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World currency options market efficiency

Abstract

The World Currency Options (WCO) maket began trading in July 2007 on the Philadelphia Stock Exchange (PHLX) with the new features. These options are designed for monthly maturity with smaller contract size than the existing currency option contract which matures quarterly. As a result, the volume of trading has soared, increasing the efficiency of option prices. The objective of this study is to analyze the early stage performance of WCO market. We adapt the no-arbitrage put-call parity (PCP) relationship based econometric approach with accommodating all potential time series problem to examine the WCO market efficiency. The overall results strongly suggest that WCO market is efficient even though it is young and in the settling curve.

Keywords: world currency options, put-call parity, unit root, serial correlation, ARCH.
JEL Classification: G13, G14.

Introduction

The World Currency Options (WCO) is an entirely new class of currency options launched in Philadelphia Stock Exchange (PHLX) on July 24, 2007. These options are designed to mature monthly rather than quarterly. Before WCO market, the currency options were traded only for maturity months: March, June, September and December on the PHLX. Further, each currency option contract represents 10,000 units of the underlying currency, except for Japanese yen (1,000,000), which is smaller than the existing currency option contract, opening up the world of currency trading to those with smaller investment accounts. As a result, the volume of trading has soared, increasing the efficiency of option prices. This paper provides a systematic analysis of the efficiency issues in the WCO market for six major currencies: Australian dollar (AUD), British pound (BP), Canadian dollar (CAD), Euro (EUR), Japanese yen (JPY) and Swiss franc (SF). Empirical analysis is carried out based on the well-accepted PCP no-arbitrage condition to examine whether the WCO market is efficient.

Giddy (1983) and Grabbe (1983) were among the first to develop relationships for put and call options such as the put-call parity theorem for foreign currency, which must be satisfied to prevent dominance or arbitrage possibilities. Several studies have performed the options market efficiency test without allowing for transaction costs (see, for example, Trippi, 1977; Chiras and Manaster, 1978; Shastri and Tandon, 1985; Bodurtha and Courtadon, 1986). The results, in general, did not support market efficiency.

Phillips and Smith (1980) provided a systematic treatment of the transaction costs facing traders in the organized options market. They included explicit costs, in the form of commissions and other fees, and implicit costs, such as bid-ask spreads for pricing of transaction services. The explicit costs of commissions and other fees are institution-dependent. The implicit cost of the bid-ask spread is the difference between the highest quote to buy and the lowest offer to sell the asset in the market. Phillips and Smith (1980) also documented the transaction cost ranges for individual investors, options market makers and arbitrageurs when they initiate trades in either stocks or options. Their studies indicated relatively high transaction costs incurred by an individual investor, but refuted the assumption of several previous researchers that market maker transaction costs are negligible. Their results indicate that the larger the transaction cost, the wider the band is within which prices can swing without creating arbitrage opportunities.

Keim (1989) and Yadav and Pope (1990) estimated 1 percent as an average bid-ask spread in their PCP tests. Subsequently, Puttonen (1993) used an estimate of a 2 percent bid-ask spread for the Helsinki Stock Exchange, which is regarded as much more thinly traded than its U.S. and English counterparts, and the FOX index, which consists of the 25 most liquid stocks. Nisbet (1992) identified significant numbers of PCP deviations in the presence of bid-ask spreads that almost disappear when commissions are taken into account with bid-ask spreads as transaction costs. Chateauneuf et al. (1996) pointed out that bid-ask spreads differ from the traditional formalization of proportional transaction costs. Brunetti and Torricelli (2005) suggested that other types of costs (e.g., clearing fees, short selling costs and so on) should be considered in addition to bid-ask spreads and commissions to be more precise about the transaction costs.

El-Mekkaoui and Flood (1998) conducted PCP tests for exchange-traded (PHLX) German mark options market efficiency in the presence of transaction costs using intra-daily data. In their studies, a foreign exchange transaction fee of 0.0625 percent was taken from Surajaras and Sweeney (1992). Note that Rhee and Chang (1992) used a transaction cost of 0.0409 percent for the spot

Deutsche Mark (DEM). Mittnik and Rieken (2000) examined the informational efficiency of the relatively new German DAX-index options market in the presence of transaction costs. In their studies, a fee of DM0.40 per contract for market makers trading DAX options at the German options and futures exchange (DTB) and 0.1 percent of the index value (half of the lowest discount-broker fee charged to private investors for trading German stocks) represented the trading costs.

Overall, the literature provides several weaknesses in the traditional methodology used to examine PCP holds for options market efficiency. First, most researchers reported the number of PCP violations without setting up the minimum arbitrage profit margin to establish the currency options market's efficiency. The PCP violation should not be said to contribute to the options market's inefficiency if it fails to attract the arbitrageur with its generated profit. Second, the PCP violations were substantially decreased in the presence of transaction costs. Since transaction costs vary across markets and currencies, it is not easy to standardize the data in order to apply study results to all currencies across markets. In most cases, therefore, the researchers used transaction costs as a proxy. Consequently, the number of PCP violations both with and without transaction costs makes the currency option market efficiency reported in the literature misleading.

To conquer the weaknesses of the traditional method, an econometric approach can be used where the issues of transaction cost estimation and PCP violation both with and without transaction costs are not included in the analysis. Hoque et al. (2008) conducted econometric analysis to test the validity of the PCP condition for the currency options with quarterly maturity. They failed to conclude that the currency options markets are efficient. The newly launched WCO markets offer currency options with monthly maturity. This paper provides PCP relationship based econometric framework accommodating all potential time series problems to examine the WCO market efficiency. We find that the WCO market is efficient.

The paper is organized as follows. Section 1 gives the research methodology. Section 2 provides data descriptions and analysis. Section 3 discusses the econometric analysis and the results. Finally, the last section concludes the paper.

1. Methodology

In this section, the PCP relationship based statistical analysis model is developed. Table 1 describes the notations and definitions of the variables used in this study. The PCP condition states that there exists a deterministic relationship between put and call prices if both options are written on the same currency and have the same exercise prices and expiration dates. The PCP relationship is based on the arbitrage principle as stated in Eq. (1),

Table 1. Notations and descriptions of the variables

Variables	Notations	Descriptions
Call price	C_t	Call price in domestic currency at time t.
Put price	P_t	Put price in domestic currency at time t.
Spot price	S_t	Spot price in domestic currency at time t for one unit of foreign currency.
Strike price	X_t	Option exercise price in domestic currency at time t for one unit of foreign currency.
Domestic interest rate	$R_{t,d}$	Domestic currency risk-free interest rate at time t.
Foreign interest rate	$R_{t,f}$	Foreign currency risk-free interest rate at time t.
Option life	T	Expiration time of the option.

$$C_{tj} + X_{tj} e^{-R_{tj,d}T} = P_{tj} + S_{tj} e^{-R_{tj,f}T}, \quad (1)$$

where $\forall_j = AUD, BP, CAD, EUR, JPY, SF$. Now we rearrange Eq. (1) and consider that $(C_{tj} - P_{tj}) = Y_{tj}$, $\left(S_{tj} e^{-R_{tj,f}T} - X_{tj} e^{-R_{tj,d}T}\right) = X_{tj}$ to develop the regression Eq. (2) as follows:

$$Y_{tj} = \lambda_0 + \lambda_1 X_{tj} + \varepsilon_{tj}, \quad (2)$$

for the statistical analysis. If the PCP relationship is violated, an arbitrage opportunity arises, indicating the options mispricing. Under the null hypothesis that PCP is valid, the coefficients λ_0 and λ_1 in Eq. (2) should be 0 and 1, respectively, to conclude that the options market is efficient.

The following steps are followed to estimate the unbiased values of coefficients λ_0 and λ_1 in Eq. (2) by conducting the unit root tests and accommodating the potential autocorrelation and conditional heteroskedasticity. First, the unit root test is carried out for Y_{tj} and X_{tj} at level. We take into account the first difference of Y_{tj} and X_{tj} in the regression analysis if the unit root is found for any of these variables. Secondly, accommodate potential autocorrelation and conditional heteroskedasticity, Eq. (2) needs to be augmented as shown in Eq. (3),

$$Y_{tj} = \lambda_0 + \lambda_1 X_{tj} + \sum_i^p \phi_i Y_{(tj-i)} + \sum_i^q \theta \varepsilon_{(tj-i)} + \varepsilon_{tj}. \quad (3)$$

Without accommodating the serial correlation and heteroskedasticity, the result would lead to biased and inconsistent inferences for λ_0 and λ_1, as shown in the econometric analysis section. The choice of the lag order, p and q, will be driven by the results of the diagnostic tests and various information criteria.

In the presence of GARCH(r,s) error in Eq. (3), following Bollerslev (1986), ε_{tj} can be decomposed to

$$\varepsilon_{tj} = \eta_{tj}\sqrt{h_{tj}}, \qquad \eta_{tj} \approx iid(0,1)$$

$$h_{tj} = \omega + \sum_{i=1}^{r} \alpha_i \varepsilon_{tj-i}^2 + \sum_{i=1}^{s} \beta_i h_{tj-i}, \tag{4}$$

with the conditions $\omega > 0$, $\alpha_i \geq 0$ and $\beta_i \geq 0$ to ensure $h_t > 0$. Once the presence of GARCH error is confirmed by the LM test of Bollerslev (1986), the lag order, *r* and *s*, will be determined by further diagnostic tests and various information criteria as suggested in Bollerslev (1986).

2. Data descriptions and analysis

This study includes the six major currency options, the AUD, BP, CAD, EUR, JPY and SF of the WCO market traded in the PHLX. The WCO market started trading on July 24, 2007 (Offshore A-Letter, 2007), but data is only available from December 18, 2007 in the DATASTREM. In this study, the at-the-money (ATM) put-call pairs and ATM strike price are obtained from December 24, 2007 to December 18, 2009, which represents the total number of 520 daily observations for each sample currency. Since the options expire on the third Saturday of each month, the sample period begins (December 24, 2007, Monday) after the options expiry date (December 21, 2007) and the sample period ends (December 18, 2009, Friday) before the options expiry date of December 19, 2009. The maximum lifespan of the sample currency options is one month. The data set consists of the daily closing spot exchange rates and daily risk-free interest rates for all currencies including the U.S. dollar, for the sample period which is also obtained from DATASTREAM. All of these data are available on request.

We start the empirical analysis with a discussion of the time series properties of the data used in this paper. Table 2 reports the descriptive statistics for call, put, strike, and spot prices and interest rates for all sample currency. For most of the data series, the mean and median values are close and the skewness indicates the non-symmetric distribution. However, Jarque-Bera (JB) normality test rejects the approximately normal distribution assumption for sample currencies. These results are similar to those reported by Hoque et al. (2008). Since the mean of strike prices is same as the mean of spot prices, the sample currency options are traded ATM.

Table 2. Descriptive statistics of variables

Currency	Statistical measures	Variables				
		Call price	Put price	Strike price	Spot price	Interest rate
AUD	Mean	0.0159	0.0188	0.8222	0.8222	0.0519
	Median	0.0153	0.0175	0.8450	0.8437	0.0447
	Skewness	1.4012	1.8769	-0.4109	-0.4085	0.1909
	Kurtosis	6.3424	9.3431	1.7462	1.7447	1.2132
	JB	412.21*	1177.1*	48.687*	48.602*	72.327*
BP	Mean	0.0260	0.0284	1.7153	1.7153	0.0255
	Median	0.0238	0.0268	1.6500	1.6503	0.0124
	Skewness	0.9765	1.1895	0.1481	0.1497	0.2175
	Kurtosis	3.6126	4.6814	1.5688	1.5680	1.1571
	JB	90.778*	183.87*	46.284*	46.374*	77.685*
CAD	Mean	0.0158	0.0159	0.9126	0.9126	0.0132
	Median	0.0151	0.0155	0.9325	0.9327	0.0084
	Skewness	0.7034	0.8368	-0.3670	-0.3675	0.4687
	Kurtosis	3.3424	3.7419	1.7391	1.7406	1.8561
	JB	45.420*	72.608*	46.124*	46.069*	47.388*
EUR	Mean	0.0223	0.0232	1.4334	1.4334	0.0216
	Median	0.0203	0.0219	1.4425	1.4432	0.0176
	Skewness	0.9098	0.9751	-0.1870	-0.1854	0.1006
	Kurtosis	3.3653	3.8961	2.0025	1.9994	1.2062
	JB	74.637*	99.801*	24.589*	24.671*	70.597*
JPY	Mean	0.00018	0.00017	0.00987	0.00987	0.00521
	Median	0.00017	0.00016	0.00980	0.00979	0.00625
	Skewness	1.1764	1.7036	0.14773	0.14860	-0.47281
	Kurtosis	4.6739	7.1998	1.79975	1.80439	1.57333
	JB	180.652*	633.680*	33.104*	32.8856*	63.4747*
SF	Mean	0.0149	0.0146	0.9240	0.9240	0.01275
	Median	0.0145	0.0144	0.9200	0.9221	0.00610
	Mkewness	1.0039	0.9897	-0.1756	-0.1758	0.26788
	Kurtosis	5.1300	4.7762	2.0118	2.0197	1.41397
	JB	185.64*	153.25*	23.820*	23.501*	60.721*
USD	Mean					0.0158
	Median					0.0058
	Skewness					0.6051
	Kurtosis					2.1521
	JB					47.305*

Notes: The Jarque-Bera (JB) statistic follows a chi-square distribution with 2 degree of freedom. The critical value of the chi-square distribution is 5.99 at the 5% level of significance. The statistical level at 5% is denoted by *.

Next, the time series properties of the data were examined. The standard Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are applied to investigate whether a unit root is present in the Y_{tj} and X_{tj} data series. The ADF test accommodates serial correlation and time trends by explicitly specifying the autocorrelation structure. The PP test accommodates heteroskedasticity and autocorrelation using the non-parametric method. As shown in Phillips and Perron (1988), the PP test has better power than ADF under a wide range of circumstances and hence, is more appropriate to use for the time series data analyzed in this paper. The ADF and PP unit root tests run on levels of the regression analysis variables Y_{tj} and X_{tj}. The results are given in Table 3. The Y_{tj} and X_{tj} reject the null hypothesis of unit root at a high level of significance under both ADF and PP tests for all currencies.

Table 3. Unit root tests on the variable level

Currency	Test	Variables	
		Call and put price difference (Y_{tj})	Discounted spot and strike price difference (X_{tj})
AUD	ADF PP	-7.7972 -18.8035	-17.6315 -179597
BP	ADF PP	-6.3182 20.4230	-9.6834 -19.4337
CAD	ADF PP	-21.3794 -21.4062	-20.9583 -21.0999
EUR	ADF PP	-11.3418 -17.6604	-12.4782 -18.6208
JPY	ADF PP	-8.8067 -14.4157	-15.7362 -15.7996
SF	ADF PP	-19.2792 -20.0788	-21.0231 -21.2591

Notes: The critical values for the ADF and PP tests are -3.4440, -2.8674 and -2.5699 at the 1%, 5% and 10% levels of significance, respectively. The critical values for the KPSS test are 0.7390, 0.4630 and 0.3470 at the 1%, 5% and 10% levels of significance, respectively.

3. Econometric analysis

In this section, econometric analysis is conducted by estimating Eq. (2), the PCP relationship statistical model. The regression results are given in Table 4. To detect the possible presence of serial correlation problems and ARCH effects, LM (Lagrange multiplier) tests are employed. The P-value of the F-statistic under serial correlation test is zero for all currencies except CAD. Further, the P-value of the F-statistic under ARCH test is zero for AUD, CAD and EUR. The mixed LM test results indicate that the null hypothesis of serial correlation and ARCH in the residual is rejected for most of the currencies.

Table 4. Regression tests without accommodation of serial correlation and ARCH effects $Y_{tj} = \lambda_0 + \lambda_1 X_{tj} + \varepsilon_{tj}$

Options on currency	Intercept (λ_0)	Slope (λ_1)	Serial correlation	ARCH
	Coefficient (P-value)	Coefficient (P-value)	F-statistic (P-value)	F-statistic (P-value)
AUD	-0.0018 (0.0000)	0.8625 (0.0000)	31.5223 (0.0000)	51.8222 (0.0000)
BP	-0.0016 (0.0000)	0.9396 (0.0000)	11.5541 (0.0000)	0.0048 (0.9450)
CAD	-0.0002 (0.0041)	0.9305 (0.0000)	0.9451 (0.3893)	48.1619 (0.0000)
EUR	-0.0005 (0.0001)	1.1101 (0.0000)	30.3749 (0.0000)	16.2126 (0.0000)
JPY	0.0533 (0.0021)	1.0464 (0.0000)	51.4058 (0.0000)	0.1686 (0.8449)
SF	0.0001 (0.1529)	0.8320 (0.0000)	11.0841 (0.0000)	1.6185 (0.2039)

Notes: Tests of H_0: $\lambda_0 = 0$ and $\lambda_1 = 1$. The P-values are in parentheses below the estimated coefficients. The null hypothesis of the LM test is that there is no serial correlation in the residual up to the lag order p, where the number of lag $p = max(r, q)$ for *ARMA (r, q)*. Similarly, the null hypothesis of the ARCH LM test is that there is no ARCH up to the order given in the residual. The P-values reject the null hypotheses of the LM tests for serial correlation and ARCH.

To accommodate the serial correlation and ARCH effects, Eq. (2) was re-estimated by employing Eqs. (3) and (4), respectively. The results are summarized in Table 5. The P-values for the F-statistic under LM tests indicate that the data failed to reject the null hypothesis of no serial correlation and ARCH in the residual for all currencies. For all currencies except JPY and SF, the null hypothesis, H_0: $\lambda_0 = 0$, can be rejected at any reasonable significance level, indicating that the intercepts are statistically different from 0 in most of the cases. However, the estimates of λ_1 are statistically greater than 0 for all currencies.

Table 5. Regression tests accommodating serial correlation and ARCH effects $Y_{tj} = \lambda_0 + \lambda_1 X_{tj} + \varepsilon_{tj}$

Options on currency	Intercept (λ_0)	Slope (λ_1)	Serial correlation		ARCH	
	Coefficient (P-value)	Coefficient (P-value)	F-statistic (P-value)	ARMA	F-statistic (P-value)	GARCH
AUD	-0.0020 (0.0000)	0.7787 (0.0000)	0.6727 (0.5108)	(1,2)	2.7137 (0.1001)	(6,1)
BP	-0.0017 (0.0000)	0.8645 (0.0000)	13.8746 (0.0214)	(0,3)	0.4596 (0.4981)	(0,0)
CAD	-0.0003 (0.0001)	0.9435 (0.0000)	0.9451 (0.3893)	(0,0)	0.2005 (0.6545)	(1,1)
EUR	-0.00056 (0.003)	1.0782 (0.0000)	1.7295 (0.1784)	(1,0)	2.0216 (0.1557)	(0,0)

Table 5 (cont). Regression tests accommodating serial correlation and ARCH effects $Y_{tj} = \lambda_0 + \lambda_1 X_{tj} + \varepsilon_{tj}$

Options on currency	Intercept (λ_0)	Slope (λ_1)	Serial correlation	ARCH	Options on currency	Intercept (λ_0)
	Coefficient (P-value)	Coefficient (P-value)	F-statistic (P-value)	ARMA		Coefficient (P-value)
JPY	0.0519 (0.0969)	1.0778 (0.0000)	0.0049 (0.9950)	(1,2)	0.8649 (0.3528)	(7,2)
SF	0.0002 (0.2624)	0.8227 (0.0000)	1.6571 (0.1917)	(1,1)	0.1343 (0.7141)	(8,5)

Notes: Tests of H_0: $\lambda_0 = 0$ and $\lambda_1 = 1$. The P-values are in parentheses below the estimated coefficients. The null hypothesis of the LM test is that there is no serial correlation in the residual up to the lag order p, where the number of lag p = max(r, q) for ARMA (r, q). Similarly, the null hypothesis of the ARCH LM test is that there is no ARCH up to the order given in the residual. The P-values reject the null hypotheses of the LM tests for serial correlation and ARCH.

The null hypothesis, H_0: $\lambda_1 = 1$, test results are reported in Table 6. The regression results for slopes λ_1 from Table 5 are reproduced in Table 6 with the standard errors under T-tests. The standard errors are given in parentheses below the estimated coefficients. A T-test reveals that the null hypothesis, H_0: $\lambda_1 = 1$, cannot be rejected at any reasonable significance level. To obtain a precise level of significance, a Wald test was conducted, and the results are also presented in Table 6. Under the Wald test, the P-value below the F-statistic in parentheses indicates that the null hypothesis, H_0: $\lambda_1 = 1$, cannot be rejected at the 1 percent level of significance for all currencies. As a whole, the results indicate that the slopes λ_1 are not statistically different from 1 at the higher level of significance. The evidence of the econometric analysis strongly suggests that PCP holds for all currencies which confirms the WCO market efficiency.

Table 6. Analysis of equality of slope coefficients to 1

Options on currency	Slope ($\lambda_1 = 1$)	
	T-tests coefficient (std. error)	Wald tests F-statistic (P-value)
AUD	0.7787 (0.1488)	2.2140 (0.1374)
BP	0.8645 (0.0904)	2.2467 (0.1345)
CAD	0.9435 (0.0479)	1.3876 (0.2394)
EUR	1.0782 (0.0805)	0.9444 (0.3316)
JPY	1.0778 (0.0726)	1.1496 (0.2841)
SF	0.8227 (0.1070)	2.7440 (0.0982)

Notes: Tests of H_0: $\lambda_1 = 1$. The regression results of slopes from Table 5 are reproduced in Table 6 with their standard errors. The standard errors are in parentheses below the estimated coefficients. For the Wald test, the P-values are in parentheses below the estimated coefficients.

Conclusion

The World Currency Options (WCO) market began trading in July 2007 on the Philadelphia Stock Exchange (PHLX). The WCO market started with six major currencies: the Australian dollar, British pound, Canadian dollar, Euro, Japanese yen and Swiss franc. These options are designed to mature monthly rather than quarterly. Before WCO market, the currency options were traded only for the maturity months: March, June, September and December in the PHLX. The WCO market has also attracted investors with smaller investment accounts. Consequently, the volume of trading has soared, making option prices more efficient. The objective of this study is to examine the performance of newly launched WCO market.

In this study, the econometric approach is adapted where the thorny issues of transaction cost estimation and PCP violation both with and without transaction costs are not encountered. This paper contributes to the literature a robust PCP relationship econometric framework accommodating all potential time series problems that can be used to analyze the PCP condition to determine options market efficiency. Under the econometric analysis, the results indicate that the PCP holds at high level of significance for all sample currency options markets. The overall PCP test results imply that the WCO market is efficient although the market still is young and in the settling curve. The robustness of the WCO market efficiency will attract market participants, even including novice investors, to trade currency options for different purposes, including investment and financial risk management. Further, the WCO market efficiency represents equilibrium market price which can be used as market's best forecast regarding future options price (see Hoque et al., 2009).

In this study, the monthly maturity options market efficiency test results are inconsistent with the findings of Hoque et al. (2008) where they used options with quarterly maturity. Interestingly, this inconsistency indicates the options market efficiency could be sensitive to the choice of currency options maturity. We left it for future research.

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