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THE LONG-HORIZON INVALIDITY OF UNCOVERED INTEREST PARITY (UIP) AFTER THE GLOBAL FINANCIAL CRISIS: THE CASE OF THAILAND AND SINGAPORE USING PANEL COINTEGRATION TEST

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Abstract: *This paper aims at examining the empirical change in the long-horizon validity of Uncovered Interest Parity (UIP) in comparison between Thailand and Singapore. The precise form of UIP is tested through Pedroni panel cointegration in order to avoid the misspecification from the approximated form of UIP and allow heterogeneity across the countries. The obtained results indicate that there exists a long-run cointegration between the gross domestic return and the uncovered gross foreign returns. Based on this outcome, the techniques of Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) are applied to the data. The results obtained from both methods of panel cointegration estimates show that patterns of long-run cointegrating coefficients of Thailand and Singapore are similar. Also these results exhibit that the UIP holds for both countries only the period before the Global Financial Crisis. These outcomes suggest that there have been other factors influencing the determination of exchange rates of both currencies since the crisis, which include the increasing dominances of euro and yen on both currencies and the changing patterns of capital flows. These evidences suggest the monetary authorities to closely monitor the changing determination of their currencies, and also raise the concern on the formulation of monetary policies based on conventional UIP concept.*

Keywords: *Uncovered Interest Parity, Exchange Rate, Pedroni Panel Cointegration, Fully Modified OLS, Dynamic OLS, Global Financial Crisis, Thailand, Singapore.*

1. INTRODUCTION

In 1980s, Thailand as well as many Southeast Asian countries deregulated their financial and economic system, which led their economies to extensively expose to external volatilities. That is, investors would easily move their capital to the countries whose return is more preferable. With this repetitive manner, the difference in return will be equalized by the movement in exchange rate. According to figure 1, during the highlighted period where global financial crisis occurred, the return in Thailand started to be higher than that of the US. However, the exchange rates of THB against USD kept appreciating over time. Therefore, the

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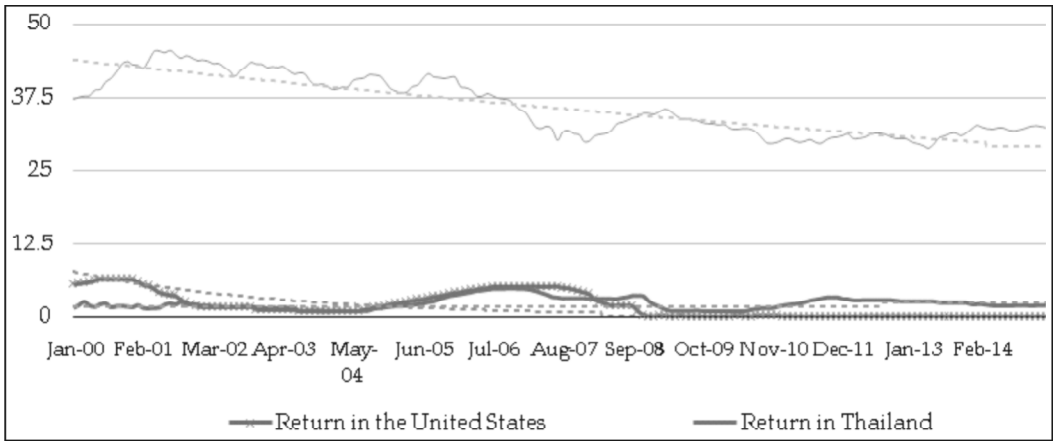

Figure 1: Returns in Thailand and the United States and Exchange rates (THB/$)

question arises as whether the relationship between the return differentials and the movement of exchange rates would hold during and after the crisis. This relationship is studied within the context of the international financial theory called uncovered interest parity (UIP). That is, no one should be able to strive for an arbitrary profit from the interest rate differential between countries as ex-post exchange rate change will counterbalance the arbitrary return.

A number of studies attempt to study a pool of countries including both developed and developing countries. To illustrate, Tang (2010) shows that the validity of UIP is stronger in a developed country, Singapore, than in other developing countries such as Thailand, Indonesia, Malaysia, and the Philippines.

The panel cointegration technique developed by Pedroni (2004) is conducted in this paper to study UIP hypothesis in long horizon. This practice expands the limitability of sample sizes and time spans, which are constrained by the traditional time-series cointegration practice. Plus, it allows heterogeneity across the countries. With the use of this technique, Tang (2010) provides the results that are in line with the UIP theory in case of Thailand and Singapore over the past 3 decades. Therefore, this paper will employ this technique as a reference.

Consequently, since the difference of the validity of UIP exists between developed and developing countries, the paper intents to examine the validity of UIP in Thailand by employing cointegration techniques and compare the results with the developed country in ASEAN, Singapore, so as to gain a better understanding. The paper is organized as follows: Section 2 discusses many points of views regarding UIP testing from many researches. Section 3 presents model specification and empirical methods to test hypothesis. The source of data and data testing are illustrated in Section 4. Section 5 elaborates the empirical results from the long-run estimations. Lastly, conclusion and policy recommendation are presented in Section 6.

2. LITERATURE REVIEW

During the crisis, exchange rates and interest rates are very volatile, which might cause UIP to perform differently from other periods. More surprisingly, Flood and Rose (2001) illustrates that UIP works better in the countries with crisis as the high volatility leads to more emphasis on financial markets. In addition, it indicates that the dissimilarity of UIP performance is not significantly different between rich and poor countries. On the other hand, this analysis is conducted through OLS estimation, which potentially misleads the results due to *heterogeneity* problem. According to Frankel and Poonawala (2006), and Mehl and Cappiello (2007), this heterogeneity exists between developing and developed countries.

The controversy over model specification is as well another issue as Holmes and Maghrebi (2003) captures the nonlinearities in the real interest differentials of Singapore and Thailand by conducting a logistic smooth transition autoregression (STAR) model. Additionally, Chang and Su (2014) also confirms that the nonlinear threshold unit-root test is more suitable than the linear model when testing this parity. In the contrary, Mehl and Cappiello (2007) proves that UIP is linear in a medium and long horizons.

Furthermore, Tang (2010) conducts the test on the precise form of UIP by using the technique called Pedroni panel cointegration from Pedroni (2000) in order to avoid the misspecification error of the approximate form of UIP as it assumes that the multiplication of the change in exchange rate and foreign return is not significant, which might not be true if the change in exchange rates is huge and/ or when there are high interest rates. Also, the precise form of UIP has to be studied to avoid spurious cointegration (Tang, 2010). This study of the validity of UIP in the long horizon shows that the slope coefficients (β) from UIP testing are positive for both Thailand and Singapore. Plus, the value of for Singapore is close to the theoretical value of unity; whereas the β for Thailand is still less than 1.

These results imply that the financial market in Singapore is more liberalized and integrated more with the US. Then, in order to understand the structural change during the global financial crisis of UIP better, the analysis on both Thailand as a developing country and Singapore as a developed country has to be studied and compared by utilizing the technique used by Pedroni (2000) Tang (2010) and Tangpornpaiboon, and Puttanapong, (2016).

3. MODEL AND ECONOMETRIC METHODOLOGY

3.1 The Precise Form of UIP

Following Tang (2010), this paper studies the precise form of UIP as follows:

$$(1+i_t)=\frac{S^e_{t+1}}{S_t}(1+i^*_t) \tag{2}$$

where S_t is the domestic price of one unit of the foreign currency at time t, i_t is the yield on the domestic asset, and i_t^* is the yield on the foreign asset. The $(1 + i_t)$ is the gross domestic return and $\frac{S_{t+1}^e}{S_t}(1+i_t^*)$ is the expected uncovered gross foreign return. That is, the returns in a domestic currency denominated asset is equal to the returns in a foreign currency denominated assets.

3.2 Econometric Testing

Due to the data limitation on the expectation of future spot rate S_{t+1}^e, and the assumption of rational expectation, can be assumed to be equal to the actual future spot price S_{t+1}, on average. Therefore, the equation to be performed in the panel cointegration test will be as below:

$$(1+i)_p = \alpha_j + \delta_{jt} + \beta_j \left[\left(\frac{S_{t+1}}{S_t} \right) \left(1 + i^* \right) \right]_{jt} + \epsilon_{jt} \tag{3}$$

where δ_{jt} is the deterministic trend and is the country-specific effect. The null hypothesis is H_0 :$\beta_j = 0$. If the null hypothesis is not rejected, the precise form of UIP is valid. The beta coefficients are tested with the null hypothesis of $\beta = 0$ instead of $\beta = 1$; because, in reality, it is likely impossible to have beta coefficients close to the value of unity as the theory suggests. The divergence from the value of unity exists because the central banks of Thailand and Singapore stabilize their exchange rates with the baskets of currencies, not only US dollars (Azis and Puttanapong, 2008). Therefore, the values of beta coefficients greater than zero are sufficient enough to confirm the existence of UIP.

4. DATA AND EMPIRICAL TESTING

4.1 Data

The monthly nominal exchange rates of Thai Baht against US dollar (THB/USD) and Singapore dollar against US dollar (SGD/USD) are gathered from January 2000 to February 2015. In addition, the interbank overnight rates of Thailand, Singapore, and the United States are collected in monthly basis.[1]

4.2 Panel Unit Root Tests

In order to pursue further studies, firstly the series of data need to be tested whether they are non-stationary and at which order of integration would convert the series to be stationary. Gross domestic return and uncovered gross foreign return are

[1] See Appendix B for Data Summary and Appendix C for the relationship between interest rates and exchange rates of Singapore.

tested by three-panel unit root tests; LLC, ADF and PP[2], from which the results are shown in Table 2. The results fail to reject the null hypothesis of unit root at levels for both series of data. That is, the series follow random walk. Furthermore, after testing the first difference of the series, the results suggest the rejection of unit root. That is, the series are stationary at first difference, $I(1)$. Thereafter, the series should be further tested by panel cointegration tests.

Table 2
Panel unit root tests

	Gross domestic return		*Uncovered gross foreign return*	
	Level	*First difference*	*Level*	*First difference*
Null: Unit root (assumes common unit root process)				
Levin, Lin and Chu t*	–0.33008(4)	–3.88880(3)*	–2.07863(4)*	–11.4089(3)*
Null: Unit root (assumes individual unit root process)				
ADF-Fisher Chi-square	2.77476(4)	42.7827(3)*	4.41833(4)	139.125(3)*
PP - Fisher Chi-square	1.47661(4)	154.018(3)*	42.7698(4)	36.8414(3)*

Notes: (1) * presents the rejection of the null hypothesis in which the series are non-stationary at 5% level of confidence.
(2) The number in parenthesis specifies the number of lag terms under Schwarz criterion.

4.3 Panel Cointegration Tests

After verifying that the series have unit root, they then need to be tested by the panel cointegration tests by Pedroni (2000) and Ahmad, and Mazlan (2015) in order to see whether there exists a long-run relationship between the gross domestic return and the uncovered gross foreign return. Pedroni's technique begins with the null hypothesis of no cointegration by employing seven statistical tests, which are categorized as within-dimension and between-dimension. Within-dimension test assumes that the values of beta coefficients of each country are constrained under the same alternative value of beta coefficients; whereas, between-dimension test allows heterogeneity of the cointegrating vectors. Within-dimension testing consists of four statistics, which are panel-v, panel-rho, panel-PP and panel-ADF. The rest three statistics are between-dimension, which are group-rho, group-PP, and group-ADF.

The results are shown in Table 3. Pedroni panel cointegration tests prove that there exists cointegration in the series in the model with intercept for all seven statistical tests at 5% level of significance. For the model with intercept and trend, only one statistical test fails to reject the null hypothesis of no cointegration at 5%

[2] The three-panel unit root tests are Levin-Lin-Chu (2002), which assumes balanced panels; and Fisher-type tests of ADF and PP tests from Choi (2001), which assumes unbalanced panels

level of significance. Therefore, it can be concluded that there exists a long-term relationship between the gross domestic return and the uncovered gross return for Thailand and Singapore.

Table 3
Pedroni panel cointegration tests

Test Statistics	*Intercept*	*Intercept and trend*
Alternative hypothesis: Common AR coefs. (within-dimension)		
Panel v-Statistic	1.653470*	0.317510
Panel rho-Statistic	–4.158900*	–3.330901*
Panel PP-Statistic	–2.758820*	–2.594607*
Panel ADF-Statistic	–2.671156*	–2.900060*
Alternative hypothesis: Individual AR coefs. (between-dimension)		
Group rho-Statistic	–5.374532*	–3.427714*
Group PP-Statistic	–3.395891*	–2.871594*
Group ADF-Statistic	–3.270492*	–3.195286*

Notes: (1) *presents the rejection of the null hypothesis of no cointegration at 5% level of confidence.
(2) The 362 observations are the pool of Thailand and Singapore.
(3) The lag terms are automatically specified by Schwarz criterion with a maximum lag of 13.

4.4 FMOLS and DMOLS estimators from 2000 to January 2015

Next step, the series are tested by both FMOLS and DOLS in order to observe the long-run relationship between the gross domestic return and the uncovered gross foreign return. The long-run cointegrated coefficients are obtained through these estimations. The main difference between FMOLS and DOLS is that DOLS incorporates endogenous feedback effect when the first difference values of the uncovered gross foreign return are added in Eq. (3) (Tang, 2010). The model is estimated with the assumption of country-specific effect and time trend as in Eq. (3), and without this assumption. The coefficients obtained from the former model indicate the pure effect of the uncovered gross foreign return on the gross domestic return; whereas, the latter model helps explaining the overall contribution from country-specific effect, time trend, and the uncovered gross foreign return on the gross domestic return.

Table 4 presents the panel and individual beta coefficients from FMOLS and DOLS for the period from 2000 to January 2015. The t-statistics are also reported in the parenthesis with the null hypothesis of $\beta=0$. The beta coefficients are significantly greater than zero at 5% level of significance. Then, UIP does exist in both Thailand and Singapore. However, there is still a concern regarding a structural change in financial system due to the GFC. Then, the series needs to be estimated in different time intervals as shown in Table 5, 6, and 7.

Table 5 shows the panel and individual beta coefficients from FMOLS and DOLS for the period from 2000 to 2006, which is pre-crisis period. During this time, the beta coefficients are significantly greater than zero at 5% level of significance. Therefore, it can be concluded that there exists UIP in both countries during the pre-crisis.

The estimated beta coefficients for all series during the GFC from 2007 to 2009 are shown in Table 6. The test statistics reject the null hypothesis of $\beta = 0$ at 5% level of significance. That is, the estimators are not significantly greater than zero. So, UIP does not hold true during the crisis.

For the post-crisis period from 2010 to January 2015, the estimated beta coefficients for all series are not significantly greater than zero at 5% level of significance as shown in Table 7. That is, the relationship between the gross domestic return and the gross foreign return does not exist during the post-crisis period.

Table 4
FMOLS and DOLS estimators of the series for the entire period from 2000 to January 2015

	FMOLS		*DOLS*	
Trend and constant terms	*Yes*	*No*	*Yes*	*No*
Panel estimation	0.327931 (8.252049*)	0.998584 (455.3566*)	0.337989 (7.517358*)	0.998666 (461.9473*)
Thailand	0.279725 (4.411266*)	1.003826 (280.1701*)	0.292579 (3.903895*)	1.003890 (282.6997*)
Singapore	0.385557 (8.796032*)	0.993355 (448.2182*)	0.391489 (8.441166*)	0.993436 (456.4472*)

Notes: 1. *rejects the null hypothesis of no cointegration at 5% level of confidence.

Table 5
FMOLS and DOLS estimators of the series from 2000 to 2006

	FMOLS		*DOLS*	
Trend and constant terms	*Yes*	*No*	*Yes*	*No*
Panel estimation	0.338607 (8.556830*)	0.989108 (336.1076*)	0.333276 (7.869523*)	0.989409 (341.4016*)
Thailand	0.264305 (4.222407*)	0.990875 (197.7458*)	0.258268 (3.683627*)	0.991245 (198.0310*)
Singapore	0.433755 (11.45529*)	0.987356 (321.9424*)	0.430853 (12.47578*)	0.987575 (327.5434*)

Notes: 1. *Rejects the null hypothesis of no cointegration at 5% level of confidence.

Table 6
FMOLS and DOLS estimators of the series during the GFC from 2007 to 2009

	FMOLS		*DOLS*	
Trend and constant terms	*Yes*	*No*	*Yes*	*No*
Panel estimation	0.054014 (1.074894)	0.998288 (303.7995*)	0.098563 (1.088882)	0.998242 (311.4143*)
Thailand	0.054703 (0.704541)	1.004453 (247.5012*)	0.105384 (0.710568)	1.004389 (248.0728*)
Singapore	0.051321 (0.903138)	0.992087 (227.1531*)	0.087769 (0.869998)	0.991981 (228.8105*)

Notes: 1. *Rejects the null hypothesis of no cointegration at 5% level of confidence.

Table 7
FMOLS and DOLS estimators of the series during the GFC from 2010 to January 2015

	FMOLS		*DOLS*	
Trend and constant terms	*Yes*	*No*	*Yes*	*No*
Panel estimation	0.090486 (1.347918)	1.012246 (463.6112*)	0.146844 (1.227547)	1.012374 (483.6089*)
Thailand	0.159431 (1.289665)	1.021876 (519.3856*)	0.278848 (1.221585)	1.021884 (591.6079*)
Singapore	–0.000213 (–0.018358)	1.002617 (548.8670*)	–0.002209 (–0.123855)	1.002841 (657.5087*)

Notes: 1. * rejects the null hypothesis of no cointegration at 5% level of confidence.

5. DISCUSSION OF THE RESULTS

5.1 Results of the Period Before the GFC (from 2000 to 2006)

Before the GFC, UIP is proved to exist in both Thailand and Singapore. Additionally, the validity of UIP is stronger in Singapore due to greater beta coefficients, which implies that Singapore economy is more financially integrated with the US. In other words, Singaporean financial assets are believed to be more equivalent to those of the US (Tang, 2010). On the other hand, it is noticeable that the beta coefficients are still far less than the value of unity, which supports the issue of currency basket proposed by Azis and Puttanapong (2008). The currency baskets of Thai baht and Singapore dollar are estimated using rolling estimation model employed from Akiyama and Kawai (2000).[3] Their trends are depicted in figure 2 and figure 3, respectively. According to the trends, the weight of US dollars

[3] Akiyama and Kawai (2000) proposes rolling estimation on a target currency with three major currencies, which are US dollar, Euro, and Japanese Yen. The model specification is illustrated in Appendix D.

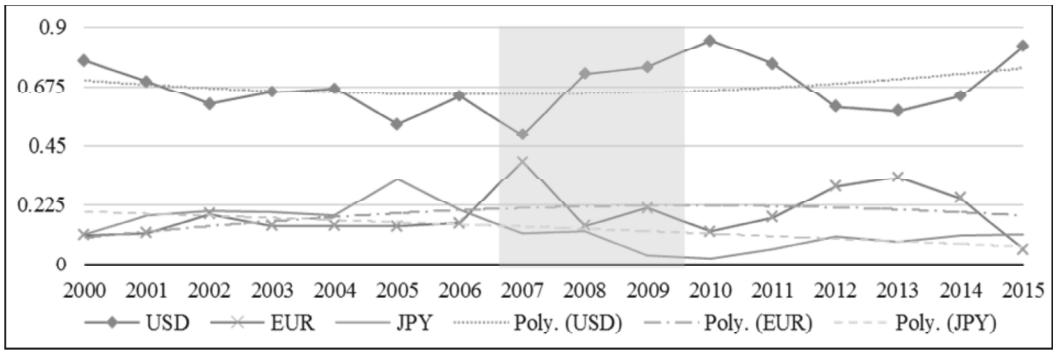

Figure 2: The composition of the currency basket of Thai baht from 2000 to 2015[4]

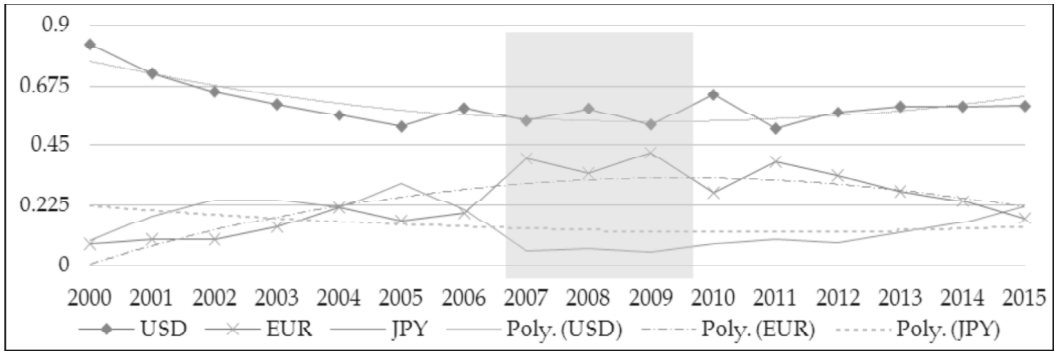

Figure 3: The composition of the currency basket of Singapore dollar from 2000 to 2015[5]

domination is greater in SGD currency basket than in THB currency basket during the pre-crisis period, which leads to the greater validity of UIP in Singapore than in Thailand.

5.2 Results of the Period During the GFC (from 2007 to 2009)

During the time of crisis, the validity of UIP does not hold in both Thailand and Singapore. According to Azis and Shin (2013), during the first phases of GFC, the large amount of US dollars was absorbed by the borrowing from foreign banks. These banks used this fund as a non-core liability to expand their loans to the domestic consumers. This practice was widely done in many Asian countries. Then, instead of having currency depreciation due to higher domestic return, they had currency appreciation as they extensively borrowed in US dollars. It is also notable that the beta coefficients are higher in Thailand than in Singapore, which is caused by the higher level of US dollars domination in THB currency basket during the crisis.

[4,5] The highlighted area indicates the period of GFC during 2007-2009.

5.3 Results of the Period After the GFC (from 2010 to 2015)

In line with the results during the crisis, UIP does not hold after the GFC in Thailand and Singapore. Azis and Shin (2013) explains the period after the crisis as the second phases of liquidity. Their research shows that the bank liabilities in Singapore increased more quickly given the lower Fed funds rates. In addition, because of the cheaper US dollars due to the quantitative easing together with THB appreciation, Thai banks increased their non-core liabilities more and more through foreign banks borrowing. The practice done by Singapore and Thailand potentially fueled further currency appreciation. More importantly, because of the substantial decrease in the level of dollar denomination in SGD basket substantially and the foreign banks borrowing, the beta coefficients of Singapore are pushed below zero.

5.4 Comparison of Results Between Thailand and Singapore

Many research papers indicate that the difference in the validity of UIP lies between developed and developing countries. The results from this paper, however, show that the UIPs of Thailand and Singapore exhibit the same pattern through the GFC. That is, the validity of UIP only exists during the pre-crisis period and becomes invalid since the crisis. The main drivers of this pattern are the excessive foreign borrowing and the level of USD domination in the currency baskets of THB and SGD rather than the level of development in each country.

5.5 The Invalidity of UIP and Carry Trade

The rejection of the pure-effect coefficients of UIP from the model with a time trend and a constant term raises another concern of arbitrary profit from carry trade, in which an investor is arbitrarily better off in borrowing in currency with lower interest rates and investing in currency with higher interest rates. In reality, carry trade goes beyond this pure effect of the uncovered gross foreign return on the gross domestic return. That is, many associated risk factors like country-specific effect and time trend need to be considered when doing carry trade. According to Table 5, 6, and 7, the beta coefficients of the model without a time trend and a constant term are significantly greater than zero at 5% level of significance. In addition, the values of these coefficients are nearly to one, implying that the incorporated effect of the uncovered gross foreign return, time trend, and country-specific effects has approximately one to one relationship with the gross domestic return. According to Figure 4 and 5, the 12-month average profits from carry trades in Thailand and Singapore cluster around zero mean value, which implies that there should be no arbitrary profit from carry trade in the long-run.[6] Therefore, the issue of carry trade is not a concern yet.

[6] The calculation of the profit from carry trade is explained in Appendix E.

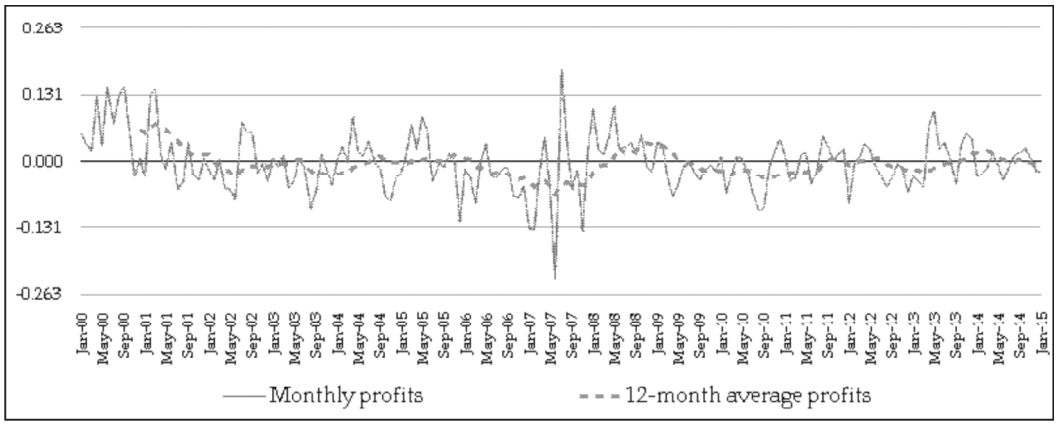

Figure 4: The profit from carry trade between THB and USD

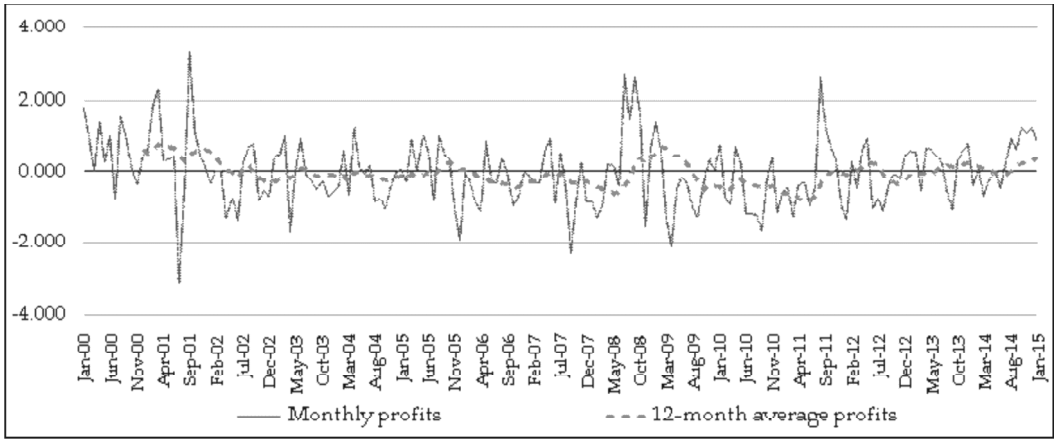

Figure 5: The profit from carry trade between SGD and USD

6. CONCLUSION AND POLICY RECOMMENDATION

This paper examines the long-horizon validity of the precise form of UIP in Thailand and Singapore in the period passing through the GFC by using Pedroni panel cointegration technique and long-run estimation. The results from the cointegrated tests of Thailand and Singapore have the same pattern from 2000 to 2015. Then, in this case, the developed and developing countries exhibit the same pattern. During the pre-crisis period of 2000-2006, the cointegrated estimation suggests the presence of UIP in both countries. In the contrary, this parity was invalid during the crisis from 2007 to 2009 and also in the post crisis from 2010 to 2015.

The divergence from UIP hypothesis is resulted from the expansion of non-core liabilities of Thai and Singaporean banks through excessive USD borrowing, and the recomposition in THB and SGD currency baskets. That is, during the crisis, when the domestic returns in Thailand and Singapore were greater than the return

in the United States; instead of having the currencies against USD depreciation as theory suggests, they appreciated because Thai and Singaporean banks borrowed the excessive amount of USD as it costed lower than the domestic borrowing. Moreover, the lower USD domination in the currency baskets also worsens the validity of UIP in both countries.

As for policy recommendation, the rejection of the pure-effect of the uncovered gross foreign returns on gross domestic returns implies the arbitrary profit from carry trade; however, when country-specific effect and time trend are incorporated in the model, the repetitive profit from carry trade is not feasible in the long horizon. This implies that no one should be able to strive for the arbitrary profit on average over the long run since the uncovered gross foreign return and associated risks are already incorporated in the interest rates and exchange rates movements. Nonetheless, the central banks of Singapore and Thailand still need to consider the potential gain from carry trade in the future when recomposing their currency baskets or conducting monetary policies. In addition, another point to be concerned is that the excessive foreign borrowing by the banks in both countries also increases liquidity risk. Then, it is important for the central banks to implement macroprudential regulations in order to control this risk.[7]

Looking ahead, the relationship between the recomposition of currency basket and the validity of UIP still deserves more attention in further studies. Also, the limited observations during the crisis is the issue when observing long-term relationship through cointegrated technique, which deserves larger pool of developed and developing countries in future investigation.

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[7] Azis and Shin (2013) asserts that monetary policy is not enough to solve the excessive expansion of non-core liabilities. Macroprudential tools need to be accessed instead.

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APPENDICES

Appendix A: Summary of Literatures on Validity Testing of UIP

Paper	*Technique*	*Country*	*Sample period*	*Key findings*
Flood and Rose (2001)	OLS estimation on the precise form of UIP	23 developing and developed countries	1990s	UIP is valid in the short run for emerging market currencies. Plus, there is no significant differences between rich and poor countries. However, there is still heterogeneity error across the countries.

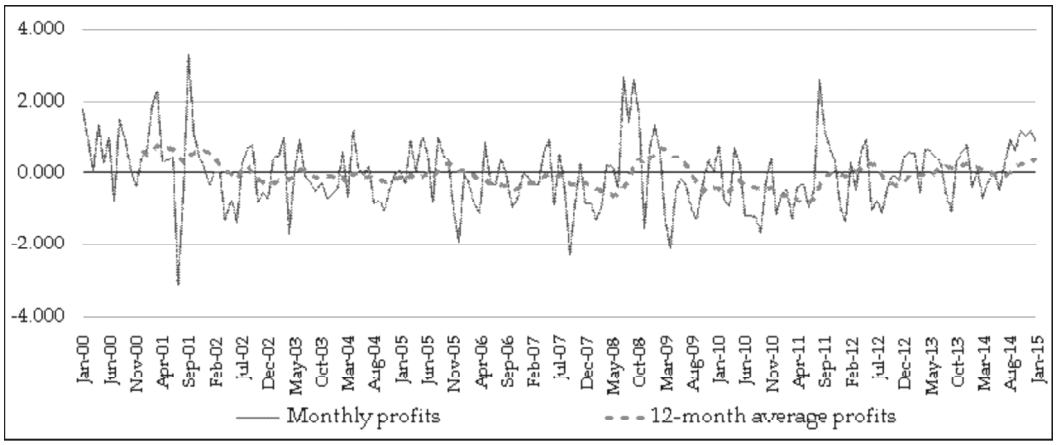
Cont. Appendix A

Paper	*Technique*	*Country*	*Sample period*	*Key findings*
Francis, Hasan, and Hunter (2002)	Multivariate generalized autoregression conditional heteroscedasticity (GARCH)	Chile, Colombia, Mexico, India, Korea, Pakistan, Malaysia, Thailand, and Turkey	1980 to 2000	The deviations from UIP is significantly from a time-varying component and the liberalization of capital markets.
Chin and Meredith (2004)	Long-horizon regressions, simulation, and impulse response	G-7	1980 to 2000	UIP is invalid during the short-run. However, in the long run, UIP is found to be valid.
Holmes and Maghrebi (2004)	Logistic smooth transition autoregression (STAR)	4 South-east Asia with respect to Japan and the United States	1997M1 to 2000M3	The real interest parity exhibits nonlinearity.
Alper, Ardic, and Fendoglu (2007)	A survey of literature review	Globally	–	Emerging markets have distinguishing risk premiums and financial systems.
Mehl and Cappiello (2007)	Fama regression	7 mature currencies and emerging market currencies	1970s to mid 2006	UIP is proved to be linear in medium and long horizons.
Frankel and Poonawala (2010)	Seemingly unrelated regression (SUR)	14 emerging market currencies	1996M12 to 2004M4	Yen carry trade and dollar carry trade are profitable on average. The biases in the forward rates of emerging market currencies are small.
Tang (2010)	Pedroni panel cointegratoin and long-run estimation	ASEAN-5	1978Q1 to 2008Q4	Only UIP of Singapore is valid because its economy is integrated more with the US.
Chang and Su (2014)	Nonlinear threshold unit-root test	Hong Kong, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, and Thailand	1998M1 to 2012M12	UIP is proved to have nonlinearity properties rather than the linear ones.

Appendix B: Data Summary (*data are obtained from CEIC database)*

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
THB/USD	182	36.20027	4.958794	29.0573	45.6414
SGD/USD	182	1.515225	0.2045511	1.2089	1.8394
Return in the US	182	1.992751	2.115693	0.0673684	6.549545
Return in Thailand	182	2.343293	1.035692	0.96	4.95
Return in Singapore	182	1.21525	1.022914	0.21806	3.54688

Appendix C: Relationship between interest rates and exchange rates of Singapore



Appendix D: The estimation of THB and SGD currency baskets

The model to be performed rolling estimation of the currency baskets is employed from Azis and Puttanapong (2008) as follows:

$$\Delta e_t^j = \alpha + \beta_1 \Delta e_t^{USD} + \beta_2 \Delta e_t^{EUR} + \beta_3 \Delta e_t^{JPY} + u_t$$

where Δe_t^j is log daily change in the currency j on date t and u_t is a disturbance term. The exchange rates are quoted against Swiss France, which is a based currency. The source of data is from the online database of University of British Columbia's Sauder School of Business.

Table I
THB currency baskets from 2000 to 2015

Year	*USD*	*EUR*	*JPY*
2000	0.772690619	0.112319983	0.114989398
2001	0.693715888	0.120072293	0.186211819
2002	0.607077013	0.191373661	0.201549326
2003	0.652469857	0.147874944	0.199655199
2004	0.666992619	0.148616069	0.184391312

Cont. table I

Year	*USD*	*EUR*	*JPY*
2005	0.532666451	0.145823986	0.321509563
2006	0.636971887	0.157506342	0.205521771
2007	0.491423524	0.389867787	0.118708689
2008	0.723097403	0.148083271	0.128819326
2009	0.748873699	0.213453239	0.037673062
2010	0.847456065	0.126422783	0.026121151
2011	0.762280447	0.179177152	0.058542402
2012	0.598608097	0.293958129	0.107433774
2013	0.582657177	0.329786485	0.087556338
2014	0.636653458	0.250684556	0.112661986
2015	0.827097538	0.058601207	0.114301254

Table II
SGD currency baskets from 2000 to 2015

Year	*USD*	*EUR*	*JPY*
2000	0.831552602	0.079097845	0.089349553
2001	0.723621007	0.09457217	0.181806823
2002	0.656962255	0.095263006	0.247774739
2003	0.610092074	0.14322342	0.246684506
2004	0.56827094	0.215129881	0.21659918
2005	0.524876007	0.165126624	0.309997369
2006	0.595467823	0.195179628	0.209352549
2007	0.545155057	0.400354409	0.054490534
2008	0.594495174	0.345462122	0.060042705
2009	0.531921207	0.419540026	0.048538766
2010	0.646074016	0.275730212	0.078195772
2011	0.51731029	0.387862633	0.094827077
2012	0.578807046	0.337669034	0.08352392
2013	0.601730873	0.276812167	0.12145696
2014	0.601686357	0.241672294	0.156641349
2015	0.603766587	0.175395853	0.220837559

Appendix E: The Calculation of the Profit from Carry Trade

Carry trade is a trade, in which an investor borrows in the currency with a lower interest rate and invest in the currency with a higher interest rate. This process needs to be accounted for the future exchange rate fluctuation. The calculation is described as below:

Firstly, the initial investment is assumed to be 100 unit of domestic currency. It is exchanged to USD at the spot exchange rate. Then, the initial investment in foreign currency is $\frac{100}{E_1}$, where E_1 is a spot exchange rate of the domestic currency against USD.

At the end of the period, the initial investment grows to $\frac{100e^{r_f t}}{E_1}$, where r_f is the US interest rate and t is a timeframe. In other words, the investment will grow to $\frac{100e^{r_f t}E_2}{E_1}$, where E_2 is a future exchange rate of the domestic currency against USD. The cost of investment is $100e^{r_d t}$, where r_d is a domestic interest rate. Therefore, the profit will be $\frac{100e^{r_f t}E_2}{E_1} - 100e^{r_d t}$.