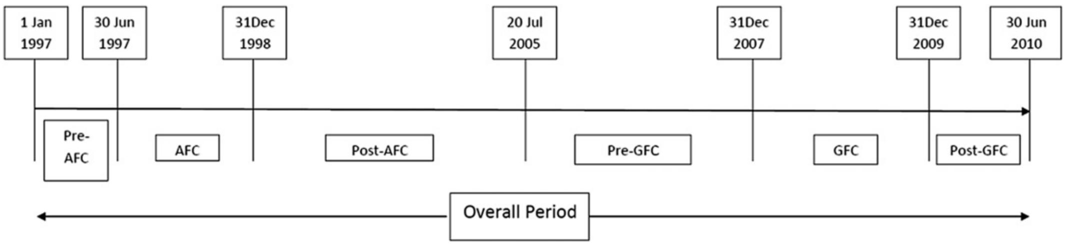

Table 3
Markets efficiency conditions. Foreign exchange market efficiency can generally be viewed from two perspectives, namely *within-country* and *across-country*. From the *within-country* perspective, market is efficient if the forward rates are unbiased predictor of future spot exchange rates. This condition can be tested with both regression and cointegration techniques. Fama (1984) regresses the changes of spot rates on the corresponding period forward premium and the resulting coefficients α and β must be insignificantly different from 0 to 1 respectively in order to meet the efficiency condition. Meanwhile Pilbeam and Olmo (2011) have suggested a similar but different form of regression to test the efficiency condition: the ratio between spot and lagged forward rates is to be deducted by one before regressing on a constant. The market is efficient if the constant is insignificantly different from 0. The unbiasedness of forward rates as predictor of future spot rates can also be tested with Johansen cointegration: the market is efficient if spot and forward exchange rates are cointegrated. In contrast, from the *across-country* perspective, the market is efficient if there is no cointegration among different series of exchange rates.

Perspective	Type of test	Efficiency condition	Econometric representation
i) *Within-country*	Fama (1984) regression	Forward rates are unbiased predictor of future spot exchange rates	$\Delta S_{t+m} = \alpha + \beta(f_t^m - S_t) + \mu_t$ $H_0 : (\alpha, \beta) = (0, 1)$
	Pilbeam & Olmo's (2011) model	Forward rates are unbiased predictor of future spot exchange rates	$\left[\left(\frac{S_{t+1}}{F_t}\right) - 1\right] = \alpha + \varepsilon_{t+1}$ $H_0 : \alpha = 0$
	Johansen cointegration	Spot and forward exchange rates are cointegrated	$S_{i,t} \sim I(1);\ f_{i,t-m} \sim I(1);\ (S_{i,t} - \beta_i f_{i,t-m}) \sim I(0)$
i) *Across-country*	Johansen cointegration – Bivariate	No cointegration between two series of different spot exchange rates	$S_{i,t} \sim I(1);\ S_{j,t} \sim I(1);\ (S_{i,t} - \alpha_k S_{j,t}) \sim I(0)$
	Johansen cointegration – Multivariate[a]	No cointegration among series of different spot exchange rates	

[a] Not included in the analysis.

3.1.1. Johansen cointegration test

Before we can apply this technique, we determine the order of integration of spot and forward exchange rates, respectively. To ascertain the robustness of the results, we rely on the augmented Dickey and Fuller (ADF)(1979), Phillip and Perron (PP)(1988), and Kwiatkowski et al. (KPSS)(1992) unit root tests. The ADF and PP tests have the null hypothesis of nonstationarity while the KPSS test has a null hypothesis of stationarity. A trend and intercept are included in all the unit root tests. If conflicting results emerge, we have the majority results dictate.

Table 4 summarizes unit root test results for both spot and forward exchange rates. From the ADF, PP and KPSS unit root tests, most of the spot and forward exchange rate series contain unit roots with I(1) processes. However, there are some exceptions in which these currencies are stationary. The I(0) exchange rate series, such as Indonesian rupiah and Thai baht for the whole period, the Malaysian ringgit for the whole and pre-AFC periods, the Indonesian rupiah for the pre-AFC period and the Chinese yuan for GFC period, are omitted from the cointegration tests.

For the Johansen cointegration test, the trace statistics (λ-trace) and maximum eigenvalue (λ-max) tests are used as the test statistics with critical values tabulated by Mackinnon et al. (1999). These two tests start with the first null hypothesis of no cointegrating rank (i.e. $r = 0$, in which r is the number of cointegrating rank) against the alternative of one (or at least one) (i.e. $r \geq 1$) cointegrating rank. If the first null hypothesis is rejected, we move on to test for the second hypothesis of H_0: $r = 1$ against H_1: $r \geq 2$. We repeat the same process until we fail to reject the null hypothesis and the final null indicates the number of cointegrating rank among the series. The variables are cointegrated if r is more than zero and less than the number of variables, k, (i.e. $0 < r < k$). If r is equal to the number of variables, (i.e. $r = k$), it implies the variables are independent and this is a case of trivial cointegration in which the relationship is useless. We deem trivial cointegration as equivalent to no cointegration. Lags are included to eliminate the serial correlation in the residuals. To conduct the cointegration test, we assume that there is an intercept and a trend in the cointegrating equations.[5] Spot and forward exchange rates are tested for cointegration. The lag length

[5] Our results are robust to the use of the alternative assumption of an intercept but no trend in the cointegrating equations.

Table 4
Unit roots test results on spot and forward exchange rates. Acronyms for sample currencies are: Australian dollar (AUD); Chinese yuan (CNY); Japanese yen (JPY); Korean won (KRW); Indonesian rupiah (IDR); Indian rupee (INR); Malaysian ringgit (MYR); New Zealand dollar (NZD); Philippine peso (PHP); Singaporean dollar (SGD); Thai baht (THB) and Taiwan dollar (TWD). Unit root tests are conducted prior to the cointegration test. Exchange rate series which are tested as stationary are to be excluded from cointegration test. We have employed three (3) popular unit root tests, namely Augmented Dickey–Fuller (ADF), Phillip–Perron (PP) and Kwiatkowski et al. (KPSS) tests. The lag length in the ADF test, meant to address the issue of serial correlation, is chosen based on the minimization of Akaike Information Criterion (AIC). Meanwhile the PP test is specifically devised to cater for mild serial correlation when testing for a unit root and therefore no lag is needed in this equation. The residual spectrum at frequency zero in the PP test is estimated through the Bartlett kernel approach. The critical values for the ADF and PP tests are as tabulated by Mackinnon et al. (1999). Similar to the PP test, the residual spectrum at frequency zero in the KPSS test is estimated through the Bartlett kernel approach. The Lagrange-Multiplier test statistic computed is compared against the critical values as tabulated by Kwiatkowski et al. (1992). The currencies shown in the Table are stationary at the critical value of at least 0.10 level. If a currency is tested as stationary by two or more stationarity tests, it is excluded from the Johansen cointegration test. The currency in bold indicates exclusion. The I(0) exchange rate series, such as Indonesian rupiah and Thai baht for the whole period, the Malaysian ringgit for the whole and pre-AFC periods, the Indonesian rupiah for the pre-AFC period and the Chinese yuan for GFC period, are omitted from the cointegration tests.

	Whole period	Pre-AFC subperiod	AFC subperiod	Post-AFC subperiod	Pre-GFC subperiod	GFC subperiod	Post-GFC subperiod
ADF							
Spot	**IDR**, **MYR**, THB	**INR**, PHP	–	–	–	**CNY**	–
Forward	**IDR**, **MYR**, **THB**, TWD	THB	–	–	SGD	**CNY**	–
PP							
Spot	**MYR, THB**	**INR, MYR, PHP**	**–**	**–**	**–**	**CNY**	**–**
Forward	**IDR**, **MYR**, **THB**	**MYR**, PHP	–	–	THB	**CNY**	–
KPSS							
Spot	**IDR**, INR, NZD	**INR**, NZD	–	–	–	–	CNY, NZD
Forward	–	**MYR**	INR	–	–	INR, MYR	CNY, NZD

chosen for this cointegration test is lag 22 given the overlapping nature of the data (Hansen and Hodrick, 1980; Baillie and Bollerslev, 1989). The spot and forward exchange rates are cointegrated if there is one and only one cointegrating rank. If they are cointegrated, we can infer that the forward rate is an unbiased predictor of future spot rate and, this finding, in turn, supports the *within-country* market efficiency.

The results of the Johansen cointegration tests are summarized in Table 5. A few interesting observations emerge: (i) In the AFC period, the Thai baht is the only currency that displays a clear sign of inefficiency. The sudden flotation of the Thai baht could have distorted its market efficiency in this period and its effect appears spilled over to the other currency markets in the region; (ii) In the GFC period, the Japanese yen is the only currency which is inefficient while the other currencies maintain their state of efficiency. The disturbance of efficiency in the JPY market could be due to the massive unwinding of the Japanese yen-carry trade in this period[6]; and (iii) In the post-AFC and the post-GFC subperiods, almost all of the currencies, with the exception of Chinese yuan, display cointegration between their respective spot and forward exchange rates. This indicates the *within-country* currency markets remain efficient subsequent to the turbulent crisis periods.[7]

Most of the *within-country* foreign exchange markets are efficient as evidenced by the cointegrating relationship between spot and forward exchange rates. Even though the Philippine peso, Singaporean

[6] The Japanese yen is the popular funding currency in a carry trade strategy because of a persistently low interest-rate environment in Japan. Interested readers may refer to Melvin and Taylor (2009), Clarida et al. (2009), Galati et al. (2007) and Peltomäki, 2008 for recent discussions on carry trade phenomenon.

[7] The results from the *within-country* Johansen cointegration test do not provide clear distinction on which of the two crises (i.e. AFC and GFC) is the more disturbing event to the foreign exchange market efficiency in the Asia Pacific. However, our assertion that the AFC is the more disturbing event is drawn from the overall results which include the Fama regression and Pilbeam and Olmo's (2011) models.

Table 5
Within-country efficiency test results. Acronyms for sample currencies are: Australian dollar (AUD); Chinese yuan (CNY); Japanese yen (JPY); Korean won (KRW); Indonesian rupiah (IDR); Indian rupee (INR); Malaysian ringgit (MYR); New Zealand dollar (NZD); Philippine peso (PHP); Singaporean dollar (SGD); Thai baht (THB) and Taiwan dollar (TWD). We conducted Johansen cointegration test between the spot and forward exchange rate series for each country. The test statistics for this cointegration exercise are trace statistics (λ-trace) and maximum eigenvalue (λ-max) with the critical values tabulated by Mackinnon et al. (1999). A cointegration between spot and forward exchange rates implies market efficiency in which the forward rates are unbiased predictor of future spot rates. As we have only two variables for each currency market, the market is efficient only and only if there is one cointegrating vector. This table shows the number of cointegrating vector at the critical value of at least 0.05 level. NA indicates not applicable either due to the stationarity property of the spot or forward exchange rate series or both or data availability issue.

	Whole period		Pre-AFC subperiod		AFC subperiod		Post-AFC subperiod		Pre-GFC subperiod		GFC subperiod		Post-GFC subperiod	
	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max
AUD	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CNY	NA	NA	NA	NA	NA	NA	NA	NA	1	1	NA	NA	0	0
IDR	NA	NA	1	1	1	1	1	1	1	1	1	1	1	1
INR	1	1	NA	NA	0	0	0	0	0	0	0	0	0	0
JPY	1	1	1	1	1	1	1	1	1	1	2	2	1	1
KRW	1	1	NA	NA	NA	NA	1	1	1	1	1	1	1	1
MYR	NA	NA	NA	NA	1	1	NA	NA	1	1	1	1	1	1
NZD	1	1	2	2	1	1	1	1	1	1	1	1	1	1
PHP	2	2	NA	NA	1	1	1	1	2	2	1	1	1	1
SGD	2	2	1	1	1	1	1	1	1	1	1	1	1	1
THB	NA	NA	NA	NA	2	2	1	1	1	1	1	1	1	1
TWD	2	2	2	2	1	1	1	1	1	1	1	1	1	1

dollar and Taiwan dollar spot and forward exchange rates are trivially cointegrated for the whole period, they are cointegrated in most of the subperiods.[8] It is interesting to note that the Indian rupee spot and forward exchange rates are cointegrated in the whole period but not cointegrated in the subperiods. In a nutshell, the above findings suggest that the state of efficiency in the Asia-Pacific currency markets is resilient to the two crises. The forward exchange rates remain as unbiased predictor of future spot rates as evidenced by the cointegrating relations.

3.1.2. Forward premium

Earlier tests of foreign exchange market efficiency are based on the unbiasedness hypothesis of forward rate as a predictor of future spot rate (Bilson, 1981; Fama, 1984; Froot and Thaler, 1990; Baillie and Bollerslev, 1989, 2000; Bansal and Dahlquist, 2000; Sarno, 2005; Gilmore and Hayashi, 2008; Frankel and Poonawala, 2010). Instead of providing an unbiased prediction to the changes of future spot rate, empirical evidence shows that the forward premium is not only biased but also wrong.

Fama's (1984) conventional regression in Eq. (1) is replicated for two main reasons: first, none of the recent studies use the data beyond 2005 while our data run through 2010 straddling the GFC[9]; and second, we believe that this study is the first which evaluates the impact of the GFC on the forward premium:

$$\Delta S_{t+m} = \alpha + \beta\left(f_t^m - S_t\right) + \mu_t, \tag{1}$$

[8] Two studies that examine the impact of the AFC report similar results. For example, Jeon and Seo (2003) report that exchange rates are more tightly cointegrated after the crisis, possibly due to foreign exchange market interventions, the contagion effect, and coordinated macroeconomic policies under the IMF's mandate. Kan and Andreosso-O'Callaghan, 2007 report that the *within-country* efficiency characterize the post-AFC foreign currency markets in the region even though full market efficiency has yet to be realized.

[9] Study periods of a few recent studies end: May 2003 (Kan and Andreosso-O'Callaghan, 2007); September 2005 (Chakraborty and Evans, 2008); December 2005 (Burnside et al., 2009); April 2004 (Frankel and Poonawala, 2010); and January 2006 (Pilbeam and Olmo, 2011).

where s and f denote spot and forward exchange rates in logarithm respectively, Δs is the change in the spot exchange rate from time t to $t+m$ with m indicating the maturity period of the forward contract, and μ is the regression error term.

Panel A of Table 6 reports the Wald F-test statistic for the null hypothesis of $(\alpha, \beta) = (0, 1)$ against the alternative of at least one is not true as well as the estimates of β for each currency. The results confirm a widespread rejection of the unbiasedness hypothesis of the forward rate for almost all of the periods for all currencies, which is consistent with the vast majority of the relevant literature. The inclusion of the three subperiods surrounding the GFC makes little difference. Next, we analyze the estimation of the beta coefficients from the individual currency. For the whole period, five of the 12 currencies show negative betas. They include: Australian dollar, Indian rupee, Japanese yen, New Zealand dollar, and Singaporean dollar. The countries with negative beta are richer and more liberalized in terms of foreign exchange regulations (with the exception of India) than those countries with positive beta. A negative beta indicates that the forward bias puzzle is severe. These findings are consistent with those of Frankel and Poonawala (2010) and Bansal and Dahlquist (2000) who point out that the forward bias puzzle is less pronounced in developing countries. The results that show the developing economies seem to report a better efficiency condition in the whole period may appear counterintuitive. Frankel and Poonawala (2010) suggest that the emerging market currencies are more prone to situation of high inflation and hence more predictable with the forward premium. Moving on to the subperiod, our analyses indicate that: (i) In the AFC and GFC subperiods, most of the currencies from more developed countries show positive beta while those from the developing countries show negative beta coefficient. This finding shows that the crisis period is rather an exception to the observations of Frankel and Poonawala (2010) and Bansal and Dahlquist (2000). The forward bias puzzle is more prominent in the developing countries and absent from the wealthier ones during time of crisis; (ii) In time of tranquillity, which is represented by the post-AFC and post-GFC subperiods, the majority of the currencies (especially those from developed countries) report negative beta coefficient. This finding is consistent with the observation by Clarida et al. (2009) who point out that negative beta coefficient happens mostly in the periods of low volatility.

Some of the estimation periods contain relatively short time series and therefore the resulting estimates of the parameters for each individual currency may require the robustness tests (especially the pre-AFC and the post-GFC subperiods in which both contain 129 observations each). We address this concern by pooling the various currencies and employ a panel estimation technique. The intercept of the pooled time-series cross-section regression is allowed to vary across currencies with a random effect but fixed through time.[10] The first pooled sample contains all the 12 currencies. We exclude China and Malaysia in the second pooled sample because of their fixed exchange rate regimes for a substantial time period in proportion to the whole period. The next four pooled samples are grouped based on the income level and the degree of exchange market liberalization. For income level we use Gross National Income (GNI) per capita as of 2009 available from the World Bank database and for the degree of exchange market liberalization we depend on the availability of NDF markets.

The third pooled regression is for high-income nations (Australia, Japan, Korea, New Zealand, Singapore and Taiwan). The fourth pooled regression is for the rest of the countries categorized as middle-income nations (fourth pooled sample). The second criterion used is the extent of foreign exchange liberalization for the particular country and this is measured by the existence of NDF markets. Currencies that are traded in the NDF markets are deemed as less-liberalized and those not traded are considered as liberalized. Chinese yuan, Korean won, Indonesian rupiah, Indian rupee, Malaysian ringgit, Philippine peso, Thai baht and Taiwan dollar belong to the former and the rest of currencies are in the latter. The fifth pooled regression is for the liberalized markets and the sixth pooled regression for the less-liberalized markets.

The beta coefficient estimates from the pooled regression are summarized in Panel B of Table 6. The estimated beta coefficients become more accurate for all of the pooled samples as well as across all subperiods except for the post-GFC period as indicated by the higher t-values. The exclusion of Chinese

[10] Hausman test indicates that a random-effect model is more appropriate than the fixed-effect model for the pooled time-series cross-section regression in our case.

Table 6

Fama's (1984) conventional regression results. Acronyms for sample currencies are: Australian dollar (AUD); Chinese yuan (CNY); Japanese yen (JPY); Korean won (KRW); Indonesian rupiah (IDR); Indian rupee (INR); Malaysian ringgit (MYR); New Zealand dollar (NZD); Philippine peso (PHP); Singaporean dollar (SGD); Thai baht (THB) and Taiwan dollar (TWD). One of the popular way to test for the unbiasedness hypothesis of spot exchange rate is to regress the changes of spot exchange rate on the corresponding lagged forward premium which is popularly known as Fama regression: $\Delta S_{t+m} = \alpha + \beta(f_t^m - S_t) + \mu_t$. The market is efficient if α and β are jointly equal to 0 and 1, respectively. We have conducted Fama's (1984) regression for each individual currency as well as in the form of several pooled samples. * and ** indicate significance at the 0.05 and 0.10 levels. Figures in parentheses are standard error of estimate. Panel A shows the results for each individual currency. The first column under each subperiod indicates the Wald test for the joint hypothesis of $(\alpha,\beta) = (0,1)$ while the next column shows the beta estimate. We notice that there is a widespread rejection of market efficiency as shown by the Wald statistics. Meanwhile a negative beta indicates that the forward bias puzzle is severe. In the crisis periods, most of the currencies from developed countries show positive beta while those from the developing countries show negative beta coefficient. Meanwhile in time of tranquillity as represented by the post-AFC and post-GFC subperiods, the majority of the currencies report negative beta coefficient. Results from Panel B, which pooled the currencies based on the countries' characteristics, show that currencies of high-income and liberalized exchange regulation tend to show positive beta estimates whereas those of middle-income and less-liberalized regulation show positive beta estimates. NDF denotes non-deliverable currency forwards.

Panel A: individual currency	Whole period		Pre-AFC subperiod		AFC subperiod		Post-AFC subperiod		Pre-GFC subperiod		GFC subperiod		Post-GFC subperiod	
	Wald *F*-stat	β estimate	Wald *F*-stat	β estimate	Wald *F*-stat	β estimate	Wald *F*-stat	β estimate	Wald *F*-stat	β estimate	Wald F-stat	β estimate	Wald *F*-stat	β estimate
AUD	14.54*	−0.17 (0.22)	1.04	1.11 (0.71)	4.64*	0.86 (0.39)	13.47*	−0.73 (0.59)	4.78*	−0.31 (0.55)	2.52**	0.29 (0.81)	0.11	−0.35 (3.39)
CNY	–	0.58 (0.18)	–	–	–	–	–	–	1.05	0.62 (0.31)	–	–	3.17*	−0.13 (2.37)
IDR	14.19*	0.19 (0.15)	0.29	−1.00 (3.09)	2.75**	−2.96 (2.05)	3.20*	0.26 (0.3)	0.53	2.20 (1.24)	0.29	−1.39 (8.37)	1.45	−0.21 (17.81)
INR	8.69*	−0.74 (0.76)	–	–	8.32*	−2.14 (1.25)	16.53*	0.47 (1.49)	17.39*	−2.20 (0.76)	0.07	−0.05 (3.25)	0.57	−0.09 (8.53)
JPY	6.20*	−0.21 (0.72)	0.00	0.51 (13.35)	1.31	−0.19 (4.64)	5.53*	−0.55 (1.11)	2.91**	−0.26 (4.07)	0.33	0.71 (0.54)	3.07*	0.26 (0.33)
KRW	1.41	0.01 (0.91)	–	–	–	–	7.22*	0.24 (1.60)	0.42	0.44 (1.78)	0.16	1.36 (1.61)	0.07	−0.51 (4.44)
MYR	1.53	1.01 (0.4)	0.82	1.22 (0.35)	6.42	−0.85 (0.66)	–	–	4.41*	1.18 (2.41)	0.94	−1.69 (1.96)	2.43**	0.95 (1.65)
NZD	13.18*	−0.13 (0.47)	0.19	0.65 (1.78)	2.18	0.67 (0.73)	18.00*	−0.81 (0.59)	3.06*	0.38 (1.91)	0.96	0.42 (1.18)	0.50	−0.13 (1.69)
PHP	0.32	0.84 (0.67)	103.33*	0.15 (0.28)	0.36	0.47 (1.90)	3.85*	−1.44 (1.03)	20.20*	0.51 (1.27)	0.21	0.30 (2.41)	0.79	0.55 (3.86)
SGD	3.78*	−0.45 (0.77)	7.13*	−4.53 (3.36)	2.70**	−1.42 (1.11)	12.15*	−1.29 (0.92)	1.55	−0.35 (3.18)	1.27	−0.07 (0.91)	4.14*	−0.64 (0.59)
THB	9.72*	0.29 (0.16)	18.59*	−0.56 (0.96)	1.31	2.00 (0.98)	8.76*	−1.12 (0.63)	26.55*	0.19 (0.26)	14.57*	0.16 (0.16)	4.79*	−0.51 (1.64)
TWD	2.19	0.58 (0.26)	7.85*	0.58 (4.28)	1.50	−1.19 (2.16)	0.15	0.89 (0.41)	2.08	0.16 (4.13)	0.14	1.11 (1.24)	1.29	−0.96 (3.47)

Panel B: pooled samples	β estimate	β estimate	β estimate	β estimate	β estimate	β estimate	β estimate
Pooled	0.0541 (0.0109)	−0.1180 (0.3955)	−0.1506 (0.0426)	0.0554 (0.0102)	0.1575 (0.0241)	0.2188 (0.0524)	−0.0865 (0.2942)
Pooled ex-MYR&CNY	0.2114 (0.0375)	−0.1456 (0.4012)	−0.3939 (0.2719)	0.2370 (0.0388)	0.1492 (0.0263)	0.2086 (0.0586)	−0.1055 (0.2950)
Pooled high-income	−0.0517 (0.0818)	1.2206 (0.5751)	−0.0795 (0.2478)	−0.4399 (0.0936)	−0.0588 (0.1521)	0.5362 (0.1610)	0.2787 (0.3168)
Pooled medium income	0.2233 (0.0389)	−0.5649 (0.4519)	−0.7000 (0.3251)	0.2536 (0.0396)	0.1738 (0.0254)	0.1361 (0.0496)	0.1912 (0.3395)
Pooled non-NDF	−0.1096 (0.0897)	1.2370 (0.5758)	0.0707 (0.2764)	−0.7307 (0.1111)	−0.0624 (0.1833)	0.4378 (0.2210)	0.2012 (0.4340)
Pooled NDF	0.2250 (0.0386)	−0.5696 (0.4434)	−0.6016 (0.3103)	0.2560 (0.0393)	0.1742 (0.023)	0.1683 (0.0511)	−0.1746 (0.2842)

yuan and Malaysian ringgit from the pooled sample generally increased the precision of the estimates of the beta coefficients although the sign of the estimate remains unchanged. For the whole period, high-income countries report negative beta coefficient, while the middle-income countries positive beta coefficient. The sign of the beta estimates for these two pooled samples are different for three of the six subperiods. This finding shows that the forward bias puzzle, as indicated by negative beta coefficient, is not a pervasive phenomenon which happens across all the currency markets at the same time. Therefore those trading strategies (e.g. currency carry trade) which rely on the failure of the forward unbiasedness hypothesis are not foolproof even during the low-volatility period as suggested by Clarida et al. (2009).

Stimulated by Bansal and Dahlquist (2000), we introduce the degree of foreign exchange market regulation to assess its impact in addition to country income level. The existence of NDFs is a proxy we use. For the whole period, the currencies without NDF markets (implying liberalized regulatory regime) exhibit negative beta coefficient, while those with NDF markets (implying less-liberalized regulation) positive beta coefficient. Out of the six subperiods, the beta coefficients for these two pooled samples show different sign for five subperiods. This finding shows that the foreign exchange regulatory regime is another important attribute in determining the existence of forward bias puzzle. Generally, our results from the pooled Fama (1984) regression indicate that the currencies of high-income and liberalized exchange regulation tend to show negative beta estimates whereas those of middle-income and less-liberalized regulation show positive beta estimates. These results are consistent with those reported by Frankel and Poonawala (2010) and Bansal and Dahlquist (2000), which indicates that country-specific attributes are important in explaining the forward premium puzzle.

3.1.3. Reconciliation of mixed findings

Since the cointegration test and Fama's conventional regression test yield mixed results on market efficiency, we use the Pilbeam and Olmo (2011) approach to reconcile the differences. Pilbeam and Olmo (2011) claim that the conventional Fama regression which regresses log changes of spot exchange rate (Δs_{t+1}) on forward premium will likely result in spurious regression because the volatility of $\Delta s_{t+1}$is usually much larger than the forward premium. They have subsequently employed a Taylor expansion of the log-returns of the exchange rate series, which is also known as the delta method, in order to propose a solution to the potential bias of the conventional Fama regression. They use two forms of regression models to test for the forward unbiasedness hypothesis. The data used are at level instead of the usual form in logarithm. The first alternative model suggested is:

$$\left[\left(\frac{S_{t+1}}{F_t}\right) - 1\right] = \alpha + \varepsilon_{t+1} \tag{2}$$

With a constant risk premium, Eq. (2) would suffer from misspecification. In view of this, Pilbeam and Olmo (2011) propose the following model to include a proxy for risk premium:

$$\left[\left(\frac{S_{t+1}}{F_t}\right) - 1\right] = \alpha + \rho\frac{1}{F_t} + \varepsilon_{t+1} \tag{3}$$

Market is efficient when $\alpha = 0$ under Eq. (2) and $\alpha = \rho = 0$ under Eq. (3). Pilbeam and Olmo (2011) find efficiency for four major currencies (Swiss franc; Japanese yen; Euro; and Pound sterling) during the period of 1978–2006 in stark contrast to the conventional regression approach. Since their study focuses on only the four major currencies, Asia-Pacific currencies represent a valuable subject of out-of-sample test of the Pilbeam and Olmo model. The use of overlapping data to estimate the parameters of Fama regression gives rise to the problem of serial correlation. This complication is overcome with the use of generalized method of moment (GMM) estimation technique. The standard error of estimates is heteroscedasticity and autocorrelation consistent. The null hypothesis of the regression is tested by using the Wald statistic, which has a chi-square distribution with k degrees of freedom, where k is the number of restrictions.

The results from Eqs. (2) and (3) are presented in Table 7. Panel A reports the estimation of the constant from Eq. (2) while Panel B summarizes the Wald statistics for the test of $\alpha = \rho = 0$ under Eq.

Table 7

The Pilbeam and Olmo (2011) regressions. Acronyms for sample currencies are: Australian dollar (AUD); Chinese yuan (CNY); Japanese yen (JPY); Korean won (KRW); Indonesian rupiah (IDR); Indian rupee (INR); Malaysian ringgit (MYR); New Zealand dollar (NZD); Philippine peso (PHP); Singaporean dollar (SGD); Thai baht (THB) and Taiwan dollar (TWD). Pilbeam and Olmo (2011) have suggested a modified-form of regression from Fama's (1984) conventional regressions. We have adopted the Pilbeam and Olmo (2011) model to test for the forward unbiasedness hypothesis. We infer that the market is efficient if the coefficient estimates are insignificantly different from zero. * and ** indicate significance at the 0.05 and 0.10 level respectively. Panel A shows the estimate of the α of Eq. (2) while Panel B, which assumes the existence of risk premium, shows the Wald statistics results for ($\alpha = \beta = 0$). The results show, generally, that the markets are efficient *within-country* and thus consistent with the findings from Johansen cointegration. Under Panel A, we found that currency markets under free-float exchange rate regime (Australia, New Zealand, and Japan) are more resilient as compared to regulated currency markets (i.e. the rest of the markets) because the free-float currency markets show a more stable and consistent efficiency pattern. Meanwhile from Panel B, we observed instability of markets efficiency in the region during the AFC period. This empirical evidence implies that AFC is a more destabilising event than the GFC.

	Whole period	Pre-AFC subperiod	AFC subperiod	Post-AFC subperiod	Pre-GFC subperiod	GFC subperiod	Post-GFC subperiod
Panel A: Eq. (2) – α estimates							
AUD	−0.0014	0.0065	0.0126	−0.0038	−0.0057	−0.0024	0.0071
CNY	−0.0004	0.0000	0.0000	0.0000	0.001	−0.0023**	0.0000
INR	−0.0020	0.0000	0.0085	−0.0029**	−0.0075	0.0020	−0.0036
IDR	0.0091	0.0000	0.0760	0.0041	−0.0016	−0.0047	−0.0110
JPY	0.0018	−0.0001	0.0067	0.0026	0.0047	−0.0074	0.0012
KRW	−0.0012	0.0000	0.0000	−0.0089	−0.0028	0.0119	0.0066
MYR	0.0120	0.0007	0.0359	0.0000	−0.0031**	0.0006	−0.0090*
NZD	−0.0014	0.0031	0.0148**	−0.0051	−0.0058	0.0014	0.0042
PHP	−0.0006	−0.0028*	0.0156	0.0000	−0.0124*	0.0006	−0.0037
SGD	0.0011	0.0044	0.0077	0.0017	−0.0036	−0.0008	0.0001
THB	−0.0057	−0.0152	0.0095	0.0012	−0.0309**	−0.0073	−0.0044
Panel B: Eq. (3) – Wald statistics for ($\alpha = \rho = 0$)							
AUD	0.4970	0.6223	2.3485**	0.2695	0.3498	0.3788	0.6678
CNY	0.7355	0.0000	0.0000	0.0000	2.1226	4.902627*	0.0194
INR	1.7556	0.0000	1.0243	3.9254*	0.7900	0.8491	1.3570
IDR	0.6825	0.9115	0.6834	0.2673	0.7094	0.1135	3.4618*
JPY	0.4663	0.0511	1.0898	1.4779	1.5425	1.5083	1.3153
KRW	0.4257	0.0000	0.4257	1.6182	0.7719	1.6195	0.2756
MYR	1.5665	0.7748	3.0237**	0.0000	0.5937	0.3237	0.6445
NZD	0.3832	18.7606*	3.8999*	0.4116	0.5221	0.4435	2.0095
PHP	2.5143**	393.59*	3.2241*	1.2085	6.17169*	0.6719	1.0635
SGD	0.5065	5.2806*	3.6728*	1.5473	0.6797	0.3407	4.4280*
THB	0.5928	1.5078	3.8636*	1.5337	28.7062*	0.5179	0.5634

(3). Assuming the absence of risk premium, the preferred interpretation of market efficiency is drawn from Panel A. In the whole period, all currency markets show evidence of '*within-country*' efficiency and this efficiency is only broken in the intermittent periods. Currency markets under free-float exchange rate regime (Australia, New Zealand, and Japan) are more resilient as compared to regulated currency markets (i.e. the rest of the markets) because the free-float currency markets show a more stable and consistent efficiency pattern. Market interventions in the regulated markets could have contributed to the breakdown of market efficiency. Antell and Vaihekoski (2012, 2007) have also shown that the equity risk premium is lower under a free-float exchange rate regime. These advantages augur well for a nation to adopt a free-float regime. An interesting point to note from Panel B is the instability of markets efficiency in the region during the AFC period. Under the assumption of risk premium, we observed that six of the 12 currency markets (i.e. Australia, Malaysia, New Zealand, Philippines, Singapore and Thailand) display a sign of inefficiency during the AFC subperiod as compared to only one (i.e. China) during the GFC subperiod. As a result, we conclude that AFC is obviously a more destabilising event.[11]

[11] As pointed out by an anonymous referee, there is a possibility of improved policy adopted by the monetary authority during the GFC and hence less disturbance in the GFC than the AFC.

In brief, the alternative models suggested by Pilbeam and Olmo (2011) show that forward unbiasedness hypothesis hold true in most periods and hence we may conclude that foreign exchange markets are efficient *within-country*. The results reported in Table 7 are generally consistent with the results from Johansen cointegration test.

3.2. Across-country *market efficiency*

Baillie and Bollerslev (1989) are the pioneers in utilizing the Engle and Granger (1987) two-step cointegration method in explaining the state of efficiency in a system of multiple exchange rates series. They find six stochastic trends in the system which in turn implies one common cointegrating vector binding this system of exchange rates. Hence, they conclude that the weak form efficient markets hypothesis is violated. Studies which employed the Johansen (1991, 1995) multivariate cointegration tests have generally documented the results similar to those of Baillie and Bollerslev (1989) (Crowder, 1994; Kan and Andreosso-O'Callaghan, 2007). This approach to investigating market efficiency using a system of exchange rates is known as the *across-country* efficiency test Kan and Andreosso-O'Callaghan, 2007.

For *across-country* market efficiency tests, we rely only on bivariate cointegration test as the multivariate approach is likely to yield results against market efficiency. The lag length chosen is five.[12] If the series of exchange rates are cointegrated, there is evidence to show the presence of a long-run relationship among the currencies. Any deviation of one series from the equilibrium relationship indicates that the subsequent movement of the series will return to the long-run relationship (Jeon and Seo, 2003). This implies that the subsequent changes in the exchange rates are therefore predictable. Hence this relationship clearly violates the main tenet of the efficient markets hypothesis.

3.2.1. *Bivariate cointegration model*

In the bivariate test, each nonstationary currency spot rate is tested for cointegration with another nonstationary currency spot rate. The results from the bivariate cointegration test are reported in Table 8. For the overall period, none of currency pairs shows any sign of cointegration. This finding testifies to the *across-country* efficiency in the Asia-Pacific region and is comparable to what has been reported by Kan and Andreosso-O'Callaghan (2007). In the AFC period, mostly Thai baht crosses exhibit some sign of cointegration. We may interpret that Thai baht served as the main driver of currency co-movement in this period.[13] This finding supports the notion of the *tom-yum* effects during the AFC.[14]

During the GFC subperiod, none of the currency pairs shows evidence of cointegration, which indicates that the Asia-Pacific foreign currency markets have not been affected by the crisis unlike the AFC period. From the *across-country* bivariate cointegration test results, the AFC is a more disturbing event for the Asia-Pacific region more than the GFC. Perhaps the financial institutions based in the Asia-Pacific region are not *fatally* hurt by the GFC. Dooley and Hutchison (2009) report that emerging markets responded to the deteriorating situation in the U.S. financial system.

3.3. *Robustness tests*

We have regrouped our six subperiods into three distinct periods under one single model. We treat all the non-crisis subsample periods as one single group of non-crisis sample and leave AFC and GFC as two distinct subperiods. With this regrouping of sample periods, we address the concern about a small number of observations in some subperiods (e.g. pre-AFC and post-GFC). We introduced dummy variables to account for the reclassification of the whole sample into three subsample periods. The model we estimate for each individual currency is as follows:

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[12] Our results are robust to the selection of varying lags of 10, 15, 20 and 25 in the cointegration tests.

[13] We have conducted a Granger-causality test and find that Korean won is the main driver during the AFC period. Nevertheless, this test is sensitive to the choice of the lag length.

[14] The *tom-yum* effect refers to the contagious effect in the Asia-Pacific region from the crash in the value of the Thai baht in July 1997. Chung (2005) and Gong et al. (2004) provide useful analyses about the contagion effects during the AFC.

Table 8
Across-country efficiency (bivariate) test results. Acronyms for sample currencies are: Australian dollar (AUD); Chinese yuan (CNY); Japanese yen (JPY); Korean won (KRW); Indonesian rupiah (IDR); Indian rupee (INR); Malaysian ringgit (MYR); New Zealand dollar (NZD); Philippine peso (PHP); Singaporean dollar (SGD); Thai baht (THB) and Taiwan dollar (TWD). We tested for *across-country* efficiency with the Johansen cointegration technique. We argue that market efficiency is violated when the spot exchange rates are cointegrated because it implies predictability of one exchange rate from another exchange rate. The test statistics for this cointegration exercise are trace statistics (λ-trace) and maximum eigenvalue (λ-max) with the critical values tabulated by Mackinnon et al. (1999). In a bivariate cointegration test, each nonstationary currency spot rate is tested for cointegration with another nonstationary currency spot rate. The table below shows the number of cointegrating vector at the 0.05 level. NA indicates not applicable either due to the stationarity property of the spot exchange rate series or data availability issue. Generally, the markets are efficient in Asia Pacific (AP). The most number of violations in market efficiency is during the AFC subperiod and mostly confined to THB crosses. The results show that the AFC is a more disturbing event for the AP region as compared to the GFC.

	Whole period		Pre-AFC subperiod		AFC subperiod		Post-AFC subperiod		Pre-GFC subperiod		GFC subperiod		Post-GFC subperiod	
	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max
AUD–CNY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUD–IDR	NA	NA	0	0	0	0	0	0	0	1	0	0	0	0
AUD–INR	0	0	NA	NA	0	0	1	1	0	0	0	0	0	0
AUD–JPY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUD–KRW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUD–MYR	NA	NA	NA	NA	0	0	NA	NA	0	0	0	0	0	0
AUD–NZD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUD–PHP	0	0	NA	NA	0	0	0	0	0	0	0	0	0	0
AUD–SGD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUD–THB	NA	NA	0	0	1	1	1	1	0	0	0	0	0	0
AUD–TWD	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CNY–IDR	NA	NA	NA	NA	NA	NA	NA	NA	0	1	NA	NA	0	0
CNY–INR	NA	NA	NA	NA	NA	NA	NA	NA	0	0	NA	NA	0	0
CNY–JPY	NA	NA	NA	NA	NA	NA	NA	NA	0	0	NA	NA	0	0
CNY–KRW	NA	NA	NA	NA	NA	NA	NA	NA	0	0	NA	NA	0	0
CNY–MYR	NA	NA	NA	NA	NA	NA	NA	NA	0	0	NA	NA	0	0
CNY–NZD	NA	NA	NA	NA	NA	NA	NA	NA	0	0	NA	NA	0	0
CNY–PHP	NA	NA	NA	NA	NA	NA	NA	NA	0	0	NA	NA	0	0
CNY–SGD	NA	NA	NA	NA	NA	NA	NA	NA	0	0	NA	NA	0	0
CNY–THB	NA	NA	NA	NA	NA	NA	NA	NA	0	0	NA	NA	0	0
CNY–TWD	NA	NA	NA	NA	NA	NA	NA	NA	0	0	NA	NA	0	0
IDR–INR	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0
IDR–JPY	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0
IDR–KRW	NA	NA	0	0	0	0	0	0	0	0	0	1	0	0
IDR–MYR	NA	NA	NA	NA	0	0	NA	NA	0	0	0	0	0	0
IDR–NZD	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0
IDR–PHP	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0
IDR–SGD	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0
IDR–THB	NA	NA	0	0	1	1	0	0	0	0	0	0	0	0
IDR–TWD	NA	NA	0	0	0	0	0	1	0	0	0	0	0	0
INR–JPY	0	0	NA	NA	0	0	0	0	0	0	0	0	0	0
INR–KRW	0	0	NA	NA	0	0	0	0	0	0	0	0	0	0

Table 8 (*continued*)

	Whole period		Pre-AFC subperiod		AFC subperiod		Post-AFC subperiod		Pre-GFC subperiod		GFC subperiod		Post-GFC subperiod	
	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max	λ-trace	λ-max
INR–MYR	0	0	NA	NA	0	0	NA	NA	0	0	0	0	0	0
INR–NZD	0	0	NA	NA	0	1	1	1	0	0	0	0	0	0
INR–PHP	0	0	NA	NA	0	1	0	0	0	0	0	0	0	0
INR–SGD	0	0	NA	NA	0	0	1	1	0	0	0	0	0	0
INR–THB	NA	NA	NA	NA	1	1	0	0	0	0	0	0	0	0
INR–TWD	0	0	NA	NA	0	0	0	0	0	0	0	0	0	0
JPY–KRW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JPY–MYR	NA	NA	NA	NA	0	0	NA	NA	0	0	0	0	0	0
JPY–NZD	0	0	0	0	0	1	0	0	0	0	0	0	0	0
JPY–PHP	0	0	NA	NA	0	0	0	0	0	0	0	0	0	0
JPY–SGD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JPY–THB	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0
JPY–TWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KRW–MYR	NA	NA	NA	NA	0	0	NA	NA	0	0	0	0	0	0
KRW–NZD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KRW–PHP	0	0	NA	NA	0	0	0	0	0	0	0	0	0	0
KRW–SGD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KRW–THB	NA	NA	0	0	1	1	0	0	0	0	0	0	0	0
KRW–TWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MYR–NZD	NA	NA	NA	NA	0	0	NA	NA	0	0	0	0	0	0
MYR–PHP	NA	NA	NA	NA	0	0	NA	NA	0	0	0	0	0	0
MYR–SGD	NA	NA	NA	NA	0	0	NA	NA	0	0	0	0	0	0
MYR–THB	NA	NA	NA	NA	0	0	NA	NA	0	0	0	0	0	0
MYR–TWD	NA	NA	NA	NA	0	0	NA	NA	0	0	0	0	0	0
NZD–PHP	0	0	NA	NA	0	0	0	0	0	0	0	0	0	0
NZD–SGD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NZD–THB	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0
NZD–TWD	0	0	0	0	0	0	2	2	0	0	0	0	0	0
PHP–SGD	2	2	NA	NA	0	0	0	0	0	0	0	0	0	0
PHP–THB	NA	NA	NA	NA	2	2	0	0	0	0	0	0	0	0
PHP–TWD	0	0	NA	NA	0	0	0	0	0	0	0	0	1	1
SGD–THB	NA	NA	0	0	1	1	0	0	0	0	0	0	0	0
SGD–TWD	0	0	0	0	0	0	1	1	0	0	0	0	0	0
THB–TWD	NA	NA	0	0	1	1	2	0	0	0	0	0	0	0

$$\begin{aligned} \Delta S_{t+m} &= \beta_1 D_1 \left(f_t^m - S_t\right) + \beta_2 D_2 \left(f_t^m - S_t\right) + \beta_3 D_3 \left(f_t^m - S_t\right) + \mu_t \\ D_1 &= \begin{cases} 1, & \textit{for non} - \textit{crisis subperiods} \\ 0, & \textit{otherwise} \end{cases} \\ D_2 &= \begin{cases} 1, & \textit{AFC period} \\ 0, & \textit{otherwise} \end{cases} \\ D_3 &= \begin{cases} 1, & \textit{GFC period} \\ 0, & \textit{otherwise} \end{cases} \end{aligned} \tag{4}$$

If the market is efficient, the beta estimates should all equal to unity, $\beta_1 = \beta_2 = \beta_3 = 1$. As expected, we found a widespread rejection of market efficiency. The Australian dollar, Indian rupee, Japanese yen, Korean won, New Zealand dollar and Singapore dollar report negative β_1 while the rest show positive β_1, which represents the non-crisis period beta coefficient. These findings support our results and interpretation in the previous section that forward bias puzzle is prominent during the tranquil period for rich economies. Clarida et al. (2009) report that the forward bias puzzle is an artifact of high-volatility regime and therefore in the period of tranquillity, which is characterised by low volatility, the forward bias puzzle disappears. From the Wald test on the equality of all the beta coefficients for each currency, we cannot reject the null hypothesis of equality for all, except for Australian dollar and New Zealand dollar. For the Australian dollar, the beta coefficient for non-crisis period is different from one during the AFC period. Meanwhile, for New Zealand dollar, the beta coefficients are all significantly different from one. Generally, the result shows that there are no significant differences between the beta coefficients of non-crisis period with those estimated for the crisis period.

We have also conducted a pooled Fama regression, Pilbeam and Olmo (2011) models and Johansen cointegration using the regrouped samples. The results are generally consistent with our findings reported in the previous sub-sections. However, we believe our original compartmentalization of the whole period into six subperiods provides us with more reliable and richer results in comparison with this regrouped samples for three reasons. First, the use of dummy variables to segregate among the non-crisis, AFC and GFC periods might distort the regression and cointegration test results. Second, the non-crisis period in this regrouping is a very broad period which encompasses the majority of the whole period. Therefore its interpretation is also broad and general without distinction between extended non-crisis and recent post-crisis. Third, the regrouped samples give us a general view instead of a dynamic view of the state of market efficiency for each currency. Nevertheless, these robustness tests provide greater credence to our findings and interpretations.

4. Summary of key findings

Our key findings can be summarised into four main points. First, the *within-country* efficiency test shows that the Asia-Pacific foreign exchange markets are generally efficient and resilient to crises with only a handful of currency markets that show a sign of inefficiency in the subsample periods. Second, the forward unbiasedness hypothesis holds true in many of the markets most of the time and forward bias puzzle is merely a statistical phenomenon. Third, from the pooled Fama regression, the finding of negative beta coefficient is prevalent among the high-income and more liberalized nations during the overall and normal periods. On the other hand, this phenomenon is present among the middle-income and less-liberalized nations during the turbulent periods. This finding sheds more light into the results reported in Bansal and Dahlquist (2000) and Frankel and Poonawala (2010), in which they pointed out that the emerging markets currencies are less biased as compared to more developed countries' currencies. Fourth, the foreign exchange markets are efficient *across-country* when tested using the bivariate cointegration method. In the bivariate cointegration test, the *tom-yum* effect is prominently disturbing the Asia-Pacific foreign exchange markets during the Asian financial crisis period. The overall results indicate that the 1997–1998 Asian financial crisis was a more disturbing event than the 2008–2009 global financial crisis in the Asia-Pacific region. Nevertheless, we do not believe that the crisis itself was a more disturbing event; rather it is the policy failure of Asian countries. Convincing evidence compiled by Calvo and Reinhart (2000) suggests that countries that claim they allow their exchange rates to float mostly did not, which indicates an epidemic case of "fear of floating". However, in the subprime crisis period, the reportedly massive unwinding of Japanese yen-carry trade is not affecting any of the Asia-Pacific foreign exchange market efficiency.

5. Conclusion

We conclude this paper by discussing the implications of our results to the academic, policy makers and market practitioners. From the academic perspective, we have shown that the EMH is generally valid in the long run and only report some evidence of inefficiency during certain subsample periods. Our results lend credence to the arguments in support of market efficiency and forward unbiasedness hypothesis put forth by Fama (1998), Baillie and Bollerslev (2000) and Lothian and Wu (2011).

From the policy making perspective, our results indicate that the free-float foreign exchange regime to be more resilient than the managed-float counterpart as the currencies under the former regime tend to display a more consistent pattern of efficiency. If the concern of the monetary authority is the market efficiency, they should adopt a free-float regime. However, more often than not, the main concern of the monetary authority is the general welfare of the state of economy instead of market efficiency.

Finally, there are reports showing the forward bias puzzle is exploited by market participants and traded for profits [e.g. Burnside et al. (2007); Galati et al. (2007); Clarida et al. (2009); Hochradl and Wagner (2010)]. Our results show that this trading strategy may not be a wise one as the forward bias puzzle is only a temporary phenomenon waiting for market correction. We witness the reversal of fortune for carry trade when the estimated Fama beta turns from negative to positive which happened throughout our sample period. Therefore we do not think that the recommendation from Hochradl and Wagner (2010) regarding the superiority of carry trade as a trading strategy is a sound one. Of course, our paper has the benefit of hindsight to include the GFC which Hochradl and Wagner (2010) does not. As a caveat, our comment related to carry trade is based on general observation from our results. A more in depth and specialised research is necessary to verify our hypothesis regarding the effectiveness of currency carry trade.

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