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INTRA-DAILY PUT CALL PARITY IN THE PHLX CURRENCY OPTIONS MARKET

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ABSTRACT

Intra-daily Put Call Parity in The PHLX Currency Options Market.

Mazen El-Mekkaoui

This study examines the Put-Call Parity efficiency of the PHLX currency options market for the Deutsche Mark for the period between 30 September 1992 to 1 October 1993. Using a large database of currency option data, a sample of 7968 American and European put and call options are tested for the presence of reversal and conversion profit opportunities. Data from two data providers and eleven different exchange rate measures are used. Exchange rates recorded in the PHLX market surveillance tape and originally reported by Telerate are used in conjunction with more frequently observed exchange rate data collected by Olsen & Associates and reported by Reuters. The presence of positive PCP deviations is examined with transactions costs and specifically taking into account simultaneity of the data. Censored regressions are used to determine the causes of these positive PCP deviations. The results from all exchange rate measures indicate that less than 3.571 % of the sample result in profitable opportunities. This is true for all strategies except for the European conversion. Upon further examination, this result is shown to be sample specific. A degree of intra-daily and intra-weekly seasonality was found in the number of positive deviations from Put-Call Parity. This is explained by thin markets and high spreads. The conclusion is drawn that the prices of PHLX Deutsche Mark currency options for this period are consistent with Put-Call Parity Theorem.

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To Nabila and Saad

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SUMMARY OF TABLES AND FIGURES

1. INTRODUCTION

The foreign currency option has become a vital tool for foreign exchange risk management. Like futures, these options allow managers to preserve the value of their future international cashflows by locking in the exchange rate at which these cashflows can be exchanged. Unlike futures, however, options have limited risk since the option holder is not compelled to exercise his options. The market for foreign currency options consists of an interbank market which is centered around London, New York and Tokyo, and exchange-based markets centered in Philadelphia (PHLX), and Chicago (CME).

By far, the most traded currency is the Deutsche Mark and the predominant exchange for currency options is the Philadelphia Stock Exchange (PHLX). The primary aim of this study is to investigate the efficiency of Deutsche Mark options on the PHLX by testing whether the Put Call Parity Theorem (PCP) holds. The intuition behind PCP is that for any rationally priced Call (Put) option, there is a "replicating" portfolio consisting of the underlying currency , the Put (Call) and borrowing/lending the present value of the exercise price. In the first strategy, a call is written and the replicating portfolio is bought. This is known as a put to call conversion. In the second strategy, the put is written and the replicating portfolio is bought. This is known as a reversal (or inverse conversion). In an efficient market, these two alternatives would yield the same payoffs and therefore should be equivalently priced.

In conducting this study, American and European options are treated separately and are investigated for both conversions and reverse conversions. In the presence of more accurate foreign exchange rate data, special emphasis will be placed on the effect of the exchange rate on any possible profitable arbitrage opportunities. Transaction costs and simultaneity (matching of option prices with their underlying currency) will be directly taken into account.

This study starts with a selective review of the literature in Section 2. This includes the literature on Foreign Exchange markets, Foreign Currency Option Valuation and Put Call Parity. Section 3 describes the sources of the data used and data preparation. The methodology used in this study will be presented in Section 4. Finally, results and conclusions are presented in Sections 5 and Section 6 respectively.

2. SELECTIVE REVIEW OF THE LITERATURE

2.1 Foreign Exchange Markets

2.1.1 The Philadelphia Stock Exchange

Currency options have become a vital tool in international financial management. These options offer corporate hedgers the flexibility in managing foreign cash-flow risks by locking in an exchange rate (the exercise price) for future cash-flows while retaining the ability to take advantage of any favorable movements in the exchange rate. Currency

options have been trading for some time in the over-the-counter market. These options are tailor-made to a company's specific needs as to the amount, maturity and the exercise price of the option. In contrast, the introduction of Foreign Currency Options trading on organized exchanges has made FX options more widely accessible. These options have standardized features and involve a smaller transaction size relative to their OTC counterparts. Commercial and investment banks which write over-the-counter options to their clients can balance their risks by buying and selling exchange traded options contracts through foreign currency options brokers.

The Philadelphia Stock Exchange (PHLX) started trading options on currencies in 1982. Options denominated in U.S. dollars are available on the Australian Dollar, the British Pound, the Canadian Dollar, the Deutsche Mark, the European Currency Unit, the French Franc, the Japanese Yen, and the Swiss Franc. "Cross rate" options are also available for the Deutsche Mark denominated in Japanese Yen, the British Pound denominated in Deutsche Mark, and the British Pound denominated in Japanese Yen. These options are American and European for regular options (except for the ECU which is only American), and European for cross rate options. Finally, "long-term options" (options with maturities of more than one year) are strictly European.

American and European options expire on the Saturday before the third Wednesday of the expiry month for regular options, and on the Saturday following the last Friday of the expiry month for "month-end" options. Expiry months for regular

options are in March, June, September, December and the two nearest months. For month-end options, the three nearest months are available.

This study will focus on short-term Deutsche Mark options. These by far account for the largest volume of transactions in the foreign currency market with 7,153,609 contracts trading between October 1992 and September 1993. These options have a contract size of DM 62,500, and premiums are quoted in cents per unit DM.

2.1.2 Intra-daily Foreign Exchange

There is an abundant literature on foreign exchange markets that have studied the properties of daily exchange rate distributions. Only recently, however, have studies begun to examine exchange rate prices using intra-daily data not previously available.

Muller *et al.* (1990) examine the statistical properties of a large sample of exchange rates for four currencies between March 1986 and March 1989. Their main result shows that price change distributions become more leptokurtic the higher the frequency used. Among other results, autocorrelation coefficients of hourly price changes show that intradaily data suffers from considerable heteroskedasticity, and that a strong intra-daily seasonal pattern exists. Uneven patterns in the volatility during a given day are found with the maximum volatility being about 4 times as large as the minimum. This maximum volatility is found when both the European and American markets are trading.

Minimum volatilities occur during the lunch-break hours for both the European and the Asian markets. Bid-Ask spreads are found to be in the magnitude of 0.1 % , rising to 0.5 % in periods of high volatility. (The bid-ask spread is found to be non-symmetric - can never be negative). These spreads are higher, the lower the activity is in the market. It is found that the Deutsche Mark, which has the largest volume traded, also has the lowest bid-ask spread. Finally, significant patterns are found in the spreads between different currencies. This is attributed to different geographical markets having more or less interest in certain currencies than others.

Dacorogna *et al.* (1993) examine the issue of intra-daily seasonality found in Muller *et al.* (1990) by directly accounting for the geographical location of trading institutions over a period of 4 years. A new activity measure is developed and is used to estimate activity functions for the three main markets (East Asia, Europe, and America), as well as the data as a whole. The authors confirm the presence of a geographical component with negligible market activity around noon in East Asia, moderate activity for lunch-break in Europe, and no difference for market activity during lunch-hour in America. Overlap between different market functions is found with the largest overlap being between the European and American markets. The authors also examine the robustness of their activity measure to the use of different data providers by comparing the week-hour shares of the Knight Ridder and Reuter quotes. Since each data source will have a different number of price changes per minute depending on their market coverage and policy, they find that these functions differ significantly. This is because "...Knight

Ridder data is about half as frequent as Reuters and covers East Asian markets quite poorly."

Baillie and Bollerslev (1989) use a GARCH methodology with dummies for time of day to test the interaction between markets. Taking the analogy from Engle et al. (1990), the authors examine whether news is transmitted accross markets as in "meteor showers" or whether news remains localized in one market as in a "heat wave." The authors find strong evidence for the meteor showers hypothesis although there is also some evidence for the heat wave.

Other studies have investigated the intra-daily behavior of foreign exchange rates. First, Rhee and Chang (1992) examine the profitability of covered interest arbitrage using intra-daily Reuters quotes for a one month period between April and May 1988. They find that while traditional covered interest arbitrage yields no abnormal returns, one-way arbitrage opportunities still exist. These temporary disequilibriums between spot and forward prices may not be translated directly into profits by arbitrageurs. However, persistence of such disequilibriums is indicative of market inefficiency because it shows that the market is slow to react. Bollerslev and Domowitz (1993) look at bid-ask spreads and trading patterns in Deutsche Mark exchange rates. Using the frequency of quote arrival as proxy for market activity, their results confirm that in Asian and European markets, there is a bi-modal distribution of activity around the respective lunch hours while the American market exhibits a uni-modal distribution which peaks at lunch hour.

Bollerslev and Domowitz also document a U-shape pattern in volatility with spikes at the beginning and at the end of a trading day. Finally, Guillaume *et al.* (1995) provide a good survey of the literature on the intra-daily foreign exchange markets.

2.1.3 The Data Providers

The market for financial information is large and growing. It is composed of the market for historical information and the market for real-time data. These are mainly used by banks and institutional traders and among their biggest uses is the need for reliable real-time foreign exchange quotes.

Three data vendors dominate in the field of foreign exchange; Reuters with a market share of 62 % ; Telerate with 24 % market share; and Knight Ridder which has a market share of 4% (ICC, Nov 1991). Most financial institutions dealing with foreign exchange subscribe to several sources at the same time. However, Reuters' lead in the real-time information industry is so surpassing, that in 1991, approximately 100 % of FX market participants subscribed to Reuters, even when they had a subscription to another source of information. Reuters' dominance and continued leadership can be traced to its early entry into the market which has created barriers of entry for late-starting FX data vendors like Telerate. There is a natural tendency of information users to rely on a primary source for their information (even when they are subscribed to several sources). Furthermore, there are substantial switching costs associated with changing data vendor

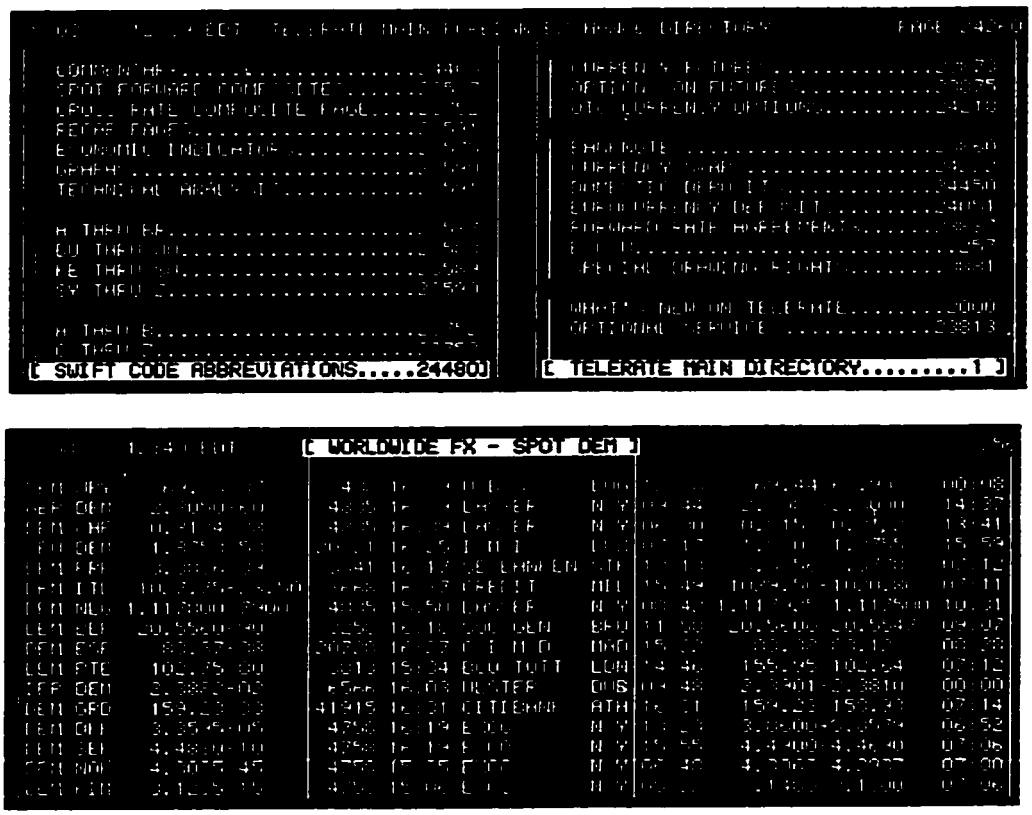
since switching results in users having to get used to the new systems. (ICC, Nov 1991)

Three things are very important for traders on the foreign exchange desks; the accuracy of the data, the speed and efficiency of data transmission, and finally, the breadth of the data (Burger, 1991). First, Reuters' news service credibility has given it trustworthiness as a supplier of reliable FX real-time data. In addition, Reuters wide international presence has enhanced its reputation as a source for accurate FX quotes.

Another important factor for FX traders is the speed of quote arrival. Data format plays an important role in how efficiently data is transmitted to the client and consequently, how much time it takes. Two formats are provided. A "page-based" system requires a dedicated terminal and therefore provides more security for the data provider. However, precious time can be lost in transmitting the data to the end-user since the data has to be arranged into its separate components. On the other hand an "elemental feed" can be "snatched" by other providers and is therefore less secure. However, this architecture provides a speedier and more efficient system for relaying data and offers an advantage to the end-user. Telerate is the only data provider that does not use an elemental feed, making it a slower alternative to Reuters (Spinner 1994). Reuters' "open architecture" has the added benefit that it allows its clients to receive their feeds on their existing Information Technology (IT) networks, without the requirement of a dedicated Reuters terminal.

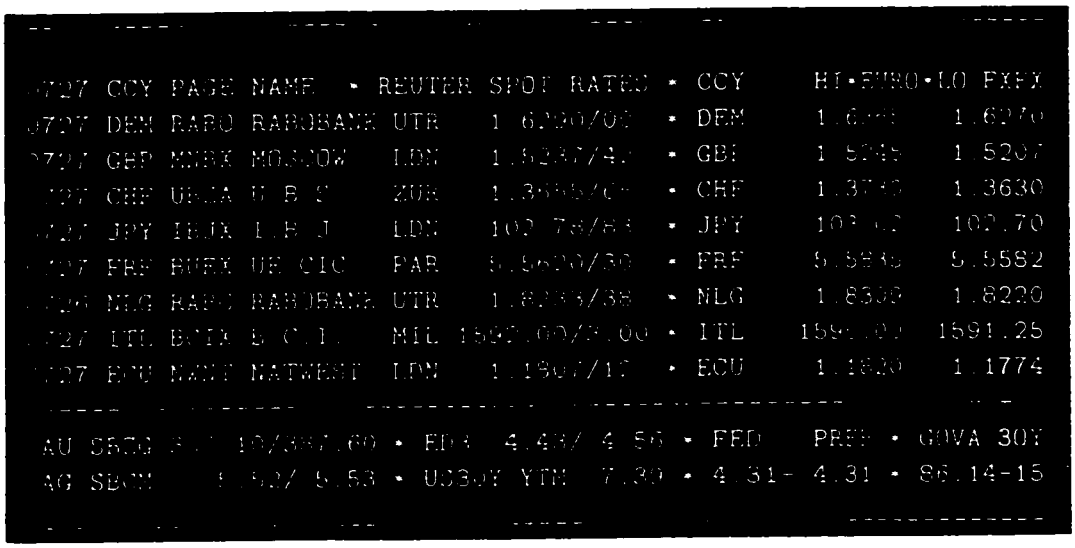
According to Spinner (Oct 1994) market data providers also differ in terms of data content. It is not only important to have fast and reliable information, it is also important where the data came from and its scope. Currently, Reuters has a total of 4700 data contributors in 158 countries compared with Telerate's 2000 contributors in 160 countries making Reuters market coverage much wider (according to Reuters (1997) and Telerate (1997) respectively). Private conversations with currency option traders at the PHLX indicate that the majority of market makers use both Telerate and Reuters terminals for trading. However, the consensus was that Reuters was the preferred data provider. Figure 1 shows a Telerate foreign exchange screen capture. For example, the first quote on the screen gives a real-time quote for the DEM/JPY currencies at a bid of 69.33 and an ask of 69.37. The following columns give; the Telerate page number, 3438; the time of the quote at 16:39 GMT; the quoting bank UBS at the city of Lugano; the high of the day at 69.44 recorded at 12:38 GMT; and finally, the low of the day at 68.90 recorded at 00:08 GMT. The Reuters screen capture in figure 2 also provides similar data. For example, the second quote in figure 2 is a quote for the Deutsche Mark against the U.S dollar. The first column provides the time of quote (GMT); the second column the currency quoted, DEM; the third column is the quoting bank's code, RABO; the name of the institution, Rabobank, is then given; then the city of the quote, UTR (Utrecht, Netherlands); the sixth column provides the bid and ask for the currency pair as 1.6290/00; and finally, the last two columns give the high and low of the day at 1.6365 and 1.6270 respectively.

Figure 1. Telerate Foreign Exchange Page Screen.



Note: Telerate's Foreign Exchange Terminal provides a directory for foreign exchange instruments in the top part of the screen. The second part provides foreign exchange rate quotes for a certain currency. The columns represent , respectively, the currency pair, the bid and ask quotes, the Telerate page number, time of the quote (GMT), the quoting institution, the city, and finally, the time of and the highest and lowest quotes of the day. (Source : Dow Jones Telerate web page).

Figure 2. Reuters Foreign Exchange Page Screen.



Note: Columns represent , respectively, time of the quote (GMT), the name of the currency, the quoting institution's abbreviation, the quoting institution's name, the city of the quoting institution, the bid and ask prices, and finally, the highest and lowest quotes of the day. (Source: Guillaume et al (1995)).

2.2 Foreign Currency Options

2.2.1 Foreign Currency Option Valuation

The currency option pricing model was originally developed by Garman and Kohlhagen (1983) based on the "constant dividend yield" model of Merton (1973). This theoretical work on FX options was further refined by Biger and Hull (1983), Giddy (1983), and Grabbe (1983).

Garman and Kohlhagen (1983) mathematically derive a formula for foreign currency option valuation under the following assumptions:

a) the currency spot price follows a process of Geometric Brownian motion where spot price movements can be represented as, $dS = mS\,dt + sS\,dz$, where z is a standard Wiener process.
b) option prices are a function of only one stochastic variable, the spot price.
c) there are no transaction costs, margin requirements or taxes.
d) interest rates in domestic and foreign markets are constant.

The authors' main argument stems from the fact that "the excess risk-adjusted expected returns of securities" is the same for all securities in an arbitrage-free continuous time economy. Applying Ito's Lemma to a call option, and recognizing that the standard deviation of the options return is a function of the standard deviation of the currency return, Garman and Kohlhagen obtain a differential equation that governs the movement of the options price over time,

$$\frac{\delta C}{\delta T} = \frac{\sigma^2}{2} S^2 \frac{\delta^2 C}{\delta S^2} - r_D C + (r_D S - r_F S) \frac{\delta C}{\delta S}$$

This leads to the well known solutions for foreign currency option pricing under the boundary conditions C(S,0) = max (0, S-X) for call options and P(S,0) = max (0, X-S), for puts

$$C(S,T) = e^{-r_F T} SN(x + \sigma\sqrt{T}) - e^{-r_D T} XN(x)$$

where,

$$x \equiv \frac{\ln(S / X) + [r_D - r_F - (\sigma^2 / 2)]T}{\sigma\sqrt{T}}$$

where σ is the standard deviation of the currency return, r_F and r_D are respectively the foreign and domestic risk-free rates of interest, T is time to maturity for the option, S is the spot price for the currency in terms of domestic units per foreign units, X is the exercise price, and N(.) is the cumulative normal distribution function. This model is different from the standard Black-Scholes model in that the foreign interest rate now appears in the equation. This interest rate is effectively a constant dividend yield for the owner of the foreign currency and forms part of the expected return on the option. This relationship can be restated in terms of forward prices if we assume that Interest Rate Parity holds. Thus,

$$F = e^{(r_D - r_F)T} S$$

where F is the forward price of the currency at delivery. Substituting this into the above solution for currency options, we get the alternate solution,

$$C(F,T) = [FN(x+\sigma\sqrt{T}) - XN(x)]\,e^{-r_D T}$$

where,

$$x \equiv \frac{\ln(F/X) - (\sigma^2/2)T}{\sigma\sqrt{T}}$$

These solutions only hold for European type options as the early exercise privilege of American currency options would seriously bias prices derived from these equations.

Grabbe (1983) considers the case of stochastic interest rates as reflected in the prices of domestic and foreign discount bonds. The model proposed is an extension to the Garman-Kohlhagen model but is derived from different assumptions regarding the stochasticity of interest rates. In addition to the diffusion process for the currency spot price, Grabbe also assumes that domestic and foreign bond prices also follow this process and arrives at a different differential equation. The solution to this differential equation yields the same model as the Garman-Kohlhagen model. The difference, however, relies on the diffusion processes assumed for interest rates and this is reflected in the variances which are inputs to both models. Thus for Grabbe,

$$\sigma^2 = \int \frac{1}{t}(\sigma_B^2 + \sigma_G^2 - 2\sigma_{GB})du$$

whereas in Garman and Kohlhagen,

$$\sigma^2 = \int \frac{1}{t}\sigma_S^2 du$$

Finally, Grabbe attempts to find a closed-form solution for American FX options, but fails to do so because of the early exercise risk inherent in American options.

These two papers spawned a whole literature on the subject foreign currency option valuation under different assumptions. The main shortcomings of the Garman and Kohlhagen and the Grabbe models are the assumptions of constant volatility, constant interest rates, and a "pure" diffusion process for the underlying exchange rate movements. Amin and Jarrow (1991) and Hilliard, Madura and Tucker (1991) find different solutions to varying interest rates. Chesney and Scott (1989), Hull and White (1987), and Scott and Tucker (1989) propose models that allow the volatility parameter of the option pricing model to be stochastic. Finally, Tucker, Peterson and Scott (1988) and Shastri and Wethyavivorn (1990) deal with the last assumption and develop a model with different distributional assumptions for the underlying exchange rate.

An important factor in pricing American-style options is accounting for the "early exercise premium." For an American call option holder, the higher foreign interest rates are relative to domestic rates, the greater is the incentive for early exercise. This allows the option holder to earn the higher "dividends" from the foreign currency. If the proceeds from early exercise outweigh any time-value that the option might have then early exercise is optimal. Conversely, an American put option holder may exercise early to gain greater proceeds from investing on the U.S dollar. Therefore, the level of the interest rate differential for the two currencies can induce rational early exercise of the option and the

value of this early exercise increases the American option premium over its European equivalent. Jorion and Stoughton (1989) empirically test this premium and, as expected, find that this premium for call (put) options increases (decreases) the higher the foreign interest rate is relative to the domestic one. They also find that the early exercise premium increases with time to maturity, is highest for options which are nearest-the-money, and is approximately 2 % of the option price. These results are confirmed in several studies such as Adams and Wyatt (1987b).

Zivney (1991) uses actual transaction data from the CBOE's S&P 100 to estimate the early exercise premiums for call and put options. Using European Put Call Parity, the author examines the difference in theoretical values between an American put-call pair and an otherwise equivalent European pair (using at-the-money American implied interest rates). This difference would yield the early exercise premium. Using regression methodology, Zivney finds that the value of the early exercise premium behaves like a normal option, increasing with increases in the risk-free rate, increases in time to maturity, increases in the underlying asset, and decreasing with increases in the exercise price. Further findings approximate the early exercise premium for an American call at 3.5 % of the value of the call, and 10 % for an American put.

2.2.2 Put Call Parity Theorem

The put call parity theorem (PCP) was developed by Stoll (1969) and extended by Merton (1973) to account for options with continuous dividend streams. Stoll shows that given a call and put with the same underlying asset, exercise price, and expiry date two possible hedges are possible that would return the risk-free rate in equilibrium. A "long hedge" or "Conversion" would involve buying the underlying asset, writing a call, buying an equivalent put, and borrowing the present value of the exercise price. This is possible because a long call and the portfolio of a long share and long put together with borrowing, yield the same payoff at expiry and should therefore yield the same return. Conversely, a "short-hedge" or "Reversal" strategy could be used by writing a put, buying a call, shorting the underlying asset, and lending an amount equivalent to the present value of the exercise price. Again, in equilibrium this would yield the risk-free rate. In an efficient options market, therefore, these two strategies should not yield any profits.

Gould and Galai (1974) consider the effects of taxes, transactions costs and margin requirements. They conclude that PCP inequalities still hold in the presence of taxes and that "margin requirements do not represent an additional friction" to the model. Klemkosky and Resnick (1979) modify PCP theory to allow for known dividends and derive boundary conditions for the values of American puts and calls. These conditions depend on the assumption that early exercise of the call (put) in the long-hedge (short-hedge) does not occur. This assumption is shown to be valid if the "present value of the

dividends foregone is less than the present value of return that could be earned from investing the exercise price at the risk-free rate..." Klemkosky and Resnick show that if this condition holds at the time of inception of the long-hedge strategy, the American call may not be rationally exercised. However, for the short-hedge, the condition for the American put has to be met throughout the life of the option and cannot therefore provide certain profit, since at any point the put owner could rationally exercise his/her option. Other empirical PCP studies test futures options and index options. These include Chance (1988), Evnine and Rudd (1985), Blomeyer and Boyd (1988), Jordan and Seale (1985), and Nisbet (1992). While these tests have generally improved with time as better data became available, their results are mixed as to whether PCP holds or not.

Grabbe (1983) applies PCP theory to the case of Foreign Currency Options where the underlying asset is a foreign discount bond which pays a continuous dividend stream and the present value of the exercise price is borrowed (lent) by selling (buying) a domestic discount bond. Tables 1a and 1b present the put-call parity boundaries for European and American calls in the presence of transaction costs. Conversions and reversals are presented in panel A and panel B respectively. For all strategies, two portfolios exist which in an efficient market, should be equivalent. Portfolio A represents writing the call (or put) option and portfolio B is composed of the underlying currency, borrowing (or lending) the exercise price and buying the put (or call) option. If the two protfolios are not equivalent, then arbitrage is possible. In this study, any positive difference between portfolio A less portfolio B is an opportunity for profit (Δ).

Table 1a. Derivation of European Put-Call Parity Boundaries with Transaction Costs

Panel A: European Long Hedge (Conversion)

Opening Transaction	Cost at time t	Payoff at Maturity (T) if		
		$S_T \le X - T_{PE}$	$X - T_{PE} \le S_T \le X + T_{CE}$	$S_T \ge X - T_{CE}$
A: Write Call	$C - T_C$	0	0	$-S_T + X$
B: Buy Put	$-P - T_P$	$X - S_T - T_{PE}$	0	0
Buy zero coupon bond that pays 1unit of foreign currency at maturity	$-S_t e^{-r_f(T-t)}$	S_T	S_T	S_T
Borrow PV (X)	$(X - T_{PE} - T_S)e^{-r_d(T-t)}$	$-X + T_{PE} + T_S$	$-X + T_{PE} + T_S$	$-X + T_{PE} + T_S$

Since the pay-offs at all times are ≥ 0, this strategy represents a profit opportunity unless $C \le S e^{-rfT} + P - Xe^{-rdT}$. T_S represents the currency bid-ask spread at maturity. Bid and ask indicators disregarded for clarity. (Source: Cox and Rubinstein (1985)).

Panel B: European Short Hedge (Reversal)

Opening Transaction	Cost at time t	Payoff at Maturity (T) if		
		$S_T \le X - T_{PE}$	$X - T_{PE} \le S_T \le X + T_{CE}$	$S_T \ge X - T_{CE}$
A: Write Put	$P - T_P$	$-X + S_T$	0	0
B: Buy Call	$-C - T_C$	0	0	$S_T - X - T_{CE}$
Sell zero coupon bond that pays 1unit of foreign currency at maturity	$S_t e^{-r_f(T-t)}$	$-S_T$	$-S_T$	$-S_T$
Lend PV (X)	$(-X - T_{CE} - T_S)e^{-r_d(T-t)}$	$X + T_{CE} + T_S$	$X + T_{CE} + T_S$	$X + T_{CE} + T_S$

Since the pay-offs at all times are ≥ 0, this strategy represents a profit opportunity unless $P \le S e^{-rfT} + C - Xe^{-rdT}$. T_S represents the currency bid-ask spread at maturity. Bid and ask indicators disregarded for clarity. (Source: Cox and Rubinstein (1985)).

Table 1b. Derivation of American Put-Call Parity Boundaries with Transaction Costs

Panel A: American Long Hedge (Conversion)

Opening Transaction	Cost at time t	Payoff at any time (u) if		
		$S_u \le X - T_{PE}$	$X - T_{PE} \le S_u \le X + T_{CE}$	$S_u \ge X - T_{CE}$
A: Write Call	$C - T_C$	0	0	$-S_u + X$
B: Buy Put	$-P - T_P$	$X - S_u - T_{PE}$	0	0
Lend 1unit of foreign currency	$-S_t$	$S_u e^{r_f(u-t)}$	$S_u e^{r_f(u-t)}$	$S_u e^{r_f(u-t)}$
Borrow X	$Xe^{-r_d(T-t)} - T_{PE} - T_S$	$(T_{PE} + T_S)e^{r_d(u-t)} - Xe^{r_d(T-u)}$	$(T_{PE} + T_S)e^{r_d(u-t)} - Xe^{r_d(T-u)}$	$(T_{PE} + T_S)e^{r_d(u-t)} - Xe^{r_d(T-u)}$

Since the pay-offs at all times are ≥ 0, this strategy represents a profit opportunity unless $C \le S + P - Xe^{-rdT}$. T_S represents the currency bid-ask spread at maturity. Bid and ask indicators disregarded for clarity. (Source: Cox and Rubinstein (1985)).

Panel B: American Short Hedge (Reversal)

Opening Transaction	Cost at t	Payoff at any time (u) if		
		$S_u \le X - T_{PE}$	$X - T_{PE} \le S_u \le X + T_{CE}$	$S_u \ge X - T_{CE}$
A: Write Put	$P - T_P$	$-X + S_u$	0	0
B: Buy Call	$-C - T_C$	0	0	$S_u - X - T_{CE}$
Sell zero coupon bond that pays 1unit DM at maturity	$S_t e^{-r_f(T-t)}$	$-S_u e^{-r_f(T-u)}$	$-S_u e^{-r_f(T-u)}$	$-S_u e^{-r_f(T-u)}$
Lend X	$-X - T_{CE} - T_S$	$(X + T_{CE} + T_S)e^{r_d(u-t)}$	$(X + T_{CE} + T_S)e^{r_d(u-t)}$	$(X + T_{CE} + T_S)e^{r_d(u-t)}$

Since the pay-offs at all times are ≥ 0, this strategy represents a profit opportunity unless $P \le C - S e^{-rfT} + X$. T_S represents the currency bid-ask spread at maturity. Bid and ask indicators disregarded for clarity. (Source: Cox and Rubinstein (1985)).

2.2.3 Efficiency Tests of the Foreign currency options Market - Theoretical Models

This category of the literature deals with the empirical testing of the efficiency of the foreign currency options market. Two methodologies are used. The direct methodology uses theoretical models and compares them to actual market prices. The second method involves using rational arbitrage relationships and testing actual prices relative to each other.

Direct tests of efficiency compare theoretical model prices with market prices and are therefore joint tests of model specification. Shastri and Tandon (1986) test a modified version of the Black-Scholes using both historical and weighted implied volatilities as inputs. While using a European model with American options, the authors preclude the early exercise problem by choosing a daily sample where foreign interest rates are sufficiently low such that the probability of early exercise is minimal. They find that model prices vary significantly from observed prices but suggest that *ex ante* trading strategies cannot be profitably concluded.

Adams and Wyatt (1987a) use dynamic programming techniques to estimate American option prices which include the early exercise premium. Using regression techniques they find that the American model (as derived in Grabbe 1983), while improving on the European version, still does not completely explain the residuals over actual prices. Their results generally lend credence to the idea that a significant early

exercise premium exists, if the foreign interest rate is sufficiently higher than the domestic one. To account for these results, model errors from these regressions are then regressed on the degree the option is in or out-of-the-money, time to maturity, and the interest rate differential. If the market is truly efficient, then these explanatory variables should explain the model errors. However, this is not the case as some residual error is still left unexplained.

Bodurtha and Courtadon (1987) develop an American option pricing model that takes into account interest rate risk. Using the PHLX database, the authors examine American option prices by solving the Garman-Kohlhagen European differential equation numerically, employing a "backward induction" algorithm first proposed by Parkinson and Mason. To account for interest rate uncertainty, interest rates are implied from the "equivalent" IMM currency futures prices. The results of this study show that the American model generally overprices at-the-money options more than in or out-of-the-money options. This overpricing is found to decrease as maturity of the option increases. They conclude that these results are most consistent with random jumps in the spot currency price.

Johnson (1986) uses a different approach to test the efficiency of the Foreign Currency Options market. By comparing the implied volatilities of call options with those of put options, these volatilities should be equivalent to each other as well as to the volatility of the "proportional change" in the exchange rate in an efficient market. Using

the Biger and Hull (1983) valuation formulas, implied volatilities are calculated and averaged using alternative weighting schemes for both portfolios. The results indicate that with the exception of the Deutsche Mark, the market for all other currencies are efficient. These results were robust to the different weighting schemes used. It is hypothesized that during the sample period chosen (1983), a "special trading relationship" existed between the U.S. and Germany, which caused observed inefficiency in this market. Several shortcomings remain. Besides using daily closing prices instead of transactions data, the grouping of options in portfolios represents a loss of information that can affect the results. For more reliable conclusions, observations must be examined separately.

2.2.4 Efficiency Tests of the Foreign currency options Market - PCP Tests

Other tests conducted to investigate the efficiency of the Foreign Currency Options market use rational option pricing relationships such as Put Call Parity Theorem and arbitrage boundary conditions. These are "the most promising for market efficiency since they do not rely on any probability assumptions and are therefore the least ambiguous" (Grabbe (1987)). The main problems with using these inequalities, however, is that perfectly synchronized observation of the data has to be ensured.

Shastri and Tandon (1985) attempt to test the efficiency of the Foreign Currency Options market by testing lower boundary conditions, exercise price and Put Call Parity relationships. The PHLX database along with Eurocurrency rates are used to determine

daily option premiums, spot exchange rates, and domestic and foreign bond prices. This results in a sample size of 3019 calls and 1720 puts for the sample period from 14 December 1982 to 22 November 1983. The results indicate that for this period, market efficiency only holds with respect to the exercise price conditions. As for European PCP, a conversion strategy resulted in approximately 34 % violations (28 % for the Deutsche Mark). In nearly 40 % of the sample tested, these violations represented large profit opportunities being in the magnitude of $ 50 or larger per contract. Violations from Reversal strategies for European options were not reported. Using American PCP, a reversal strategy presented 1.64 % percentage violations (2.27 % for the Deutsche Mark). When the number of violations for the latter strategy are broken up into different maturities, it is found that most of these violations occur for the shorter maturities. However, not much confidence can be placed in these results since the authors use daily settlement prices rather than transactions prices. Furthermore, transaction costs are not taken into account.

Bodurtha and Courtadon (1986) conduct the most thorough test of foreign currency options market efficiency to date. This study specifically accounts for transactions costs and simultaneity of prices in testing the American version of Put Call Parity derived in Cox and Rubinstein (1985, p. 152) To examine the effects of non-simultaneity and transactions costs, these inequalities are tested using both transactions prices and closing prices for PHLX options for the period February 28, 1983 to September 14, 1984. Furthermore, these tests are conducted both with and without

transactions costs to measure the influence these might have on efficiency. Daily observations of U.S. Treasury Bills are used as a proxy for the domestic risk-free rate, and a "transaction cost-adjusted interest rate parity (IRP) relation is used to impute the foreign interest rate." The results are very supportive of market efficiency with the percentage violations for the conversion and the reversal of the Deutsche Mark equal to 0.75 % and 1.79 %, respectively. When the relationships are tested using simultaneous prices and in the presence of transactions costs, the number of violations virtually disappears. This reduction in number of violations appears to be more sensitive to the nonsimultaneity bias than the transactions costs bias. The authors reach the conclusion that these results are consistent with market efficiency.

While this article provides strong evidence for efficiency, there are several problems which are not accounted for. First, the authors assume that futures rates are insignificantly different from forward rates and neglect the effects of marking to market. Second, Grabbe (1986 ch. 4 ; 1987 p. 226) reports that the interest rate parity theory that governs the relationship between spot and forward rates does not hold with respect to Treasury Bills. Since Eurocurrency deposit rates are typically in the magnitude of 1 % higher than T-Bill rates, this would imply that a rational relationship such as PCP may not hold for these options (the probability of early exercise is greater than implied since the interest rate differential using Eurocurrency rates is greater than that implied by using T-Bill rates). Martin and French (1987) use regression techniques and find that interest rates implied from option prices are generally 1.25 times greater than T-Bill rates. In addition,

since market makers use Eurocurrency deposit rates to price their options (Grabbe (1991)), the Eurocurrency rate is the appropriate rate to use in testing for efficiency. The authors match put and call pairs which trade within 15 minutes of each other. This undermines their adjustments for simultaneity since during that period of time, exchange rates can greatly fluctuate. Clive Davidson, a financial journalist based in London says:

> "...huge deals are often made under conditions of extreme volatility. During some periods quoted prices can change 20 times a minute for major currencies, with prices on the U.S. dollar/Deutschemark rate, for example, changing up to 18,000 times in a single day. The dollar/Deutschemark rate can move 3 % in 10 minutes and up to 16 % in one week."

Finally, given a trade for a call and a trade for a put, two observable exchange rates are possible. Bodurtha and Courtadon do not examine the choice of which exchange rate to use. This study will use exchange rates measured at different times and will match puts and calls which trade within less than 8 minutes of each other.

3. DATA

This study uses all observed transactions prices for the Deutsche Mark from the PHLX database for the sample period from October 1, 1992 to September 30, 1993. This translates into 53,448 put trades and 30,217 call trades. Each observation contains the number of contracts traded; the currency; the maturity date; options transaction price, time-stamped to the nearest minute (EST); and the actual spot bid and ask quotes reported by Telerate. To investigate the effect of exchange rate volatility on the efficiency of the

market, exchange rates reported by Reuters and compiled by Olsen and Associates (O&A) are also employed. O&A compile a "high-frequency" database with reported bid and ask quotes; date and time of the quote (GMT); the city and country the quote comes from as well as the quoting institution. For the Deutsche Mark a sample of 1,472,241 of intradaily quotes is obtained for the sample period. This represents approximately 4,034 observations per day with an average of 7 observations per minute. Only the minimum, maximum and average bid and ask rates for a given minute are used. For the domestic and foreign risk-free interest rates, daily Eurocurrency Deposit bid and ask rates were compiled from *The Financial Times.* These have maturities of 1 day, 1 week, 1 month, 3 months, 6 months and 1 year.

Transactions costs for this study were provided by the PHLX and the Options Clearing Corporation (OCC) and represent the market-maker's expected costs from conducting any profitable strategies. A maximum foreign exchange transaction fee of 0.0625 % was taken from Surajaras and Sweeney (1992). The maximum bid-ask spread within the sample used in this study was found to be roughly equivalent to 0.0644 % which translates to $644 per million dollars transaction. This is a rather conservative estimate as other studies (Rhee and Chang (1992)) use transactions costs of 0.0409% for the spot Deutsche Mark (DM). A minimum trade of U.S. $ 1 million was assumed representing DM 1.6 million (using the average spot exchange rate for the period). This is equivalent to 26 contracts and gives the following transaction costs per trade (per contract):

PHLX Option Comparison Charge	$	1.30	($ 0.05)
PHLX Transaction Charge	$	1.82	($ 0.07)
OCC Exercise Fee per line item	$	26.00	($ 1.00)
OCC Clearing Fees	$	2.60	($ 0.10)
FX Maximum Bid-Ask spreads	$	1250.00	

4. METHODOLOGY

4.1 Testable PCP Inequalities.

This study uses the European Put Call Parity relationships derived in Grabbe (1983) and the Bodurtha and Courtadon (1986) American option boundary conditions to test the efficiency of Deutsche Mark Foreign Currency Options. These can be formalized as follows:

For the European Conversion Strategy (Long-hedge),

$$\Delta_{ECj} = C - P - S_{aj}e^{-r_{DMb}t} + Xe^{-r_{USa}t} - T_{FX} - T_P - T_C - T_{PE}$$

For the European Reversal Strategy (Short-hedge),

$$\Delta_{ERj} = P - C + S_{bj}e^{-r_{DMa}t} - Xe^{-r_{USb}t} - T_{FX} - T_C - T_P - T_{CE}$$

For the American Conversion Strategy (Long-hedge),

$$\Delta_{ACj} = C - P - S_{aj} + Xe^{-r_{USa}t} - T_{FX} - T_P - T_C - T_{PE}$$

For the American Reversal Strategy (Short-hedge),

$$\Delta_{ARj} = P - C + S_{bj}e^{-r_{DMb}t} - X - T_{FX} - T_C - T_P - T_{CE}$$

where Δ_{ij} is the profit from the i^{th} strategy, respectively, European Conversion (EC), European Reversal (ER), American Conversion (AC), and American Reversal (AR), for the j^{th} measure of the exchange rate (where j=PHLXC, PHLXP, OAHIP, OAAVP, OALOP, OAHIM, OAAVM, OALOM, OAHIC, OAAVC, and OALOC (See figure 3)), C (P) are the call (put) premium for the option with an exercise price X and time to maturity t,

b and a are the bid and ask indicators,

r_{DM} and r_{US} are the foreign and domestic risk-free rates,

T is the transaction cost associated with the foreign exchange transaction (FX), purchasing a call (C), purchasing a put (P), exercising a call (CE), and exercising a put (PE).

4.2 Synchronicity and Data Preparation.

If Put Call Parity is to hold then perfect synchronicity of the data has to be ensured. For a given put, a call with the same exercise price and maturity must trade at exactly the same time. To investigate the effect of this synchronicity problem, puts and calls in this study were matched into different categories according to the relative difference (window) in their time of trade. Only put-call pairs which traded within less than 8 minutes of each other were chosen. This generates windows of size 0 (for perfectly matched puts and calls), 2 minutes, 4 minutes, 6 minutes, and 8 minutes. Since the PHLX observations are time-stamped to the nearest minute there

minute and the effective windows are actually 1 minute, 3 minutes, 5 minutes, 7 minutes, and 9 minutes. Based on these criteria, a total sample of 9,972 American and European put-call pairs was obtained. These are then matched with their German and U.S. Eurodeposit interest rates to get a final sample of 7,968 put-call pairs of which 616 are European and 7352 are American.

With the different sized windows available, bid and ask exchange rates reported in the PHLX Surveillance tape (from Telerate) are recorded at the put time of trade and the call time of trade. When two transactions happen less than one minute apart there is a possibility that the two options trading in the same minute have a different recorded exchange rate. This difference can occur since one transaction could be recorded at the beginning of the minute, while the other transaction could be recorded at the end of the minute. Therefore, even for perfectly matched put-call pairs (0 window), the exchange rate reported at the put trade time may be different than the exchange rate reported at the call trade time.

Using the Reuters data (i.e., O&A), three different exchange rate times could be used. For each put-call pair, the time of trade for the put, the time of trade for the call and the mid-time between the put and call trades are different points in time where the exchange rate is recorded. In total for the sample size of 7,968 put-call pairs, a total of 23,904 different Reuters exchange rate times is obtained (3 times the sample size). Furthermore, because of the very high frequency of the O&A dataset, several exchange

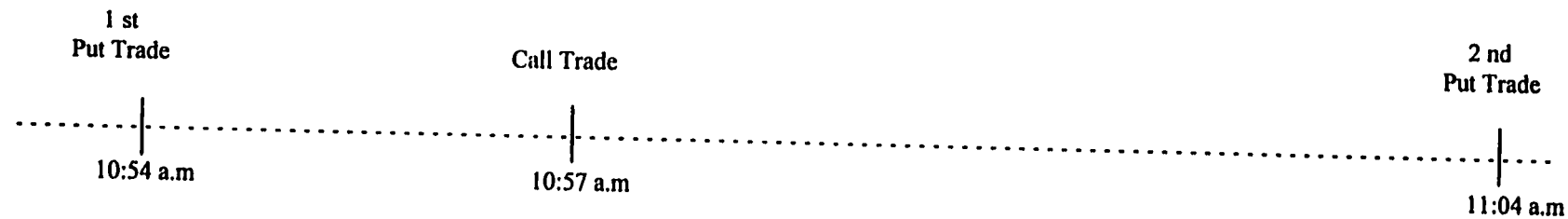
rate quotes are available during any given minute. Therefore, only the minimum, the maximum, and the mean bid and ask quotes in a given minute are retrieved.

Ultimately, the final dataset contains eleven different values for the bid and ask exchange rates (See Figure 3). First, for each put-call pair there are three different times where the exchange rate can be observed; the put trade time, the call trade time and the mid-time between trades; and for each of these minutes there is a minimum, a maximum and a mean O&A bid and ask quote. It is only for perfectly matched (to the nearest minute) put-call pairs that the three observed times are equivalent. Second, for each put-call pair, the exchange bid and ask rates quoted by Telerate at the time the call is traded and exchange rate quotes at the time the put is traded are recorded.

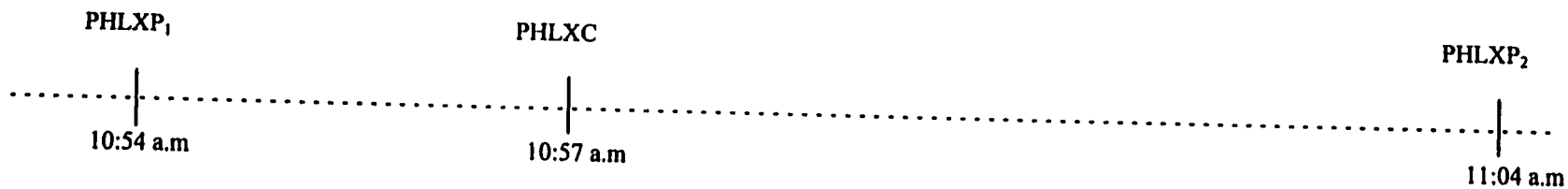
4.3 Calculating Interest Rates.

To calculate interest rates, Eurodeposit bid and ask rates were interpolated to correspond to the maturity of the options. While the interest rate differential is an important consideration in executing European conversions and reversals, absolute accuracy in the level of the interest rate was not deemed to be an issue since the errors resulting from not using a more accurate method of estimating the interest rates would only modestly affect the magnitudes of the deviations from PCP rather than the validity of the actual equation. Since, any errors from inaccurate interest rates will be overwhelmed by errors from using different variables for exchange rates, this issue is no longer

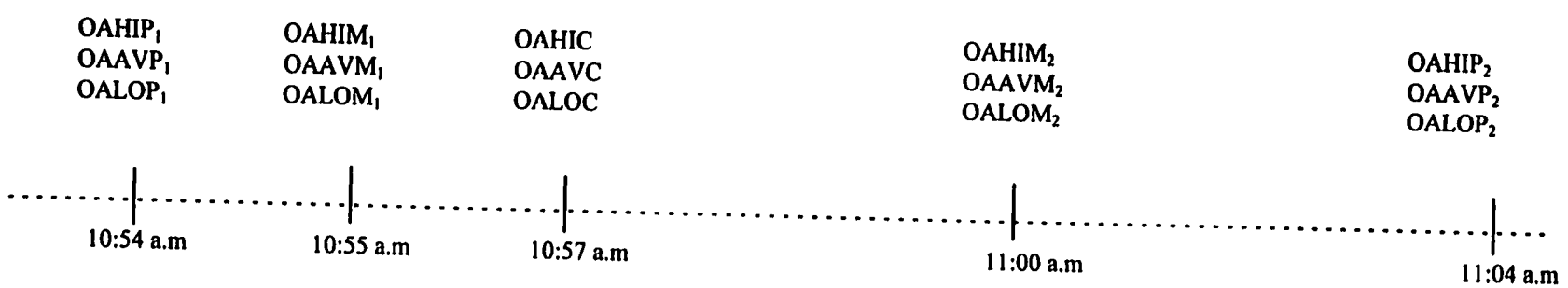
Figure 3. Time Line of different Exchange Rate Measures (for Telerate and Reuters data)



Panel A: Telerate Exchange Rate Measures (PHLX)



Panel B: Reuters Exchange Rate Measures (O&A)



examined for European PCP. For example, in a European conversion strategy with C=1, P=1, X=1, S=1, r_{DM} =0.09, r_{US} = 0.03, then with $C - P + Xe^{-r\,US} - Se^{-r\,DM}$, a 1 % error in the interest rate estimate will affect the inequality by less than 1 % whereas an equivalent error in the FX rate will affect the inequality by approximately 16 %.

For American options care has to be taken in interpreting results from any violations in American PCP strategies. The relative interest rate differential between U.S interest rates and Deutsche Mark interest rates can increase the riskiness of the long and short profitable hedges. If the interest rate differential is great, early exercise is more likely and the conversion and reversal strategies might fall apart (since early exercise of the written option will make the strategy risky). For the American conversion, the investorur is short the call and this strategy is not risk-free if the German interest rate is higher than the U.S interest rate. Even if the American conversion strategy reveals some possible arbitrage profits, these are not true arbitrage profits since the option holder can exercise his/her option at *any* time before the investor can terminate the strategy. For the reversal strategy, the investor is short the put and early exercise of this option will undermine his/her strategy. This is more likely when the German interest rate is lower than the U.S interest rate. In this sample period (see Figures 4 and 5) the German yield curve tended to be decreasing but at all times higher than the U.S yield curve which tended to be stable. This suggests that the American PCP inequality is more likely to hold for the reversal strategy than for the conversion strategy since the put owner will forego a high foreign interest rate if he/she exercises their option. Some risk remains for the

Figure 4 : DM Interbank Eurodeposit Interest Rates (from 30/9/92 to 30/9/93)

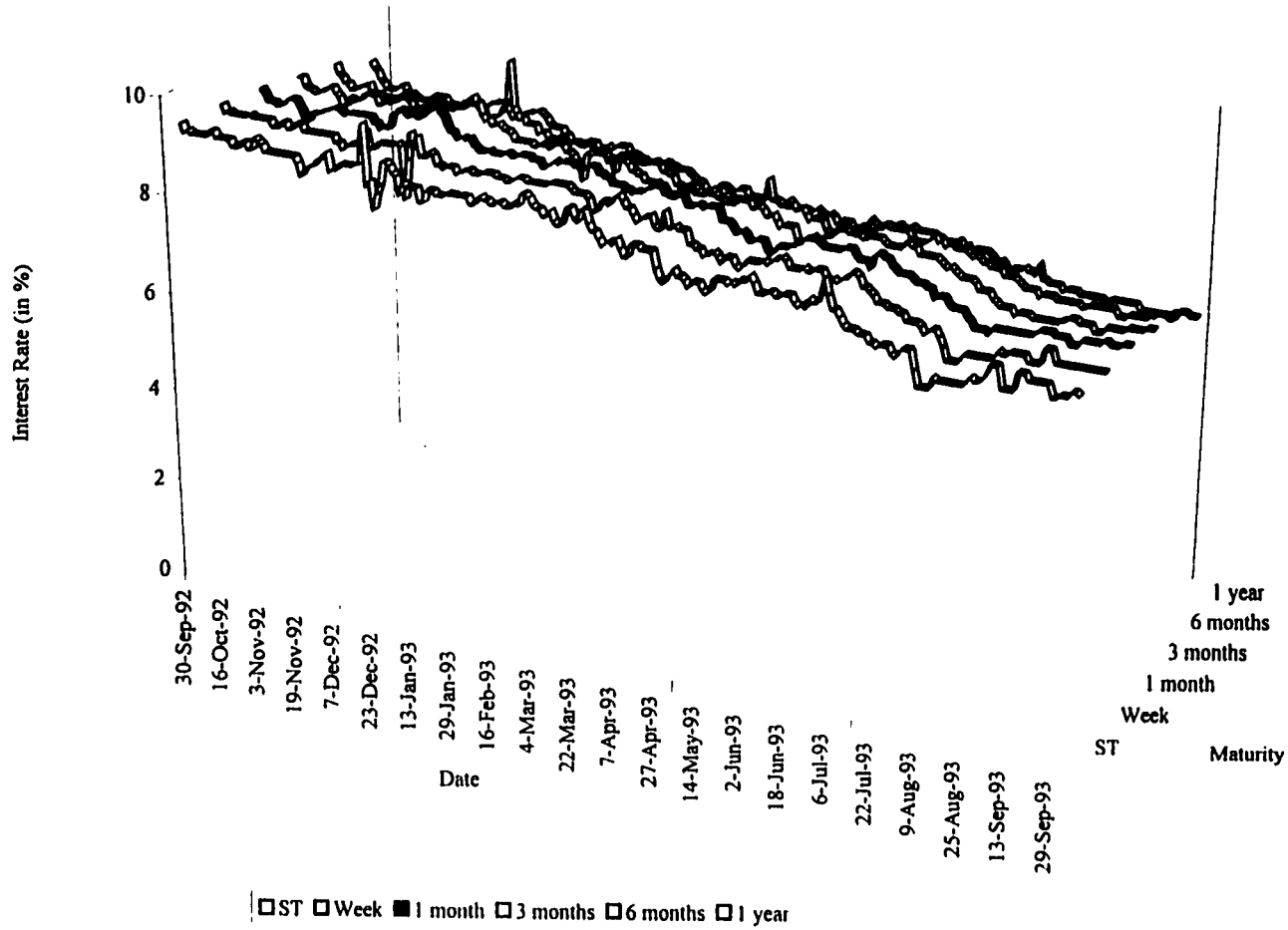
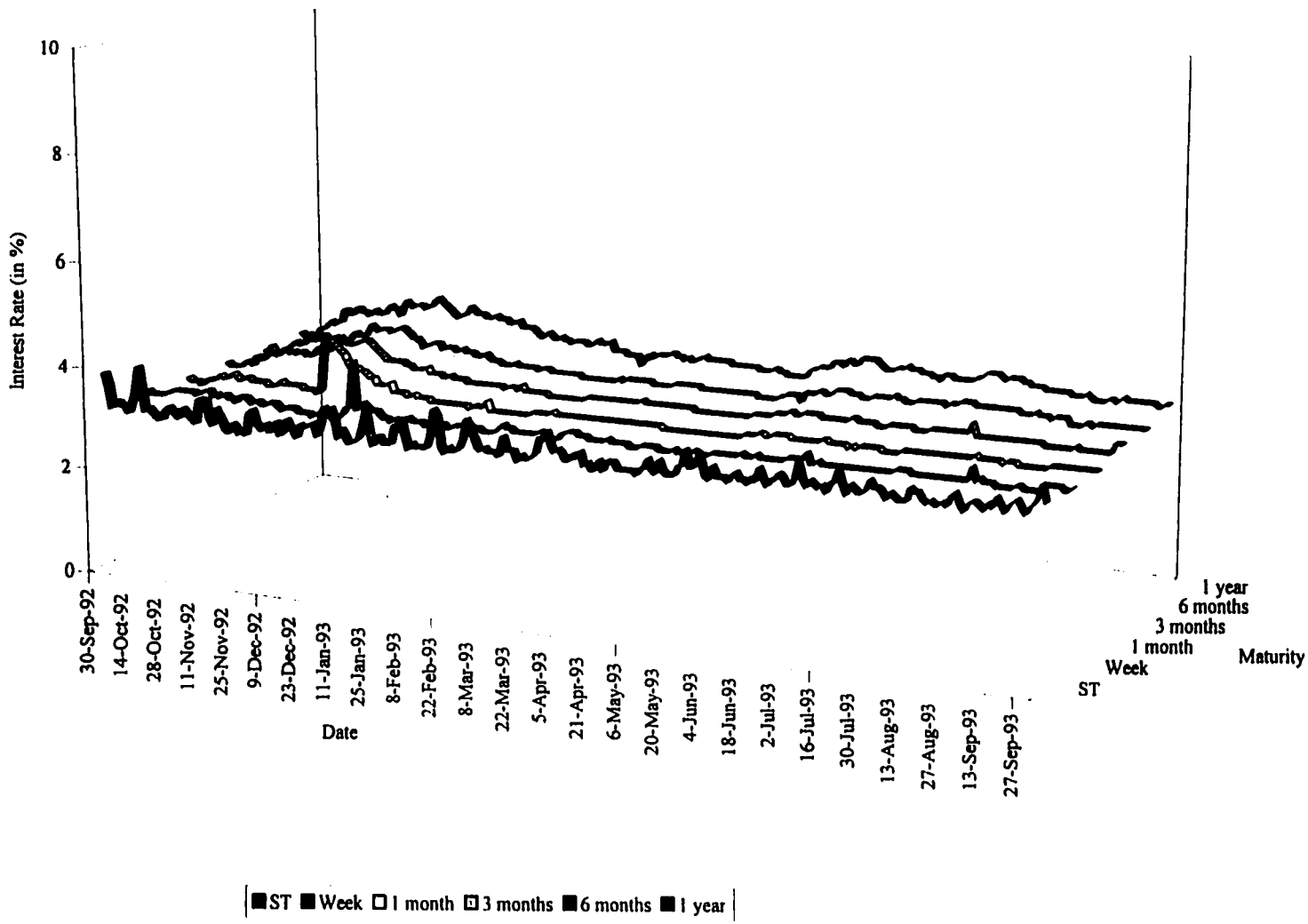


Figure 5 : US Interbank Eurodeposit Interest Rates (from 30/9/92 to 30/9/93)



investor however, since a put can be rationally exercised at any time before expiration (Klemkosky and Resnick 1979). This risk is, nevertheless, minimal unless the option is deep-in-the-money since the exercise value of the put in this case is more likely to compensate for the interest foregone from being long in the foreign currency.

4.4 Cross-sectional Regressions.

Once the PCP deviations have been calculated for the four different strategies, using the eleven measures of exchange rates, a final cross-sectional regression is used to explain these deviations. As hypothesized in this section, several factors will affect the magnitude of a PCP deviation. Tobit regressions will be used to estimate the significance of these factors on the magnitude of positive deviations from Put-Call Parity. The Tobit regression is used since for negative deviations none of the strategies will be carried out, yet leaving these out of any model represents a loss of information. A Tobit regression sets the dependent variables in this case as missing (censored) and proceeds to estimate the relationship under the assumption of a normal distribution for the non-censored (i.e. positive) log-transformed PCP deviations. The form the regression will take is :

$$\Delta_{ij}^{*} = \max(\Delta_{ij},0) = \alpha_{ij} + \delta_{1ij} DOM + \delta_{2ij} \mathrm{IRD} + \delta_{3ij} MAT + \delta_{4ij} WIND + \sum_{1}^{k} \delta_{5ijk} TD_{k} + \varepsilon_{ij}$$

where DOM is the degree of moneyness proxied as (C-P). This measure ranges from the positive when the call is in-the-money and the call premium has a higher value than the

put premium, to the negative when the put is in-the-money and the put premium has the higher value than the call premium.

IRD is the interest rate differential measured as (r_{DM} - r_{US}),

MAT is maturity of the option measured in days,

WIND is the absolute difference in minutes between the time of trade of the call and the time of trade of the put, and

TD_k is a dummy variable for time of day where k=1 is morning session (from 7.00 a.m. to 11.00 a.m.), k=2 is the the evening session (from 6.00 p.m. to 10.00 p.m.) and k=3 is the early morning session (from 11.00 p.m. to 4.00 p.m.)

5. RESULTS AND IMPLICATIONS

5.1 General Results

A preliminary examination of the result tables (tables 2 and 3 for American strategies and tables 4 and 5 for the European strategies) shows that with the exception of the European Conversion strategy, the percentage deviations from PCP are consistently below 3.571 %.(for the European reversal OALOC exchange rate) The deviations found were mainly for short-term maturity options (less than 30 days). Since options become more volatile the closer they get to maturity (Martin and French, 1987), this result is as expected. For the European Conversion strategy, the percentage of deviations from PCP for all measures of the exchange rate ranged from 31.33 % (for the OALOP exchange rate) to 38.15 % (for the OAHIM exchange rate). This does not appear to be consistent

Table 2. Deviations for American Reversal Strategy by Window size.

Panel A: Full Sample

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-6021.614	-6062.818	-6418.725	-6103.147	-5848.224	-6389.754	-6090.252	-5835.581	-6373.171	-6123.945	-5839.447
Standard Deviation	9374.4986	6912.7553	6609.8062	6558.5048	6563.0676	6598.2431	6559.4327	6567.8412	6575.3458	7073.8862	6573.8527
Minimum Deviation	-58458	-57817.52	-58005.02	-57855.89	-57507.76	-58005.02	-57663.21	-57569.95	-58432.83	-233645.8	-57755.54
Maximum Deviation	549375.55	116782.66	50025	50111.932	50387.307	50025	50111.932	50387.307	50025	50111.932	50387.307
Median Deviation	-4262.099	-4259.563	-4452.251	-4139.46	-3914.882	-4373.873	-4086.748	-3857.269	-4336.647	-4058.948	-3870.137
Profitable Deviations	207	177	73	115	143	96	107	147	70	113	133
Sample Size	7352	7352	7352	7352	7352	7352	7352	7352	7352	7352	7352
% Deviations	2.816	2.408	0.993	1.564	1.945	1.306	1.455	1.999	0.952	1.537	1.809

Panel B: 1 minute window

Mean	-6251.497	-6243.237	-6548.555	-6286.108	-6062.125	-6548.555	-6286.108	-6062.125	-6548.555	-6286.108	-6062.125
Standard Deviation	7478.9724	7470.375	7288.1599	7249.6656	7254.0885	7288.1599	7249.6656	7254.0885	7288.1599	7249.6656	7254.0885
Minimum Deviation	-54500.77	-54794.61	-54657.26	-54545.35	-54377.43	-54657.26	-54545.35	-54377.43	-54657.26	-54545.35	-54377.43
Maximum Deviation	50300.392	51258.186	50025	50111.932	50387.307	50025	50111.932	50387.307	50025	50111.932	50387.307
Median Deviation	-4293.201	-4377.075	-4362.185	-4112.421	-3962.296	-4362.185	-4112.421	-3962.296	-4362.185	-4112.421	-3962.296
Profitable Deviations	31	31	13	17	23	13	17	23	13	17	23
Sample Size	1253	1253	1253	1253	1253	1253	1253	1253	1253	1253	1253
% Deviations	2.474	2.474	1.038	1.357	1.836	1.038	1.357	1.836	1.038	1.357	1.836

Note: See Figure 3 for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100).

Table 3. Deviations for American Conversion Strategy by Window size.

Panel A: Full Sample

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-9979.385	-9933.052	-9608.975	-9841.175	-10095.24	-9594.999	-9852.821	-10104.63	-9584.824	-9840.573	-10097.75
Standard Deviation	11362.892	9468.962	9722.2202	9721.6746	9716.4617	10066.497	9712.2167	9714.2579	10002.112	9719.3474	9705.4302
Minimum Deviation	-561973.4	-122705.2	-73337.23	-75466.61	-75555.51	-75185.17	-75651.84	-75777.84	-74445.24	-74652.32	-75555.51
Maximum Deviation	1642.2557	4291.1529	10934.421	10934.421	10934.421	218255.72	10901.761	21034.052	198681.87	23973.918	11065.041
Median Deviation	-7889.971	-7938.212	-7494.697	-7745.166	-7912.927	-7494.773	-7734.969	-7925.971	-7500.534	-7669.164	-7922.46
Profitable Deviations	46	52	94	57	35	71	49	34	79	66	38
Sample Size	7352	7352	7352	7352	7352	7352	7352	7352	7352	7352	7352
% Deviations	0.626	0.707	1.279	0.775	0.476	0.966	0.666	0.462	1.075	0.898	0.517

Panel B: 1 minute window

Mean	-10501.83	-10511.91	-10194.59	-10400.15	-10622.19	-10194.59	-10400.15	-10622.19	-10194.59	-10377.64	-10622.19
Standard Deviation	9780.7121	9797.6656	9781.962	9795.5509	9791.0139	9781.962	9795.5509	9791.0139	9781.962	9842.0323	9791.0139
Minimum Deviation	-70236.91	-70236.91	-68980.16	-69129.32	-69183.57	-68980.16	-69129.32	-69183.57	-68980.16	-69129.32	-69183.57
Maximum Deviation	1008.1608	1008.1608	9206.4704	9194.0557	9020.218	9206.4704	9194.0557	9020.218	9206.4704	23973.918	9020.218
Median Deviation	-8333.359	-8333.359	-8289.933	-8564.173	-8586.561	-8289.933	-8564.173	-8586.561	-8289.933	-8564.173	-8586.561
Profitable Deviations	4	5	13	10	2	13	10	2	13	11	2
Sample Size	1253	1253	1253	1253	1253	1253	1253	1253	1253	1253	1253
% Deviations	0.319	0.399	1.038	0.798	0.160	1.038	0.798	0.160	1.038	0.878	0.160

Note: See Figure 3 for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100).

Table 4. Deviations for European Reversal Strategy by Window size

Panel A:Full Sample

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-2992.548	-2970.415	-3154.785	-2940.017	-2728.088	-3151.11	-2900.973	-2694.203	-3221.082	-2943.298	-2741.723
Standard Deviation	2155.9445	2188.6847	2172.5353	2090.7678	2061.4455	2154.9907	2055.4828	2047.2252	2203.5877	2062.6886	2030.6436
Minimum Deviation	-12664.89	-12664.89	-12634.32	-12407.58	-12191.79	-12634.32	-12407.58	-12191.79	-12634.32	-12407.58	-12191.79
Maximum Deviation	4360.1784	4360.1784	954.52205	1242.1828	1515.9568	954.52205	1331.7826	1787.0793	876.90649	1331.7826	1787.0793
Median Deviation	-2630.345	-2403.447	-2634.208	-2378.574	-2075.813	-2643.813	-2464.235	-2075.813	-2682.417	-2543.569	-2328.034
Profitable Deviations	19	18	8	9	17	5	9	16	4	16	22
Sample size	616	616	616	616	616	616	616	616	616	616	616
% Deviations	3.084	2.922	1.299	1.461	2.760	0.812	1.461	2.597	0.649	2.597	3.571

Panel B: 1 minute window

Mean	-3272.306	-3308.281	-3419.852	-3132.61	-2949.801	-3419.852	-3132.61	-2949.801	-3419.852	-3132.61	-2949.801
Standard Deviation	2386.3638	2393.5163	2491.1985	2298.2206	2294.019	2491.1985	2298.2206	2294.019	2491.1985	2298.2206	2294.019
Minimum Deviation	-12664.89	-12664.89	-12634.32	-12407.58	-12191.79	-12634.32	-12407.58	-12191.79	-12634.32	-12407.58	-12191.79
Maximum Deviation	355.33184	514.59355	391.72674	820.02851	1046.2287	391.72674	820.02851	1046.2287	391.72674	820.02851	1046.2287
Median Deviation	-2829.186	-2755.884	-2739.57	-2643.813	-2643.813	-2739.57	-2643.813	-2643.813	-2739.57	-2643.813	-2643.813
Profitable Deviations	3	3	1	1	5	1	1	5	1	1	5
Sample size	158	158	158	158	158	158	158	158	158	158	158
% Deviations	1.899	1.899	0.633	0.633	3.165	0.633	0.633	3.165	0.633	0.633	3.165

Note: See Figure 3 for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100).

Table 5. Deviations for European Conversion Strategy by Window size

Panel A:Full Sample

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-542.4656	-549.3051	-406.8001	-590.152	-784.909	-403.8197	-605.5398	-807.7667	-413.8371	-599.3598	-764.7136
Standard Deviation	1832.5473	1854.7765	1782.6938	1753.0513	1731.2566	1765.9003	1735.2413	1732.5226	1743.0523	1711.5344	1715.0939
Minimum Deviation	-7746.918	-7746.918	-4300.439	-4567.352	-5003.133	-4412.801	-4763.95	-5032.637	-4619.331	-4619.331	-5021.198
Maximum Deviation	7753.244	7753.244	7629.4961	7468.8046	7296.9675	7629.4961	7468.8046	7296.9675	7629.4961	7468.8046	7296.9675
Median Deviation	-706.2789	-844.5122	-754.656	-849.5438	-1097.295	-738.5973	-798.9759	-1041.208	-654.4104	-756.2359	-926.1658
Profitable Deviations	214	206	220	194	193	235	194	194	231	206	194
Sample size	616	616	616	616	616	616	616	616	616	616	616
% Deviations	34.740	33.442	35.714	31.494	31.331	38.149	31.494	31.494	37.500	33.442	31.494

Panel B: 1 minute window

Mean	-326.1552	-291.1123	-247.3409	-437.6804	-607.5839	-247.3409	-437.6804	-607.5839	-247.3409	-437.6804	-607.5839
Standard Deviation	2007.6422	2010.825	1955.1272	1932.1929	1914.172	1955.1272	1932.1929	1914.172	1955.1272	1932.1929	1914.172
Minimum Deviation	-4113.453	-4113.453	-3453.279	-4179.739	-4406.234	-3453.279	-4179.739	-4406.234	-3453.279	-4179.739	-4406.234
Maximum Deviation	7753.244	7753.244	7629.4961	7468.8046	7296.9675	7629.4961	7468.8046	7296.9675	7629.4961	7468.8046	7296.9675
Median Deviation	-564.9601	-512.9959	-555.1964	-622.4095	-756.2359	-555.1964	-622.4095	-756.2359	-555.1964	-622.4095	-756.2359
Profitable Deviations	59	60	64	53	53	64	53	53	64	53	53
Sample size	158	158	158	158	158	158	158	158	158	158	158
% Deviations	37.342	37.975	40.506	33.544	33.544	40.506	33.544	33.544	40.506	33.544	33.544

Note: See Figure 3 for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100).

Table 6: Tobit Regression Results for all strategies for PHLX Put Exchange rate, the PHLX Call Exchange rate, and the O&A Average Exchange rate between Put and Call Trades for the Mean Time

$$\Delta^{*}_{it} = \max(\Delta_{it}, 0) = \alpha_{it} + \delta_{1it} DOM + \delta_{2it} IRD + \delta_{3it} MAT + \delta_{4it} WIND + \sum_{i}^{i} \delta_{5it} TD_{i} + \varepsilon_{it}$$

	American Conversion			European Conversion			American Reversal			European Reversal		
	PHLXC	PHLXP	OAAVM	PHLXC	PHLXP	OAAVM	PHLXC	PHLXP	OAAVM	PHLXC	PHLXP	OAAVM
Log Likelihood for Normal	-3938.596	-2170.418	-2725.465	-2051.323	-1959.297	-1815.955	-3049.703	-2506.045	-3630.125	-234.802	-228.178	-116.676
Noncensored Values	46	52	49	214	206	194	207	177	107	19	18	9
Left Censored Values	7306	7300	7303	402	410	422	7145	7175	7245	597	598	607
Scale	6400.111	2275.205	2376.166	1949.37	1852.965	1660.58	49096.615	21121.844	2632.827	6034.906	6555.9801	5766.282
S.E scale	34.974	13.047	9.653	102.367	98.603	90.608	2667.087	1368.25	23.209	1205.743	1360.673	1706.509
Intercept	-30435.39	-5439.168	-7880.111	-10995.31	-13965.2	-13451.11	-162593.2	-68669.51	-12508.22	-355.784	1169.686	-21834.26
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.9591)	(0.8752)	(0.0652)
DOM	50.723	22.226	7.936	-0.38	-0.191	-0.726	11.012	-16.642	0.687	3.102	4.493	7.729
(Degree of Moneyness)	(0.0001)	(0.0001)	(0.0001)	(0.4082)	(0.6683)	(0.0797)	(0.6671)	(0.1439)	(0.4492)	(0.4958)	(0.3748)	(0.2943)
IRD	1960.368	487.284	251.136	1057.106	1654.46	1490.557	13499.971	5607.15	1193.005	-2300.933	-2737.659	1594.203
(Interest Rate Differential)	(0.0046)	(0.0164)	(0.1395)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0882)	(0.0633)	(0.4005)
MAT	-1024.91	-1153.326	-220.706	35.926	38.805	39.36	-1098.657	-582.848	-145.289	-23.198	-26.818	-43.821
(Maturity in days)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0794)	(0.0534)	(0.0741)
WIND	769.061	-485.33	-383.09	150.226	-158.107	-27.149	943.88	763.142	-411.876	-23.657	-99.056	-101.844
(Window size between trades)	(0.0282)	(0.0001)	(0.0001)	(0.0865)	(0.0774)	(0.7478)	(0.4703)	(0.1841)	(0.0001)	(0.9719)	(0.8898)	(0.8995)
TD7-11	6133.335	-1123.539	-884.918	1214.445	1186.767	968.929	19006.32	5818.874	-222.115	-5533.566	-4043.002	-3007.156
(Dummy for NY morning)	(0.0020)	(0.0004)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0032)	(0.3376)	(0.0196)	(0.0559)	(0.2227)
TD18-22	-2833.106	-10435.41	8239.804	NA	NA	NA	12812.917	-2235.082	10301.884	NA	NA	NA
(Dummy for Asia morning)	(0.9224)	(0.9987)	(0.0001)	NA	NA	NA	(0.3313)	(0.7483)	(0.0001)	NA	NA	NA
TD23-04	10059.049	1611.82	-3100.292	-1646.578	-1303.932	-461.117	11181.484	3149.136	476.187	5842.247	5643.156	5396.74
(Dummy for Europe morning)	(0.0001)	(0.0001)	(0.0027)	(0.0090)	(0.0271)	(0.3933)	(0.1398)	(0.3375)	(0.1946)	(0.0018)	(0.0054)	(0.0289)

Note: Numbers in parenthese represent p-values for the estimates defined as Pr>Chi. NA indicates that no observations are available for that particular variable. See figure 3 for definition of exchange rate variables

with market efficiency. On examination of the sample, roughly 100 put-call pairs (90 % of the positive deviations for this strategy) were for options with maturities between 121 and 180 days (See table Table A9, panel E). These however can be explained by methodology (See Section 5.5. p. 52 below).

For American Reversals, the use of Reuters exchange rate data (instead of Telerate) decreased the number of positive PCP deviations that are possible for all measures of the exchange rate (average, high or low at the different measurement times). This same pattern also to exist for the European Reversal strategy. For the conversion strategies, the number of profitable PCP deviations for all Reuters exchange rate measures as compared with the Telerate data vary depending on the level of the exchange rate used. In other words, the high and low rates for Reuters data produced PCP deviations which were greater and smaller than the Telerate measures used. For example, roughly double the number of profitable opportunities (table 3A) exists in one case for the high put time Reuters rate relative to the Telerate exchange rate. For the average Reuters rates, the number of positive PCP deviations in a conversion is more or less equivalent to (but generally higher) than the Telerate rates used. Since in a reversal, the arbitrageur is long the foreign currency while in a conversion the arbitrageur is short the foreign currency, it seems that the Reuters data may have captured more of the negative jumps in the Deutsche Mark that are likely to have happened in a period where it was declining. (See Figure 6). An alternative explanation for this is that the Telerate rate recorded by the PHLX lags the Reuters rate. This is quite possible given the data format differences

Figure 6 : Daily Exchange Rate Movements for the Deutsche Mark from 1 Oct 1992 to 30 Sept 1993

discussed in the Section 1. With the DM falling over the sample period, a lagging Telerate price would generally overestimate the true level of the DM such that more profitable opportunities would appear to exist for the strategy where the investor is long the Mark (the reversal), and less when the investor is short the Mark (the conversion) using this data.

For the cross-sectional regressions (table 6), two of the independent variables used are expected to have comparable effects for all strategies. The WIND variable measures the difference in time of trade of the put-call pair and is used as a proxy for simultaneity of the data. Bodurtha and Courtadon (1986) find that non-synchronicity in prices is a more important consideration than the level of the transactions costs in examining put-call parity in the FX option market. In this study, the exchange rate is examined at the different times of the put trade, the call trade and the mid-time between trades. Therefore, for any given strategy, as the window size increases, the call and the put prices become less perfectly matched. However, increasing the size of the window also changes the time of the put, call trades and the mid-window observation of the exchange rate. Consequently, the spot exchange rate used for any of the strategies for any of the measures of the exchange rate will differ across different sized windows. This will affect the magnitude of the deviations depending on the number of upticks versus downticks within that window. The regression results are mixed across exchange rate measures, with some of the parameter coefficients being positive while others are negative. The Reuters measures in particular exhibit more tendency to be negative than the Telerate measures.

With its higher frequency, Reuters prices are more volatile than Telerate prices and are likely to exhibit more directional changes (jumps) within a certain time interval size. As the window size increases, the likelihood that the exchange rate has moved out of equilibrium with option prices also increases thus violating PCP. For the Reuters data as compared with the Telerate data, increasing the window size means further separating the exchange rate from one or the other of the put or call transactions and the point in time that the exchange rate is measured at. This, therefore, is an important consideration for PCP.

As for the time dummy (TD) variables in the Tobit regressions, there appears to be a significant pattern in the profitability of PCP strategies as a function of the time of day. The PHLX has two trading sessions during the day. The first starts at 11.30 p.m (EST) and continues throughout the night until closing at 2.30 p.m. the next day. Then another trading session starts at 6.00 p.m and finishes at 10.00 p.m. With a more or less 24 hour day in exchange rate markets, this trading structure was established to accommodate investors during the openings and closings of different geographically located exchange markets. Therefore, the first session roughly coincides with opening of trading in Asia (6-10 p.m). This continues until lunch hour in Asia where market activity falls markedly. Trading then resumes at 11.30 p.m which coincides with the end of lunch-hour in Asia. PHLX trading continues as trading in Europe opens at roughly 3.00 a.m (EST) and then finally, trading in North America at 8.00 a.m. With higher market activity during the early hours of the day and with quotes coming from different geographical

locations, this would increase the volatility of the Deutsche Mark and could therefore affect the magnitude of deviations from PCP. During the early hours of the GMT day, Guillaume et al. (1995, Figure 3). confirm that exchange rate volatility is higher. This would require faster adjustment of options prices to their underlying assets and produce higher deviations from a PCP strategy. While no strong patterns are evident in the time dummy variables in the regressions, a significant positive coefficient exists for the evening trading session for American options. As figures A3 and A6 (See Appendix) further illustrate, the percentage of positive PCP deviations over number of put-call pairs during the evening hours shows a large increase from morning levels. This can be attributed to thin trading during these hours. This pattern only exists for Reuters data since Reuters quotes can exhibit spreads of more than five times the average daily spread during these less active times of the day (Muller et al. 1990). With the greater spreads in the FX market, it is likely that PHLX spreads are proportionately higher, especially since the volume of trades on the PHLX during these times of the day is the lowest. In the absence of any information on bid-ask spreads on the PHLX options, it is possible that these positive deviations during evening trading do not represent real arbitrage opportunities. Using posted bid and asked prices rather than actual transaction prices might eliminate these profitable opportunities. An analysis of this subset of the dataset (i.e. all profitable OAAVM opportunities during evening trading) shows that the median positive deviation for American reversals and conversions is $982 and $953 respectively. Therefore, 50 % of all these profitable opportunities are quite small. With a transaction size of $ 1 million, this represents approximately 0.1%. If the PHLX bid-ask spread on

put and call options is 0.05 % for each call and each put in a put call pair, then these profitable opportunities will cease to exist.

Upon examining the morning session alone (Figures A4 and A7), the percentage of profitable opportunities appears to increase with the higher volatilities of the opening and closing of different geographical markets as identified by Bollerslev and Domowitz (1993) and Dacorogna et al. (1993).

Figure A8 shows that there is also weekly seasonality in the number of profitable opportunities with the number of positive deviations increasing on Fridays. Furthermore, for American conversions, 60 % of the evening opportunities happened on Fridays. This could be attributable to thinner markets and higher spreads on Friday. However, higher spreads in the FX market may not translate into real arbitrage opportunities since PHLX market makers would likely increase their spreads on currency options. Again, as in the case of evening profitable opportunities, the magnitude of these deviations was also small with medians of $ 825 for positive reversal deviations and $906 for positive conversion deviations (the size of the bid-ask spread has to be approximately 0.05 % to eliminate these profits). This is an issue for future research when bid-ask information from the PHLX becomes available.

The other independent variables in the regressions are expected to have different signs according to the strategy used. This difference is due to the definition of these

variables in this study presented in Section 4.4 (page 35).and can be determined from the conversion and reversal inequalities presented in Section 4.1.

For reversal strategies, the magnitude of positive deviations should be negatively related to the DOM variable. For conversions, this relationship should be positive. Maturity (MAT) for all strategies should be negatively related to magnitude of positive PCP deviations in an efficient market. As for the interest rate differential (IRD), for European strategies, a lower IRD should result in less deviations from PCP for conversions, and more deviations from PCP for reversals.

For American strategies, this relationship is not as straightforward. From the inequalities in section 4.1, a lower U.S interest rate (greater IRD) in the conversion strategy should increase deviations from PCP. Moreover, a higher DM interest rate (greater IRD) should increase the premium of the short call (and decrease the premium for the put) and consequently, increase the positive PCP deviations. For the reversal, a higher DM interest rate (greater IRD) should decrease the size of the positive PCP deviation. Furthermore, a higher DM interest rate would decrease the put premium and increase the call premium, thus also reducing the magnitude of the PCP deviation. However, a put option is always subject to early exercise risk and any positive deviation may not be real. Therefore, the sign for IRD in an American reversal is not determinable. The signs for the different variables in the regression can be summarized as follows:

Table 7. Expected Signs for All Strategies Using Cross-Sectional Tobit Regressions.

	American Reversal	American Conversion	European Reversal	European Conversion
DOM	–	+	–	+
IRD	ND	+	–	+
MAT	–	–	–	–

Note : ND means not determinable.

5.2 Results for American Reversals

In a period with a falling DM exchange rate, put options are more in-the-money than calls, and therefore have a higher intrinsic value. Since in an American reversal the arbitrageur is short the put and long the call, there is more pressure on the PCP to be violated. (P-C is more positive, and therefore there is a greater possibility of it being greater than zero). This, however, does not represent an arbitrage opportunity since there remains some risk from this strategy, which is the risk due to early exercise. This risk is moderated by two factors, the degree of moneyness and the interest rate differential. With a higher interest rate differential, the holder of the put option would have to forego the high "dividends" (i.e., the foreign interest earned) from owning the DM. This would reduce the probability of early exercise and the value of the put. However, given a sufficient intrinsic value (P-X) which will happen when the put is deep in-the-money, early exercise is still highly likely since the exercise value of the option will compensate for any of the lost interest (ie. the opportunity cost of being long in the DM).

From the Tobit regressions, it can be seen that the interest rate differential (IRD) for the American reversal strategy significantly positively influences the magnitude of the

deviation. Since the DM interest rate was generally falling over this period while the US interest rate was relatively stable, the magnitude of the deviation from this strategy is likely to have been affected solely by the DM interest rate. From the reversal inequality, a decrease in the DM interest rate, *ceteris paribus*, will increase the magnitude of the deviations, hence a negative relationship should exist. However, it is possible that any increase in the DM interest rate is translated into greater exchange rates, thus increasing PCP deviations rather than decreasing them.

As for the degree of the money variable, a highly positive value for DOM would mean that the call option is in-the-money or, conversely, the put option is out-of-the-money. From the reversal inequality, an in-the-money put would result in higher values on the left-hand side. The results of the regressions however, are not very significant (Table 6).

5.3 Results for American Conversions

In the American conversion, the arbitrageur is short the call and long the put. Given a more in-the-money put, there is a smaller possibility that PCP would be violated (since C-P is more negative). Furthermore, whatever deviations that exist using this strategy, these are subject to early exercise and are therefore not riskless. This is because with a high interest rate differential, the call option holder will be motivated to exercise his/her call, since being long in the underlying currency will yield a high rate of interest.

For the arbitrageur, any profitability from conducting such a strategy will be subject to that risk.

For this strategy, the DOM parameter in the Tobit regressions is positive. This is because with an increase in the degree of moneyness of the call, the call premium would become higher and the left-hand side of the conversion inequality will increase.

From the American PCP conversion inequality, the IRD variable in the regression should be positive. However, since only the U.S. interest rate appears in the left-hand side of the regression, and since this interest rate was more constant (although rising) than the DM interest rate, IRD should be less significant for this strategy than in the reversal strategy. This does seem to be the case in the Tobit regressions. Since an increase in the U.S Eurodeposit rate decreases the value of the right-hand side of the American conversion inequality, this increase should result in smaller PCP deviations. An increase in the U.S rate, however, decreases IRD. Therefore, the positive sign of the regression parameter is as predicted.

5.4 Results for European Reversals

A European reversal (P-C) in a deep in-the-money put environment, is more likely to be violated than a conversion. This strategy has the least amount of profitable opportunities of all the other strategies and as such, the results of the regressions are not

as significant. However, the results seem to be of the right sign for all the variables. That is the direct relationship predicted in the European reversal inequality and is confirmed by the Tobit regressions.

In this strategy both the German and the U.S. interest rates appear on the right-hand side of the inequality and a smaller interest rate differential would result in a higher deviation on the left-hand side. As the regressions show, the parameter for IRD is negative. As in the American reversal, the higher the DOM variable, the put is less in-the-money and therefore, the magnitude of the deviations should decrease. The regressions do not show a negative sign for DOM as predicted. The parameter estimates, however, are insignificant.

5.5 Results for European Conversions

From the PCP inequalities, there should be fewer positive deviations from PCP for European conversions than for the reversal, but this was not the result of this analysis. While IRD shows the predicted sign (positive), the other parameters do not behave predictably. Particularly, DOM and MAT do not have the correct signs. From the inequality for the European conversion, a higher DOM (call in-the-money) should result in a higher deviations, that is a positive relationship. This parameter from the regression is negative although it is not deeply significant. As for time to maturity of the option, this has a positive relationship with the size of the deviations. This is counterintuitive since,

as mentioned earlier, options become more volatile the nearer to maturity they are and deviations are therefore more likely to occur as an option approaches expiry. On re-examination of the sample most of the deviations occured for options with a maturity of 121 to 180 days (more specifically, 138 days). Since the methodology of this study uses all possible put call pairs, these results are likely to be exaggerated by multiple counting of the same incident. When duplicates are taken out of the sample, the frequency of profitable opportunities is greatly reduced (See figure A9). Nevertheless, the number of deviations that remains without repetition is still larger than can be explained by methodology alone. This could be an instance of a bad price. These remaining observations were composed of a bunch of very closely timed trades that were made in a matter of five minutes (more than 100 put call pairs, with quite a large number of contracts traded). These trades are likely to have been in response to a significant drop in the value of the U.S. dollar (and U.S. treasury rates) on open of trading in New York on Monday the 26th of April 1993 (See figure A13). Following 7 months highs in the same run on gold in Europe, demand for the dollar quickly decreased making DM calls temporarily undervalued with respect to the exchange rate.and the put overvalued. The market is likely to have reacted by buying calls, raising their price, and selling puts, reducing their price. and this could explain the excessive violations of this strategy. From the European conversion inequality in Section 4.1, the bias from not using posted bid-ask spreads is large in this case since the call is being written at the ask (instead of the bid) and the put is being bought at the bid (instead of the ask). Therefore, the bias will be two spreads, and given a sufficiently wide bid-ask spread as is likely for the infrequently

traded European options, these profitable opportunities may be eliminated. With a median of $ 1195 for positive deviations for this strategy a spread of around 0.06 % is likely to eliminate these positive deviations. Finally, the effect of this event on American conversions was non-existent. This is likely due to the greater volume in trading and lower spreads for American options.

5.6 Sensitivity Analysis for Transaction Costs for European Strategies

A sensitivity analysis was performed to assess the effect of transaction costs on market efficiency. A simulated dataset containing ever-increasing levels of transactions costs was created for each European observation with a zero window. Figures 7A. and 7B. illustrate how the number of positive PCP deviations fall with increasing transaction costs. For the European reversal strategy it can be seen that the number of profitable opportunities falls quickly as the level of transactions costs increases. The European Conversion, however, needs approximately $2100 of transaction costs to reach a zero level of deviations from PCP.

Figure 7A : Sensitivity Analysis for Transaction Costs Using 1 Minute Window European Observations : REVERSAL STRATEGY

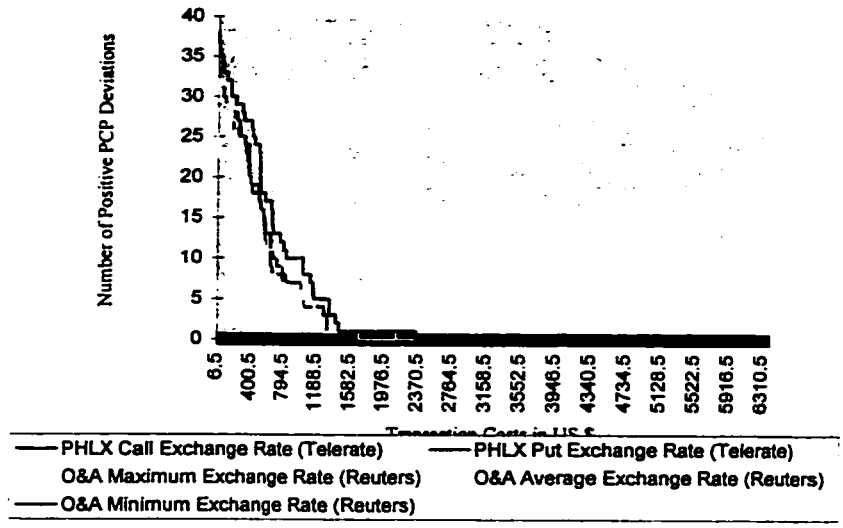
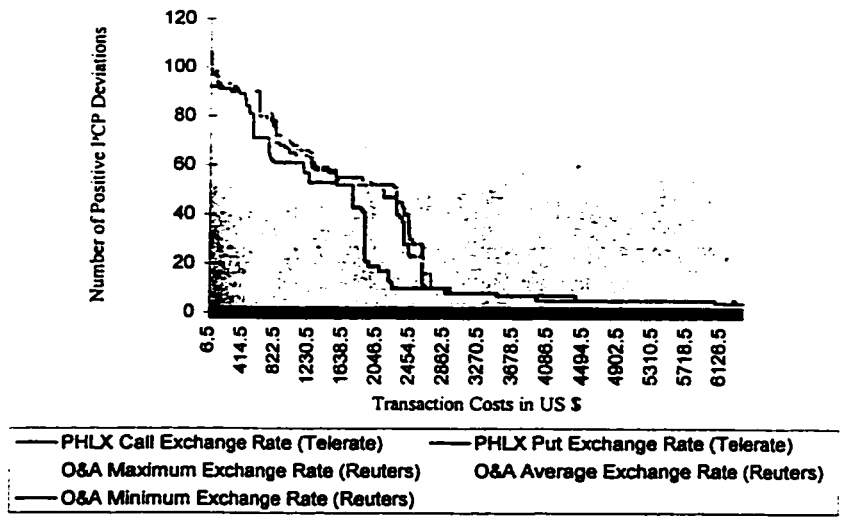


Figure 7B : Sensitivity Analysis for Transaction Costs Using European 1 Minute Window Observations : CONVERSION STRATEGY



6. CONCLUSION

The results of this study are largely consistent with market efficiency in the PHLX currency option market for the Deutsche Mark. With more frequent and accurate Reuters exchange rate data, the number of positive PCP deviations for all strategies (with the exception of European conversions) was in all cases less than 3.571 %. This was true regardless of whether the exchange rate was measured at the put time of trade, the call time of trade, or the mean time between put and call trades. This result was also robust to the level of Reuters exchange rate used during the measurement minute, with profitable opportunities increasing or decreasing according to which strategy was used, but with all exchange rate measures it was less than 3.571 %. In the absence of exact bid and ask premiums for the options, this percentage of positive deviations from Put Call Parity is exaggerated For both American strategies and for the European reversal strategy, cross-sectional regressions seem to indicate that positive deviations from PCP seem to conform to theory.

For European conversions the percentage of positive PCP deviations is large being between 31 % and 38 % for all exchange rate measures. Furthermore, the cross-sectional regression parameters are not as predicted. This is found to be due to multiple counting of a bunch of trades conducted at a very volatile period at the PHLX, where call and put prices were disrupted temporarily. These profitable opportunities decrease dramatically as

the sample is examined without repetition and are expected to be even lower if bid-ask spreads are taken into account.

Intradaily and intraweekly seasonality in the number of positive PCP deviations was found for the case of the American options. This seasonality was found during periods of large foreign exchange spreads and thin markets. These higher spreads are likely to be offset by higher bid-ask spreads on the PHLX during these same periods. Until data on these bid-ask spreads becomes available, it is not clear whether these profitable opportunities reflect an inefficiency in the market. Further study of seasonality in FX option prices is therefore recommended.

It can be concluded that the use of Reuters data offers an informational advantage over Telerate in this study. Since the Deutsche Mark depreciated over the sample period, it could be expected that the reversal strategy is less likely to hold than the conversion strategy. Compared to Telerate, using Reuters data seemed to increase the number of possible profitable opportunities across different exchange rate measures for conversions and decrease them for reversals. A further examination of the distributions of exchange rate quotes from different data providers is therefore required especially because of the technical differences between the two data providers examined here.

Finally, several limitations of this study have to be allowed and could be areas for future research. First, while transactions costs were directly accounted for in constructing

the strategies, the size of the option bid-ask spreads was not accounted for since this information has not been recorded in the PHLX Surveillance tapes. Second, with large intradaily volatility in the FX market, possible future research could compare theoretical option pricing models using the Reuters data used in this research.

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8. APPENDIX I - TABLES

Table A1. Summary statistics for returns of Foreign Exchange Series.

	Mean Return	St. Deviation of returns	Variance	Skewness	Kurtosis
OHIC	0.0000191518	0.002518567	6.34318E-06	6.738774453	2145.988467
OAVC	0.0000190489	0.00249298	6.21495E-06	8.012659117	2116.215773
OLOC	0.0000168049	0.001294334	1.6753E-06	1.37240857	35.61930955
OHIM	0.0000191393	0.002517279	6.33669E-06	8.520246799	2182.256557
OAVM	0.0000167903	0.00128709	1.6566E-06	1.537275485	36.02846318
OLOM	0.0000168388	0.001320199	1.74293E-06	1.264940585	39.67798449
OHIP	0.0000168426	0.001306549	1.70707E-06	1.674436765	36.2383173
OAVP	0.0000167676	0.001287547	1.65778E-06	1.535319295	36.20209152
OLOP	0.0000168015	0.001291858	1.6689E-06	1.397982204	35.16751401
PHLXP	0.0000188270	0.002355911	5.55031E-06	5.789540059	1554.223718
PHLXC	0.0000449531	0.007999408	6.39905E-05	39.02680624	4434.408587

Note: The returns in this table are calculated from between observations of varying intervals. Since these are only meant for comparison between different exchange rate measures, they cannot be taken as an accurate reflection of returns the DM exchange rate for the sample period. Caution must be also be used in interpreting these returns, since for O&A exchange rate measures (Reuters), the return distribution: for the high, average and low series within a given minute. For PHLX exchange rate measures (Telerate), these series distributions are per minute. (See Figure 3, page 32 for explanation of exchange rate measures).

Table A2. Full Deviation Results for American Reversal Strategy by Window size.

Panel A: Full Sample

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-6021.614	-6062.818	-6418.725	-6103.147	-5848.224	-6389.754	-6090.252	-5835.581	-6373.171	-6123.945	-5839.447
Standard Deviation	9374.4986	6912.7553	6609.8062	6558.5048	6563.0676	6598.2431	6559.4327	6567.8412	6575.3458	7073.8862	6573.8527
Minimum Deviation	-58458	-57817.52	-58005.02	-57855.89	-57507.76	-58005.02	-57663.21	-57569.95	-58432.83	-233645.8	-57755.54
Maximum Deviation	549375.55	116782.66	50025	50111.932	50387.307	50025	50111.932	50387.307	50025	50111.932	50387.307
Median Deviation	-4262.099	-4259.563	-4452.251	-4139.46	-3914.882	-4373.873	-4086.748	-3857.269	-4336.647	-4058.948	-3870.137
Profitable Deviations	207	177	73	115	143	96	107	147	70	113	133
Sample Size	7352	7352	7352	7352	7352	7352	7352	7352	7352	7352	7352
% Deviations	2.816	2.408	0.993	1.564	1.945	1.306	1.455	1.999	0.952	1.537	1.809

Panel B: 1 minute window

Mean	-6251.497	-6243.237	-6548.555	-6286.108	-6062.125	-6548.555	-6286.108	-6062.125	-6548.555	-6286.108	-6062.125
Standard Deviation	7478.9724	7470.375	7288.1599	7249.6656	7254.0885	7288.1599	7249.6656	7254.0885	7288.1599	7249.6656	7254.0885
Minimum Deviation	-54500.77	-54794.61	-54657.26	-54545.35	-54377.43	-54657.26	-54545.35	-54377.43	-54657.26	-54545.35	-54377.43
Maximum Deviation	50300.392	51258.186	50025	50111.932	50387.307	50025	50111.932	50387.307	50025	50111.932	50387.307
Median Deviation	-4293.201	-4377.075	-4362.185	-4112.421	-3962.296	-4362.185	-4112.421	-3962.296	-4362.185	-4112.421	-3962.296
Profitable Deviations	31	31	13	17	23	13	17	23	13	17	23
Sample Size	1253	1253	1253	1253	1253	1253	1253	1253	1253	1253	1253
% Deviations	2.474	2.474	1.038	1.357	1.836	1.038	1.357	1.836	1.038	1.357	1.836

Panel C: 3 minute window

Mean	-6353.982	-6522.539	-6830.43	-6493.447	-6255.494	-6776.35	-6483.281	-6231.605	-6769.224	-6588.739	-6252.486
Standard Deviation	12569.027	6958.254	6960.9208	6883.9647	6879.5986	6911.6654	6871.4995	6876.6309	6897.0366	8092.5334	6886.9409
Minimum Deviation	-58458	-57430.72	-57755.54	-57416.55	-56873.69	-57755.54	-57416.55	-56873.69	-58432.83	-233645.8	-57755.54
Maximum Deviation	549375.55	13911.392	13627.945	14200.889	14446.638	13690.874	13967.855	14257.59	13690.874	13967.855	14257.59
Median Deviation	-4619.579	-4618.675	-4779.937	-4472.715	-4232.209	-4691.446	-4483.074	-4185.542	-4674.94	-4515.126	-4180.144
Profitable Deviations	65	55	34	38	49	33	34	46	33	37	46
Sample Size	2828	2828	2828	2828	2828	2828	2828	2828	2828	2828	2828
% Deviations	2.298	1.945	1.202	1.344	1.733	1.167	1.202	1.627	1.167	1.308	1.627

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100).

Table A2. (continued) Full Deviation Results for American Reversal Strategy by Window size.

Panel D: 5 minute window

Mean	-6317.953	-6262.872	-6637.52	-6312.058	-6045.508	-6656.895	-6296.497	-6031.335	-6587.032	-6292.868	-6039.7
Standard Deviation	7180.3397	7180.1942	6944.5509	6906.5034	6910.8476	6990.9072	6915.1143	6926.2666	6903.4926	6907.4956	6934.0062
Minimum Deviation	-57670.38	-57817.52	-58005.02	-57855.89	-57507.76	-58005.02	-57663.21	-57569.95	-57694.29	-57613.47	-57383.37
Maximum Deviation	12496.415	12496.415	5565.3184	5835.8313	6106.4935	6046.3335	6046.3335	6046.3335	5986.1808	5986.1808	5986.1808
Median Deviation	-4293.201	-4134.029	-4508.55	-4177.746	-3973.465	-4379.332	-4177.746	-3869.879	-4386.306	-4073.714	-3957.998
Profitable Deviations	46	32	12	28	29	28	28	37	12	28	28
Sample Size	1461	1461	1461	1461	1461	1461	1461	1461	1461	1461	1461
% Deviations	3.149	2.190	0.821	1.916	1.985	1.916	1.916	2.533	0.821	1.916	1.916

Panel E: 7 minute window

Mean	-5249.412	-5248.162	-5645.332	-5340.067	-5043.686	-5620.354	-5340.638	-5077.884	-5629.425	-5298.683	-5019.511
Standard Deviation	5939.9331	5959.2813	5526.8641	5509.7413	5528.1437	5505.0243	5513.2572	5520.6004	5516.8957	5492.4986	5518.228
Minimum Deviation	-56279.11	-55106.08	-57076.39	-55127.61	-55046.25	-55385.18	-54958.09	-54842.78	-56400.59	-56035.28	-55046.25
Maximum Deviation	12656.415	12656.415	10723.086	10839.032	11028.266	10540.069	10723.086	10967.215	10784.107	11028.266	11150.39
Median Deviation	-3572.327	-3554.809	-3932.694	-3567.543	-3215.846	-3732.748	-3439.107	-3181.035	-3732.748	-3378.238	-3169.064
Profitable Deviations	40	30	8	14	22	11	17	17	7	19	23
Sample Size	1064	1064	1064	1064	1064	1064	1064	1064	1064	1064	1064
% Deviations	3.759	2.820	0.752	1.316	2.068	1.034	1.598	1.598	0.658	1.786	2.162

Panel F: 9 minute window

Mean	-4896.538	-4787.164	-5314.507	-4995.476	-4706.158	-5231.68	-4936.594	-4651.102	-5219.15	-4935.815	-4676.922
Standard Deviation	4413.0039	6227.5468	4125.5709	4086.6792	4095.2886	4133.6179	4134.4826	4156.6101	4141.0412	4130.4368	4147.7856
Minimum Deviation	-24769.12	-24350.65	-24493	-24335.82	-24335.82	-24493	-24226.68	-24123.35	-24697.08	-24404.57	-24238.15
Maximum Deviation	12816.415	116782.66	188.34107	438.84491	1708.5046	2134.9912	2189.852	2561.8465	872.64276	982.76486	1067.6168
Median Deviation	-3853.342	-3999.881	-3981.274	-3807.754	-3561.565	-3970.608	-3749.422	-3352.162	-3898.365	-3673.786	-3431.916
Profitable Deviations	25	29	6	18	20	11	11	24	5	12	13
Sample Size	746	746	746	746	746	746	746	746	746	746	746
% Deviations	3.351	3.887	0.804	2.413	2.681	1.475	1.475	3.217	0.670	1.609	1.743

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

Table A3. Full Deviation Results for American Conversion Strategy by Window size.

Panel A: Full Sample

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-9979.385	-9933.052	-9608.975	-9841.175	-10095.24	-9594.999	-9852.821	-10104.63	-9584.824	-9840.573	-10097.75
Standard Deviation	11362.892	9468.962	9722.2202	9721.6746	9716.4617	10066.497	9712.2167	9714.2579	10002.112	9719.3474	9705.4302
Minimum Deviation	-561973.4	-122705.2	-73337.23	-75466.61	-75555.51	-75185.17	-75651.84	-75777.84	-74445.24	-74652.32	-75555.51
Maximum Deviation	1642.2557	4291.1529	10934.421	10934.421	10934.421	218255.72	10901.761	21034.052	198681.87	23973.918	11065.041
Median Deviation	-7889.971	-7938.212	-7494.697	-7745.166	-7912.927	-7494.773	-7734.969	-7925.971	-7500.534	-7669.164	-7922.46
Profitable Deviations	46	52	94	57	35	71	49	34	79	66	38
Sample Size	7352	7352	7352	7352	7352	7352	7352	7352	7352	7352	7352
% Deviations	0.626	0.707	1.279	0.775	0.476	0.966	0.666	0.462	1.075	0.898	0.517

Panel B: 1 minute window

Mean	-10501.83	-10511.91	-10194.59	-10400.15	-10622.19	-10194.59	-10400.15	-10622.19	-10194.59	-10377.64	-10622.19
Standard Deviation	9780.7121	9797.6656	9781.962	9795.5509	9791.0139	9781.962	9795.5509	9791.0139	9781.962	9842.0323	9791.0139
Minimum Deviation	-70236.91	-70236.91	-68980.16	-69129.32	-69183.57	-68980.16	-69129.32	-69183.57	-68980.16	-69129.32	-69183.57
Maximum Deviation	1008.1608	1008.1608	9206.4704	9194.0557	9020.218	9206.4704	9194.0557	9020.218	9206.4704	23973.918	9020.218
Median Deviation	-8333.359	-8333.359	-8289.933	-8564.173	-8586.561	-8289.933	-8564.173	-8586.561	-8289.933	-8564.173	-8586.561
Profitable Deviations	4	5	13	10	2	13	10	2	13	11	2
Sample Size	1253	1253	1253	1253	1253	1253	1253	1253	1253	1253	1253
% Deviations	0.319	0.399	1.038	0.798	0.160	1.038	0.798	0.160	1.038	0.878	0.160

Panel C: 3 minute window

Mean	-10515.37	-10332.56	-10075.43	-10295.01	-10535.9	-10088.29	-10302.28	-10546.79	-9981.662	-10274.21	-10532.42
Standard Deviation	14262.967	9808.1951	10238.939	10240.121	10241.284	10220.478	10228.04	10238.946	10938.137	10227.35	10219.749
Minimum Deviation	-561973.4	-71578.65	-71323.93	-71612.58	-72064.36	-71323.93	-71612.58	-72064.36	-70584.51	-70776.66	-71357.37
Maximum Deviation	1002.2557	2366.5716	9046.4704	9034.0557	8860.218	9294.6986	8841.589	21034.052	198681.87	8841.589	8736.0111
Median Deviation	-8064.893	-8114.461	-7788.592	-7852.965	-8070.484	-7711.671	-7850.525	-8086.935	-7743.579	-7956.502	-8140.742
Profitable Deviations	16	21	44	23	20	34	21	16	36	29	15
Sample Size	2828	2828	2828	2828	2828	2828	2828	2828	2828	2828	2828
% Deviations	0.566	0.743	1.556	0.813	0.707	1.202	0.743	0.566	1.273	1.025	0.530

Note: See Figure 3 (page 32) for explanation of different exchange rate measures Profitable deviations are defined as all deviations which are greater than zero % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

Table A3 (continued). Full Deviation Results for American Conversion Strategy by Window size.

Panel D: 5 minute window

Mean	-10273.19	-10299.15	-9995.788	-10234.86	-10496.05	-10013.92	-10244.82	-10508.05	-10005.36	-10239.91	-10488.31
Standard Deviation	9924.6734	9916.976	10605.306	10588.888	10587.611	10583.005	10585.873	10585.362	10589.017	10579.191	10572.038
Minimum Deviation	-66725.68	-67045.68	-68021.6	-68163.99	-68360.14	-68163.99	-68267.52	-68520.14	-68360.14	-68609.59	-68716.53
Maximum Deviation	1171.3662	4291.1529	10934.421	10934.421	10934.421	10934.421	10901.761	10869.098	11065.041	10803.767	10542.36
Median Deviation	-8205.245	-8233.204	-7990.125	-8202.138	-8501.86	-8037.277	-8230.132	-8322.147	-7891.147	-8251.472	-8490.536
Profitable Deviations	11	11	15	9	6	10	8	6	10	8	7
Sample Size	1461	1461	1461	1461	1461	1461	1461	1461	1461	1461	1461
% Deviations	0.753	0.753	1.027	0.616	0.411	0.684	0.548	0.411	0.684	0.548	0.479

Panel E: 7 minute window

Mean	-8795.648	-8818.205	-8406.666	-8679.05	-8969.746	-8422.104	-8677.72	-8942.99	-8436.137	-8712.621	-8989.627
Standard Deviation	8290.5856	8290.1209	8516.6399	8527.1909	8513.7547	8527.5461	8512.7657	8521.6318	8528.2981	8550.6787	8553.4976
Minimum Deviation	-74109.8	-75549.8	-73337.23	-75466.61	-75555.51	-75185.17	-75651.84	-75777.84	-74445.24	-74652.32	-75555.51
Maximum Deviation	1642.2557	1086.5716	10934.421	10934.421	10934.421	10934.421	10901.761	10869.098	11195.628	11130.339	11065.041
Median Deviation	-6146.382	-6268.525	-5914.931	-6168.416	-6568.542	-5803.826	-6080.522	-6401.926	-5865.807	-6081.006	-6372.927
Profitable Deviations	9	11	14	11	5	11	8	8	11	11	7
Sample Size	1064	1064	1064	1064	1064	1064	1064	1064	1064	1064	1064
% Deviations	0.846	1.034	1.316	1.034	0.470	1.034	0.752	0.752	1.034	1.034	0.658

Panel F: 9 minute window

Mean	-8182.965	-8319.372	-7814.373	-8068.376	-8360.005	-7570.35	-8137.977	-8425.848	-7871.04	-8121.331	-8384.722
Standard Deviation	6574.5929	7856.2581	6568.2102	6574.306	6557.751	10559.434	6558.9951	6538.1433	6512.3515	6516.2572	6512.4733
Minimum Deviation	-39277.11	-122705.2	-37582.39	-37908.06	-37952.49	-37952.49	-38182.07	-38322.83	-39064.27	-39064.27	-39064.27
Maximum Deviation	1014.0328	1322.9501	1291.836	1291.836	1291.836	218255.72	1612.7092	1291.836	1061.9995	684.22706	561.86899
Median Deviation	-6894.86	-6792.069	-6279.607	-6446.169	-6676.052	-6345.745	-6585.471	-6823.265	-6486.397	-6820.185	-6997.44
Profitable Deviations	6	4	8	4	2	3	2	2	9	7	7
Sample Size	746	746	746	746	746	746	746	746	746	746	746
% Deviations	0.804	0.536	1.072	0.536	0.268	0.402	0.268	0.268	1.206	0.938	0.938

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100).

Table A4. Full Deviation Results for European Reversal Strategy by Window size

Panel A:Full Sample

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-2992.548	-2970.415	-3154.785	-2940.017	-2728.088	-3151.11	-2900.973	-2694.203	-3221.082	-2943.298	-2741.723
Standard Deviation	2155.9445	2188.6847	2172.5353	2090.7678	2061.4455	2154.9907	2055.4828	2047.2252	2203.5877	2062.6886	2030.6436
Minimum Deviation	-12664.89	-12664.89	-12634.32	-12407.58	-12191.79	-12634.32	-12407.58	-12191.79	-12634.32	-12407.58	-12191.79
Maximum Deviation	4360.1784	4360.1784	954.52205	1242.1828	1515.9568	954.52205	1331.7826	1787.0793	876.90649	1331.7826	1787.0793
Median Deviation	-2630.345	-2403.447	-2634.208	-2378.574	-2075.813	-2643.813	-2464.235	-2075.813	-2682.417	-2543.569	-2328.034
Profitable Deviations	19	18	8	9	17	5	9	16	4	16	22
Sample size	616	616	616	616	616	616	616	616	616	616	616
% Deviations	3.084	2.922	1.299	1.461	2.760	0.812	1.461	2.597	0.649	2.597	3.571

Panel B: 1 minute window

Mean	-3272.306	-3308.281	-3419.852	-3132.61	-2949.801	-3419.852	-3132.61	-2949.801	-3419.852	-3132.61	-2949.801
Standard Deviation	2386.3638	2393.5163	2491.1985	2298.2206	2294.019	2491.1985	2298.2206	2294.019	2491.1985	2298.2206	2294.019
Minimum Deviation	-12664.89	-12664.89	-12634.32	-12407.58	-12191.79	-12634.32	-12407.58	-12191.79	-12634.32	-12407.58	-12191.79
Maximum Deviation	355.33184	514.59355	391.72674	820.02851	1046.2287	391.72674	820.02851	1046.2287	391.72674	820.02851	1046.2287
Median Deviation	-2829.186	-2755.884	-2739.57	-2643.813	-2643.813	-2739.57	-2643.813	-2643.813	-2739.57	-2643.813	-2643.813
Profitable Deviations	3	3	1	1	5	1	1	5	1	1	5
Sample size	158	158	158	158	158	158	158	158	158	158	158
% Deviations	1.899	1.899	0.633	0.633	3.165	0.633	0.633	3.165	0.633	0.633	3.165

Panel C: 3 minute window

Mean	-2560.816	-2540.97	-2722.547	-2513.039	-2287.026	-2732.992	-2521.689	-2313.38	-2712.317	-2487.071	-2324.646
Standard Deviation	1990.2559	1971.657	1959.1562	1912.6337	1882.3306	1910.007	1868.7915	1861.2895	1968.2241	1903.1983	1894.2361
Minimum Deviation	-10572.22	-10572.22	-10383.3	-10383.3	-10383.3	-10383.3	-10383.3	-10383.3	-10491.31	-10491.31	-10491.31
Maximum Deviation	4360.1784	4360.1784	876.90649	1119.4548	1180.1105	876.90649	1331.7826	1787.0793	876.90649	1331.7826	1787.0793
Median Deviation	-2218.102	-2168.947	-2341.584	-2072.055	-1888.329	-2278.866	-2020.94	-1868.957	-2234.545	-2075.095	-1895.199
Profitable Deviations	10	10	5	5	9	1	5	8	1	11	13
Sample size	200	200	200	200	200	200	200	200	200	200	200
% Deviations	5.000	5.000	2.500	2.500	4.500	0.500	2.500	4.000	0.500	5.500	6.500

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

Table A4 (continued). Full Deviation Results for European Reversal Strategy by Window size

Panel D: 5 minute window

Mean	-3182.636	-3217.961	-3452.044	-3283.347	-3022.962	-3422.375	-3116.565	-2944.826	-3631.598	-3256.39	-3013.975
Standard Deviation	2267.8111	2318.8488	2165.2529	2128.3311	2042.8881	2268.5605	2140.8209	2123.3895	2358.3826	2161.4695	2053.8583
Minimum Deviation	-7232.876	-7540.297	-7231.827	-6959.679	-6730.392	-7446.581	-6830.717	-6730.392	-7088.609	-6895.202	-6730.392
Maximum Deviation	2116.6631	2116.6631	954.52205	1242.1828	1515.9568	954.52205	1143.9395	1305.3488	603.92829	730.11522	1164.9901
Median Deviation	-2675.784	-2516.696	-2888.683	-2645.436	-2408.625	-2888.683	-2668.342	-2328.207	-2864.632	-2604.505	-2359.823
Profitable Deviations	5	4	1	2	2	3	3	3	2	4	4
Sample size	130	130	130	130	130	130	130	130	130	130	130
% Deviations	3.846	3.077	0.769	1.538	1.538	2.308	2.308	2.308	1.538	3.077	3.077

Panel E: 7 minute window

Mean	-3083.308	-3126.208	-3348.742	-3176.463	-3019.178	-3304.041	-3111.779	-2840.804	-3317.169	-3082.864	-2894.781
Standard Deviation	2015.0359	2090.0066	2037.9155	2013.5603	1996.4698	1939.7334	1928.7984	1930.6249	1964.6612	1869.2121	1859.6221
Minimum Deviation	-7134.799	-7444.036	-7303.189	-7290.814	-7241.311	-7303.189	-6838.914	-6684.058	-6684.058	-6684.058	-6684.058
Maximum Deviation	2785.0902	2785.0902	-516.4179	-516.4179	-516.4179	-940.0614	-717.6188	-387.0255	-516.4179	-466.9467	-305.3923
Median Deviation	-2734.903	-2388.262	-2765.008	-2378.574	-2378.574	-2986.072	-2858.56	-2074.545	-2682.417	-2530.519	-2378.574
Profitable Deviations	1	1	0	0	0	0	0	0	0	0	0
Sample size	92	92	92	92	92	92	92	92	92	92	92
% Deviations	1.087	1.087	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Panel F: 9 minute window

Mean	-3244.867	-2581.303	-2823.658	-2622.794	-2396.633	-2924.119	-2674.225	-2408.419	-3447.198	-3159.753	-2771.312
Standard Deviation	1566.7625	1783.3286	1808.5769	1784.2691	1783.7317	1599.0828	1648.8543	1591.8109	1600.9152	1534.6484	1543.5762
Minimum Deviation	-6361.706	-7134.799	-7117.532	-6962.764	-6807.947	-6498.165	-6498.165	-6498.165	-6188.188	-5958.678	-5878.014
Maximum Deviation	-530.9484	-7.670509	9.7673747	9.7673747	9.7673747	-549.2818	-299.6908	-105.4728	-557.1657	-516.495	-105.4728
Median Deviation	-3692.493	-1612.974	-1819.83	-1696.926	-1451.027	-2311.141	-1961.132	-1758.382	-3965.726	-3610.763	-2924.595
Profitable Deviations	0	0	1	1	1	0	0	0	0	0	0
Sample size	36	36	36	36	36	36	36	36	36	36	36
% Deviations	0.000	0.000	2.778	2.778	2.778	0.000	0.000	0.000	0.000	0.000	0.000

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

Table A5. Full Deviation Results for European Conversion Strategy by Window size

Panel A:Full Sample

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-542.4656	-549.3051	-406.8001	-590.152	-784.909	-403.8197	-605.5398	-807.7667	-413.8371	-599.3598	-764.7136
Standard Deviation	1832.5473	1854.7765	1782.6938	1753.0513	1731.2566	1765.9003	1735.2413	1732.5226	1743.0523	1711.5344	1715.0939
Minimum Deviation	-7746.918	-7746.918	-4300.439	-4567.352	-5003.133	-4412.801	-4763.95	-5032.637	-4619.331	-4619.331	-5021.198
Maximum Deviation	7753.244	7753.244	7629.4961	7468.8046	7296.9675	7629.4961	7468.8046	7296.9675	7629.4961	7468.8046	7296.9675
Median Deviation	-706.2789	-844.5122	-754.656	-849.5438	-1097.295	-738.5973	-798.9759	-1041.208	-654.4104	-756.2359	-926.1658
Profitable Deviations	214	206	220	194	193	235	194	194	231	206	194
Sample size	616	616	616	616	616	616	616	616	616	616	616
% Deviations	34.740	33.442	35.714	31.494	31.331	38.149	31.494	31.494	37.500	33.442	31.494

Panel B: 1 minute window

Mean	-326.1552	-291.1123	-247.3409	-437.6804	-607.5839	-247.3409	-437.6804	-607.5839	-247.3409	-437.6804	-607.5839
Standard Deviation	2007.6422	2010.825	1955.1272	1932.1929	1914.172	1955.1272	1932.1929	1914.172	1955.1272	1932.1929	1914.172
Minimum Deviation	-4113.453	-4113.453	-3453.279	-4179.739	-4406.234	-3453.279	-4179.739	-4406.234	-3453.279	-4179.739	-4406.234
Maximum Deviation	7753.244	7753.244	7629.4961	7468.8046	7296.9675	7629.4961	7468.8046	7296.9675	7629.4961	7468.8046	7296.9675
Median Deviation	-564.9601	-512.9959	-555.1964	-622.4095	-756.2359	-555.1964	-622.4095	-756.2359	-555.1964	-622.4095	-756.2359
Profitable Deviations	59	60	64	53	53	64	53	53	64	53	53
Sample size	158	158	158	158	158	158	158	158	158	158	158
% Deviations	37.342	37.975	40.506	33.544	33.544	40.506	33.544	33.544	40.506	33.544	33.544

Panel C: 3 minute window

Mean	-900.5014	-881.3411	-749.0356	-932.1731	-1137.147	-738.5371	-925.5682	-1110.982	-771.4678	-958.8944	-1110.427
Standard Deviation	1725.3653	1698.5637	1640.1321	1603.4963	1588.7863	1625.2431	1590.9316	1596.8069	1647.3261	1608.5109	1622.6319
Minimum Deviation	-7746.918	-7746.918	-4109.893	-4283.95	-4552.637	-4109.893	-4565.335	-5021.198	-4139.331	-4565.335	-5021.198
Maximum Deviation	5500.6201	5797.9878	5527.6013	5527.6013	5527.6013	5527.6013	5527.6013	5527.6013	5473.4847	5473.4847	5473.4847
Median Deviation	-1004.363	-975.5301	-871.2668	-1156.665	-1320.812	-872.1656	-1111.645	-1298.872	-890.9357	-1067.037	-1298.546
Profitable Deviations	48	49	57	46	46	59	46	46	56	46	46
Sample size	200	200	200	200	200	200	200	200	200	200	200
% Deviations	24.000	24.500	28.500	23.000	23.000	29.500	23.000	23.000	28.000	23.000	23.000

Note: See Figure 3 (page 32) for explanation of different exchange rate measures Profitable deviations are defined as all deviations which are greater than zero % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100).

Table A5 (continued). Full Deviation Results for European Conversion Strategy by Window size

Panel D: 5 minute window

Mean	-439.293	-380.4426	-158.0206	-343.6667	-575.1966	-185.7528	-428.1966	-621.1234	-214.1829	-408.6457	-555.5412
Standard Deviation	1942.8998	1984.0347	1854.0228	1803.5101	1738.8251	1886.7026	1828.4576	1820.1868	1803.0771	1762.5569	1755.0729
Minimum Deviation	-5864.487	-5864.487	-4300.439	-4567.352	-5003.133	-4412.801	-4763.95	-5032.637	-4619.331	-4619.331	-4651.669
Maximum Deviation	2789.6085	3097.1892	3085.6161	2800.4979	2619.7698	3055.8144	2682.8151	2433.5592	2697.1662	2517.7502	2433.5592
Median Deviation	-704.581	-746.5832	-540.1263	-711.5912	-896.2554	-428.0642	-703.8088	-849.5438	-473.3297	-680.5119	-930.7286
Profitable Deviations	52	54	54	52	51	58	52	52	53	52	52
Sample size	130	130	130	130	130	130	130	130	130	130	130
% Deviations	40.000	41.538	41.538	40.000	39.231	44.615	40.000	40.000	40.769	40.000	40.000

Panel E: 7 minute window

Mean	-425.3871	-420.7219	-233.8059	-399.8138	-537.5408	-232.4248	-421.2131	-687.5639	-370.6863	-508.955	-657.1369
Standard Deviation	1654.2752	1758.6921	1709.2888	1692.1634	1680.2571	1611.4677	1607.9178	1644.4366	1502.9917	1493.49	1554.1551
Minimum Deviation	-5789.403	-5789.403	-2764.17	-2764.17	-2764.17	-2348.458	-2682.045	-3414.779	-2594.444	-2687.856	-3414.779
Maximum Deviation	3072.1529	3381.5276	3239.961	3227.5648	3177.9772	3673.6278	2849.3321	2743.8709	2619.7698	2619.7698	2619.7698
Median Deviation	-703.5793	-844.5122	-849.5438	-849.5438	-1020.131	-232.203	-592.3132	-849.5438	-545.3244	-613.3018	-920.8945
Profitable Deviations	34	34	36	34	34	45	34	34	37	34	34
Sample size	92	92	92	92	92	92	92	92	92	92	92
% Deviations	36.957	36.957	39.130	36.957	36.957	48.913	36.957	36.957	40.217	36.957	36.957

Panel F: 9 minute window

Mean	-174.5084	-776.2226	-545.807	-735.7217	-995.7513	-456.5195	-675.7833	-982.992	11.019533	-231.263	-563.9712
Standard Deviation	1347.6209	1491.3436	1422.0887	1443.9796	1474.0402	1323.1419	1342.7425	1289.4111	1326.4797	1270.1738	1272.5201
Minimum Deviation	-2619.282	-3242.774	-3397.404	-3397.404	-3397.404	-2783.125	-2783.125	-2939.871	-2440.275	-2556.8	-3050.964
Maximum Deviation	2453.4035	3072.1529	3053.9861	2923.7616	2743.8709	2433.5592	2433.5592	2433.5592	2123.0509	1893.1481	1812.3458
Median Deviation	439.36248	-1320.237	-1223.751	-1408.279	-1715.979	-793.4529	-1100.771	-1408.279	740.28413	391.00988	-179.3881
Profitable Deviations	21	9	9	9	9	9	9	9	21	21	9
Sample size	36	36	36	36	36	36	36	36	36	36	36
% Deviations	58.333	25.000	25.000	25.000	25.000	25.000	25.000	25.000	58.333	58.333	25.000

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

Table A6. Full Deviation Results for American Reversal Strategy by Maturity

Panel A: Maturities of less than 30 days

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-2337.769	-2436.962	-2847.501	-2567.71	-2304.459	-2829.449	-2552.413	-2291.071	-2834.043	-2559.677	-2298.073
Standard Deviation	9104.949	2966.8368	1855.4377	1800.2321	1791.246	1850.6034	1806.4521	1801.8605	1864.2434	1809.2073	1813.3662
Minimum Deviation	-22660.02	-21432.34	-21870.18	-21334.16	-20950.96	-21870.18	-21334.16	-20950.96	-22635	-21219.23	-21104.27
Maximum Deviation	549375.55	116782.66	50025	50111.932	50387.307	50025	50111.932	50387.307	50025	50111.932	50387.307
Median Deviation	-2510.559	-2411.83	-2750.485	-2465.595	-2169.73	-2766.877	-2466.68	-2147.727	-2720.796	-2462.587	-2154.399
Profitable Deviations	191	164	70	112	140	93	104	144	67	110	128
Sample Size	3924	3924	3924	3924	3924	3924	3924	3924	3924	3924	3924
% Deviations	4.867	4.179	1.784	2.854	3.568	2.370	2.650	3.670	1.707	2.803	3.262

Panel B: Maturities between 31 and 60 days

Mean	-6272.91	-6278.509	-6614.835	-6216.107	-5967.475	-6547.054	-6189.259	-5940.101	-6493.514	-6304.799	-5939.575
Standard Deviation	1961.7781	1918.767	2331.5484	1881.7166	1847.6395	2264.4831	1886.9142	1861.4466	2158.296	5424.169	1869.0201
Minimum Deviation	-22660.02	-21432.34	-21870.18	-21334.16	-20950.96	-21870.18	-21334.16	-20950.96	-22635	-233645.8	-21104.27
Maximum Deviation	13911.392	13911.392	13690.874	14200.889	14446.638	13690.874	13967.855	14257.59	13690.874	13967.855	14257.59
Median Deviation	-6178.995	-6177.96	-6383.856	-6090.613	-5777.856	-6365.823	-6090.613	-5693.115	-6404.832	-6090.613	-5822.769
Profitable Deviations	12	9	3	3	3	3	3	3	3	3	5
Sample Size	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001
% Deviations	0.600	0.450	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.250

Panel C: Maturities between 61 and 90 days

Mean	-10481.78	-10363.62	-10894.1	-10572.64	-10329.22	-10897.24	-10601.11	-10348.43	-10889.88	-10603.99	-10347.6
Standard Deviation	2516.2607	2526.9294	3231.4968	3153.7615	3163.4488	3148.1898	3076.5538	3113.0584	3069.8619	3087.8837	3127.6211
Minimum Deviation	-22660.02	-21432.34	-35427.9	-34960.71	-34365.51	-34365.51	-34216.6	-33868.99	-34365.51	-34216.6	-33868.99
Maximum Deviation	4814.4658	4814.4658	-6088.806	-5756.484	-5305.663	-6450.102	-5874.374	-5540.747	-5358.673	-5231.181	-4933.57
Median Deviation	-10375.31	-10353.14	-10696.96	-10410.8	-10139.08	-10708.2	-10409.28	-10225.09	-10700.51	-10465.03	-10274.9
Profitable Deviations	4	4	0	0	0	0	0	0	0	0	0
Sample Size	888	888	888	888	888	888	888	888	888	888	888
% Deviations	0.450	0.450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

Table A6 (continued). Full Deviation Results for American Reversal Strategy by Maturity

Panel D: Maturities between 91 and 120 days

Mean	-14364.23	-14343.31	-15070.12	-14727.37	-14490.03	-15048.8	-14725.35	-14440.78	-14963.61	-14658.73	-14407.42
Standard Deviation	3369.267	3271.4355	2768.4025	2624.3353	2612.6471	2778.7909	2644.1021	2672.556	2764.399	2712.9388	2729.291
Minimum Deviation	-22660.02	-21432.34	-21870.18	-21334.16	-20950.96	-21870.18	-21334.16	-20950.96	-22635	-21219.23	-21104.27
Maximum Deviation	-6294.586	-6294.586	-8142.898	-8103.015	-7857.943	-8367.316	-8293.404	-7800.932	-8541.547	-7983.344	-7857.943
Median Deviation	-14436.18	-14394.64	-14930.57	-14829.63	-14447.17	-14908.27	-14732.43	-14436.41	-14885.97	-14732.43	-14362.51
Profitable Deviations	0	0	0	0	0	0	0	0	0	0	0
Sample Size	124	124	124	124	124	124	124	124	124	124	124
% Deviations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Panel E : Maturities between 121 and 180 days

Mean	-21832.38	-21847.56	-22848.14	-22614.55	-22373.6	-22840.87	-22592.58	-22387.19	-22790.06	-22548.8	-22374.72
Standard Deviation	3763.2259	3737.3647	5497.7728	5508.6363	5511.2493	5507.7541	5516.4868	5519.9968	5455.4925	5491.3313	5531.0748
Minimum Deviation	-31828.37	-31849.88	-37665.78	-37529.38	-37188.22	-37665.78	-37529.38	-37324.71	-37665.78	-37495.27	-37324.71
Maximum Deviation	-13485.3	-13056.01	-10127.49	-9978.115	-9652.058	-10195.37	-10066.39	-9991.697	-10195.37	-10066.39	-9991.697
Median Deviation	-21311.38	-21498.7	-21748.16	-21297.83	-21207.4	-21680.59	-21292.65	-21072.12	-21680.59	-21261.5	-21072.12
Profitable Deviations	0	0	0	0	0	0	0	0	0	0	0
Sample Size	258	258	258	258	258	258	258	258	258	258	258
% Deviations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Panel F: Maturities of more than 180 days

Mean	-36647.98	-36647.75	-33657.2	-33417.44	-33183.83	-33627.56	-33414.9	-33183.2	-33635.07	-33442.29	-33250.24
Standard Deviation	6921.4479	6852.893	8979.4301	8936.0601	8962.5175	8940.212	8910.9046	8930.1809	8939.1711	8955.678	8936.7636
Minimum Deviation	-58458	-57817.52	-58005.02	-57855.89	-57507.76	-58005.02	-57663.21	-57569.95	-58432.83	-58006.25	-57755.54
Maximum Deviation	-22660.02	-21432.34	-21870.18	-21334.16	-20950.96	-21870.18	-21334.16	-20950.96	-22076.72	-21219.23	-21104.27
Median Deviation	-36702.9	-36542.9	-34921.96	-34921.96	-34921.96	-34921.96	-34921.96	-34921.96	-34978.56	-34893.65	-34808.73
Profitable Deviations	0	0	0	0	0	0	0	0	0	0	0
Sample Size	162	162	162	162	162	162	162	162	162	162	162
% Deviations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

Table A7. Full Deviation Results for American Conversion Strategy by Maturity

Panel A: Maturities of less than 30 days

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-4497.211	-4388.967	-3945.231	-4186.319	-4450.585	-3965.757	-4201.86	-4464.833	-3962.128	-4186.439	-4450.567
Standard Deviation	9367.9416	3483.7741	2693.8557	2699.557	2697.0167	2694.846	2703.3977	2700.0707	2702.6718	2733.3767	2692.3108
Minimum Deviation	-561973.4	-122705.2	-56649.48	-56736.73	-57013.11	-56649.48	-56736.73	-57013.11	-56649.48	-56736.73	-57013.11
Maximum Deviation	1642.2557	4291.1529	10934.421	10934.421	10934.421	10934.421	10901.761	10869.098	11195.628	23973.918	11065.041
Median Deviation	-3815.97	-3818.886	-3412.639	-3679.221	-4007.359	-3434.68	-3649.081	-3947.597	-3388.005	-3611.19	-3942.476
Profitable Deviations	46	52	85	48	26	61	40	24	69	57	29
Sample Size	3923	3923	3923	3923	3923	3923	3923	3923	3923	3923	3923
% Deviations	1.173	1.326	2.167	1.224	0.663	1.555	1.020	0.612	1.759	1.453	0.739

Panel B: Maturities between 31 and 60 days

Mean	-10655.31	-10646.03	-10517.44	-10725.06	-10958.51	-10437.57	-10748.2	-10976.17	-10543.12	-10734.11	-10984.27
Standard Deviation	2424.3271	2438.1069	2371.7453	2390.7772	2419.1335	5631.2706	2370.343	2496.3504	2321.7362	2327.765	2349.4723
Minimum Deviation	-29356.1	-29356.1	-29385.4	-29779.68	-29894.2	-29321.84	-29468.04	-29703.34	-29321.84	-29468.04	-29703.34
Maximum Deviation	-3893.101	-3398.195	-5223.685	-5241.167	-5515.143	218255.72	-5417.803	21034.052	-5325.06	-5649.739	-5788.954
Median Deviation	-10477.96	-10618.71	-10443.59	-10793.41	-11015.5	-10433.08	-10712.74	-10999.32	-10461.11	-10713.31	-10987.99
Profitable Deviations	0	0	0	0	0	1	0	1	0	0	0
Sample Size	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
% Deviations	0.000	0.000	0.000	0.000	0.000	0.050	0.000	0.050	0.000	0.000	0.000

Panel C: Maturities between 61 and 90 days

Mean	-16932.07	-17039.21	-16456.1	-16701.93	-16964.36	-16429.32	-16672.68	-16933.94	-16374.07	-16663.09	-16932.11
Standard Deviation	2430.9558	2389.0524	3312.8163	3316.7355	3305.7406	3271.4451	3286.0198	3271.5314	3260.9312	3299.1146	3312.34
Minimum Deviation	-30688.07	-30688.07	-24043.76	-24209	-24361.58	-24043.76	-24209	-24361.58	-24043.76	-24209	-24361.58
Maximum Deviation	-11381.58	-11701.58	8115.4525	7625.4897	7034.057	7394.7642	7106.2178	6528.6598	7394.7642	7106.2178	6528.6598
Median Deviation	-17155.71	-17195.03	-16930.93	-17125.99	-17445.38	-16781.68	-17075.52	-17354.6	-16904.77	-17109.1	-17389.9
Profitable Deviations	0	0	9	9	9	9	9	9	9	9	9
Sample Size	887	887	887	887	887	887	887	887	887	887	887
% Deviations	0.000	0.000	1.015	1.015	1.015	1.015	1.015	1.015	1.015	1.015	1.015

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

Table A7 (continued). Full Deviation Results for American Conversion Strategy by Maturity

Panel D: Maturities between 91 and 120 days

Mean	-24171.42	-24210.44	-23488.37	-23737.22	-23968.65	-23520.72	-23746.87	-24043.04	-23529.37	-23768.98	-24060.14
Standard Deviation	4118.1464	4133.7376	4191.2295	4250.612	4255.7393	4166.7898	4212.3901	4203.4606	4248.7781	4207.9639	4219.9731
Minimum Deviation	-31492.1	-31492.1	-31489.19	-31784.65	-31911.33	-31609.76	-31682.12	-31911.33	-31428.91	-31561.53	-31609.76
Maximum Deviation	-14244.39	-14884.39	-14479.28	-14600.89	-14722.54	-14418.48	-14448.88	-14479.28	-13264.75	-14066	-14296.91
Median Deviation	-24841.5	-25360.42	-24458.27	-24617.33	-24859.84	-24556.68	-24741.07	-24859.84	-24556.68	-24746.96	-24866.75
Profitable Deviations	0	0	0	0	0	0	0	0	0	0	0
Sample Size	123	123	123	123	123	123	123	123	123	123	123
% Deviations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Panel E: Maturities between 121 and 180 days

Mean	-32750.78	-32737.14	-31681.25	-31928.72	-32185.81	-31672.03	-31945.31	-32167.89	-30815.71	-31981.33	-32155.11
Standard Deviation	4998.3076	4998.9547	6067.7159	6074.9577	6046.0252	6009.8221	6033.157	6039.4862	15553.592	6048.3439	6048.4114
Minimum Deviation	-44402.19	-44402.19	-47360.98	-47516.26	-47855.22	-47149.3	-47255.13	-47290.41	-47149.3	-47255.13	-47290.41
Maximum Deviation	-18374.47	-18374.47	-18464.19	-18531.16	-18933.18	-18330.27	-18444.1	-18598.14	198681.87	-18444.1	-18598.14
Median Deviation	-33095.28	-33137.99	-32523.38	-32983.78	-33182.61	-32523.38	-32983.78	-33112.9	-32545.99	-33026.82	-33182.61
Profitable Deviations	0	0	0	0	0	0	0	0	1	0	0
Sample Size	258	258	258	258	258	258	258	258	258	258	258
% Deviations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.388	0.000	0.000

Panel F: Maturities of more than 180 days

Mean	-49526.29	-49565.05	-52632.08	-52840.83	-53068.84	-52623.61	-52833.69	-53070.4	-52606.15	-52803.43	-53020.87
Standard Deviation	6808.4055	6866.0256	10403.737	10381.001	10384.403	10399.435	10365.876	10385.224	10383.122	10388.366	10438.566
Minimum Deviation	-74109.8	-75549.8	-73337.23	-75466.61	-75555.51	-75185.17	-75651.84	-75777.84	-74445.24	-74652.32	-75555.51
Maximum Deviation	-34507.47	-34027.47	-34012.86	-34375.94	-34639.03	-34513.73	-34570.11	-34952.41	-34639.03	-34758.09	-34952.41
Median Deviation	-47895.31	-47895.31	-47544.87	-47805.88	-48143.23	-47544.87	-47805.88	-48143.23	-47544.87	-47805.88	-48143.23
Profitable Deviations	0	0	0	0	0	0	0	0	0	0	0
Sample Size	161	161	161	161	161	161	161	161	161	161	161
% Deviations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100).

Table A8. Full Deviation Results for European Reversal Strategy By Maturity

Panel A: Maturities of less than 30 days

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-1834.7	-1739.352	-1877.511	-1702.965	-1509.774	-1884.286	-1701.864	-1487.559	-1922.533	-1749.404	-1563.557
Standard Deviation	1149.3013	1092.3317	1026.3804	964.02403	906.577	1025.4815	971.45844	898.30283	1061.7597	1026.879	949.11353
Minimum Deviation	-6075.53	-6075.53	-6134.298	-5233.301	-5007.444	-6134.298	-5045.094	-4253.852	-4693.586	-4542.863	-4379.53
Maximum Deviation	4360.1784	4360.1784	954.52205	1242.1828	1515.9568	954.52205	1331.7826	1787.0793	876.90649	1331.7826	1787.0793
Median Deviation	-1776.627	-1634.114	-1796.987	-1694.758	-1471.925	-1805.633	-1582.887	-1467.191	-1883.682	-1708 976	-1612.247
Profitable Deviations	13	12	8	8	14	4	8	13	3	15	19
Sample size	369	369	369	369	369	369	369	369	369	369	369
% Deviations	3.5230	3.2520	2.1680	2.1680	3.7940	1.0840	2.1680	3.5230	0.8130	4.0650	5.1491

Panel B: Maturities between 31 and 60 days

Mean	-1437.626	-1772.557	-1972.318	-1731.74	-1355.183	-2012.994	-1553.663	-1353.69	-2053.547	-1637.803	-1338.985
Standard Deviation	1317.8884	1046.7152	1184.4928	1088.3107	1017.0536	1224.9344	1107.809	1102.8227	1311.7173	1158.4384	1147.1034
Minimum Deviation	-4892.716	-3836.58	-5606.08	-4537.665	-2966.29	-4942.73	-4025.895	-3946.093	-5606.08	-4438.009	-3946.093
Maximum Deviation	-57.5098	-257.3217	-380.6422	-105.4106	67.486035	-252.6462	-169.4314	67.486035	-252.6462	-169.4314	67.486035
Median Deviation	-830.7385	-1167.822	-1175.877	-996.1066	-595.7296	-1175.877	-717.6188	-537.6762	-1175.877	-851.0811	-595.7296
Profitable Deviations	0	0	0	0	1	0	0	1	0	0	1
Sample size	27	27	27	27	27	27	27	27	27	27	27
% Deviations	0.000	0.000	0.000	0.000	3.704	0.000	0.000	3.704	0.000	0.000	3.704

Panel C: Maturities between 61 and 90 days

Mean	-909.3393	-1024.825	-2215.763	-1981.566	-1831.459	-2166.508	-1890.509	-1694.277	-2094.356	-1869.977	-1668.276
Standard Deviation	1971.6753	2004.9778	1245.5128	1292.9418	1343.4727	1313.3059	1297.2903	1394.5909	1332.1031	1324.4538	1289.6042
Minimum Deviation	-3227.684	-3227.684	-3350.978	-3270.442	-3218.035	-3638.496	-3218.035	-3218.035	-3638.496	-3391.241	-3218.035
Maximum Deviation	2116.6631	2116.6631	-72.86494	181.38521	340.99708	270.74594	449.51357	820.99708	270.74594	270.74594	340.99708
Median Deviation	-471.4765	-1101.169	-2864.375	-2548.279	-2430.128	-2872.657	-2603.583	-2366.877	-2745.304	-2603.583	-2366.877
Profitable Deviations	6	6	0	1	2	1	1	2	1	1	2
Sample size	15	15	15	15	15	15	15	15	15	15	15
% Deviations	40.000	40.000	0.000	6.667	13.333	6.667	6.667	13.333	6.667	6.667	13.333

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100).

Table A8 (continued). Full Deviation Results for European Reversal Strategy By Maturity

Panel D: Maturities between 91 and 120 days

Mean	-4129.001	-3974.249	-4219.294	-4088.41	-3872.631	-4220.131	-4021.867	-3811	-4329.695	-4086.391	-3919.82
Standard Deviation	963.20345	723.13486	791.40429	802.93175	762.01673	715.02394	726.47672	653.79168	774.16107	864.02894	795.60553
Minimum Deviation	-4942.783	-4417.846	-4825.161	-4693.247	-4322.441	-4825.161	-4693.247	-4322.441	-4825.161	-4756.067	-4448.169
Maximum Deviation	-2747.452	-2903.506	-3055.83	-2908.378	-2735.226	-3184.014	-2998.137	-2863.492	-3184.014	-2818.603	-2735.226
Median Deviation	-4412.884	-4287.821	-4498.092	-4376.008	-4216.429	-4435.674	-4198.043	-4029.033	-4654.802	-4385.446	-4247.943
Profitable Deviations	0	0	0	0	0	0	0	0	0	0	0
Sample size	4	4	4	4	4	4	4	4	4	4	4
% Deviations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Panel E: Maturities between 121 and 180 days

Mean	-5292.428	-5353.836	-5554.758	-5258.869	-5022.951	-5527.185	-5168.444	-4969.511	-5662.736	-5197.79	-4975.531
Standard Deviation	871.14916	1005.3428	1123.9541	957.94991	924.6909	1079.2222	859.52974	883.84881	1070.158	835.95969	825.93509
Minimum Deviation	-7232.876	-7540.297	-11108.94	-8002.817	-7241.311	-11108.94	-6962.764	-6807.947	-11108.94	-6895.202	-6730.392
Maximum Deviation	-3167.087	-2857.85	-3148.188	-2918.678	-2838.014	-3148.188	-2931.087	-2713.89	-3148.188	-2993.126	-2838.014
Median Deviation	-5363.139	-5303.467	-5406.827	-5027.903	-4780.296	-5512.926	-5027.903	-4782.1	-5549.296	-5323.964	-4782.1
Profitable Deviations	0	0	0	0	0	0	0	0	0	0	0
Sample size	188	188	188	188	188	188	188	188	188	188	188
% Deviations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Panel F: Maturities of more than 180 days

Mean	-7881.29	-7869.592	-7914.271	-7781.141	-7656.014	-7918.645	-7765.389	-7634.133	-8153.649	-7826.255	-7668.697
Standard Deviation	4009.0331	4008.902	3914.8776	3871.9451	3824.8264	3909.4891	3891.8248	3852.3825	3717.6512	3831.942	3826.0172
Minimum Deviation	-12664.89	-12664.89	-12634.32	-12407.58	-12191.79	-12634.32	-12407.58	-12191.79	-12634.32	-12407.58	-12191.79
Maximum Deviation	-3132.373	-3132.373	-3438.834	-3353.535	-3325.098	-3495.691	-3148.753	-3040.638	-3808.539	-3650.773	-3381.97
Median Deviation	-7522.184	-7522.184	-7394.869	-7288.577	-7115.101	-7394.869	-7288.577	-7115.101	-7394.869	-7255.006	-7115.101
Profitable Deviations	0	0	0	0	0	0	0	0	0	0	0
Sample size	13	13	13	13	13	13	13	13	13	13	13
% Deviations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: See Figure 3 (page 32) for explanation of different exchange rate measures Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

Table A9. Full Deviation Results for European Conversion Strategy by Maturity

Panel A: Maturities of less than 30 days

	PHLXC	PHLXP	OAHIP	OAAVP	OALOP	OAHIM	OAAVM	OALOM	OAHIC	OAAVC	OALOC
Mean	-1412.054	-1481.424	-1360.669	-1519.455	-1704.639	-1332.409	-1499.921	-1694.468	-1300.701	-1457.163	-1632.569
Standard Deviation	1120.1111	1064.8805	1000.7566	963.39188	917.73212	1027.5303	980.36182	906.58017	1080.0112	1029.6219	966.58399
Minimum Deviation	-7746.918	-7746.918	-4300.439	-4567.352	-5003.133	-4300.439	-4616.536	-5021.198	-4109.893	-4565.335	-5021.198
Maximum Deviation	1154.3021	2063.3343	1984.5344	1984.5344	1984.5344	1984.5344	1783.5511	1104.6356	1670.4624	1368.7677	1108.6085
Median Deviation	-1415.035	-1559.823	-1443.394	-1551.951	-1715.979	-1443.394	-1617.151	-1748.413	-1431.372	-1604.498	-1691.32
Profitable Deviations	33	24	35	15	15	47	15	15	43	27	15
Sample size	369	369	369	369	369	369	369	369	369	369	369
% Deviations	8.943	6.504	9.485	4.065	4.065	12.737	4.065	4.065	11.653	7.317	4.065

Panel B: Maturities of between 31 and 60 days

Mean	-1823.389	-1506.235	-1364.939	-1658.648	-1982.892	-1376.721	-1867.962	-2337.192	-1381.366	-1799.162	-2139.243
Standard Deviation	1204.178	921.13386	1125.3507	998.17751	890.93465	1136.7401	1077.0814	1268.8316	1174.0007	1089.1054	1204.3542
Minimum Deviation	-3107.788	-3205.786	-2960.081	-3030.554	-3344.601	-2896.022	-2979.3	-3414.779	-2896.022	-2979.3	-3414.779
Maximum Deviation	1350.4056	84.285873	2033.487	1003.4375	-493.0447	1369.1758	624.12431	371.09299	1369.1758	664.06522	371.09299
Median Deviation	-2631.881	-1997.337	-2078.09	-2304.484	-2542.603	-2136.129	-2682.045	-3216.395	-2194.176	-2594.889	-2833.152
Profitable Deviations	1	2	3	1	0	6	1	1	6	1	1
Sample size	27	27	27	27	27	27	27	27	27	27	27
% Deviations	3.704	7.407	11.111	3.704	0.000	22.222	3.704	3.704	22.222	3.704	3.704

Panel C: Maturities of between 61 and 90 days

Mean	-2895.405	-2779.8	-1621.396	-1854.464	-2018.579	-1693.834	-1949.745	-2146.149	-1820.494	-1989.003	-2161.072
Standard Deviation	2145.1912	2160.1254	1582.6917	1592.5182	1652.1166	1564.1466	1597.3973	1663.7067	1582.1719	1622.3303	1580.6455
Minimum Deviation	-5864.487	-5864.487	-4275.16	-4357.74	-4619.331	-4412.801	-4763.95	-5032.637	-4619.331	-4619.331	-4619.331
Maximum Deviation	-413.4922	-413.4922	-52.75848	-179.432	-398.3112	-52.75848	-271.5794	-340.7016	-52.75848	-156.398	-546.2795
Median Deviation	-3378.257	-2276.051	-854.1516	-1096.008	-1209.975	-956.7503	-1070.685	-1273.301	-956.7503	-1070.685	-1273.301
Profitable Deviations	0	0	0	0	0	0	0	0	0	0	0
Sample size	15	15	15	15	15	15	15	15	15	15	15
% Deviations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: See Figure 3 (page 32) for explanation of different exchange rate measures Profitable deviations are defined as all deviations which are greater than zero % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

Table A9 (continued). Full Deviation Results for European Conversion Strategy by Maturity

Panel D: Maturities of between 91 and 120 days

Mean	369.21797	175.11417	453.87844	297.6693	27.517978	312.41189	177.23244	45.238523	469.28989	221.25865	58.433307
Standard Deviation	803.40823	767.98886	643.91065	664.44112	728.29277	658.6716	616.92563	539.39089	699.05301	776.97181	825.9895
Minimum Deviation	-810.7945	-966.9005	-510.8125	-684.0814	-1024.376	-639.154	-696.9185	-703.3372	-574.9791	-928.0429	-1152.85
Maximum Deviation	915.63642	691.64155	817.04206	718.95231	580.50747	769.28627	718.95231	580.50747	895.09873	781.86896	706.36802
Median Deviation	686.015	487.8578	754.64208	577.90312	276.97038	559.75766	343.44795	151.89189	778.51998	515.6043	340.10743
Profitable Deviations	3	3	3	3	3	3	3	3	3	3	3
Sample size	4	4	4	4	4	4	4	4	4	4	4
% Deviations	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000

Panel E: Maturities of between 121 and 180 days

Mean	1253.8224	1316.9869	1427.7581	1211.2744	1009.2818	1393.1452	1163.1954	976.62399	1303.1071	1089.6899	967.14825
Standard Deviation	832.55872	962.39038	945.57193	932.31501	892.24981	899.66198	856.34354	850.80074	838.70649	821.71181	820.68136
Minimum Deviation	-895.9712	-1205.346	-916.9491	-1146.852	-1227.654	-916.9491	-979.0744	-1041.208	-916.9491	-991.5004	-1227.654
Maximum Deviation	3072.1529	3381.5276	3686.0117	3650.8196	3177.9772	3673.6278	2923.7616	2743.8709	2840.745	2619.7698	2619.7698
Median Deviation	1286.5044	1136.4413	1234.9503	1089.8627	817.01356	1361.0788	1089.8627	919.48815	1361.0788	1070.9351	919.48815
Profitable Deviations	168	168	168	168	168	168	168	168	168	168	168
Sample size	188	188	188	188	188	188	188	188	188	188	188
% Deviations	89.362	89.362	89.362	89.362	89.362	89.362	89.362	89.362	89.362	89.362	89.362

Panel F: Maturities of more than 180 days

Mean	3258.1849	3257.2958	3264.4695	3141.1867	3036.1283	3255.7069	3134.6117	3014.2044	3290.6192	3165.6417	3036.3487
Standard Deviation	3717.306	3772.9897	3604.4504	3599.4766	3567.1686	3615.4103	3607.9066	3595.7066	3587.8587	3570.6472	3558.5272
Minimum Deviation	-1064.039	-1064.039	-850.8007	-1084.354	-1135.637	-964.7143	-1169.829	-1420.647	-736.9149	-947.6255	-1078.656
Maximum Deviation	7753.244	7753.244	7629.4961	7468.8046	7296.9675	7629.4961	7468.8046	7296.9675	7629.4961	7468.8046	7296.9675
Median Deviation	3052.3443	3052.3443	2666.2549	2559.7428	2385.907	2666.2549	2559.7428	2385.907	2946.4318	2666.2549	2385.907
Profitable Deviations	9	9	11	7	7	11	7	7	11	7	7
Sample size	13	13	13	13	13	13	13	13	13	13	13
% Deviations	69.231	69.231	84.615	53.846	53.846	84.615	53.846	53.846	84.615	53.846	53.846

Note: See Figure 3 (page 32) for explanation of different exchange rate measures. Profitable deviations are defined as all deviations which are greater than zero. % Deviations is defined as number of profitable deviations divided by total sample size (multiplied by 100)

9. APPENDIX II - FIGURES

Figure A1 : Distribution of Put Call Pairs per Time of Day

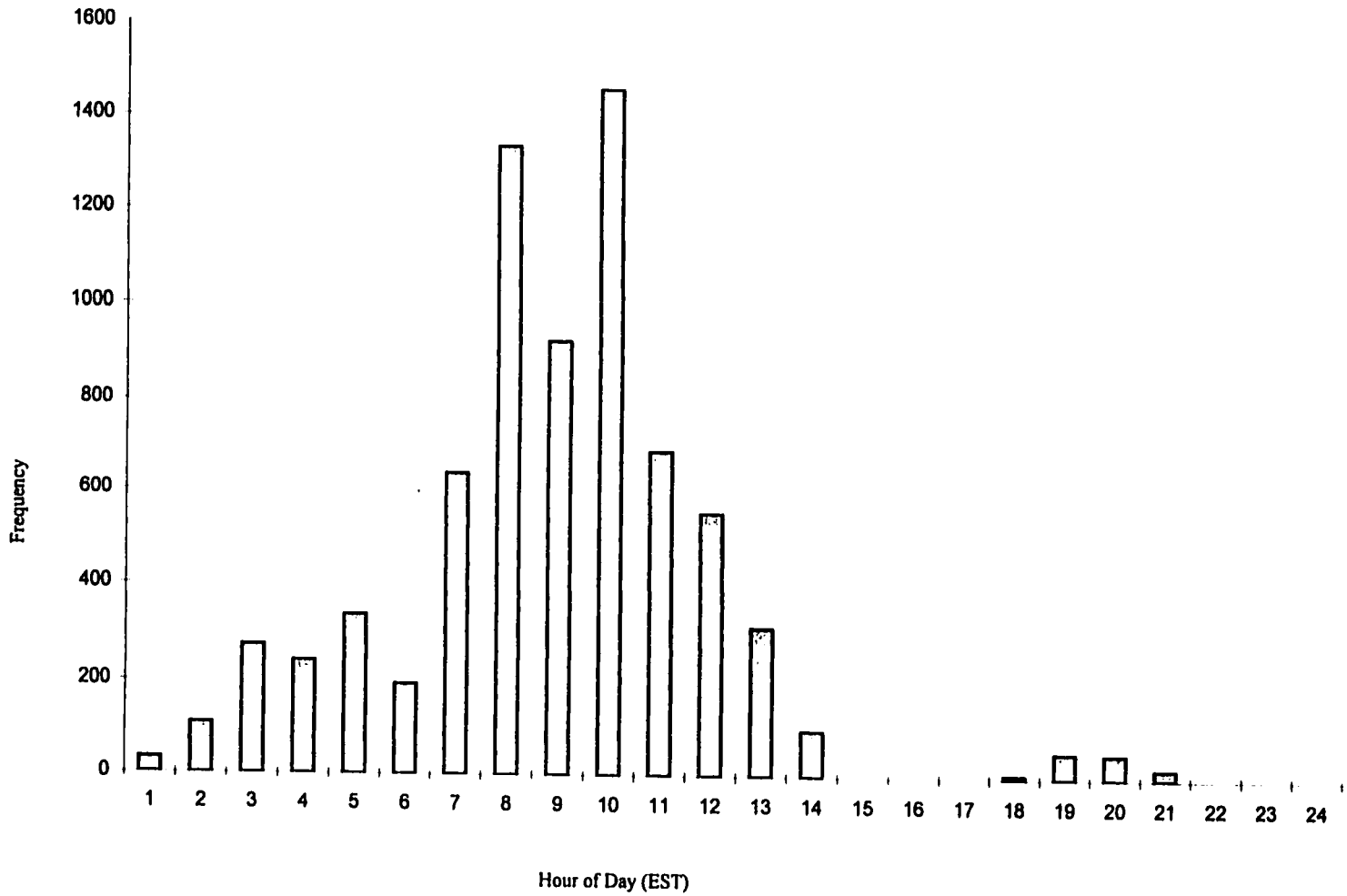


Figure A2 : Frequency of Profitable American Reversal Opportunities per Time of Day (EST)

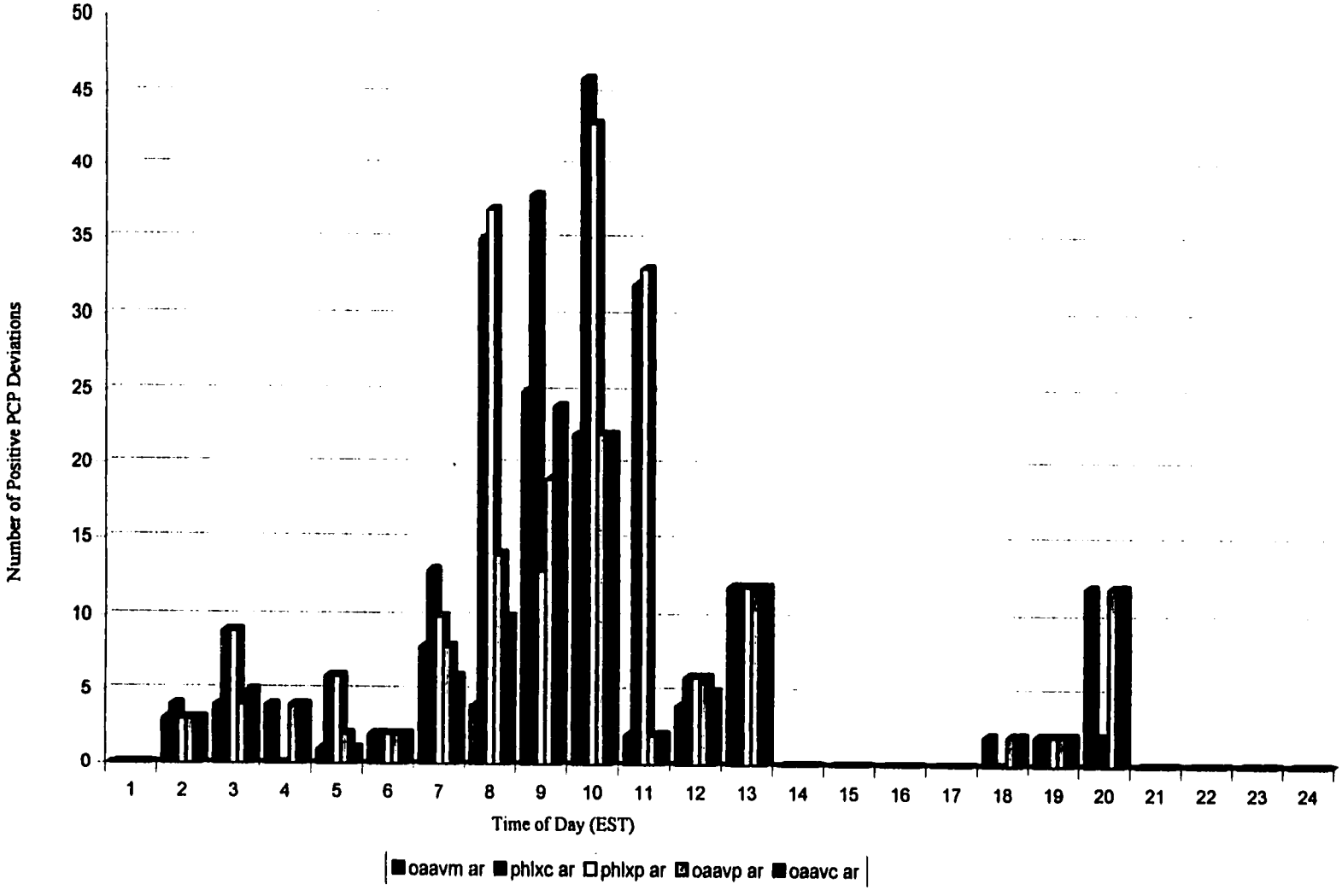


Figure A3 : Percentage of Profitable American Reversal Opportunities per Time of Day (EST)

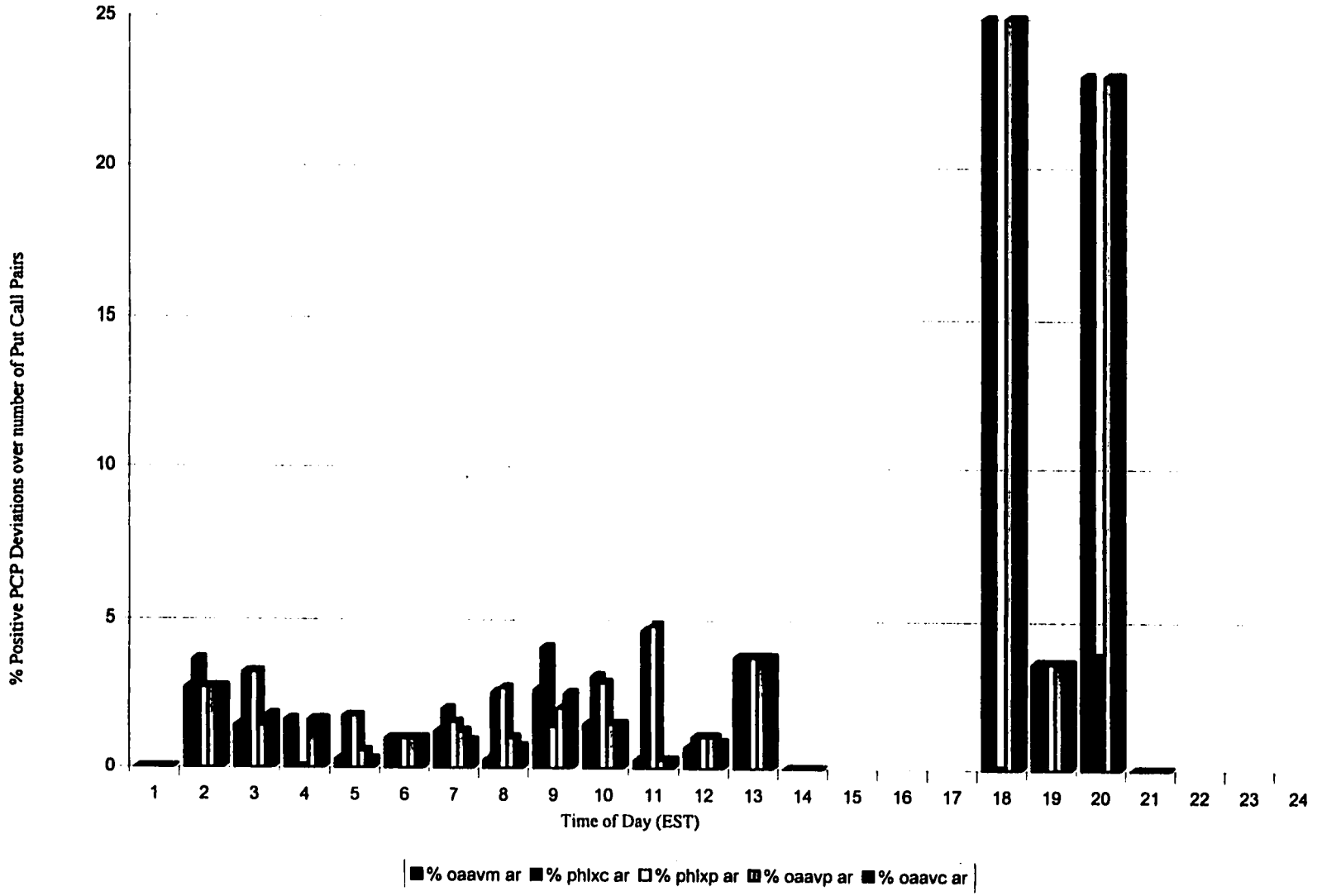


Figure A4 : American Reversal Opportunities as % of Put Call Pairs : PHLX Morning Session

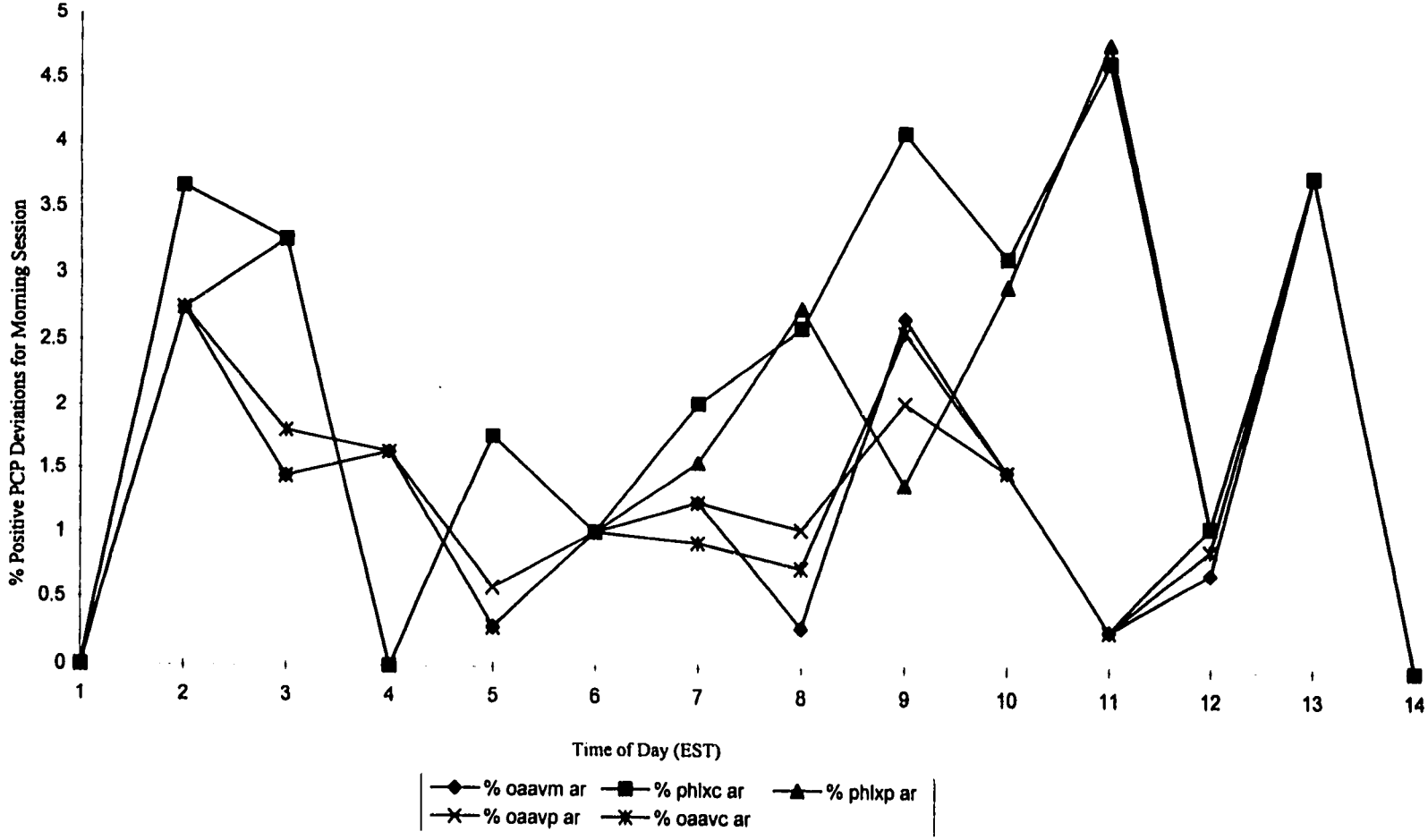


Figure A5 : Frequency of Profitable American Conversion Opportunities per Time of Day (EST)

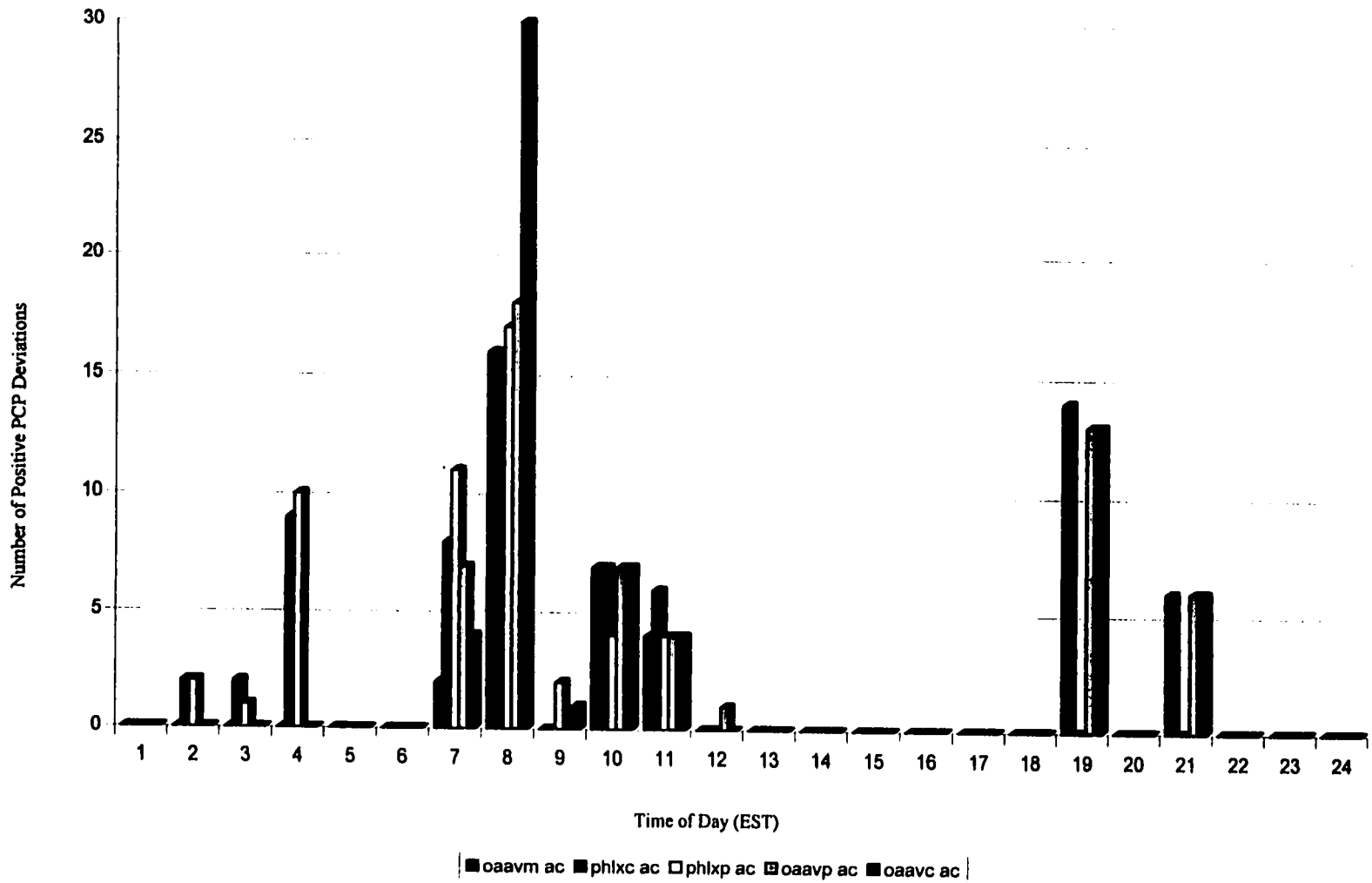


Figure A6 : Percentage of Profitable American Conversion Opportunities per Time of Day (EST)

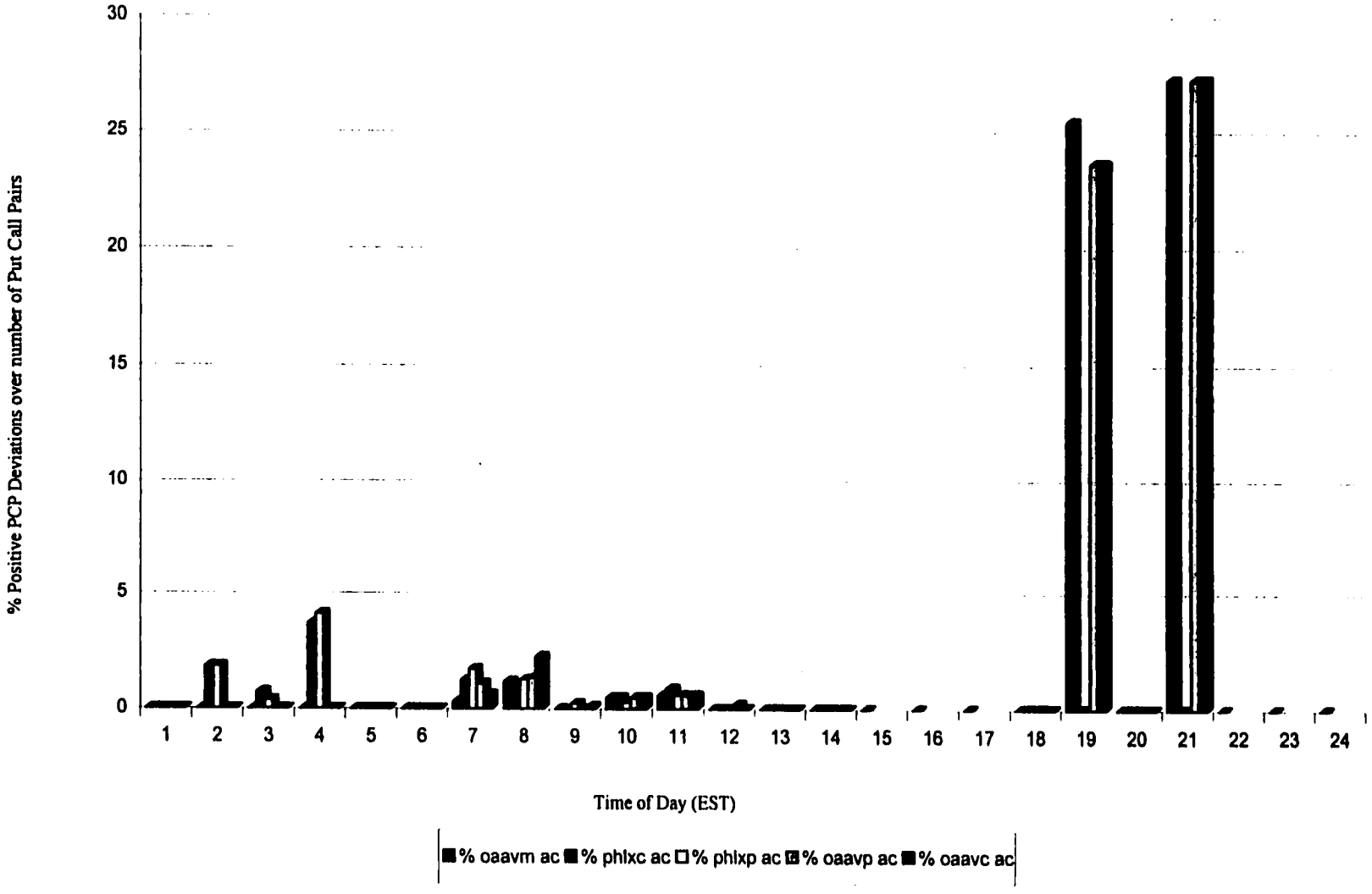


Figure A7 : American Conversion Opportunities as % of Put Call Pairs : PHLX Morning Session

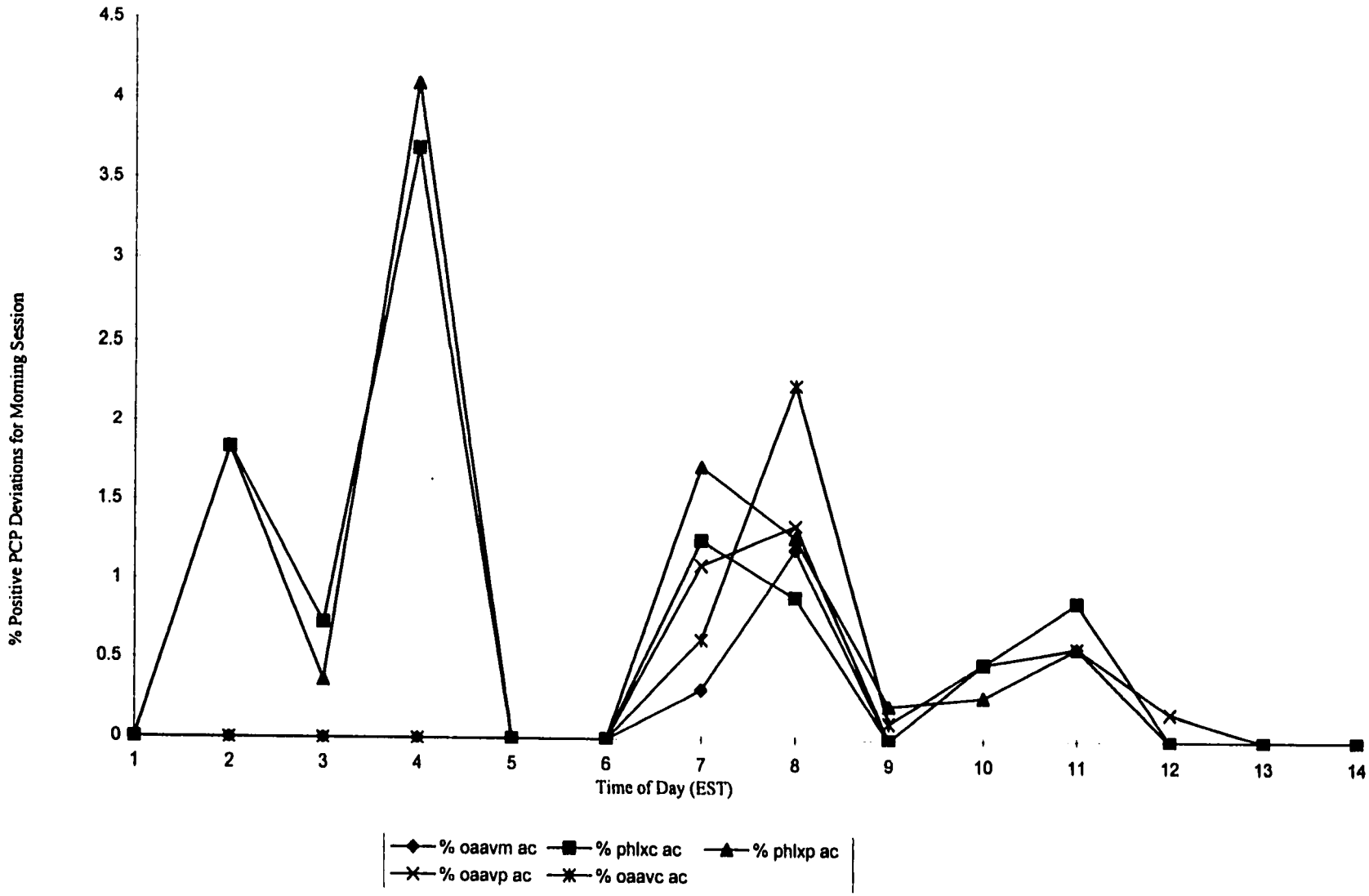


Figure A8 : Percentage of Positive American PCP Deviations per Day of Week

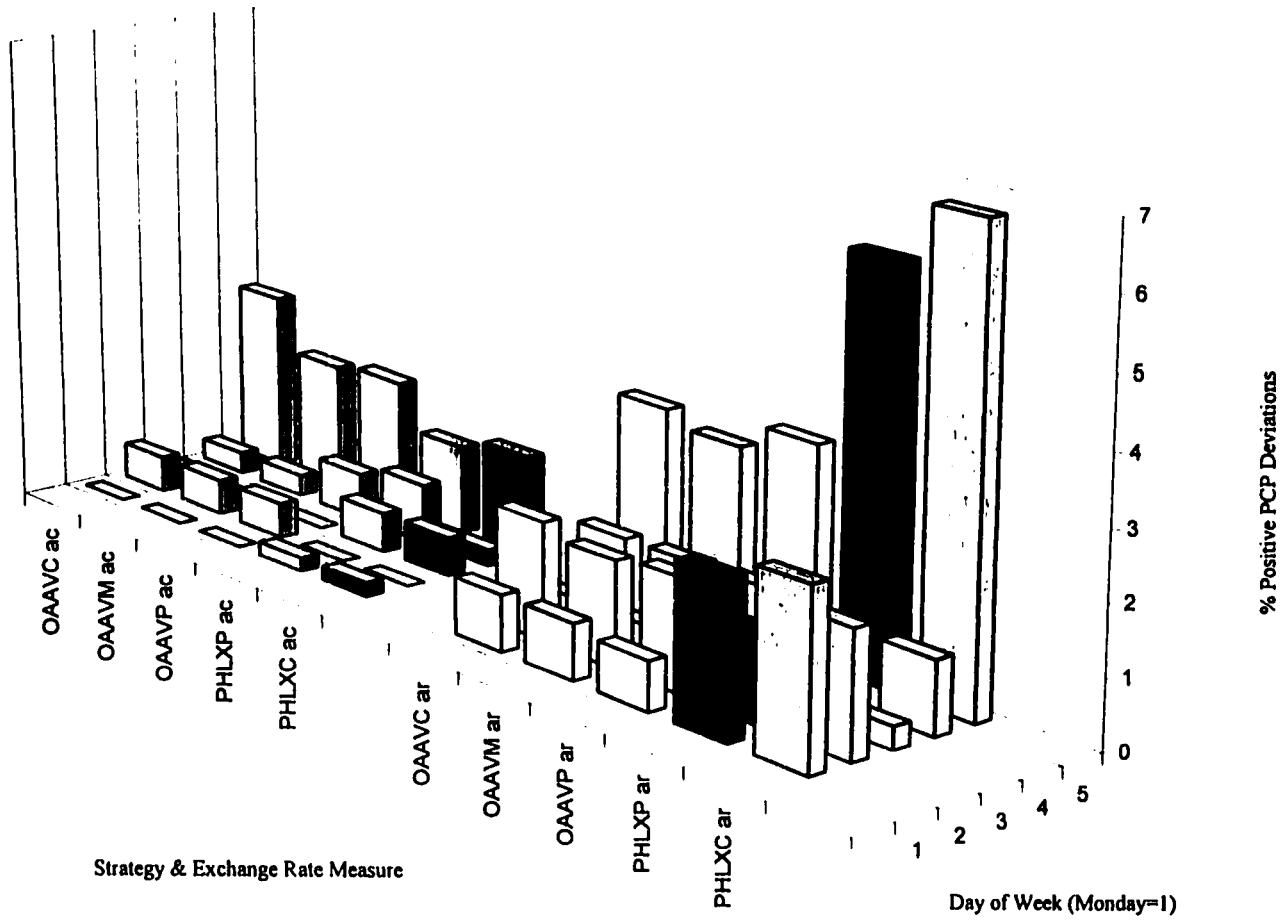


Figure A9 : Frequency of Positive European Conversion PCP Deviations per Maturity

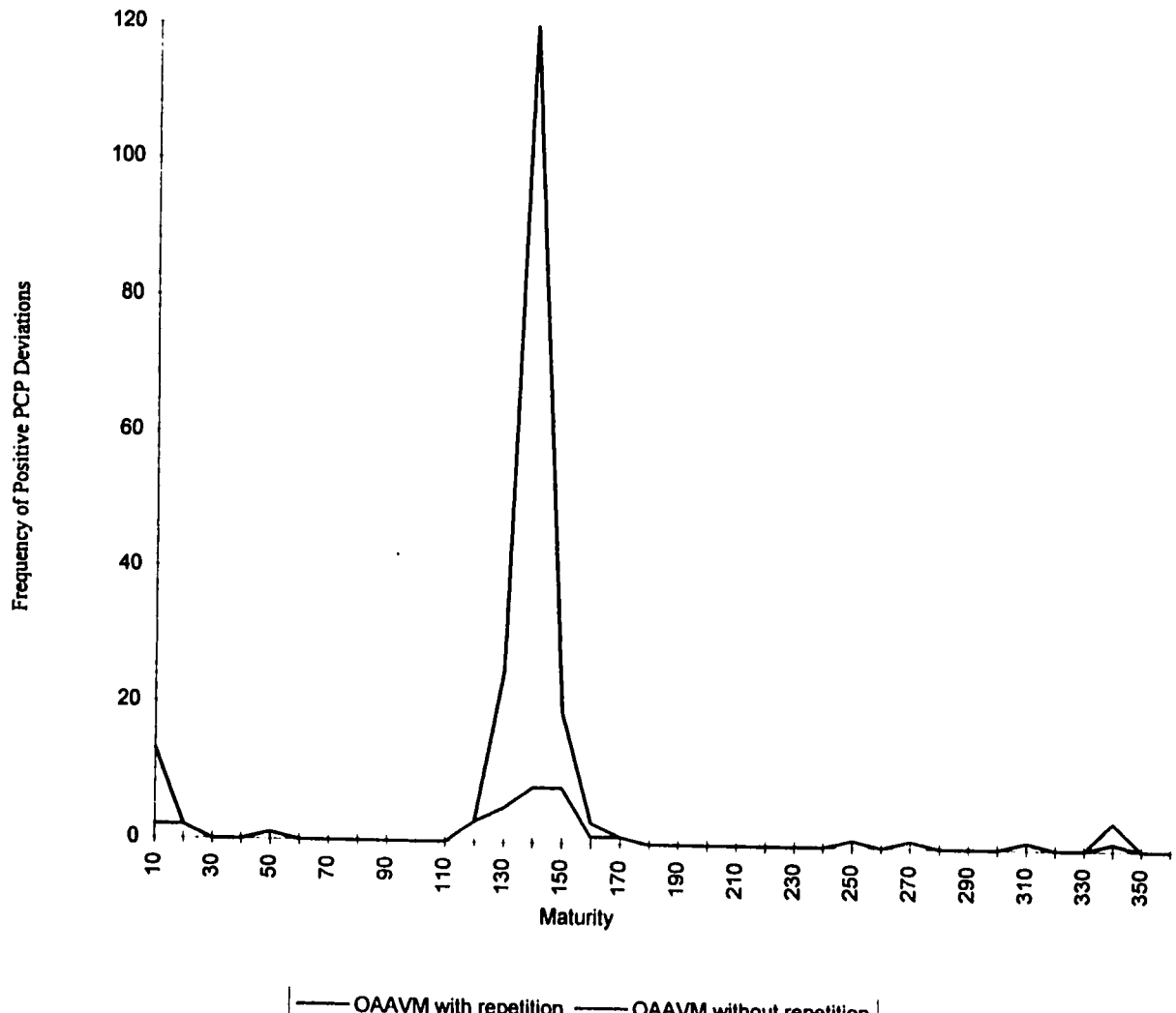
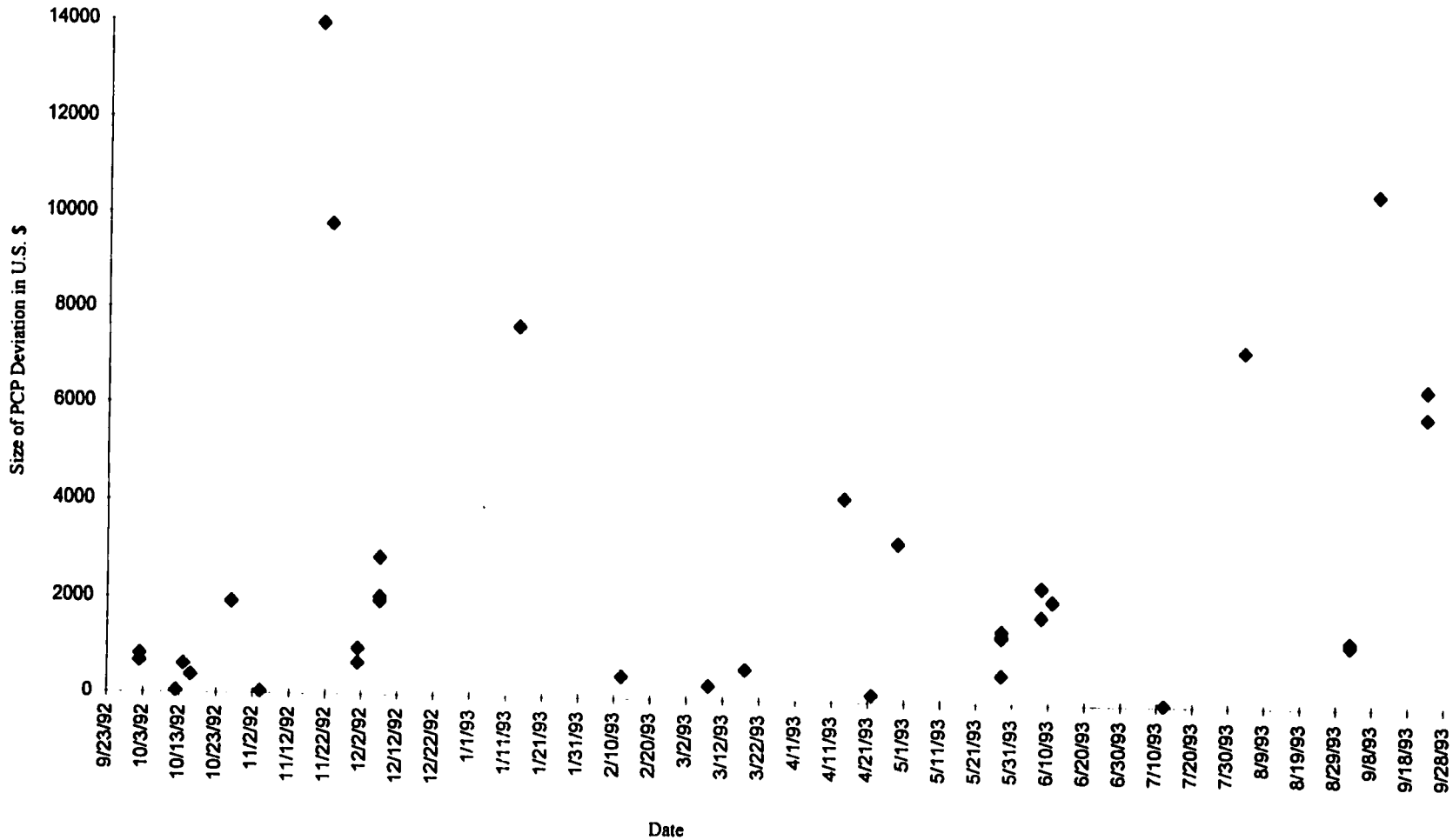


Figure A10 : Profitable American Reversal Opportunities by Date (OAAVM exchange rate)



◆"Note : A large arbitrage opportunity of $ 50111.93 is recorded on 10/08/92. It is omitted from this graph as an out-lier"

Figure A11 : Profitable American Conversion Opportunities by Date (OAAVM exchange rate)

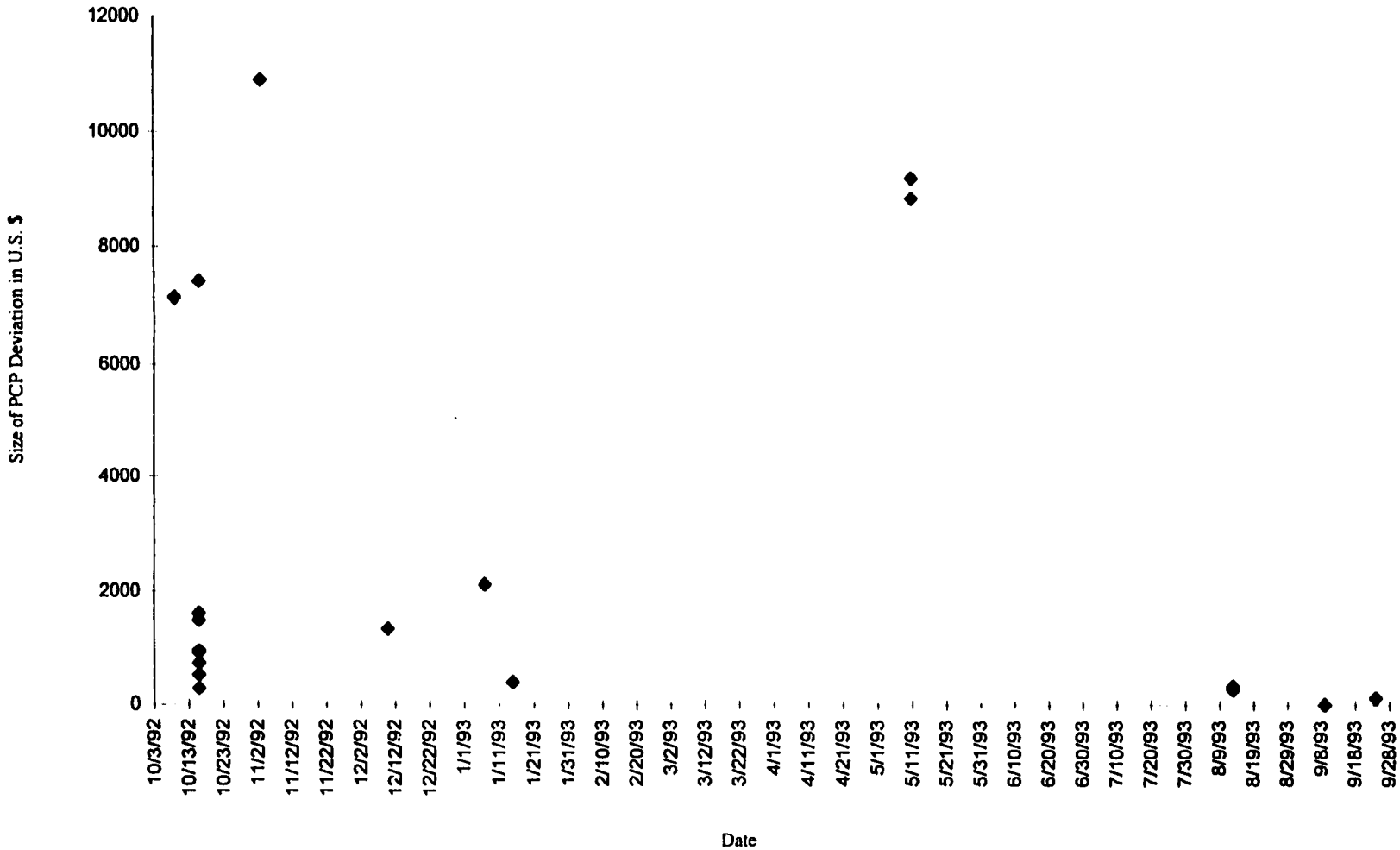


Figure A12: Profitable European Reversal Opportunities by Date (OAAVM exchange rate)

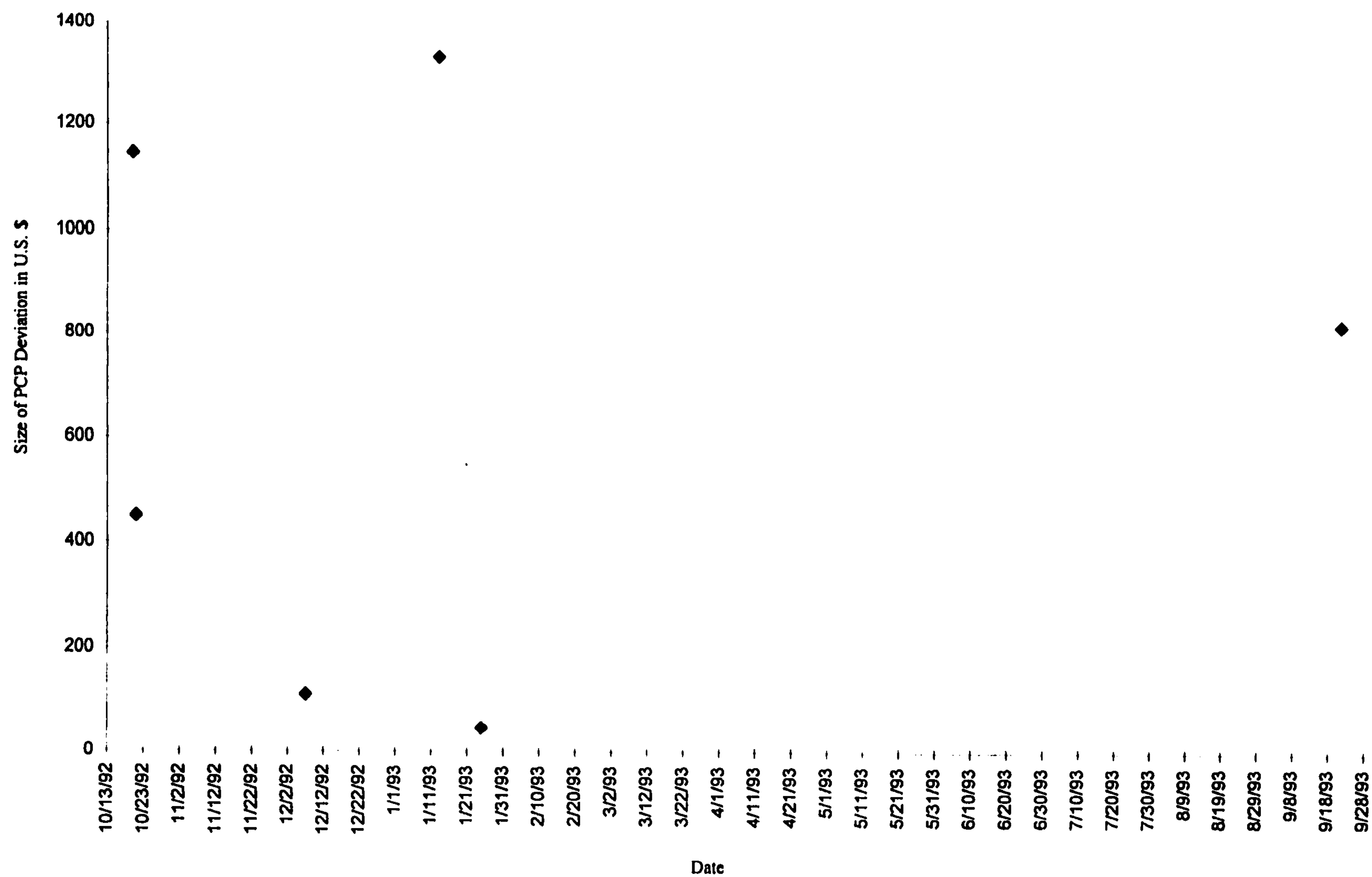
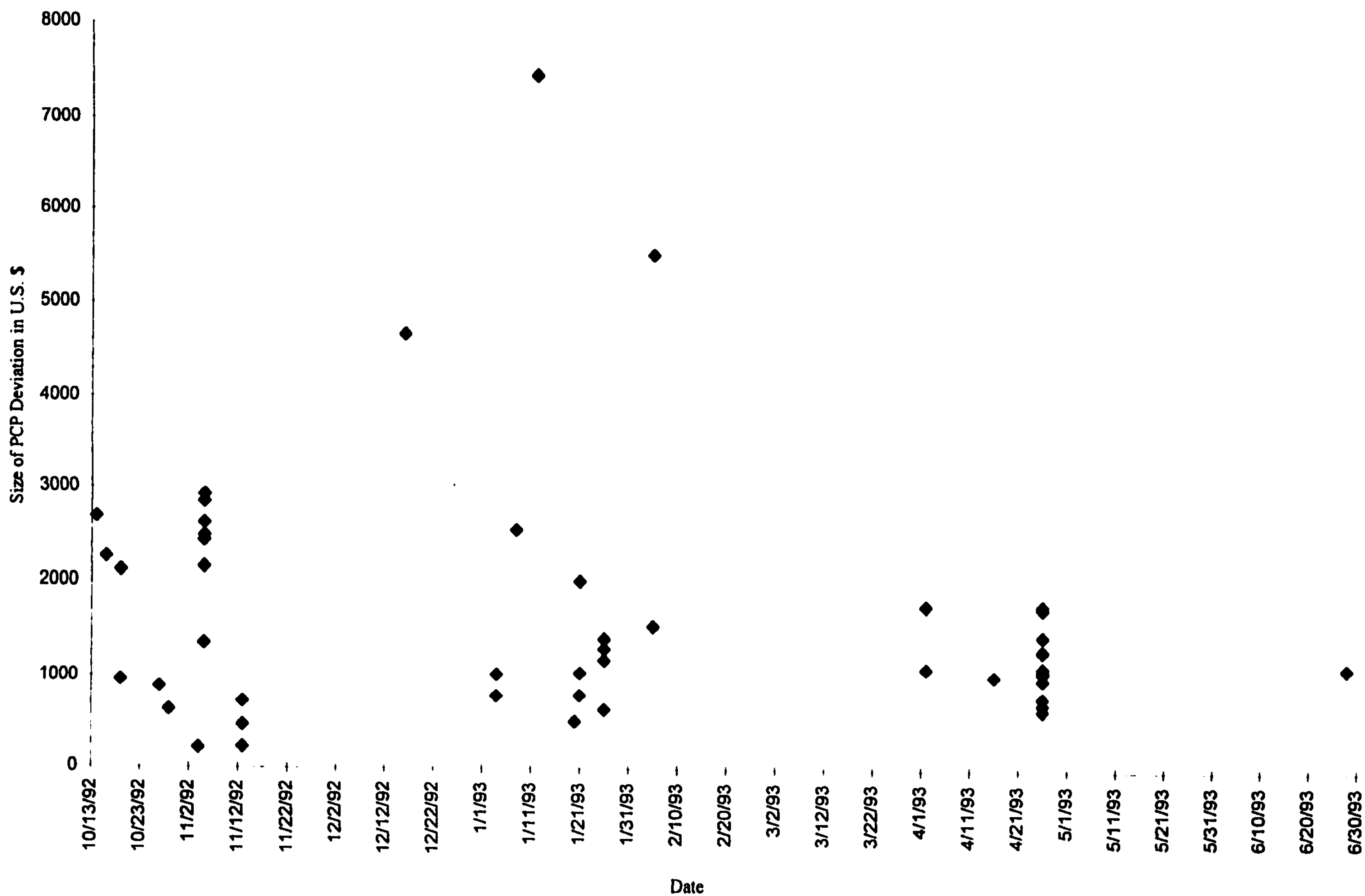
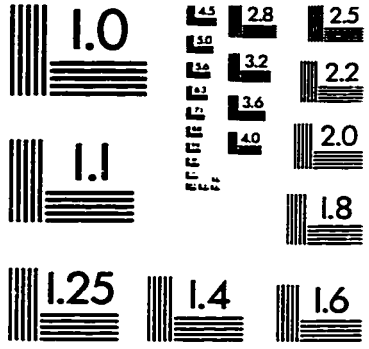
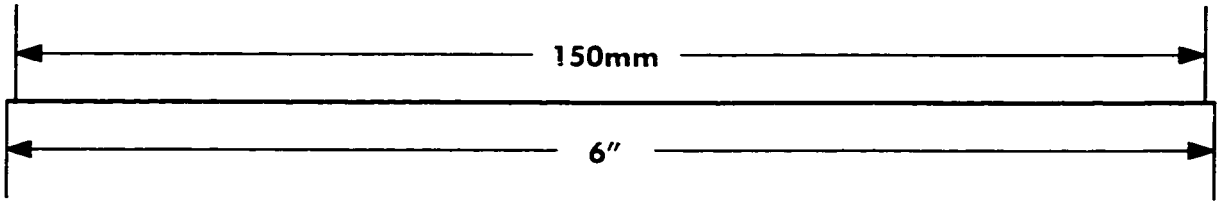


Figure A13 : Profitable European Conversion Opportunities by Date (OAAVM exchange rate)



TEST TARGET (QA-3)





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