Technical Report: FX Derivatives Market Maker

Max R. Chellew

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Abstract

This technical report provides a walkthrough and explanation of the roles a foreign exchange (FX) derivatives market maker (MM) undertakes when issuing and fulfilling Forward and European Option contracts. The report will use fictional clients and live market data to model the actions MMs takes when issuing these contracts. These include quoting derivative contracts to clients, hedging against the FX market risk exposure and model validation using financial Greek risk measures (Greeks). The experiment outlined in this report seeks to model these processes and will serve as a contextual supplement to the generalised explanation of theory discussed during the report. Furthermore, the experiment will also provide further talking points on: the effect on profitability using different spot prices in the forward rate quote calculations has, the validity of using basic Greeks to measure the full risk profile of forward and options contracts and the effect being in-the-money (ITM) or out-the-money (OTM) has on the spot delta of an option.

Contents

1 Introduction

The role of an FX derivative MM is to provide market liquidity to an FX derivative market through issuing and fulfilling contracts to and with clients [1]. The underlying asset for derivative contracts traded on an FX market is the currency pair of the exchange. MMs provide bid and ask quotes to buyers and sellers of these FX derivatives, profiting off the margin between the bid and ask quotes.

When fulfilling a derivative contract, MMs inherently take on positions in both the base and foreign currencies of the contract [4]. In doing so, MMs subject themselves to market risk, which is the risk of loss due to changes in market conditions [3]. To reduce exposure to market risk, MMs often hedge against their own expected positions[4]. Delta hedging is a hedging strategy that protects against any losses (or gains) in mark-to-market (MtM) value that may be incurred due to increases (or decreases) in the price of the underlying asset of the derivative contracts.

Model validation is also something that MMs need to consider throughout the life of each contract. Fulfilling and hedging an FX derivative relies heavily on financial pricing models, which are required to stay true to their theory. Although delta hedging provides protection against any changes in the value of the underlying asset [4]. There are many other input factors besides the spot rate which determine the price of a derivative contract and are therefore also underlying risks that MMs should be aware of. One way to measure the risk performance of these financial models is to consider certain Greeks for each contract. Greeks measure the sensitivity of a security's value relative to the input variables used to calculate them which provides MMs with a better understanding of the risk profile of each derivative. Greeks can also be used to try to explain the profit and losses (PnL) induced by the difference between the MtM values of the securities on different days. If the PnL cannot be explained by the Greeks, this highlights that there may be other potential unknown risk factors at play.

In summary, the basic objectives of an FX derivatives MM is to supply clients with quotes, fulfil derivative contracts with their clients, hedge against market risk and perform model validation to identify any other underlying risks at play. The following sections will discuss these objectives in further detail.

2 Theory

2.1 Quoting

FX Forward contracts are an agreement between two parties to buy or sell a specific amount of one currency for another at a predetermined exchange rate upon maturity of the contract [4].

MMs provide quotes for FX forward contracts by issuing the forward exchange rate for the underlying currency pair to their clients. The forward exchange rate is quoted in the notional amount of foreign currency equal to 1 notional amount of the base currency at contract maturity. Clients who long an FX forward contract will receive a different forward exchange rate to that of clients who short the same contract the difference between these two quotes is known as the bid-ask spread.

Forward Rate Equation:

$$K(S_0, r_f, q, T) = S_0\left(\frac{e^{-qT}}{e^{-r_f T}}\right) = S_0 \cdot \exp\big[(r_f - q)T\big] \tag{1}$$

To determine the forward rate of a contract, MMs use the forward rate formula (1) derived from the Black-Scholes options pricing model (29) [4]. As stated before, MMs need to create a bid-ask spread to profit from supplying the FX derivatives market with liquidity. The difference between quotes of a long and short FX forward contract comes from using different FX spot rates in the forward rate equation. Long forward contracts are quoted using the bid FX spot rate and short forward contracts are quoted using the offer FX spot rate. MMs can increase the spread of the bid-ask forward rates to make higher profits by decreasing the bid rate and increasing the ask rate. As there are competitive rates among MMs the bid-ask spread should not be increased by too much as doing so may result in clients moving to competitors.

FX European options contracts are contracts that give the buyer the right but not the obligation to buy or sell a specific amount of one currency for another currency at a predetermined exchange rate at the maturity date of the contract [4].

Unlike an FX forward contract, FX European options contracts are quoted by issuing the implied volatility of the option contract. Often clients choose the value of the strike price of the option contract however, in the case of an at-the-money (ATM) option contract the strike price is determined by the ATM strike price. The ATM strike price of an option is the risk-free forward rate used in forward contracts with the same maturity and notional value as the option contract.

Calculating implied volatility for a European option is normally outsourced to back-end teams which focus only on providing the correct bid-ask volatility spread. Therefore, calculating implied volatility will not be covered. MMs still have the option to widen the bid-ask volatility spread to increase profits for the FX option but often don't since MMs still profit from the option premium paid by clients and therefore can remain competitive.

2.2 Hedging

Upon accepting the MMs quote for an FX derivative, the client will be long or short the contract. Subsequently, the MM will take the opposite position to their client to fulfil the contract and provide the FX forwards market with liquidity. In doing so, MMs subject themselves to the risk of loss due to adverse moments in the currency exchange rate and therefore must hedge against their own expected position to mitigate their spot delta risk exposure.

The spot delta of an FX derivatives contract is a Greek risk measure, defined as the rate of change of the FX derivative's value with respect to the spot rate of the underlying currency pair [4]. In other words, the spot delta of an FX derivatives contract is the sensitivity of the contract's value relative to any changes in the underlying spot rate of the contract. The basics of a delta hedging strategy are to take a position in the market that has an equal and opposite delta to that of the derivatives contract being hedged against. In this case, the MM would take a position in the FX spot market that has an equal and opposite spot delta that of the FX derivative contract they are hedging against. Since FX derivative MMs are normally not the

MMs of the spot market, they should not profit from any delta hedge, as they must pay the bid-ask spread of the spot market. It is nearly impossible to find a position that completely matches the delta of a derivatives contract at all points in time. MMs, therefore, settle for offsetting the spot delta of a derivatives contract periodically by adjusting their hedging position to cover the spot delta of the contract each time. The spot delta of a contract can be calculated using the spot delta equations (2) (3). MMs will want to keep the overall spot delta of all their positions within a certain range at all times to avoid major losses due to large spot rate changes.

Spot DELTA Equations (MXN):

$$\Delta_{\text{Forward}} = [\exp[(r_f - q)T] \cdot N_{FOREIGN} \tag{2}$$

$$\Delta_{\text{Call}} = [\phi(d_1)] \cdot N_{FOREIGN} \quad \Delta_{\text{Put}} = [\phi(d_1) - 1] \cdot N_{FOREIGN} \tag{3}$$

In theory, MMs want to complete a full delta hedge at the start of entering their position in a contract, however there are many reasons why this is not possible. One reason is due to market regulations. Some spot markets can be subjected to a board lot making it impossible to complete a full delta hedge as a full delta hedge requires an exact position to be taken in the spot market which is not possible due to the board lot.

2.3 Model Validation

MMs track the value of an FX derivatives contract on each day using its MtM equations (30) (31) and thus the profit and losses by finding the difference between MtM values on different dates [2]. As the MtM value of the forward contract on each date is dependent on the state of the input variables used in their calculation; it makes sense to measure the effect changes in these variables have on the MtM value of the securities. These are the measures previously described as the Greeks.

The basic Greek measures MMs use are known as DELTA, VEGA, RHO, THETA, and GAMMA [4]. DELTA is known as the rate of change of the contract's value relative to changes in the spot price. VEGA is known as the rate of change of the contract's value relative to changes in implied volatility. Local RHO is known as the rate of change of the contract's value relative to changes in local currency risk-free interest rate. Foreign RHO is known as the rate of change of the contract's value relative to changes in foreign currency risk-free interest rate. THETA is known as the rate of change of the contract's value relative to changes in time to maturity. Finally, GAMMA is known as the rate of change of DELTA relative to changes in the spot price.

By calculating the Greeks, MMs hope to gain a complete risk profile of their positions. To check this, MMs attempt to explain the changes in MtM values over different periods in time also known as the profits and losses (PnL) by summing the Greeks explained [2]. The Greeks explained are defined as the amount of PnL of a security that can be explained by a change in an input variable [4]. Mathematically the sum of the Greeks explained of a security is known as an approximation for the multivariate first-order Taylor expansion of the PnL. This method of explaining the PnL is appropriate for linear models but has limitations for non-linear models, where higher-order Taylor expansions are needed to fully explain the PnL induced by changes in market conditions [2]. This means that Greeks of higher order are needed to explain the PnL and that MMs may not have a good risk profile for the security in question.

PnL Explained by Greeks:

$$\text{PnL} \approx \Delta \cdot \partial S + \nu \cdot \partial \sigma + \rho \cdot \partial r_f + \hat{\rho} \cdot \partial + \Theta \cdot \partial T + \frac{1}{2} \cdot \Gamma \cdot \partial S \tag{4}$$

3 Method

The experiment to model the process of quoting forward and European FX contracts and preforming Delta hedging starts with evaluating the contract and positions of the fictional client as well as looking at the live market date. The client's contract details and positions can be found in table 1 whereas the live market data used in the experiment can be found in the appendix 1. Since the method is universal for all the client's contracts only one example for forward and European options contract will be covered in this section of the report. Therefore, any deviation from the method will be highlighted in the results section.

	Transaction Date	**Contract Details**	**Client's Position**	**Notes**
A	17 February 2023	102M USDMXN Forward expiring in 12 months	Long	Trade at mid
B	21 February 2023	96M USDMXN Forward expiring in 8 months	Short	Trade at the best price
C	28 February 2023	22M USDMXN at-the-money European CALL option expiring in 2 months	Long	
D	28 February 2023	123M USDMXN Forward expiring in 2 months	Short	
E	2 March 2023	66M USDMXN at-the-money European PUT option expiring in 12 months	Long	
F	2 March 2023	63M USDMXN at-the-money European CALL option expiring in 12 months	Long	

Table 1: Table caption

Performing model validation using Greeks involves evaluating the FX derivatives contract over multiple time periods and therefore will not be covered in full. The method of model validation follows its theory strictly, by first calculating the PnL explained by Greeks and real PnL, and then comparing the results. Model validation will be touched on in further detail in the results and discussion section of the report.

3.1 FX Forward Contracts

This subsection will cover client C who is Short a 123M USDMXN forward contract expiring in 2 months on February 28th, 2023.

As the client is short the contract, the MM identifies that the client is to be quoted the "bid" forward rate for this contract since the client wants to sell 123M USD for MXN at the "bid" forward rate. From the live market date, find the "bid" spot rate (18.240), USD LIBOR rate (2.00%) and MXN TIIE (10.00%). The "bid" forward rate can then be calculated using these values and the forward rate equation (1). MMs will round down to 3d.p the calculated forward rate to increase the bid-ask spread. The MMs can choose to decrease the bid forward rate further to increase profits. In this case, the bid forward rate is decreased by an extra 0.05 to avoid loss of client to competition with other MMs. The resulting bid forward quote for this contract is 18.472.

In order to delta hedge the MMs position in this forward contract, the spot delta is first calculated using the forward sport delta equation (2) (3). From the live market data 1, find the spot delta is -2236M MXN. The hedging process for this forward is to borrow N amount of the base currency at the risk-free rate LIBOR rate to buy MXN at the spot market. This is equivalent to shorting selling a USD zero-coupon bond with a coupon rate equal to that of the LIBOR interest rate and longing MXN at the spot market [4]. Note that in this case the spot market is subject to a 5M board lot of base currency therefore a full delta hedge may not be possible. Trial and error find that the best delta hedge is a hedge position of short sell120M USD and long 2189M MXN which gives us a spot delta of 2189M MXN with maturity equal to that of the forward contract.

3.2 FX Option Contracts

This subsection will cover client F who is Long 60M USDMXN at-the-money European CALL option expiring in 12 months on March 2nd, 2023.

Using the back-end team's bid-ask volatility spread (12.70%/12.90%) MMs can quote the ask volatility to clients. This offer quote is kept unadjusted since the MM will profit off the option premium regardless and wants to stay competitive.

The spot delta of the MMs position in the Call option can be calculated using the Call option spot delta equation (2) (3). Using the live market date, find the spot delta to be 591M MXN. MMs, therefore, need to find a hedging position that has an equal and opposite delta to the spot delta of the Put option found. The hedging process for shorting an FX Call option is to lend N amount of the BASE currency at the risk-free LIBOR rate, then short sell the equivalent amount of MXN at the spot market [4]. This is equivalent to longing a USD zero coupon bond with a coupon rate equal to the LIBOR rate and short-selling MXN at the spot market. Again, note that the spot market is subject to a 5M Board lot of base currency and therefore a full delta hedge may not be possible. Trial and error were used to find that the best delta hedge is a hedge position of Long 30M USD and Short 549M MXN with maturity equal to that of the call option.

4 Results

A summary of the results of the experiment will be covered in this section along with any notes worth mentioning for each client. For more detail on the data and spreadsheets used to find these results refer to A.4

4.1 Quotes & Hedging positions

Client A gets quoted a ask forward rate of 20.215. The MMs hedging position is long 100M USD and short 1876M MXN. Since the quote note is to trade at the mid, the mid spot rate was used instead of the offer spot rate to calculate the forward quote rate. The MM only profits off the bid-ask spread created from rounding down to 3 d.p. and hence has a negative total mark-to-market value of the delta hedging and forward contract positions 2a.

Client B gets quoted a bid forward rate of 19.275. The MMs hedging position is short 95M USD and long 1737M MXN. Since the quote note is to trade at the best price the bid forward rate was not increased further by the MM to keep the forward rate as competitive as possible.

Client C gets quoted an ask implied volatility of 13.00%. The MMs hedging position is long 10M USD and short 183M MXN.

Client D gets quoted a bid forward rate quote of 18.427. The MMs hedging position is short 120M USD and long 2189M MXN.

Client E gets an ask implied volatility of 12.90%. The MMs hedging position is short 30M USD and long 543M MXN.

Client F gets an ask implied volatility of 12.90%. The MMs hedging position is long 30M USD and short 549M MXN.

On March 2nd the spot delta of all of the MMs positions spikes to 179.33M MXN, thus a further Delta hedge was implemented to bring down the spot delta to within the risk range of plus-minus 100M MXN. This hedging position was found to be Long 10M USD and Short 181M MXN with a maturity of 59 days (same maturity as client C's call option contract).

4.2 Model Validation review

The unexplained PnL for all the MMs positions on February (17th, 21st, 28th) and March (2nd, 7th) are \$0, \$0, \$1, -\$7,036, and \$20,104 respectively. This is the difference between the Real PnL and PnL explained by Greeks [2]. Upon light inspection, one can find that the large unexplained on March 2nd is caused by changes in the implied volatility and USD LIBOR rate from February 28th to March 2nd. The large unexplained on March 7th, was caused by changes in the MXN TIIE rate from March 2nd to March 7th.

5 Discussion

Trading at the mid for Client A results in an overall loss for the MM after taking a hedging position. Ultimately, this is a consequence of the MM paying the bid-ask spread of the spot market when hedging and giving the client the fair market forward rate. This highlights why the forward rate quote needs to be calculated using the spot bid/ask rates and widened. Although this type of trade was executed in the experiments MMs should seek to avoid these types of forward contracts. This suggests that MMs should therefore only execute option contracts that are quoted using the spot bid/ask rates like client B or options that have their bid-ask spread widened further like for client C.

Since the unexplained PnL of the MMs positions are roughly zero on February 17th, 21st and 28th for which only forwards and hedging positions were accounted. It is reasonable to assume that the Greeks: DLETA, base RHO, foreign RHO and THETA not including GAMMA and VEGA as they are always zero for forward contracts provide a sufficient risk overview of a forward position. This is in accordance with theory since the MtM equation of a forward position is linear and thus a first-order multivariate Taylor expansion of the PnL should be sufficient in describing its value [4].

Unlike forwards, the positions held by the MM in all the options contracts show large spikes in unexplained PnLs during the experiment. This is following large changes in the USD LIBOR rate, MXN TIIE rate and the implied volatility. Therefore, suggesting that the Greeks: DELTA, base RHO, Foreign RHO, THETA, GAMMA and VEGA do not show promise in fully explaining the PnL of an option. Again, this is also in line with theory since the MtM equation of an option is far from linear. This suggests that at the very least, higher-order Greeks for the USD LIBOR rate, MXN TIIE rate and the implied volatility need to be considered in order to gain a better understanding of the risk profile of a Put and Call position [2].

In the experiment, a delta re-hedge was performed due to a spike in the overall spot delta of the MMs positions on March 7th. The hedging position was given a maturity equal to that of the call option for client C. This was done because the spot delta of an option reflects how ITM or OTM an option is [5]. ATM options are expected to have a spot delta of around plus minus 0.5, deep ITM options will have a spot delta close to plus minus 1 and deep OTM will have a spot delta close to plus minus 0. Since the spot delta of the call option moves from 0.5268 on March 2nd to 0.6552 on March 7th this would suggest that the Option is moving towards being more ITM. Therefore, offsetting the resulting spot delta of all the MMs positions until the maturity of the call option seems correct. The call option has a small time-to-maturity and hence the MM can cover any extra spot delta caused by the call option moving more ITM without performing more re-hedging until the maturity of the Call option where a re-hedge will need to be performed.

6 Conclusion

This report has outlined the objectives of an FX derivatives market maker providing clients with forward and European options contracts. Additionally it has attempted to play the role of a MM, executing these objectives using the theory outlined in the report as well as live market data and fictional clients. The experiment has provided insight into the effectiveness of using the Greeks: DELTA, base RHO, Foreign RHO, and THETA to model the risk profile of a forward contract. Consequently, also highlights the ineffectiveness of using the Greeks: DELTA, base RHO, Foreign RHO, THETA, GAMMA and VEGA to model the risk profile of the subsequent Put or Call option contracts. While performing quoting of forward options traded at the mid and best price; the experiment provides a comparison for the effect on MtM value of the overall positions for these trades after hedging. The experiment provieds a comparison for the effect on MtM.

Performing quotes for forward contracts traded at the mid and best price, provided a comparison for the effect spot rate has on MtM value of the overall positions for these trades after hedging. Upon comparing theses results, one can conclude that quoting forward rates using spot rates within the bid-ask spread will result in a loss for the market maker and should be avoided.

A Appendix

A.1 Greeks

Mathematical representation of all the basic Greeks:

DELTA:

$$\Delta_{\text{Forward}} = \frac{\partial K}{\partial S} = \exp[(r_f - q)T] \tag{5}$$

$$\Delta_{\text{Call}} = \frac{\partial C}{\partial S} = \phi(d_1) \tag{6}$$

$$\Delta_{\text{Put}} = \frac{\partial P}{\partial S} = \phi(d_1) - 1 \tag{7}$$

VEGA:

$$\nu_{\text{Forward}} = \frac{\partial K}{\partial \sigma} = 0 \tag{8}$$

$$\nu_{\text{Call}} = \frac{\partial C}{\partial \sigma} = S_0 \cdot \phi'(d_1)\sqrt{T} \tag{9}$$

$$\nu_{\text{Put}} = \frac{\partial P}{\partial \sigma} = S_0 \cdot \phi'(d_1)\sqrt{T} \tag{10}$$

RHO (Local):

$$\rho_{\text{Forward}} = \frac{\partial K}{\partial r_f} = -T \cdot S \cdot \exp[(r_f - q)T] = -T \cdot K \tag{11}$$

$$\rho_{\text{Call}} = \frac{\partial C}{\partial r_f} = T \cdot X \cdot \exp[-rT] \cdot \phi(d_2) \tag{12}$$

$$\rho_{\text{Put}} = \frac{\partial P}{\partial r_f} = -T \cdot X \cdot \exp[-rT] \cdot \phi(-d_2) \tag{13}$$

RHO (Foreign):

$$\hat{\rho}_{\text{Forward}} = \frac{\partial K}{\partial q} = T \cdot S \cdot \exp[(r_f - q)T] = T \cdot K \tag{14}$$

$$\hat{\rho}_{\text{Call}} = \frac{\partial C}{\partial q} = -T \cdot S \cdot \exp[-qT] \tag{15}$$

$$\hat{\rho}_{\text{Put}} = \frac{\partial P}{\partial q} = T \cdot S \cdot \exp[-qT] \tag{16}$$

THETA:

$$\Theta_{\text{Forward}} = \frac{\partial K}{\partial T} = (r_f - q) \cdot S \cdot \exp[(r_f - q)T] = (r_f - q) \cdot K \tag{17}$$

$$\Theta_{\text{Call}} = \frac{\partial C}{\partial T} = -\frac{S_0 \cdot \phi'(d_1) \cdot \sigma}{2\sqrt{T}} - r \cdot X \cdot \exp[-rT] \cdot \phi(d_2) \tag{18}$$

$$\Theta_{\text{Put}} = \frac{\partial P}{\partial T} = -\frac{S_0 \cdot \phi'(d_1) \cdot \sigma}{2\sqrt{T}} + r \cdot X \cdot \exp[-rT] \cdot \phi(-d_2) \tag{19}$$

GAMMA:

$$\Gamma_{\text{Forward}} = \frac{\partial \Delta}{\partial S} = \frac{\partial^2 K}{\partial S^2} = 0 \tag{20}$$

$$\Gamma_{\text{Call}} = \frac{\partial \Delta_{\text{Call}}}{\partial S} = \frac{\partial^2 C}{\partial S^2} = \frac{\phi(d_1)}{S_0 \cdot \sigma\sqrt{T}} \tag{21}$$

$$\Gamma_{\text{Put}} = \frac{\partial \Delta_{\text{Put}}}{\partial S} = \frac{\partial^2 P}{\partial S^2} = \frac{\phi(d_1)}{S_0 \cdot \sigma\sqrt{T}} \tag{22}$$

A.2 Greeks Explained

Mathematical representation of all basic Greeks explained:

DELTA Explained:

$$\Delta_{\text{Explained}} = \Delta \cdot \partial S \tag{23}$$

VEGA Explained:

$$\nu_{\text{Explained}} = \nu \cdot \partial \sigma \tag{24}$$

RHO (Local) Explained:

$$\rho_{\text{Explained}} = \rho \cdot \partial r_f \tag{25}$$

RHO (Foreign) Explained:

$$\hat{\rho}_{\text{Explained}} = \hat{\rho} \cdot \partial q \tag{26}$$

THETA Explained:

$$\Theta_{\text{Forward}} = \Theta \cdot \partial T \tag{27}$$

GAMMA Explained:

$$\Gamma_{\text{Explained}} = \frac{1}{2} \cdot \Gamma \cdot \partial S \tag{28}$$

A.3 Other Equations

Black-Scholes Option Pricing Formula:

$$\begin{gathered} C(S_0, K, r_f, q, T) = S_0 e^{-qT} \phi(d_1) - K e^{-r_f T} \phi(d_2) \\ P(S_0, K, r_f, q, T) = K e^{-r_f T} \phi(-d_2) - S_0 e^{-qT} \phi(-d_1) \end{gathered} \tag{29}$$

Where $\quad d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r_f + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}, \quad d_2 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r_f - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$

Mark-to-market Equation (FX Forward):

$$\text{MtM}_{\text{Forward}} = S \cdot N_{FOREIGN} \cdot \exp\big[-qT\big] \tag{30}$$

Mark-to-market Equation (FX Option):

$$\begin{gathered} \text{MtM}_{\text{Call}} = [S_0 e^{-qT} \phi(d_1) - K e^{-r_f T} \phi(d_2)] \cdot N_{FOREIGN} \\ \text{MtM}_{\text{Put}} = [K e^{-r_f T} \phi(-d_2) - S e^{-qT} \phi(-d_1)] \cdot N_{FOREIGN} \end{gathered} \tag{31}$$

Where $\quad d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r_f + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}, \quad d_2 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r_f - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$

A.4 Figures

Market Date =		17-Feb-23	
Prev Date=		NA	
FX Spot	Bid /	Offer	Mid
USDMXN=	18.560	18.760	18.660
EURUSD=	1.050	1.070	1.060
RATES	Bid /	Offer	Mid
USD Libor=	1.90%	2.10%	2.00%
MXN TIIE=	9.90%	10.10%	10.00%

(a) Market data on 17-Feb-23

Market Date =		21-Feb-23	
Prev Date=		17-Feb-23	
FX Spot	Bid /	Offer	Mid
USDMXN=	18.280	18.480	18.380
EURUSD=	1.060	1.080	1.070
RATES	Bid /	Offer	Mid
USD Libor=	1.90%	2.10%	2.00%
MXN TIIE=	9.90%	10.10%	10.00%

(b) Market data on 21-Feb-23

Market Date =		28-Feb-23	
Prev Date=		21-Feb-23	
FX Spot	Bid /	Offer	Mid
USDMXN=	18.240	18.340	18.290
EURUSD=	1.050	1.070	1.060
RATES	Bid /	Offer	Mid
USD Libor=	1.90%	2.10%	2.00%
MXN TIIE=	9.90%	10.10%	10.00%

(c) Market data on 28-Feb-23

Market Date =		2-Mar-23	
Prev Date=		28-Feb-23	
FX Spot	Bid /	Offer	Mid
USDMXN=	18.090	18.290	18.190
EURUSD=	1.050	1.070	1.060
RATES	Bid /	Offer	Mid
USD Libor=	1.80%	2.00%	1.90%
MXN TIIE=	9.90%	10.10%	10.00%

(d) Market data on 2-Mar-23

Market Date =		7-Mar-23	
Prev Date=		2-Mar-23	
FX Spot	Bid /	Offer	Mid
USDMXN=	17.870	18.070	17.970
EURUSD=	1.060	1.080	1.070
RATES	Bid /	Offer	Mid
USD Libor=	1.80%	2.00%	1.90%
MXN TIIE=	9.60%	9.80%	9.70%

(e) Market data on 7-Mar-23

Figure 1: Market Data

1Y VOL	Bid / Offer
ATMF =	12.50% 13.00%

(a) Volatility bid-ask quote on 28-Feb-23

1Y VOL	Bid / Offer
ATMF =	12.70% 12.90%

(b) Volatility bid-ask quote on 2-Mar-23

1Y VOL	Bid / Offer
ATMF =	12.80% 13.00%

(c) Volatility bid-ask quote on 7-Mar-23

Figure 2: 1 Y volatility bid-ask quotes

Unexplained $0	Day1 PnL ($531,636)	Value and Risk							Contract Details (Forward Contract)					
PnL Explained	PnL	MtM	SpotDelta (M MXN)	BSGamma	BSVega	Rho USD	Rho MXN	Carry	Trade Type	Notional (M USD) Past Price	Notional (M MXN) Future price	Strike	Maturity	Days to Maturity
$0	**($531,636)**	**($531,636)**	**-10.29**	0.00	0.00	($2)	$55	($33)						
$0	$100,000,000	$100,000,000	0	0.00	0.00	-10,000	0	($16,440)	D	100	102	########	17-Feb-24	365
$0	($100,535,906)	($100,535,906)	-1,876	0.00	0.00	0	10,053	($5,509)	F	-1,876	-2,073	########	17-Feb-24	365
$0	$4,270	$4,270	1,866	0.00	0.00	9,998	-9,998	$21,915	F	102	2,062	20.215	17-Feb-24	365

Figure 3: Market makers net positions on 17-Feb-23

Unexplained $0	Day1 PnL $2,305	Value and Risk							Contract Details					
PnL Explained	PnL	MtM	SpotDelta (M MXN)	BSGamma	BSVega	Rho USD	Rho MXN	Carry	Trade Type	Notional (M USD)	Notional (M MXN)	Strike	Maturity	Days to Maturity
($9,009)	**($6,704)**	**($538,340)**	**-5.39**	0.00	0.00	$15	$38	($94)						
$21,923	$21,920	$100,021,920	0	0.00	0.00	-9,893	0	$5,481	D	100	102	########	17-Feb-24	361
($1,643,552)	($1,643,475)	($102,179,381)	-1,878	0.00	0.00	0	10,105	($27,998)	F	-1,876	-2,073	########	17-Feb-24	361
$1,612,619	$1,612,546	$1,616,816	1,868	0.00	0.00	9,890	-10,050	$22,365	F	102	2,062	20.215	17-Feb-24	361
$0	($95,000,000)	($95,000,000)	0	0.00	0.00	6,299	0	($5,206)	D	-95	-96	########	21-Oct-23	242
$0	$94,483,134	$94,483,134	1,737	0.00	0.00	0	-6,264	$25,889	F	1,737	1,856	########	21-Oct-23	242
$0	$519,171	$519,171	-1,732	0.00	0.00	-6,281	6,246	($20,625)	F	-96	-1,850	19.275	21-Oct-23	242

Figure 4: Market makers net positions on 21-Feb-23

Unexplained $1	Day1 PnL $844,565	Value and Risk							Contract Details					
PnL Explained	PnL	MtM	SpotDelta (M MXN)	BSGamma	BSVega	Rho USD	Rho MXN	Carry	Trade Type	Notional (M USD)	Notional (M MXN)	Strike	Maturity	Days to Maturity
($2,105)	**$842,461**	**$304,121**	**-24.46**	55,973.82	35,153.95	($16)	$54	($4,163)						
$38,380	$38,372	$100,060,292	0	0.00	0.00	-9,704	0	$5,483	D	100	102	########	17-Feb-24	354
($700,126)	($699,910)	($102,879,291)	-1,882	0.00	0.00	0	9,977	($28,190)	F	-1,876	-2,073	########	17-Feb-24	354
$657,914	$657,707	$2,274,523	1,871	0.00	0.00	9,702	-9,923	$22,554	F	102	2,062	20.215	17-Feb-24	354
($36,453)	($36,445)	($95,036,445)	0	0.00	0.00	6,119	0	($5,208)	D	-95	-96	########	21-Oct-23	235
$647,392	$647,192	$95,130,326	1,740	0.00	0.00	0	-6,125	$26,067	F	1,737	1,856	########	21-Oct-23	235
($609,211)	($609,020)	($89,849)	-1,735	0.00	0.00	-6,102	6,107	($20,800)	F	-96	-1,850	19.275	21-Oct-23	235
$0	$10,000,000	$10,000,000	0	0.00	0.00	-162	0	$548	D	10	10	########	28-Apr-23	59
$0	($9,972,663)	($9,972,663)	-182	0.00	0.00	0	161	($2,733)	F	-182	-185	########	28-Apr-23	59
$0	$457,196	$457,196	205	55,973.82	35,159.95	174	-181	($1,408)	C	22	408	18.528	28-Apr-23	59
$0	($119,980,604)	($119,980,604)	0	0.00	0.00	1,939	0	($6,574)	D	-120	-120	########	28-Apr-23	59
$0	$119,671,952	$119,671,952	2,189	0.00	0.00	0	-1,934	$32,791	F	2,189	2,224	########	28-Apr-23	59
$0	$668,684	$668,684	-2,230	0.00	0.00	-1,982	1,971	($26,693)	F	-123	-2,267	18.427	28-Apr-23	59

Figure 5: Market makers net positions on 28-Feb-23

Unexplained -$7,036	Day1 PnL $6,188,046	Value and Risk							Contract Details					
PnL Explained	PnL	MtM	SpotDelta (M MXN)	BSGamma	BSVega	Rho USD	Rho MXN	Carry	Trade Type	Notional (M USD)	Notional (M MXN)	Strike	Maturity	Days to Maturity
($12,623)	**$6,168,387**	**$6,472,508**	**20.07**	186,079.44	538,937.93	($471)	($106)	($12,187)						
$107,473	$107,520	$100,167,812	0	0.00	0.00	-9,660	0	$5,214	D	100	102	########	17-Feb-24	352
($622,303)	($622,279)	($103,501,570)	-1,883	0.00	0.00	0	9,981	($28,360)	F	-1,876	-2,073	########	17-Feb-24	352
$511,442	$511,368	$2,785,891	1,872	0.00	0.00	9,658	-9,926	$22,992	F	102	2,062	20.215	17-Feb-24	352
($71,090)	($71,109)	($95,107,554)	0	0.00	0.00	6,071	0	($4,951)	D	-95	-96	########	21-Oct-23	233
$575,430	$575,409	$95,705,735	1,741	0.00	0.00	0	-6,109	$26,224	F	1,737	1,856	########	21-Oct-23	233
($502,915)	($502,873)	($592,722)	-1,736	0.00	0.00	-6,054	6,092	($21,213)	F	-96	-1,850	19.275	21-Oct-23	233
$2,658	$2,658	$10,002,658	0	0.00	0.00	-156	0	$521	D	10	10	########	28-Apr-23	57
($60,323)	($60,321)	($10,032,984)	-182	0.00	0.00	0	157	($2,749)	F	-182	-185	########	28-Apr-23	57
$59,991	$52,955	$510,151	223	57,016.58	34,460.45	183	-191	($1,133)	C	22	408	18.528	28-Apr-23	57
($31,889)	($31,889)	($120,012,494)	0	0.00	0.00	1,874	0	($6,247)	D	-120	-120	########	28-Apr-23	57
$723,879	$723,852	$120,395,804	2,190	0.00	0.00	0	-1,880	$32,990	F	2,189	2,224	########	28-Apr-23	57
($704,978)	($704,950)	($36,265)	-2,231	0.00	0.00	-1,915	1,916	($27,229)	F	-123	-2,267	18.427	28-Apr-23	57
$0	($30,000,000)	($30,000,000)	0	0.00	0.00	3,008	0	($1,562)	D	-30	-31	########	2-Mar-24	366
$0	$29,835,074	$29,835,074	543	0.00	0.00	0	-2,992	$8,175	F	543	600	########	2-Mar-24	366
$0	$3,334,738	$3,334,738	-559	66,032.16	258,104.76	-3,413	3,080	($11,191)	P	66	1,302	19.729	2-Mar-24	366
$0	$30,000,000	$30,000,000	0	0.00	0.00	-3,008	0	$1,562	D	30	31	########	2-Mar-24	366
$0	($30,164,926)	($30,164,926)	-549	0.00	0.00	0	3,025	($8,265)	F	-549	-607	########	2-Mar-24	366
$0	$3,183,159	$3,183,159	591	63,030.70	246,372.73	2,940	-3,257	$3,037	C	63	1,243	19.729	2-Mar-24	366

Figure 6: Market makers net positions on 2-Mar-23

Unexplained $20,104	Day1 PnL ($55,648)	Value and Risk							Contract Details					
PnL Explained	PnL	MtM	SpotDelta (M MXN)	BSGamma	BSVega	Rho USD	Rho MXN	Carry	Trade Type	Notional (M USD)	Notional (M MXN)	Strike	Maturity	Days to Maturity
$7,331	**($28,213)**	**$6,444,294**	**-1.37**	180,977.78	532,473.27	$62	($633)	($12,459)						
$26,079	$26,074	$100,193,886	0	0.00	0.00	-9,525	0	$5,216	D	100	102	########	17-Feb-24	347
($1,706,383)	($1,710,391)	($105,211,961)	-1,891	0.00	0.00	0	10,002	($27,964)	F	-1,876	-2,073	########	17-Feb-24	347
$1,670,951	$1,674,941	$4,460,832	1,880	0.00	0.00	9,523	-9,947	$22,596	F	102	2,062	20.215	17-Feb-24	347
($24,761)	($24,757)	($95,132,311)	0	0.00	0.00	5,943	0	($4,952)	D	-95	-96	########	21-Oct-23	228
$1,484,130	$1,486,454	$97,192,189	1,747	0.00	0.00	0	-6,071	$25,833	F	1,737	1,856	########	21-Oct-23	228
($1,455,245)	($1,457,567)	($2,050,289)	-1,742	0.00	0.00	-5,926	6,054	($20,821)	F	-96	-1,850	19.275	21-Oct-23	228
$2,604	$2,604	$10,005,262	0	0.00	0.00	-143	0	$521	D	10	10	########	28-Apr-23	52
($141,051)	($141,099)	($10,174,083)	-183	0.00	0.00	0	145	($2,704)	F	-182	-185	########	28-Apr-23	52
$165,627	$169,813	$679,965	267	54,098.65	30,965.66	202	-212	($613)	C	22	408	18.528	28-Apr-23	52
($31,245)	($31,240)	($120,043,734)	0	0.00	0.00	1,710	0	($6,249)	D	-120	-120	########	28-Apr-23	52
$1,692,614	$1,693,190	$122,088,993	2,194	0.00	0.00	0	-1,739	$32,450	F	2,189	2,224	########	28-Apr-23	52
($1,692,685)	($1,693,276)	($1,729,541)	-2,235	0.00	0.00	-1,748	1,772	($26,678)	F	-123	-2,267	18.427	28-Apr-23	52
($7,810)	($7,809)	($30,007,809)	0	0.00	0.00	2,968	0	($1,562)	D	-30	-31	########	2-Mar-24	361
$495,315	$496,523	$30,331,597	545	0.00	0.00	0	-3,000	$8,062	F	543	600	########	2-Mar-24	361
($505,441)	($498,534)	$2,836,204	-502	64,914.90	256,585.29	-3,042	2,764	($10,404)	P	66	1,302	19.729	2-Mar-24	361
$7,810	$7,809	$30,007,809	0	0.00	0.00	-2,968	0	$1,562	D	30	31	########	2-Mar-24	361
($500,791)	($502,012)	($30,666,938)	-551	0.00	0.00	0	3,033	($8,151)	F	-549	-607	########	2-Mar-24	361
$527,613	$536,712	$3,719,871	650	61,964.23	244,922.32	3,211	-3,577	$3,553	C	63	1,243	19.729	2-Mar-24	361
$0	$10,000,000	$10,000,000	0	0.00	0.00	-142	0	$521	D	10	10	########	28-Apr-23	52
$0	($10,055,648)	($10,055,648)	-181	0.00	0.00	0	143	($2,673)	F	-181	-183	########	28-Apr-23	52

Figure 7: Market makers net positions on 7-Mar-23

Delta Explain	BSGamma Explain	BSVega Explain	RhoUSD Explain	RhoMXN Explain	Theta	Total Explain
-$8,399.56	$0.00	$0.00	$0.00	$0.00	-$609.88	($9,009)
$0.00	$0.00	$0.00	$0.00	$0.00	$21,923.21	$21,923
-$1,531,558.95	$0.00	$0.00	$0.00	$0.00	-$111,992.74	($1,643,552)
$1,523,159.40	$0.00	$0.00	$0.00	$0.00	$89,459.65	$1,612,619

Figure 8: Greeks explained from 17-Feb-23 to 23-Feb-23

Delta Explain	BSGamma Explain	BSVega Explain	RhoUSD Explain	RhoMXN Explain	Theta	Total Explain
-$1,444.21	$0.00	$0.00	$0.00	$0.00	-$660.75	($2,105)
$0.00	$0.00	$0.00	$0.00	$0.00	$38,380.34	$38,380
-$502,796.30	$0.00	$0.00	$0.00	$0.00	-$197,329.78	($700,126)
$500,038.80	$0.00	$0.00	$0.00	$0.00	$157,874.79	$657,914
$0.00	$0.00	$0.00	$0.00	$0.00	-$36,453.33	($36,453)
$464,925.21	$0.00	$0.00	$0.00	$0.00	$182,466.72	$647,392
-$463,611.92	$0.00	$0.00	$0.00	$0.00	-$145,599.49	($609,211)

Figure 9: Greeks explained from 23-Feb-23 to 28-Feb-23

Delta Explain	BSGamma Explain	BSVega Explain	RhoUSD Explain	RhoMXN Explain	Theta	Total Explain
-$7,352.60	$2,528.50	-$70.32	$156.05	$0.00	-$7,885.08	($12,623)
$0.00	$0.00	$0.00	$97,044.78	$0.00	$10,428.70	$107,473
-$565,581.59	$0.00	$0.00	$0.00	$0.00	-$56,720.96	($622,303)
$562,479.76	$0.00	$0.00	-$97,020.92	$0.00	$45,983.24	$511,442
$0.00	$0.00	$0.00	-$61,187.85	$0.00	-$9,901.87	($71,090)
$522,981.45	$0.00	$0.00	$0.00	$0.00	$52,448.68	$575,430
-$521,504.18	$0.00	$0.00	$61,015.47	$0.00	-$42,426.24	($502,915)
$0.00	$0.00	$0.00	$1,616.44	$0.00	$1,041.40	$2,658
-$54,824.97	$0.00	$0.00	$0.00	$0.00	-$5,498.28	($60,323)
$61,534.32	$2,528.50	-$70.32	-$1,735.60	$0.00	-$2,265.53	$59,991
$0.00	$0.00	$0.00	-$19,394.13	$0.00	-$12,494.78	($31,889)
$657,899.68	$0.00	$0.00	$0.00	$0.00	$65,979.34	$723,879
-$670,337.08	$0.00	$0.00	$19,817.86	$0.00	-$54,458.79	($704,978)

Figure 10: Greeks explained from 28-Feb-23 to 2-Mar-23

Delta Explain	BSGamma Explain	BSVega Explain	RhoUSD Explain	RhoMXN Explain	Theta	Total Explain
$13,510.83	$42,145.60	$34.46	$0.00	$3,173.57	-$51,533.48	$7,331
$0.00	$0.00	$0.00	$0.00	$0.00	$26,078.54	$26,079
-$1,267,131.07	$0.00	$0.00	$0.00	-$299,431.20	-$139,820.77	($1,706,383)
$1,260,181.72	$0.00	$0.00	$0.00	$297,789.02	$112,980.56	$1,670,951
$0.00	$0.00	$0.00	$0.00	$0.00	-$24,761.11	($24,761)
$1,171,689.57	$0.00	$0.00	$0.00	$183,277.19	$129,162.95	$1,484,130
-$1,168,379.88	$0.00	$0.00	$0.00	-$182,759.48	-$104,105.95	($1,455,245)
$0.00	$0.00	$0.00	$0.00	$0.00	$2,604.18	$2,604
-$122,830.07	$0.00	$0.00	$0.00	-$4,700.35	-$13,520.78	($141,051)
$150,002.88	$12,913.83	$34.46	$0.00	$5,739.54	-$3,063.48	$165,627
$0.00	$0.00	$0.00	$0.00	$0.00	-$31,245.07	($31,245)
$1,473,960.87	$0.00	$0.00	$0.00	$56,404.17	$162,249.40	$1,692,614
-$1,501,825.66	$0.00	$0.00	$0.00	-$57,470.47	-$133,388.68	($1,692,685)
$0.00	$0.00	$0.00	$0.00	$0.00	-$7,810.46	($7,810)
$365,259.67	$0.00	$0.00	$0.00	$89,745.94	$40,308.98	$495,315
-$375,969.40	$14,955.79	$0.00	$0.00	-$92,407.47	-$52,020.11	($505,441)
$0.00	$0.00	$0.00	$0.00	$0.00	$7,810.46	$7,810
-$369,297.92	$0.00	$0.00	$0.00	-$90,738.16	-$40,754.63	($500,791)
$397,850.11	$14,275.98	$0.00	$0.00	$97,724.83	$17,762.52	$527,613

Figure 11: 2-Mar-23 to 7-Mar-23

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