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Purchasing Power Parity Revisit: A Comparison of Linear and Nonlinear Models

***Ahmad Zubaidi Baharumshah & Hooy Chee Wooi**
Department of Economics,
Faculty of Economics and Management,
Universiti Putra Malaysia,
43400 UPM, Serdang, Selangor, Malaysia

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ABSTRAK

Kajian ini cuba memperkembangkan isu Pariti Kuasa Beli (PPP) dari dua sudut. Pertama, perbandingan dibuat antara model fungsi linear PPP (OLS) dengan model fungsi tidak linear PPP (GARCH). Kedua, isu PPP diselidik semula menggunakan data yang terkini dari Januari 1980 hingga November 2002, termasuk krisis kewangan Asia untuk lima buah negara ASEAN. Keputusan empirikal mencadangkan bahawa matawang ASEAN-5 kembali ke keseimbangan nilai PPP di dalam jangka masa yang panjang. Matawang Peso Filipina dan Dollar Singapura menerima impak yang kurang daripada krisis matawang. Walaupun, Malaysia dan Thailand mengalami penurunan matawang yang besar, kedua-dua matawang tersebut kembali ke keseimbangan asal pada jangka masa yang lebih singkat daripada matawang yang lain. Selain itu, sifat tidak linear matawang ASEAN-5 juga didokumentasikan dalam kajian ini. Ini diperkuatkan dengan pencapaian yang lebih baik oleh model fungsi tidak linear daripada model fungsi linear dari segi penghasilan ramalan pertukaran asing dalam memodelkan PPP.

ABSTRACT

This paper aims to expand PPP literature by twofold. First, the performance of the conventional linear PPP model (OLS) is compared with nonlinear PPP (GARCH). Secondly, we revisit the PPP by using more recent data for the currencies of five leading members of the Association of Southeast Asia Nations (ASEAN-5), covering from January 1980 to November 2002, including the recent Asian financial crisis. Our results suggest that generally, the ASEAN-5 currencies still revert to their PPP equilibrium over long run time horizon. While all series show response to the crisis, the Philippine peso and Singapore dollar obviously received the least impact. Although Malaysia and Thailand have suffered huge undervaluation during the crisis, both Malaysian ringgit and Thai baht are found to be corrected at a quicker pace relative to the other three currencies from the misalignments. In addition, we also documented several nonlinear behaviors of the ASEAN-5 currencies and found that the nonlinear models outperform the linear model in modeling PPP, based on their superiority in out-of-sample forecasting.

Keywords: PPP, GARCH, EGARCH-M, forecasting

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* Corresponding author:
E-mail: *zubaidi@putra.upm.edu.my*

INTRODUCTION

Long since the early of last century, purchasing power parity (PPP) has been viewed as centre of exchange rate determination, as well as basis for international capital flow theories. Put simply, the PPP approach states that the exchange rate between two national currencies should move to equate the prices of an identical bundle of goods produced in the two countries. Thus, the equilibrium real exchange rate is predicted to be constant. If the current exchange rate deviate from its PPP equilibrium, there is an opportunity for arbitrage in the goods and capital markets, which will tend to drive the exchange rate towards the PPP.

While PPP is a simple and powerful idea, it has fallen out of fashion as a tool to forecast exchange rate for practitioners due to two reasons. First, exchange rate is driven not only by price or inflation differentials, as presumed by the PPP approach, but also by a wide range of other money and non-money factors, such as political stability, relative productivity, and demand shock, to name just a few. This has leads to the second reason, where most empirical studies documented that the PPP only holds (at best) over very long time horizons. In the short and medium term, exchange rate tends to deviate substantially from PPP due to shocks from the above mentioned money and non-money factors; suggesting a volatility persistency phenomenon. This is why most market analysts and practitioners usually reject the PPP approach to exchange rate determination.

Scholarly research as well, is not favorable to PPP. Since the hallmark work of Meese and Rogoff (1983), the naïve random walk model has tried to snub PPP both theoretically and empirically. The bulk of recent literature as well, fails to achieve a consensus to accept the PPP, even as a long run relationship. Academicians are still attempting to find new empirical facts by exploiting new techniques and models that are able to capture the dynamic nature of exchange rate. Recently, there is ample evidence against the linear paradigm, showing that financial time series are more likely to exhibit nonlinear dependencies (e.g. exchange rate, inflation, stock returns and interest rate parity)[1]. With this development, the subject has moved to a new direction, which is, of course, the incorporations of non-linearity in the PPP model. For example, nonlinear models such as Neural Network (NN) approaches, Threshold Autoregressive (TAR), Generalized Autoregressive Conditional Heteroscedasticity (GARCH) family of models, and Smooth Transition Autoregressive (STAR) family of models, are all widely employed in recent papers to explain the dynamic of financial time series especially the exchange rate (See for example, Liew *et al.* 2004; Sarno 2000a,b; Vilasuso 2002; Baillie and Bollerslev 1991)[2].

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1 There is a growing consensus among the profession that attempts to examine fundamental topics within finance will be less well specified, and hence, less informative, if they rely on traditional linear modeling approaches.

2 An excellent summary on the asymmetric GARCH models is found in Hentschel (1995)).

This paper aims to expand the current interest by twofold. First, the performance of the conventional linear PPP model is compared with the GARCH model advanced by Bollerslev (1986). To date, there is a lack of GARCH-based PPP literature because the standard way of PPP research is by large using the unit root and cointegration tests. Second, we revisit PPP doctrine by using more recent data for the currencies of five leading members of the Association of Southeast Asia Nations (ASEAN-5), covering from January 1980 to November 2002. This is important for the reason that nearly all of the published works focus on data up to 1998, excluding the Asian financial crisis (e.g. Baharumshah and Ariff 1997; Sazanami and Yoshimura 1999; Azali *et al.* 2001). We intend to investigate whether the recent crisis has left a significant impact on the long run PPP by using a crisis dummy.

Our results suggest that generally, the ASEAN-5 currencies still revert to PPP over long run time horizon. While the Philippine peso and Singapore dollar received the least impact from the recent crisis, both the Malaysian ringgit and Thai baht are found to have smaller cycle of PPP misalignments. In addition, we also documented several nonlinear behaviors of the ASEAN-5 currencies and found that the nonlinear models outperform the linear model, based on their superiority in out-of-sample forecasting.

This paper is organized as follow; section 1 serves as introduction; section 2 provides the literature review; this is followed by section 3, methodology and data; section 4 reports the empirical results, where the analysis is carried out in three stages - modeling of the linear and nonlinear PPP, conducting unit root test on the real exchange rates, and a comparison of within and out-of-sample forecasting performance of both types of models. The final section offers the concluding remarks.

LITERATURE REVIEW

Studies on exchange rate and its determination have received a lot of attention in the literature.[3] The central of all theory of exchange rate models are based on some form of PPP. Nevertheless, most of the empirical works have failed to reject the null hypothesis of a unit root in exchange rate. In spite of the use of numerous statistical techniques over sample periods ranging to 25 years, there has been little evidence to support the PPP hypothesis for the developing countries. For example, the article by Bahmani-Oskooee (1993) overwhelming rejects the stationarity of real exchange rates for most of the LDCs[4]. That is to say, in our present context, real exchange rates in these countries are persistent over the generalized floating exchange rate period. Similar findings were also documented in, for example, Gan (1991) for Malaysia; in Baharumshah and Ariff (1997) for the ASEAN-5 countries (ASEAN-5: Malaysia, Indonesia, Thailand,

[3] For survey on the early theoretical development on exchange rate determination, please see Macdonald and Taylor (1992) and Taylor (1995).

[4] Bahmani-Oskooee (1993) found that PPP holds for only four out o twenty-five developing countries.

Singapore and the Philippines), and in Aggarwal and Mougoue (1996) for the Asian Tigers and the ASEAN countries[5].

The failure to confirm PPP means that standard models used to determine exchange rate movements (and policy guidance) may therefore yield misleading results, as deviations from the PPP tends to be persistent and real exchange rate follows a random walk process[6]. In other words, policy guidance that is based on PPP is questionable. It is worth noting that the empirical literature suggests that a number of reasons for the failure to reject the nonstionarity of real exchange (PPP does not hold). However, two main arguments dominate. The first is that the span of available data was simply too short to provide reasonable power in the conventional tests used for nonstatinary (see Sarno (2000a,b) and Liew *et al.* (2004). The second was that real exchange rate was determined by real factors (oil shocks, productivity differentials and fiscal variables (see Rogoff (1996) and MacDonald (1997))[7].

Current research in exchange rate modeling attests that real exchange rate exhibit nonlinear dependencies in its adjustment to PPP. Hsieh (1989), Caporale and Pittis (1996), Brooks (1996), Brooks (1997), Choo *et al.* (2001), Lim *et al.* (2002) and Liew *et al.* (2004) have provided ample evidence on the exchange rates nonlinearity. In this regard, many nonlinear models have emerged to provide alternative dimension in reviewing the judgment place on PPP. Brooks (1997) for example, found that the parsimonious Neural Network (NN) and GARCH type of models do perform better in modeling the exchange rates movement. Nevertheless he reserves the full superiority of such models to capture the stochastic exchange rates dynamic and suggests that a time-varying coefficients model would be ideal. Choo *et al.* (2001) as well, have documented the success of GARCH-type of models to outperform the naïve random walk model in out-of-sample forecasting. Caporale and Pittis (1996) and Liew *et al.* (2002) on the other hand, suggest that the STAR model is well equipped to handle nonlinearity in exchange rates.

Indeed, recent work on alternative linear and nonlinear econometric modeling has re-energized empirical evidence on PPP. Baharumshah (2002) has provided a comprehensive discussion on both linear and nonlinear paradigm of the PPP for East Asia currencies, and seeing nonlinearity as a complement to long run PPP to withhold. Azali *et al.* (2001) for example, found evidence for the PPP to hold for seven Asian developing economies (ADE) with Japan, from 1977 to 1998. More recently, Taro (2002), using a panel of 13 disaggregated CPI (1960-1998) from seven major Japan cities, also supports for the PPP across

[5] For the case of the developed countries and the major currencies, the reader may refer to Engle (2000) and the articles cites therein.

[6] Failure of PPP is also consistent with a related line of study that have reported the half-life (the speed at which that deviation from PPP die out) is far to high (3-5 years) to be explained by existing theoretical model

[7] The famous Balassa-Samuelson effect arises when relative factor proportions and factor prices become imbalance due to relative differences in the rate of technological shock.

cities. Papell 's (2002) structural change panel approach as well rejects most of the unit root null, though not all in their study of 20 industrialized countries from 1973-1996. Additionally, Liew *et al.* (2002) found that the PPP withhold for ASEAN-5 and Korea in the period spans from 1968 to 2001. In short, the development of the nonlinear models (e.g. NN, GARCH, TAR, STAR), KPSS, panel unit root and panel cointegration tests, have dominated the research trend, and provide researcher an opportunity in attempting to prove the PPP using data from the current float.

MODELING STRATEGY AND THE DATA

The empirical test for a long run PPP is typically based on the following equation:

$$s_t = a + b_1 p_t + b_2 p_t^* + \varepsilon_t \tag{1}$$

where s_t is the logarithm of the nominal exchange rate in period t, defined as domestic price of foreign currency p_t, the logarithm of domestic price, p_t^* the logarithm of foreign price, a, b_1, and b_2 are the parameters, and ε_t is the error term. The restriction commonly imposed on the parameters are, $a = 0$, $b_1 = 1$ and $b_2 = -1$. With these restrictions, the error term is a measure of the deviation of real exchange rate, where:

$$\varepsilon_t \equiv s_t - p_t + p_t^* \tag{2}$$

If the PPP holds, the long-run movement of s_t, p_t and p_t^* cancels out, that is, s_t, p_t and p_t^* are cointegrated. To test for the stationarity of the real exchange rate, we applied the conventional Augmented Dickey Fuller (ADF) test on the residuals ε_t. In addition, to capture the effect of the recent financial crisis, a dummy variable (D_{crisis}) is added to equation (1) to yield:

$$s_t = a + b_1 p_t + b_2 p_t^* + cD_{crisis} + \varepsilon_t \tag{3}$$

where c measures the impact of the crisis. Equation (3) is estimated by using the Ordinary Least Square (OLS) method. To conserve space, we do not discuss the details of the tests here.

In this paper, two nonlinear models (Generalized Autoregressive Conditional Heteroscedasticity or simply GARCH) are proposed. The GARCH-type of models are proposed because they are capable to capture the excess kurtosis and volatility clustering behavior of the exchange rate. A conventional symmetrical GARCH (1,1) model and an asymmetrical Exponential GARCH

(1,1) in Mean (EGARCH-M) model are fitted to PPP, as given respectively by equation (4), (5), (6) and (7)[8] as follows:

GARCH (1, 1) (symmetrical):

$$s_t = \mu + \delta_1 p_t + \delta_2 p_t^* + cD_{crisis} + v_t \tag{4}$$

$$h_t = \omega + \beta h_{t-1} + \alpha \varepsilon_{t-1} + \theta D_{crisis} \tag{5}$$

EGARCH (1, 1)-M (asymmetrical):

$$s_t = \mu + \delta_1 p_t + \delta_2 p_t^* + \tau\sqrt{h_t} + cD_{crisis} + v_t \tag{6}$$

$$\log h_t = \omega + \beta \log h_{t-1} + \alpha\left|\frac{v_{t-1}}{\sqrt{h_{t-1}}}\right| + \gamma\frac{v_{t-1}}{\sqrt{h_{t-1}}} + \theta D_{crisis} \tag{7}$$

where h_t represents the conditional variance of the residual term. μ, δ_1, and δ_2 are the parameters in the conditional mean of the exchange rate, and v_t is the error term. The parameters in the conditional variance are given respectively by ω, α and β. The parameter θ is the coefficient measuring the impact of the recent crisis on the volatility of the exchange rate.

The EGARCH-M model has an added advantage to account for the leptokurtosis in financial time series and this enables us to test for the leverage effect of bad news. The asymmetrical effect is detained by γ.[9] The model is expected to perform better in the uncertainty (volatility) period, as it could differentiate the effects of good and bad news in the market. In addition, EGARCH-M also considers the possibility of a conditional volatility feedback effect in the exchange rate, where the coefficient of the volatility feedback is represented by the parameter τ.

The data employed in this study covered the monthly bilateral exchange rate and consumer price index (CPI) from January 1980 to November 2002.[10]

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[8] The theoretical model used most studies is based on PPP relationship. The bulk of the literature has demonstrated that PPP failed to hold in the short-run. Besides that, it is well known that the out-sample forecasts generate from simple random walk model usually outperformed structural models at short horizon. In other words, random walk tends to dominate PPP point prediction at short forecasting horizon. The predictive content of structural models like PPP are expected to significantly improve as the forecasting horizon is lengthen. We are grateful to one of the referees for pointing out his to us.

[9] The response of the PPP model (conditional volatility) to good and bad news are asymmetry if $\gamma \neq 0$ the variance equation (7), the impact is symmetry if $\gamma = 0$. The presence of the leverage effects can be tested by the hypothesis of $\gamma < 0$.

[10] The appropriate price index should cover goods that are traded internationally. Several authors have argued that the producer price index (PPI) is a better choice that the CPI. But monthly data for PPP spanning over the sample period for all the countries under investigation is unavailable for this study.

Following the common practice in the literature, all the series are expressed in logarithm. The data are collected from the IMF International Financial Statistics (IFS), various issues. The sample covers the CPI of the US and ASEAN-5; and the currencies of Indonesia rupiah, Malaysian ringgit, Philippine peso, Singapore dollar and Thai baht. ASEAN-5 is chosen because of the growing importance of ASEAN in the world economy both in terms of trade and investments. The implementation of the Asia Free Trade Area (AFTA) in 2005 has prompted this region to progress competitively. Yet the linkages among the ASEAN members have not gained much attention in the literature.

THE PPP MODELING AND FORECASTING

Table 1 presents the summary statistics for all the exchange rates and CPI series involved. Table 2, table 3 and table 4 provide the parameter estimation of PPP based on the linear OLS, nonlinear symmetrical GARCH, and nonlinear asymmetrical EGARCH-M respectively. Table 5 reports the unit root test based on ADF, while table 6 summarizes the within sample and out-of-sample forecasting comparison of the three models. We note that the lag lengths for the ADF test are chosen based on the Akaike (AIC) and Schwaz (SIC) information criteria.

A quick glance on the parameter estimation of all three PPP models seem to promise a good-fitted model (85% parameters are significant). R^2 are fairly high for all the fitted series (over 90%), except the Singapore dollar. Nevertheless, the coefficient values of the CPI are not satisfactory to withhold PPP. A further test on the price ratios using the Wald test also shows that the common PPP restriction of negative unity can be rejected at a 1% significant level.

An interesting finding however, has been documented for the crisis's dummy. The dummy variable (c) turned out to be significant in all the models, except Indonesian rupiah in EGARCH-M modeling. The exclusion of the step dummy (takes value of 1 in 1997: 07-1998: 12) in most cases yielded non-normal residuals. The Philippine peso and Singapore dollar obviously received the least impact from the crisis, by observing the coefficient values. Both the currencies together with the Thai baht, also show insignificant θ values in the nonlinear modeling, except Singapore dollar in EGARCH-M modeling, indicating that the volatility of exchange rate of these countries are not affected significantly by the currency crisis.

Volatility persistency has been a dominant trend in ASEAN-5 currencies, as a high percentage of conditional variance's variables are statistically significant. This shows that nonlinearity does exist in the PPP model and it is successfully captured by the GARCH model. The EGARCH-M model further provides evidence for asymmetrical news effect and volatility feedback effect but the leverage effect only happened in the Malaysian ringgit and Philippine peso.

Figs. 1, 2 and *3* show the implied misalignments of ASEAN-5 currencies against the US dollar. It is measured by the deviations of ASEAN-5 nominal exchange rates from the equilibrium PPP rates generated by OLS, GARCH, and EGARCH-M respectively. A positive deviation indicates undervaluation while a negative deviation means overvaluation. It appears that there were serious

TABLE 1
Summary statistics for all series

	Nominal Exchange Rates					Consumer Price Index					
	Indonesia	Malaysia	Philippine	Thailand	Singapore	US	Indonesia	Malaysia	Philippine	Thailand	Singapore
Mean	7.675	1.014	3.120	0.601	3.324	4.448	4.368	4.478	4.172	4.505	4.431
Median	7.578	0.946	3.230	0.589	3.240	4.491	4.254	4.456	4.295	4.514	4.426
Maximum	9.609	1.519	3.981	0.820	4.006	4.779	5.678	4.795	5.046	4.665	4.844
Minimum	6.438	0.757	2.004	0.329	3.016	3.934	3.278	4.071	2.838	4.220	3.855
Std. Dev.	0.864	0.186	0.539	0.145	0.228	0.226	0.672	0.201	0.651	0.119	0.277
Skewness	0.550	0.987	-0.580	-0.275	1.070	-0.333	0.461	0.017	-0.490	-0.242	0.050
Kurtosis	2.379	2.556	2.743	1.853	2.862	1.958	2.142	1.880	2.129	1.876	1.715
Jarque-Bera	18.283	46.901	16.192	18.554	52.692	17.519	18.160	14.388	19.725	17.145	19.025
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Observations	275	275	275	275	275	275	275	275	275	275	275

TABLE 2
OLS estimation results

Model: $s_t = a + b_1 p_t + b_2 p_t^* + cD_{crisis} + \varepsilon_t$

	Parameters							
ASEAN 5	a	b_1	b_2	c	R^2	*LogL*	b_1/b_2	*F-statistics*
Indonesia	2.004 (0.003)***	0.922 (0.000) ***	0.347 (0.1812)	0.453 (0.000) ***	0.950	86.577	2.657	182.289 (0.000) ***
Malaysia	0.842 (0.000)***	-0.937 (0.000) ***	0.961 (0.000) ***	0.404 (0.000) ***	0.914	404.247	-0.975	865.681 (0.000) ***
Philippine	5.791 (0.000)***	1.385 (0.000) ***	-1.908 (0.000) ***	0.101 (0.000) ***	0.948	189.590	-0.726	25.452 (0.000) ***
Singapore	7.540 (0.000)***	-1.674 (0.000) ***	0.126 (0.1947)	0.161 (0.000) ***	0.852	359.785	-13.286	180.580 (0.000) ***
Thailand	1.826 (0.000)**	-0.911 (0.000) ***	1.216 (0.010) ***	0.504 (0.000) ***	0.920	378.956	-0.749	201.851 (0.000) ***

Log L is the log-likelihood functions value. The common PPP restriction of b_1/b_2=-1 is tested by the Wald test and reported under the *F-statistics*. Values in the parentheses are the p-values. * denotes significance at 0.10 level; ** denotes significance at 0.05 level and *** denotes significance at 0.01 level. All the time series are measured in the logarithmic form.

TABLE 3
GARCH (symmetrical) estimation results

Model: $s_t = \mu + \delta_1 p_t + \delta_2 p_t^* + cD_{crisis} + v_t$; $h_t = \omega + \beta h_{t-1} + \alpha\varepsilon_{t-1} + \theta D_{crisis}$

	Parameters					
ASEAN 5	μ	δ_1	δ_2	c	R^2	*LogL*
Indonesia	0.917 (0.000)***	0.751 (0.000) ***	0.761 (0.000) ***	0.478 (0.000) ***	0.948	226.409
Malaysia	1.222 (0.000)***	-1.165 (0.000) ***	1.103 (0.000) ***	0.451 (0.000) ***	0.910	550.222
Philippine	5.812 (0.000)***	1.403 (0.000) ***	-1.918 (0.000) ***	0.028 (0.0344) **	0.939	281.429
Singapore	7.775 (0.000)***	-1.694 (0.000) ***	0.093 (0.000) ***	0.175 (0.000) ***	0.849	501.038
Thailand	2.151 (0.000)***	-0.933 (0.000) ***	1.162 (0.000) ***	0.493 (0.000) ***	0.902	581.938
	ω	α	β	θ	δ_1 / δ_2	*F-statistics*
Indonesia	1.56E-05 (0.344)	1.187 (0.000) ***	0.112 (0.148)	0.006 (0.029) **	0.987 (0.000) ***	31657.12
Malaysia	9.50E-05 (0.000) ***	0.985 (0.000) ***	-0.037 (0.456)	0.006 (0.000) ***	-1.056 (0.000) ***	4372.36
Philippine	0.001 (0.003) ***	1.095 (0.000) ***	-0.0715 (0.000) ***	4.00E-04 (0.622)	-0.731 (0.000) ***	131.07
Singapore	1.03E-04 (0.000) ***	1.108 (0.000) ***	-0.068 (0.201)	0.001 (0.354)	-18.215 (0.000) ***	14230223
Thailand	2.74E-05 (0.000) ***	1.218 (0.000) ***	-0.022 (0.571)	3.58E-04 (0.121)	-0.803 (0.000) ***	131372.10

misalignments of the ASEAN-5 currencies from the linear and nonlinear PPP equilibrium rates prior crisis. An interesting occurrence is that the Indonesian rupiah, Malaysian ringgit, and Thai baht all depict a sharp overvaluation prior to the outburst of the crisis. As expected, the asymmetrical EGARCH-M model captured the sharp overvaluations.

The crisis and the degree of its impact are shown by the sharp undervaluation received by ASEAN-5 currencies. The linear and nonlinear models all show that

TABLE 4

EGARCH-M (asymmetrical) estimation results

Model: $s_t = \mu + \delta_1 p_t + \delta_2 p_t^* + \tau\sqrt{h_t} + cD_{crisis} + v_t$; $\log h_t = \omega + \beta \log h_{t-1} + \alpha\left|\frac{v_{t-1}}{\sqrt{h_{t-1}}}\right| + \gamma\frac{v_{t-1}}{\sqrt{h_{t-1}}} + \theta Dcrisis$

	Parameters						
ASEAN 5	μ	δ_1	δ_2	τ	c	R^2	$LogL$
Indonesia	-4.132	0.472	2.074	7.755	0.004	0.983	391.999
	(0.000)***	(0.011) **	(0.000) ***	(0.000) ***	(0.449)		
Malaysia	-1.332	0.716	-0.176	-5.167	0.323	0.947	589.331
	(0.000)***	(0.000) ***	(0.127)	(0.000) ***	(0.000) ***		
Philippine	5.865	1.409	-1.925	-0.947	0.062	0.957	325.340
	(0.000)***	(0.000) ***	(0.000) ***	(0.000) ***	(0.000) ***		
Singapore	7.983	-1.692	0.039	0.479	0.201	0.780	500.467
	(0.000)***	(0.000) ***	(0.002) ***	(0.000) ***	(0.000) ***		
Thailand	0.657	-0.736	1.282	6.877	0.201	0.976	650.084
	(0.000)***	(0.000) ***	(0.000) ***	(0.000) ***	(0.001) ***		

	ω	α	β	γ	θ	δ_1 / δ_2	*F-statistics*
Indonesia	-0.313	0.030	0.956	0.367	0.226	0.228	691.547
	(0.000)***	(0.196)	(0.000) ***	(0.000) ***	(0.001) ***		(0.000) ***
Malaysia	-0.399	0.062	0.957	-0.256	0.158	-4.068	480.814
	(0.026)**	(0.013) **	(0.000) ***	(0.000) ***	(0.012) **		(0.000) ***
Philippine	-2.012	1.326	0.839	-0.464	0.181	-0.732	297.324
	(0.000)***	(0.000) ***	(0.000) ***	(0.001) ***	(0.331)		(0.000) ***
Singapore	-2.640	1.601	0.809	0.499	0.136	-43.385	9823.051
	(0.000)***	(0.000) ***	(0.000) ***	(0.003) ***	(0.000) ***		(0.000) ***
Thailand	-0.784	-0.143	0.899	0.330	0.332	-0.574	241.083
	(0.000)***	(0.000) ***	(0.000) ***	(0.000) ***	(0.478)		(0.000) ***

the undervaluation hit Indonesia the most, followed by Thailand and Malaysia, while Singapore is apparently least affected from the contagion effect, where the undervaluation is small. Nevertheless, Singapore dollar, Thai baht and Philippine peso are all undervalued after the new millennium, as shown consistently by both the linear and nonlinear models. The Malaysian ringgit however, has converged to the PPP equilibrium after the pegging to the US dollar.

An overview of PPP adjustment of the ASEAN-5 currencies across the whole sample period provides an interesting finding. Clearly, the misalignments of Malaysian ringgit and Thai baht tend to be corrected more quickly relative to others. The Malaysian ringgit and Thai baht had followed the PPP since the 1980s, except a distortion from the Asian financial crisis. The pattern is even apparent under the EGARCH-M model. Although the Singapore dollar and Philippine peso also show convergent to PPP across the period, the patterns of convergent are not so obvious and the cycle of adjustment is relatively larger than the Malaysian ringgit and Thai baht. The Indonesian rupiah on its own, shows inconsistent alignment from the PPP as indicated in the linear OLS and nonlinear GARCH models. Under the EGARCH-M modeling however, the Indonesian rupiah seems to follow the PPP nicely until the Asian financial crisis.

The results of the ADF unit root test in Table 5 show positive evidence for the PPP hypothesis. In the standard linear model, there was evidence of PPP relationships (a) between Malaysia and US, (b) between Singapore and US, (c) between Thailand and US, (d) between Indonesia and US, and (e) between Philippines and US. The hypotheses of unit root are also rejected at conventional significance levels for the GARCH-type models, showing a cointegrating vector exist between price and exchange rate, except for the Philippine peso. The PPP between the Philippines and US only holds in the asymmetrical EGARCH-M model. In short, the results indicate that the ASEAN-5 real exchange rates are stationary (or mean reverting), at least for the sample period considered in this study. The rates adjust in the short run, in a fashion to restore the long-run equilibrium relationship.

Multinational corporations aim to establish and extend their businesses in the fast growing East Asia emerging markets, including the large ASEAN countries. The recent currency crisis in Asia highlights the instability of these growing economies and stresses that firms need to closely scrutinize the foreign exchange markets. For large corporations which conduct substantial currency transfers, being able to accurately forecast the movements of the exchange rate is important in order to manage exchange rate risk. It is worth noting here that the predictive performance of exchange rate models has not been seriously undertaken in past studies. Hence, we now turn to the predictive performance of the PPP model in forecasting the ASEAN currencies against the US dollar.[11]

[11] Evaluation of the forecastibility of the ASEAN currencies based on the structural model would complement the existing literature on exchange rate models which have focused mainly on the major currencies—US dollar, German mark and the Japanese yen.

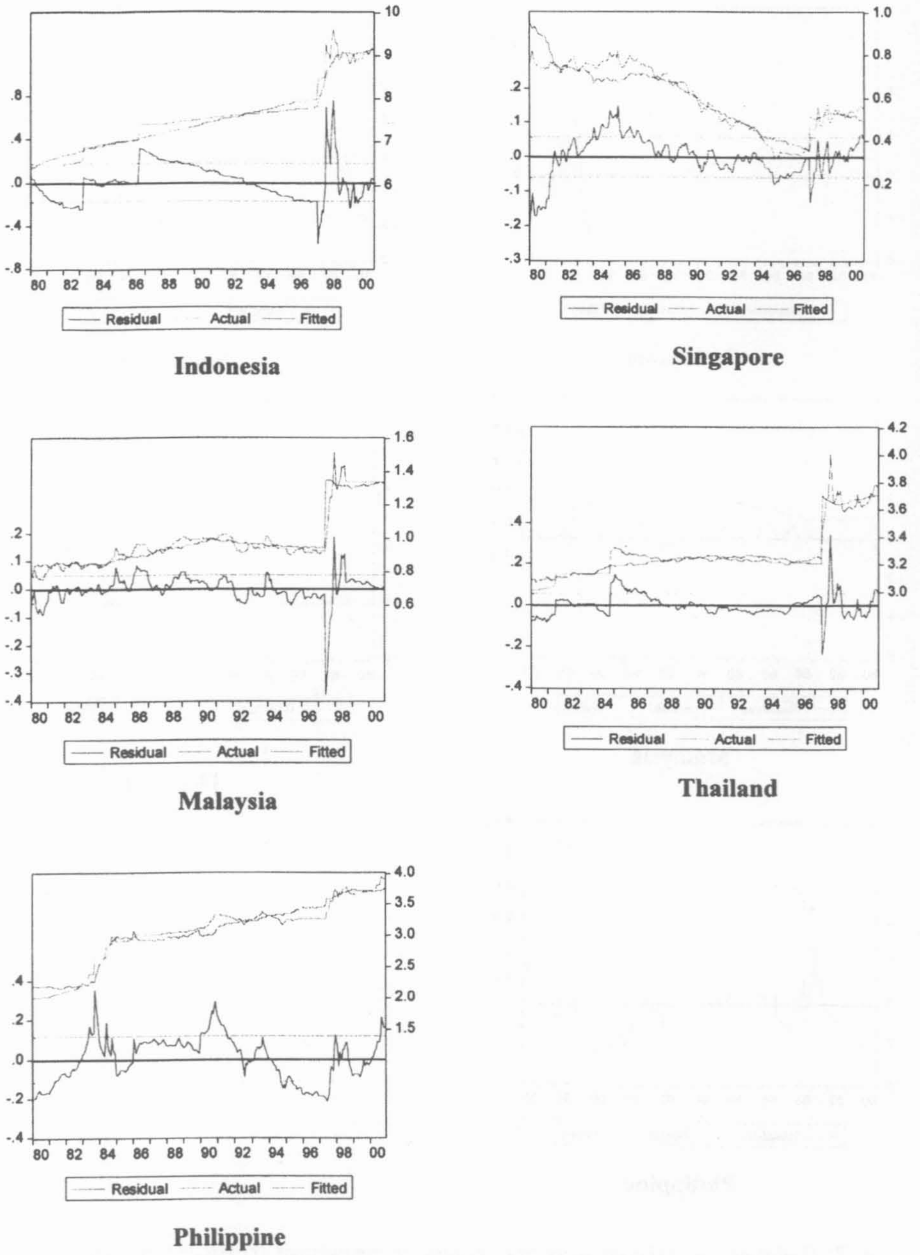

Fig. 1: Deviations of exchange rates from linear (OLS) PPP equilibrium

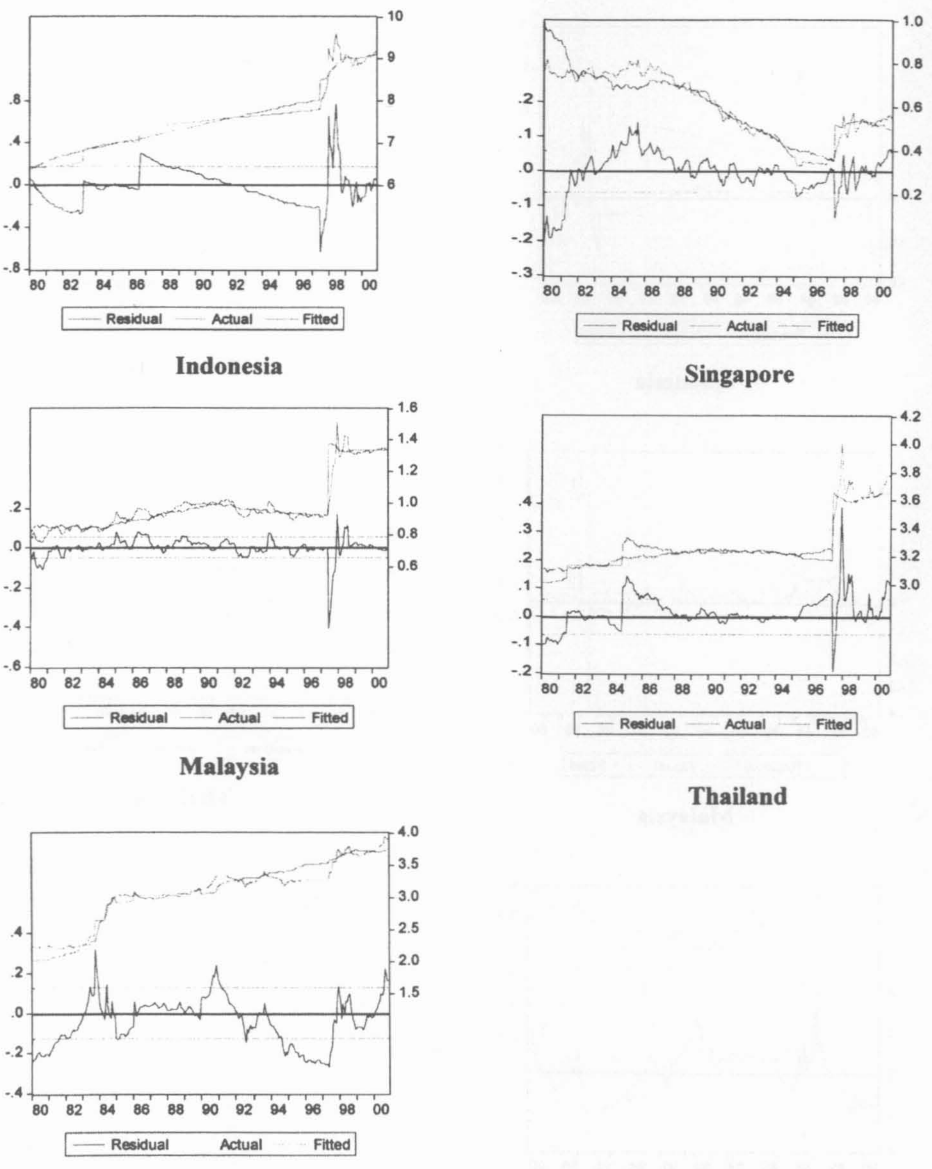

Fig. 2: Deviations of exchange rates from nonlinear symmetrical (GARCH) PPP equilibrium

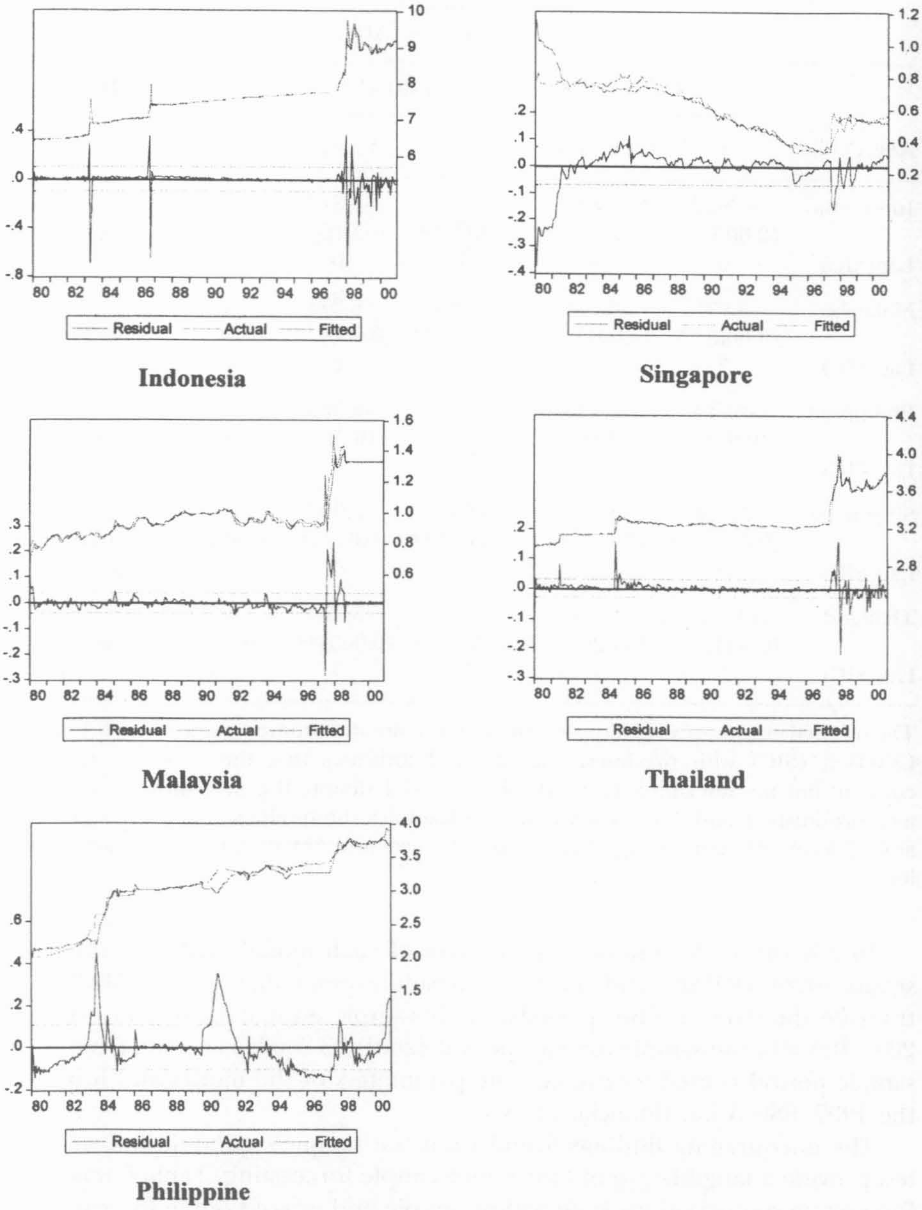

Fig. 3: Deviations of exchange rates from nonlinear asymmetrical (EGARCH-M) PPP equilibrium

TABLE 5
Unit root tests (ADF)

	OLS		GARCH		EGARCH-M	
ASEAN 5	I	I and T	I	I and T	I	I and T
Indonesia	-3.857 (0.003)***	-3.848 (0.016)**	-3.848 (0.003)***	-3.843 (0.016)**	-21.095 (0.000)***	-21.455 (0.000)***
Lag(SIC)	0	0	0	0	0	0
Malaysia	-4.637 (0.000)***	-4.658 (0.001)***	-6.284 (0.000)***	-6.271 (0.000)***	-4.512 (0.000)***	-4.581 (0.001)***
Lag(SIC)	7	7	0	0	6	6
Philippine	-2.714 (0.073)*	-2.726 (0.227)	-2.528 (0.110)	-2.523 (0.317)	-3.596 (0.007)***	-3.587 (0.033)**
Lag(SIC)	0	0	0	0	0	0
Singapore	-3.778 (0.004)***	-3.834 (0.016)**	-4.017 (0.002)***	-3.978 (0.011)**	-3.953 (0.002)***	-3.837 (0.016)**
Lag(SIC)	0	0	0	0	0	0
Thailand	-3.740 (0.004)***	-3.767 (0.020)**	-3.545 (0.008)***	-5.290 (0.000)***	-16.97 (0.000)***	-17.495 (0.000)***
Lag(SIC)	7	7	7	0	0	0

The optimal autoregressive terms of the ADF test are determined via Schwarz Information Criterion (SIC) with maximum lag of 12. I indicates that the ADF test includes a constant but no deterministic trend, while I and T denote the ADF with a constant and a deterministic trend. Values in the parentheses are the p-values. * denotes significance at 0.10 level ; ** denotes significance at 0.05 level and *** denotes significance at 0.01 level.

In this study, we compare the forecast of each model using the root mean square error (RMSE) and the mean absolute percentage error (MAPE). We truncate the data into two periods: the in-sample estimation period (1980: 01-2001: 02) and out-sample forecast period (2001: 03-2002: 11). Data from the in-sample period is used to estimate the parameters of the model and it includes the 1997/98b Asian financial crisis.

The encouraging findings found from the sample's good-fit and stationary test provide a tangible ground for out-of-sample forecasting. Table 6 reports the forecasting evaluation for both within sample and out-of-sample forecasting for all three models involved. Obviously, for within-sample forecasting, the RMSE criterion suggests that the linear PPP fits well as compared with the nonlinear PPP. MAPE in contrast holds up to the nonlinear PPP; where the asymmetrical EGARCH-M model provides the least MAPE for both the Philippine peso and Singapore dollar; and the symmetrical GARCH PPP model best forecasts the Malaysian ringgit. Both the RMSE and MAPE criteria however, show consistency in out-of-sample forecasting. The nonlinear PPP models show superiority in

TABLE 6
Comparison on forecasting performance of PPP models

		Within-Sample		Out-of-Sample	
ASEAN 5	Model	RMSE	MAPE	RMSE	MAPE
Indonesia	OLS	0.1716*	1.7038*	0.1472	1.3251
	GARCH	0.1746	1.7131	0.1264*	1.1631*
	EGARCH-M	0.4332	3.6766	0.9277	8.5423
Malaysia	OLS	0.0487*	3.0910	-	-
	GARCH	0.0498	2.8936*	-	-
	EGARCH-M	0.0975	7.6755	-	-
Philippine	OLS	0.1140*	3.2939	0.1791*	4.5065*
	GARCH	0.1234	3.3772	0.1857	4.6754
	EGARCH-M	0.1204	3.2865*	0.2055	5.1786
Singapore	OLS	0.0580*	7.1546	0.0860	14.3133
	GARCH	0.0587	6.7709	0.0844	14.0441
	EGARCH-M	0.0640	6.6623*	0.0772*	12.7781*
Thailand	OLS	0.0538*	1.1320*	0.0641	1.4796
	GARCH	0.0596	1.1352	0.1133	2.8795
	EGARCH-M	0.0958	2.1199	0.0507*	1.1085*

* denotes the smallest value of the RMSE and MAPE among the three models involved. The Malaysian ringgit has been pegged to USD since September 1, 1998. Hence, we exclude Malaysia from the out-of-sample forecasting comparison.

forecasting the Indonesian rupiah, Singapore dollar and Thai baht; where the GARCH model best fits the Indonesian rupiah, while EGARCH-M model best fits the Singapore dollar and Thai baht.

CONCLUDING REMARKS

This paper presents additional evidence on the dynamics of real exchange rates of the five largest ASEAN countries-Malaysia, Singapore, Thailand, Indonesia and the Philippines-for the years 1980 to 2002. To resolve the PPP puzzle in the emerging market economies, we based our analysis on monthly frequency data. In this paper, we also examine at the impact of the 1997 Asian financial crisis on the PPP relationship for the ASEAN-5 countries. The weight of the evidence suggests that real exchange rate for all the countries under investigation using the US dollar as the numeriare currency follows a stationary (mean reverting) process. Hence, this study provides new evidence that supports PPP hypothesis as a long-run relationship for the ASEAN-5 member countries. This finding appears to be robust as the result holds in both the linear and non-linear specifications. From the policy perspective, the evidence indicates that the ASEAN countries are returning to some form of PPP-oriented rule as a basis for their exchange rate policies in order to maintain international competitiveness and to stabilize domestic economies. The convergence between exchange rate and inflation in the ASEAN countries is also an indication that the integration process in the region has begun. In the past two decades, these countries have opened their frontiers to both international commerce and investment.

All in all, the results indicate that the linear specification yield superior within sample forecast. In contrast, the GARCH-family of models dominated the standard linear PPP model in the out-of-sample forecasts. In what follows, we also observed that the conditional variance of all the ASEAN currencies (except for the ringgit) increase significantly in the post-1997 period. We also document the fact volatility in exchange rate for the ASEAN countries may be modeled by the GARCH-type of models. The statistical analysis reveals that the Philippines peso and the Singapore dollar were the least to be affected by the currency turmoil. Although Malaysia and Thailand have suffered huge undervaluation during the crisis, both the ringgit and baht are found to be corrected at a quicker pace relative to the other three currencies from the misalignments of the PPP rate. We also found that the volatility (exchange rate risk) has somewhat increased in the post crisis period for all except the ringgit, where it was pegged to the US dollar.

Finally, direction for future research include: extending this study to more bilateral rates vis-à-vis the US dollar (or yen); and comparing with the predictability of monetary model with that of PPP. The outcome from such studies will more effectively guide practitioners and managers findings in managing exchange rate risk.

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