Abstract - The implied volatility (IV) estimation process suffers from an obvious chicken-egg dilemma: obtaining an unbiased IV requires the option to be priced correctly and calculating an accurate option price requires an unbiased IV. We address this critical issue in two steps. First, the Granger causality test is employed, which confirms the chicken-and-egg problem in the IV estimation process. Secondly, the concept of "moneyness volatility (MV)" is introduced as an alternative to IV. MV is modeled based on an option's moneyness during the life of the option's contract. The F-test, Granger-Newbold test and Diebold-Mariano test results consistently show that MV outperforms IV in estimating the exchange rate volatility for pricing options. Further, these series of tests across six major currency options substantiate the validity as well as the reliability of the results. We posit that MV offers a unique solution for pricing currency options accurately.

Keywords: Implied volatility, moneyness volatility, Granger causality test, F-test, Granger-Newbold test, Diebold-Mariano test

I. INTRODUCTION

The pricing of currency options requires the volatility of the exchange rates. It is a key parameter in the pricing model and cannot be observed directly. Traders believe that implied volatility (IV) is the best exchange rate volatility forecast, and this measure is widely used for pricing options. Using data from currency options, Scott and Tucker (1989) find that IV derived from currency options captures nearly 50 percent of the actual currency volatility. Xu and Taylor (1994) examine the informational efficiency of the currency options market in the Philadelphia Stock Exchange (PHLX). They study four currencies (British pound, Mark, Yen and Swiss franc against the U.S. dollar) over the period January 1985 to January 1992. They find that option prices contain significant information about future volatilities. Jorion (1995) examined the predictive power of IV for Mark, Yen and Swiss franc against U.S. dollar, traded in the Chicago Mercantile Exchange. Jorion's results suggest that IV contains statistical time-series models in terms of information content and predictive power. Chang and Mazzotta (2005) use OTC currency options and find that IV is not only biased and unfair but also a forecast of the actual volatility one month and three months ahead. Chang and Yuhak (2007) present evidence that the IV, in the case of option prices, contains information that is not present in past returns for the Brazilian real exchange rate against the U.S. dollar. All of the above evidence supports the conclusion that IV is more informative than daily observed volatility. Researchers also argue that there is a constraint faced in obtaining unbiased IV using market prices. The evidence of Kazarov and Tsezanos (2001) suggest that IV may be a biased representation of market expectations when option prices do not reflect equilibrium market price. Pong et al. (2004) provide similar evidence. Finally, Edelstein and Guan (2006) hold that the IV measure suffers from an obvious chicken-and-egg problem; the calculation of IV requires the option to be correctly priced, and the calculation of the appropriate option price requires an unbiased implied volatility estimate.

Summing up, IV is the best predictor of exchange rate volatility for pricing currency options but the procedure to estimate the unbiased IV presents us with a chicken-and-egg dilemma. Our proposed solution to this dilemma is as follows. First, we examine this critical issue by employing the Granger causality (GS) test. The bilateral Granger causality confirms that the unbiased IV estimation process suffers from the chicken-and-egg problem. Second, the GS test results motivate us to develop the concept of "moneyness volatility (MV)" as an alternative to IV. Third, we conduct a "horse race" between our measure (MV) and IV. The results of the F-test, the Granger-Newbold test (1976) and the Diebold-Mariano test (1995) consistently show that MV outperforms IV in pricing currency options. We find that MV removes the pitfalls of IV in estimating the exchange rate volatility for pricing currency options correctly.

The study is organized as follows. The next section explains the research methodology and describes the data used in this study. In section 3, we present and discuss the results of our empirical analysis. Our main findings are summarized in section 4.

II. METHODOLOGY AND DATA

We first describe our methodology. This is followed by the description of data used in this study. The methodology is divided into four subsections: the implied volatility, the Granger causality test, the moneyness volatility and pricing options.
A. Implied Volatility

The volatility measure implied in option prices is called implied volatility (IV). We derive IV from the option pricing model. Black and Scholes (1973, BS) developed a closed-formed solution for pricing European non-dividend-paying stock options. This model is extended by Merton (1973) for continuous dividends. Because the dividend gained on holding a foreign currency is equivalent to a continuously paid dividend on a stock, the Merton version of the BS model may be applied to foreign securities. To value currency options, stock prices are substituted for exchange rates. The European call and put option prices are as follows:

\[
C_S = \frac{S_0 - K}{e^{r(T-t)}}, \\
P_S = \frac{K - S_0}{e^{r(T-t)}},
\]

where \(S_0\) is exchange rate volatility at time \(t\) and \(K\) is put price in domestic currency at time \(T\). In low interest rate environments, the BS model can be applied to continuous dividends. Merton (1973) for continuous dividends. Alternatively, an unbiased IV can be extracted from non-dividend options. Husqvarna et al. (2006) suggest that the implied return of options is relatively low for at-the-money (ATM) options. We thus use the ATM call price CLATM and the ATM put price PLATM as inputs for equations (2) and (4), respectively, with the default upper bound limit for implied volatility of 1000% per annum and truncation tolerance at 0.0001.

\[
\sigma_{IV} = \ln\left(\frac{C_{S0}}{S_0} \cdot \frac{P_{S0}}{K}ight)
\]

The combined daily moneyness return of the call and put option is

\[
K_{IV} = \ln\left(\frac{C_{S0}}{S_0} \cdot \frac{P_{S0}}{K}ight)
\]

B. Granger Causality Test

The Granger causality test is employed to confirm that the unbiased IV estimation process suffers from the chicken-egg dilemma. It examines the options price and the IV that causes the IV and the IV that causes the options price. Specifically, this test estimates the unregulated implied volatility \(\sigma_{IV}\) as any given day as the arithmetic average of \(\sigma_{ATM}\) and \(\sigma_{IV}\).

\[
\sigma_{IV}(t) = \frac{1}{n} \sum_{i=1}^{n} \sigma_{IV}(t-i)
\]

where \(n\) is the number of observations.

C. Moneyness Volatility

The moneyness volatility (MV) is designed to estimate the exchange rate volatility. The options’ moneyness (OM) identifies whether or not an option is profitable for immediate exercise. An option is in-the-money (ITM), at-the-money (ATM) and out-of-the-money (OTM) when it provides a profit, neither a profit nor a loss, and a loss, respectively. It is a call and a put option have the same underlying at time \(t\) and strike price \(X\), their moneyness (ITM, ATM, OTM) from the next trading day \(t+1\) to the options maturity \(T\) can be expressed as

\[
\sigma_{MV}(t) = \frac{1}{n} \sum_{i=1}^{n} \sigma_{MV}(t-i)
\]

where \(n\) is the number of observations.

Next, the IV and MV performance is assessed to measure exchange rate volatility for pricing the call and put option. The Fast-FCT, Granger-Newbold test and Diebold-Mariano test are employed in their (MV and IV) performance evaluation process. Because the test procedure for the call is analogous to that for the put, we describe the methodology only for the pricing the call option. The implied volatility call pricing error \(\sigma_{IV}\) is the difference between the implied volatility call price \(C_{LV}\) and the ATM call market price \(CLATM\). For OTM observations, the implied-volatility call pricing mean square error can be calculated as

\[
MSE_{IV} = \frac{1}{n} \sum_{i=1}^{n} \left(\sigma_{IV} - \sigma_{MV} - \frac{1}{100}\right)^2
\]

Similarly, the moneyness-volatility call pricing mean square error for a observation can be calculated as

\[
MSE_{MV} = \frac{1}{n} \sum_{i=1}^{n} \left(\sigma_{MV} - \frac{1}{100}\right)^2
\]

where the moneyness-volatility call pricing error \(\sigma_{MV}\) is calculated as the difference between the moneyness-volatility call price \(C_{LV}\) and the ATM call market price \(CLATM\).
Under the null hypothesis of equal one-day-ahead pricing errors accuracy, the value of $\hat{d}$ is zero. The original Dickey-Fuller-Maritte (DM) statistic for the call is given by:

$$DM,c = \frac{d - \bar{d}}{\sigma_d} \sqrt{n}$$

The equation (16) follows a distribution with $(n-1)$ degrees of freedom. The objective of these series of tests is also to check the validity of the overall results. All of the above three tests (F-test, GN test, and DM test) are employed to evaluate the performance of IV and MV for pricing put options.

III. DATA DESCRIPTION AND ANALYSIS

This study includes the six major currency options of the Australian dollar (AUD), the British pound (GBP), the Canadian dollar (CAD), the Euro (EUR), the Japanese yen (JPY) and the Swiss franc (CHF) of the World Currency Options (WCO) market, traded on the Philadelphia Stock Exchange (PHLX). The WCO market started trading on 24 available from 19 December 2007 in the DATSTREAM. In this study, the ATM put-call pairs and the ATM strike price are obtained from 24 December 2007 to 18 December 2009. The daily closing values are used to estimate the means of the sample price for each currency. The ATM strike price is the third Saturday before the options expiry. The mean daily closing values are used in the empirical analysis from 24 December 2007 to 18 December 2009. The sample currency options' maturity is the number of days between the strike price and the maturity date. The sample currency futures' strike price and the maturity date are for all currencies, including the sample from DATSTREAM. All of these data are available on request.

IV. EMPIRICAL ANALYSIS

The empirical analysis starts with a discussion of the time-series properties of the call, put strike and spot price used in the study. Table 1 presents the descriptive statistics of medium values, mean, and standard deviation. The mean and standard deviation are not significantly distributed (Kolmogorov-Smirnov normality test rejects the appropriately normal distribution for all currencies). The mean values of the ATM call price are significantly different from the mean values of the ATM put price for all currencies except CAD and JPY. Further, the same mean values of the strike price and the spot price ensure that the sample currency options are traded ATM.

The Granger causality tests impose the restriction that the variables are non-stationary. We therefore apply the standard Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests to identify the presence of unit roots in CP (call price), PP (put price), and IV. The ADF test accommodates serial correlation and time trend by jointly specifying the ARMA and the deterministic structure. The PP test accommodates heteroskedasticity and autocorrelation using the non-parametric method. Phillips and Perron (1988) show that the PP test has stronger power than ADF under a wide range of circumstances. We also include the KPSS (1992) test, which employs a different approach than that of ADF and PP-P. To determine the presence of unit roots in the data series.

After confirming that the variables are stationary, the Granger causality test is conducted to determine the presence and nature of causality between OP (options price) and IV. The selection of the number of lags in causality tests is an important practical issue. Conventional wisdom indicates that it is better to use more rather than fewer lags (Kraft 1992). We consider 500 to be the minimum degrees of the Granger causality test, while each sample consists of 500 data points. The maximum number of lags 20 is selected for the test. Further, to ensure that the results are not sensitive to the selection of the number of lags, we choose two different lagged lengths - 10 and 20. Further, the number of lags 20 is selected for the test. Further, to ensure that the results are not sensitive to the selection of the number of lags, we choose two different lagged lengths - 10 and 20. The test results identify the unidirectional Granger causality from OP to IV.

The ADF, PP and KPSS unit root tests are run on levels of the CP, PP and IV, and the test results are given in Table 2. The CP and PP unit root tests are run on levels of the CP, PP and IV, and the test results are given in Table 2. The PP-P test is applied only for PP and CP (Table 2). The results indicate that the variables, CP, PP and IV, are stationary at least for one of the unit root tests (ADF, PP, KPSS) for each currency.

To determine the Granger causality from IV to OP, the Granger causality test was performed for equation (7) with the two null hypotheses: (1) OP does not Granger-cause the IV (CP-IV), and (2) OP does not Granger-cause the IV (PP-IV). The IV also tests for the null hypotheses of unit roots at a lag of level of 4 lags. The results indicate that both PP and CP (Table 3) for all currencies. Further, the test results are given in Table 3. For all and (2) are jointly significant for both lags 10 and 20. The test results identify the unidirectional Granger causality from OP to IV.

The F-test results are questionable if the pricing errors are not statistically different from MSELVC, MSELMC, and MSELMP. Overall, the test results indicate that MV outperforms IV in estimating the exchange rate volatility (MV) for pricing one-day-ahead options using the BS model.
equity", we have a similar conclusion stating that the MSELVMV is statistically different from the MSELVP with the GN test. The GN test results suggest that the MV approach is superior to IV in estimating the value of OT for pricing one-day-ahead options. It is consistent with the IV test results reported in Table 5.

### Table 5: Granger-Newton Test Results

<table>
<thead>
<tr>
<th>Currency</th>
<th>IV Test Results</th>
<th>GN Test Results</th>
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<tbody>
<tr>
<td>USD</td>
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<tr>
<td>AUD</td>
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<td>CAD</td>
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<td>EUR</td>
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<td>GBP</td>
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One of the main conclusions from this study is that the IV approach is more effective than the MV approach in pricing one-day-ahead options, particularly in the context of currency options. This finding is consistent with previous research, which has shown that IV is a more accurate measure of volatility compared to MV. However, the question remains as to whether this performance is due to the inherent properties of IV or whether it is due to the specific characteristics of the currency markets.

### V. Conclusion

The literature argues that implied volatility (IV) is the best predictor of exchange rate volatility for pricing currency options. Researchers also point out that the correct options price estimation requires unbiased IV, and the unbiased IV estimation requires options to be priced correctly. The overall IV estimation process is complicated by the chicken-and-egg dilemma. However, the research addresses this issue by analyzing the unbiased IV estimation process and introducing an alternative approach to IV to estimate exchange rate volatility (ER) for pricing options.

To examine the chicken-and-egg dilemma, the Granger-Newbold test is employed for option price (OP) and IV. The bidirectional causality between OP and IV confirms the presence of the chicken-and-egg issue in the unbiased IV design of a new measure "non-revenue volatility (MV)." The option's moneyness (OM) identifies whether an option is from immediate exercise. The OM provides information that affects the pricing of call and put options in the market. For example, at the time of trading, if the call and put options are OTM and OTM, respectively, for the same strike price and maturity, the put option price should be higher than the put option price. Finally, the IV is used to quasi-variance implied in option prices. Apparently, both the OM and IV contain information regarding the market prices of call and put options, and it is very reasonable for the volatility estimated from the OM's moneyness (i.e., MV) to be considered as an alternative to IV in estimating the price of options.

The F-test, Granger-Newbold (GN) test and Diebold-Mariano (DM) test are employed to investigate the performance of MV and IV to price currency options appropriately. These tests are also conducted for six major currency options (AUD, BP, CAD, EUR, JPY and SEK) on World Currency Options (WCU) traded at the Philadelphia Stock Exchange (PSE). The results of these tests confirm that the IV approach is more accurate than the MV approach in estimating the one-day-ahead option prices.

Further, Kauffman and Tezcanocin (2001) find that IV is generally better than historic volatility forecasts for horizons ranging from one day to three months. Using the OTM currency options price, Christoffersen and Mazzotta (2005) find that IV provides largely unbiased and fairly accurate forecasts of the actual volatility one month and three months ahead. Before the launching of WCO in PHX, the options traded only had a maturity of three months. Thus, the performance of IV is tested for a period of three months as an open issue concern.

We leave this for future research.

### References


