Banco de México

Documentos de Investigación

Banco de México

Working Papers

N° 2010-17

Exchange Rate Market Expectations and Central Bank Policy: The case of the Mexican Peso-US Dollar from 2005-2009

Gustavo Abarca
Banco de México

Guillermo Benavides
Banco de México

José Gonzalo Rangel
Banco de México

December 2010

Documento de Investigación
2010-17

Working Paper
2010-17

Exchange Rate Market Expectations and Central Bank Policy: The case of the Mexican Peso-US Dollar from 2005-2009*

Gustavo Abarca†
Banco de México

Guillermo Benavides‡
Banco de México

José Gonzalo Rangel§
Banco de México

Abstract: We examine two approaches characterized by different tail features to extract market expectations on the Mexican peso-US dollar exchange rate. Expectations are gauged by risk-neutral densities. The methods used to estimate these densities are the Volatility Function Technique (VFT) and the Generalized Extreme Value (GEV) approach. We compare these methods in the context of monetary policy announcements in Mexico and the US. Once the surprise component of the announcements is considered, our results indicate that, although both VFT and GEV suggest similar dynamics at the center of the distribution, these two methods show significantly different patterns in the tails. Our empirical evidence shows that the GEV model captures better the extreme values.
Keywords: Exchange rates, monetary policy, risk-neutral densities.
JEL Classification: C14, E44, E58, F31.

Resumen: Se examinan dos metodologías caracterizadas por diferentes propiedades en las colas de la distribución para extraer expectativas del tipo de cambio peso-dólar. Las expectativas son medidas con densidades de riesgo-neutral. Los métodos utilizados para estimar estas densidades son la Técnica de Función de Volatilidad (VFT) y el método de Valor Extremo Generalizado (GEV). Comparamos estos métodos en el contexto de anuncios de política monetaria en México y en Estados Unidos. Una vez que consideramos el componente sorpresivo de los anuncios, los resultados indican que, aunque ambos VFT y GEV sugieren una dinámica similar en el centro de la distribución, estos métodos muestran patrones significativamente diferentes en las colas de la distribución. Nuestra evidencia empírica muestra que el modelo GEV captura mejor los valores extremos.
Palabras Clave: Tipos de cambio, política monetaria, densidades de riesgo-neutral.

*We thank Ana Luisa Mexicano, Luis Mejía and Pablo Bravo for excellent research assistance. We are grateful to Carlos Capistrán, Santiago García and seminar participants at Banco de México, XI JOLATE Conference at San Luis Potosí and at ITAM for their helpful comments. The opinions presented in this paper are exclusively the responsibility of the authors and do not necessarily reflect the point of view of Banco de México. A previous version of this paper was awarded with the Premio Nacional de Derivados 2010 from the Mexican Derivatives Exchange (MexDer).

† Dirección General de Investigación Económica. Email: gabarca@banxico.org.mx.
‡ Dirección General de Investigación Económica. Email: gbenavid@banxico.org.mx.
§ Dirección General de Investigación Económica. Email: jgrangel@banxico.org.mx.

1. Introduction

Risk-Neutral Density (RND) estimation is of fundamental interest in several financial applications. For instance, RNDs are widely used for measuring the unobserved market expectations about asset prices. Gauging such expectations could be useful not only for pricing, hedging, and managing risk, but also for the analysis of policy decisions and their transmission mechanisms (see, among others, Bernanke and Kuttner (2005) and Taylor (2005)). Indeed, a measure of market expectations allows policy makers to assess the market's reaction to main economic events and to follow the implications of certain economic policy decisions, such as monetary policy actions by a central bank (Mc Manus (1999), Bernanke and Kuttner (2005), and Castrén (2005)).

Nowadays there are a wide variety of methods used to extract risk-neutral densities (see Bates (1991), Rubinstein (1994), Bahra (1997), Melick and Thomas (1997), and Aït-Sahalia and Lo (1998)).[1] However, besides the little consensus on a dominant methodology, there are considerably less studies that examine their performance on days of high market activity associated with the arrival of economic news. Recent exceptions are Castrén (2005) and Figlewski and Birru (2010).[2] The first study focuses on RNDs associated with currency markets in Eastern European countries and their response to foreign and local news surprises. The second paper examines the behavior of RNDs in the US equity market on the days when the Federal Reserve announces its future target for the federal funds rate (FFR). However, none of these papers compare different methodologies. While the latter applies the new approach of Figlewski (2009), the former uses the methodology of Malz (1997). In this regard, a practical comparison of methodologies is of special interest on days when fundamental information is released to the market because these days show different patterns in terms of the distribution of asset prices and

[1] Taylor (2005) enumerates several desirable properties for RND estimation. However, most researchers use a specific estimation method based on data availability, accuracy, consistent estimation, stability of estimated parameters, among others.
[2] Melick and Thomas (1997) and Soderlind (2000) also examine the response of RNDs to economic events; however, they focus on episodes of financial crisis rather than scheduled macroeconomic announcements.

therefore, the assumptions embedded in each methodology may affect the appropriate characterization of these patterns.[3]

The present paper contributes to address this issue by comparing the two mentioned methodologies in the context of monetary policy events that allow us to link news about fundamentals with changes in the market expectation of FX prices. We focus on the case of the Mexican peso to assess the implications of these methodologies.[4] The Mexican peso-US dollar market is interesting for a number of reasons: 1) options contracts on this currency offer a reasonable range of exercise prices, 2) financial markets in Mexico and the US are well synchronized in terms of trading hours, and 3) the high level of commercial integration between the two economies makes it interesting to assess the effect of monetary policy news from the two economies on the exchange rate.

Another contribution of the paper is the measurement of monetary policy shocks in Mexico from interest rates futures contracts. In particular, we apply the approach of Kuttner (2001) not only to measure monetary policy shocks in the US, but also to extract signals of changes in the market assessment of future changes in the monetary policy of the Central Bank of Mexico (Banxico).[5] In this regard, while data on federal funds rate futures contracts is available in the US, in Mexico there is only futures data on a reference rate (the Interbank Equilibrium Rate or TIIE) that characterizes the funding conditions in the local interbank market. However, we find a very high contemporaneous correlation between changes in the central bank target rate and changes in the TIIE. This correlation coefficient is of an order of magnitude of around 0.99 for the whole sample and around 0.93 for announcements days. Thus, we argue that, on monetary policy announcement days, changes in the TIIE futures mainly reflect changes in the market expectations of Banxico's monetary policy. Overall, the application of Kuttner's methodology to the case of Mexico provides a new measure for local monetary policy shocks and therefore contributes to the

---

[3] The literature on announcements and news effects on different moments of asset returns is ample. Some examples include Andersen and Bollerslev (1998), Jones, Lamont and Lumsdaine (1998), Flannery and Protopapadakis (2002), Andersen, Bollerslev, Diebold, and Vega (2003), Bomfim (2003), and Rangel (2009), among others.

[4] Other studies that have estimated RNDs for the Mexican Peso include Díaz de Leon and Casanova (2004) and Benavides and Mora (2008). However, none of them examine the effect of monetary policy scheduled announcements on RNDs.

[5] The approach of Kuttner (2001) for measuring monetary policy shocks from futures prices has been applied in a number of studies that examine US data, including Bernanke and Kuttner (2005) and Gurkaynak, Sack, and Swanson (2007). Moreover, Hamilton (2009) concludes that futures prices provide an excellent indicator of daily changes in the market's expectation of near term changes in Fed policy.

discussion of using high frequency information from local interest rate markets to gauge such shocks.

Our results show evidence that changes in the Mexican peso-US dollar exchange rate significantly respond to monetary policy surprises.[6] This finding provides empirical motivation for our event-study approach that focuses on these days to evaluate the RND methodologies. In this regard, our results indicate that for this exchange rate both the Volatility Function Technique (VFT) postulated by Malz (1997) and the Generalized Extreme Value (GEV) approach proposed by Figlewski (2009) suggest similar dynamics at the center of the distribution; however, these two frameworks lead to significantly different patterns in the tails. Indeed, our empirical evidence supports that the GEV captures better the extreme values of the distribution around monetary policy event days, given its unique procedure to allow for longer asymptotically well-behaved tails. These findings are robust to control for the surprise component of the announcement, which is measured by applying the methodology of Kuttner (2001) in both countries.

The layout of this paper is as follows. Section 2 gives a brief literature review and discusses the methodologies used to obtain the RNDs. Section 3 presents a brief data explanation. Section 4 explains the event-study analysis. A detailed empirical comparison of the two analyzed methods is also presented in this section. Finally, Section 5 concludes.

2. Literature Review and Methodology

2.1. Risk-neutral densities definition

The idea of estimating RNDs implied by option prices was first postulated by Breeden and Litzenberger (1978) motivated by the belief that there is a rich source of forward-looking financial information in derivatives markets. A way to extract this information is the estimation of an implicit probability distribution of an asset from the observed prices of options contracts on such an asset, which are traded in these financial markets. However, given that the models used to estimate these probabilities use an equivalent martingale measure of the objective (real)

[6] This evidence is based on a time series regression that only incorporates surprises from the US. Since the target rate as a policy instrument has been implemented in Mexico only since 2004, the data of target surprises in Mexico is too short to conduct reliable inference.

probability that prices assets as if agents were risk-neutral, the resulting probability density is called risk-neutral density.[7]

Breeden and Litzenberger (1978) proved that the RND can be extracted from the prices of call (or put) options. In particular, if the value of a call option is defined as:

$$c(X,T) = \int_X^{\infty} e^{-rT}(S_T - X)f(S_T)dS_T, \tag{1}$$

where c refers to the call option price, X is the exercise price, T is the time to maturity, r is the risk-free interest rate, S_T is the spot price of the underlying asset at the maturity of the option and $f(S_T)$ represents the risk-neutral probability function of the price of the underlying asset. By calculating the second partial derivative of the call price function $c(X,T)$ with respect to the different exercise prices (X), we obtain:

$$\frac{\partial^2 c(X,T)}{\partial X^2} = e^{-rT} f(X). \tag{2}$$

Rearranging this expression, it is possible to obtain the following definition:

$$f(X) = e^{rT}\left(\frac{\partial^2 c(X,T)}{\partial X^2}\right), \tag{3}$$

where $f(X)$ is the risk-neutral distribution. The assumption that the call price function is continuous for the range of exercise prices is problematic given that in practice only some prices are available or observed. Considering this limitation, Shimko (1993) proposed an interpolation method using the available exercise prices. In subsequent research, Malz (1997) proposed to interpolate across implied volatilities (using the framework of Garman and Kohlhagen (1983)) and the delta, which is the sensitivity of the option price with respect to changes in the underlying asset price. In this case, the delta has to pass through at least three points of the volatility smile as it will be explained in more detail in Subsection 2.1.1. One advantage of Malz's method is that it can be easily applied to exchange rate options. This is because traders trade quoting implied volatility as a function of the delta. Therefore, hard data on implied volatility is always available, which can be used for a smoother interpolation.

[7] This of course does not mean that investors are assumed to be risk-neutral.

Besides giving a point estimate forecast for the moments of a specific underlying asset, RNDs estimations also provide information about the whole asset price distribution expected by the market, as well as the market sentiment. For example, if an exchange rate shows RNDs with skewness that are systematically positive through time, the interpretation is that the market is expecting one of the currencies to depreciate (or keep depreciating) in the near future.

Considering the actual evidence, it could be assumed that, from a theoretical viewpoint, RND estimation can be seen as a parsimonious and reliable approach for capturing the market's belief about a future asset price distribution. The present paper compares the results from two known methods (non-parametric and parametric) to extract RNDs for exchange rates in the context of monetary policy announcements.

2.1.1. The volatility function technique

The volatility function technique (VFT) was originally postulated by Malz (1997). He extended the idea proposed by Shimko (1993) in which the application of interpolation methods to exercise prices allows to recover the RND. Shimko's method suggested a parabolic function to estimate a curve for the implied volatility function vis-à-vis exercise prices; i.e., the smile curve. The idea behind this method is to estimate a 'smoothed' smile implied volatility function, out of a relatively few exercise prices (five or less) with a parabolic function, and then generate smooth call option prices using the Black and Scholes (1973) formula (BS).

With the estimated call and put prices, the RND can be extracted by applying the previously defined Breeden and Litzenberger (1978) approach. The main difference with respect to Shimko's method is that the Malz's model does not use a parabolic function to estimate the smile curve, but instead it applies implied volatilities from option pricing strategies (risk reversals and strangles).[8] The objective is to estimate a curve matching implied volatility vis-à-vis the delta and then calculate the call option prices from it by using either BS or GK.[9]

The approach of Malz (1997) estimates a RND by interpolating the smile curve. Specifically, interpolation can be carried out in terms of the implied volatilities determined from market expectations. The considered implied volatilities are: 1) at-the-money (atm), where the forward price (F) equals the exercise price; 2) risk reversal (rr); and 3) strangle (str). For exchange rates these were taken from market traders. The implied volatilities from the above mentioned option strategies for a 25 delta can be theoretically obtained in terms of the implied volatilities of *atm* and out-of-the-money puts and calls with 25 delta options as follows.

Let rr be defined as:

$$rr_t^{25\Delta} = \sigma_t^{(\Delta_{0.25}^c)} - \sigma_t^{(\Delta_{0.25}^p)}, \tag{4}$$

and the str as:

$$str_t^{25\Delta} = 0.5\left[\sigma_t^{(\Delta_{0.25}^c)} + \sigma_t^{(\Delta_{0.25}^p)}\right] - \sigma_t^{ATM}. \tag{5}$$

Writing the volatility (σ) as a quadratic function of delta (δ), it is possible to obtain the following smile curve: [10]

$$\sigma(\delta) = atm - 2rr(\delta - 0.5) + 16str(\delta - 0.5)^2. \tag{6}$$

Once this curve is obtained a transformation is performed in which the implied volatility can be expressed in terms of exercise price (X) and not in terms of the delta. Thus, the definition of the delta function is as follows:

[8] A risk reversal is an option trading strategy that is constructed with an out-of-the-money (OTM) long position of a call option and an OTM short position of a put option, both with the same time to expiration (the investor hopes for extreme increases in the exchange rate to make a profit). A strangle is another common currency option trading strategy, which consists in taking an OTM long position of a call option and an OTM long position of a put option, both with the same time to expiration (the investor hopes for extreme movements in either direction of the exchange rate to make a profit). The options are OTM due to their lower price.

[9] Malz argued that his method is more accurate for modeling financial data given that option strategies' implied volatilities, like risk reversals and strangles, capture the market's expectations for the relative likelihood of exchange rate depreciations (implied skewness) and extreme events (excess implied kurtosis).

[10] The δ is defined as the sensitivity of the option price to a change in the spot price.

$$\delta = e^{-r_f T} * N\left(\frac{ln\left({F_t}/{X}\right) + \left(\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}\right), \tag{7}$$

where F_t is the forward price. Equation 7 is substituted into Equation 6 and Equation 8 is obtained,

$$\sigma(\delta) = atm - 2rr(e^{-r_f T} * a_1 - 0.5) + 16str(e^{-r_f T} * a_1 - 0.5)^2, \tag{8}$$

where a_1 is equal to $N\left(\frac{\ln\left({F_t}/{X}\right)+\left(\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}\right)$. To estimate the density function for the underlying asset, the Breeden and Litzenberger (1978) result is applied here. Thus, by substituting these expressions into Equation 3, it is possible to estimate the probability function for the underlying asset, which is expressed as follows:

$$f(S_T) = e^{rT}\left[F\left(b_1 + n(d_1)d_1\left(\frac{1}{X\nu\sqrt{T}}\right)^2\right) - X\left(b_2 + n(d_2)d_2\left(\frac{1}{X\nu\sqrt{T}}\right)^2\right)\right], \tag{9}$$

where b_1 is equal to $\left(\frac{n(d_1)}{X^2\nu\sqrt{T}}\right)$, and b_2 is $\left(\frac{n(d_2)}{X^2\nu\sqrt{T}}\right)$,

$$d_1 = \frac{ln\left({F_t}/{X}\right) + \left(\frac{\upsilon^2}{2}\right)T}{\upsilon\sqrt{T}},$$

$$d_2 = \frac{ln\left({F_t}/{X}\right) - \left(\frac{\upsilon^2}{2}\right)T}{\upsilon\sqrt{T}},$$

$n(x)$ is the normal density function and ν represents the option implied volatility, which makes Equation 8 equal to zero. Finally, by using different values of X, it is possible to extract the RND through option prices.

Several studies have applied the VFT. For example, Bliss and Panigirtzoglou (2002) extracted RNDs for the FTSE-100 stock index and short sterling futures. After an extensive comparison with other estimation methods, they concluded that the VFT approach shows better goodness-of-fit and stability of the parameters. However, they found that the tails of the RNDs were significantly unstable for the analyzed methods (VFT and the mixture of lognormals). Similarly, Benavides and Mora (2008) found qualitatively similar results for both methods, but applied for the Mexican peso-US dollar exchange rate. These results should not be underestimated given that an unstable tail could complicate the Value-at-Risk analysis. On the other hand, Mc Manus (1999) found that the VFT was not as accurate as the mixture of lognormals' method, which showed higher goodness-of-fit for the case of Eurodollar options. Micu (2004) extracted RNDs for twelve emerging markets currencies vis-à-vis the US dollar. Among other methods, he applied the VFT method and concluded that there is a trade-off between goodness-of-fit accuracy and stability of the parameters. Castrén (2005) used this method to examine RNDs for Eastern European currencies on days of economic releases.

2.1.2. Generalized extreme value

Based on Equations 1-3, Figlewski (2009) suggests that the $f(X_n)$ can be approximated using a numerical approach as:

$$f(X_n) \approx e^{rT} \frac{c_{n+1} - 2c_n + c_{n-1}}{(\Delta X)^2}, \tag{10}$$

where n is the cross-section value of the option with the same time to maturity. Extracting from a set of call option prices with exercise prices between X_2 and X_{N-1} (N refers to the total number of exercise prices relevant to the n options), it is possible to obtain the relevant portion of the RND. To fit the tails of the RNDs, Figlewski (2009) suggests the application of Extreme Value Theory (EVT) that derives a limit distribution for the extreme events. This is the standard Generalized Extreme Value (GEV) distribution, which has one parameter (ξ) that determines the shape of the tail. The GEV distribution function can be formally defined as:

$$F(z) = exp\left[-(1 + \xi z)^{-1/\xi}\right]. \tag{11}$$

As explained in McNeil et al. (2005), the extreme value distribution is generalized in the sense that the parametric form depends mainly on the value of ξ. When $\xi>0$, the distribution is a Frechet distribution that has heavier tails than the normal distribution; when $\xi=0$, it is a Gumbel distribution that shows tails similar to those of the normal distribution; and when $\xi<0$, we have the case of a Weibull distribution that has tails (with a finite endpoint) smaller than those of the normal distribution.

To set the location and scale of the distribution, two other parameters are introduced. Using the notation μ for location and σ for scale, the following expression defines the standardized variable:

$$z = \frac{S_T - \mu}{\sigma}. \tag{12}$$

Since we are able to set three GEV parameters, it is possible to impose three conditions on the tail. Following the notation of Figlewski (2009), we use the expressions $F_{\mathrm{EVL}}(\cdot)$ to denote the approximating left tail GEV distribution and $F_{\mathrm{EVR}}(\cdot)$ to denote the equivalent approximation of the right tail (where the subscripts L and R refer to the left and right tails, respectively). The corresponding density functions are expressed as $f_{\mathrm{EVL}}(\cdot)$ and $f_{\mathrm{EVR}}(\cdot)$. Lastly, $F_{\mathrm{EMP}}(\cdot)$ and $f_{\mathrm{EMP}}(\cdot)$ refer to the empirical risk-neutral distribution and empirical risk-neutral density function, respectively.

For the α-quantile of the risk neutral distribution, let $X(\alpha)$ denote the relevant exercise price, i.e. $F_{\mathrm{EMP}}\big(X(\alpha)\big) = \alpha$. The procedure consists in choosing the value of α where the GEV tail is supposed to begin and then choose a more extreme point on the tail, which is useful to match the GEV tail shape to that of the empirical RND. Again, in line with Figlewski (2009), α_{0R} and α_{1R} denote the relevant points in the right tail, and α_{0L} and α_{1L} the corresponding points in the left tail. There is no unique rule for choosing the values of α_0 and α_1. However, the constraints imposed in order to be able to compute the empirical RND at both points are $X_2 \leq X(\alpha_{1L})$ and $X(\alpha_{1R}) \leq X_{N-1}$. It should be pointed out that the GEV will fit the larger extreme tail of a given distribution better than the closer tail. So, there is a trade-off between the quality and the availability of the data. In this regard, quality would favor less extreme values of α_0 and α_1 relative to a tail fit that favors more extreme values.

To fit the upper tail of the RND, it is necessary to impose three conditions. The first one requires that the total probability in the tail must be the same for both the GEV approximation and the RND; and, in order to have the same shape for the RND and the GEV density (where the two overlap), the method applies two other degrees of freedom to set the two densities equal at α_{0R} and α_{1R}. Thus, the three conditions for the right tail are the following:

$$F_{EVR}\big(X(\alpha_{0R})\big) = \alpha_{0R}, \tag{13}$$

$$f_{EVR}(X(\alpha_{0R})) = f_{EMP}(X(\alpha_{0R})), \tag{14}$$

$$f_{EVR}(X(\alpha_{1R})) = f_{EMP}(X(\alpha_{1R})). \tag{15}$$

Using standard optimization procedures, it is feasible to find the GEV parameter values that satisfy these conditions.

Given that the GEV is the distribution of the maximum values in a sample, its right tail relates to the probabilities of such maximum values. In order to fit the left tail, it is necessary to reverse the sign and define the GEV distribution on $-z$. The initial choice was to connect the left and right tails at α_0 values of 5% and 95%, respectively. However, for the exchange rate options that we analyze, market prices for options with the relevant exercise prices were not always available for both tails. Therefore, we have chosen default values of $\alpha_{0L} = 0.05$ and $\alpha_{0R} = 0.92$, with $\alpha_{1L} = 0.02$ and $\alpha_{1R} = 0.95$ as the relevant connection points. In cases where no data were available for these α values, we set $\alpha_{1L} = F_{EMP}(X_1) + 0.02$, the lowest connection point available from the data, and $\alpha_{0L} = \alpha_{1L} + 0.03$. For the right tail, $\alpha_{1R} = F_{EMP}(X_N)$ - 0.02, and $\alpha_{0R} = \alpha_{1R}$ - 0.03.

3. Data

3.1. Exchange rates and interest rates

The data for the exchange rate consists of daily spot and futures quotes obtained from Banco de México's financial database 'SIE' and the Mexican Derivatives Exchange (MexDer), respectively.[11] The daily data for the spot exchange rate Mexican peso-US dollar consist of daily averages of quotes offered by major Mexican banks and other financial intermediaries. The futures prices considered are quotes of the nearby expiration traded contracts at the MexDer. Spot exchange rates, as well as *atm*, *rr*, and *str* implied volatilities were obtained from a dataset of the investment bank UBS.[12] These implied volatilities direct quotes are a weighted average of major operations that UBS and other financial institutions conducted in the Mexican peso-US dollar currency option over-the-counter market. UBS obtains a poll of several transactions and provides

[11] Banco de México is Mexico's Central Bank, with web page: http://www.banxico.org.mx.
MexDer web page is http://www.mexder.com.mx.

[12] The implied volatility data are taken from quotes made on volatility trading and not over option prices. In other words, it is hard data for volatility. It is common practice among option traders to trade with volatility quotes in exchange rate option markets (See Malz (1997), and Cooper and Talbot (1999) for more details).

a representative reading of the market. The quotes are in units called vols, following the conventions usually expressed by dealers. The database is available for subscribers only. At-the-money implied volatility considers a delta of 50, risk-reversal and strangles are associated with a 25 delta. These are the most common ones in this type of trading. We use implied volatilities for two types of maturities: three weeks and one month. For the RND estimation we focus on the one month maturity. However we also consider a shorter maturity (three weeks) for robustness checks.[13] The sample period under analysis includes almost four years of daily data, from September 2, 2005 to June 30, 2009.

The data on interest rates considers two types of series. To analyze changes in the stance of monetary policy, we use data on the Central Bank's overnight target (objective) interest rates. These data are published by Banco de Mexico and the Federal Reserve System (FED), respectively. The series were downloaded from their respective web pages.[14] In Mexico, the overnight interest rate objective has been formally disclosed since January 2008. When there is no overnight objective interest rate data in Mexico (i.e., before 2008), the overnight interest rate for Federal Mexican Government Bonds is used instead. This is a good proxy given that whenever Banco de Mexico announced its desired interest rate level, the Federal Mexican Government interest rates reacted immediately to the announcement. These rates have changed in the right direction and in the same order of magnitude on announcement days, during the period in which both are available. For example, if Banco de Mexico relaxed the desired level of interest rate for 50 basis points, we observed a decrease of 50 basis points in the overnight Federal Mexican Government Bond interest rate on the same day of the announcement.

To estimate RNDs, we use the domestic and foreign risk-free discount rates, which consist of daily 28-day secondary market interest rates of Mexican Certificates of Deposit (CDs), obtained from the same source and the equivalent maturity US CDs, obtained from the Federal Reserve (FED) web page. We choose these interest rates because they are highly liquid in the secondary market and we can find the relevant maturity for our study (i.e., one month ahead).

[13] Comparing among different volatility forecast models, Benavides and Capistrán (2009) show that the three-week option implied volatilities, within a conditional combination model, were the most accurate in terms of forecasting realized volatility for the Mexican Peso-USD exchange rate.
[14] The FED web page is http://www.federalreserve.gov/. Banco de México web page was given in footnote 11.

4. Exchange Rate and Interest Rate Monetary Policy Events

4.1. Event-study analysis

As mentioned above, we perform a detailed analysis of several situations related to central bank monetary policy actions. For Mexico and the US, we consider these actions as the time episodes in which the central banks decided to change (or not) the objective interest rate. In the case of changes, we classify them as upward and downward movements. Thus, we have three possible scenarios in terms of objective interest rate monetary policy actions. The central bank can decide to cut the objective interest rate, increase it, or not to move it at all.

After identifying interest rate movements, we consider the effect of surprises on the estimated RNDs. The surprises are measured from federal funds rate (FFR) futures prices following the methodology of Kuttner (2001). Data on such interest rate futures contracts are obtained from the Chicago Board of Trade for the US. For the case of Mexico, there are no future contracts on the target rate. Nonetheless, we can extract information about interest rate expectation in Mexico from futures contracts on a reference rate (the Interbank Equilibrium Rate or TIIE) that reflects funding conditions in the Mexican interbank market. These are liquid contracts traded at the MexDer. Under the assumption that, on days of monetary policy announcements, variations in the expectations about this rate mainly reflect changes in the market expectation of Banxico's monetary policy, we use it to measure monetary policy surprises. This assumption is supported by a high correlation (0.93) between changes in the TIIE and changes in the target rate on Banxico announcement days. Following Andersen et al. (2003), we formally define a surprise as the standardized difference between a realization and an expectation. An expectation will be the forecast obtained from futures data ($\hat{y}$) and the realization is what actually occurred (y). The surprises can be classified as positive or negative. A positive surprise occurs when the expectation is lower than the realization ($y>\hat{y}$). For example, if an increase of 25 basis points in the target interest rate was expected and the actual increase was 50, then we have a positive surprise of 25 basis points. Conversely, a negative surprise occurs when the realization is lower than an expectation ($y<\hat{y}$), e.g. an increase of 25 basis points in the target interest rate was expected and the actual increase was 0, then we have a negative surprise of 25 basis points. As discussed in Andersen et al. (2003), it is likely that, for some specific macroeconomic announcements, the sign of the surprise (either positive or negative) will affect exchange rate fluctuations (and/or exchange rate expectations), asymmetrically; i.e. positive surprises may have different impacts than negative surprises on exchange rate expectations. Based on this and other previous literature, we also analyze the response of RNDs to positive and negative surprises in order to gauge asymmetries in the formation of FX expectations when a policy shock occurs. In our study we also consider scenarios of no surprise episodes (i.e., those where the expectations are equal to the realizations).

To be in line with recent literature about surprises gauged from futures markets; we relate the three possible scenarios (upward movement, downward movement and no change in target interest rates) with surprises in the market and its impact to our estimated RNDs. According to the methodology of Kuttner (2001), a 1-day monetary policy surprise is defined as follows:

$$\Delta \check{r}_t^u = \frac{m}{m-t}\left(F_{s,t}^0 - F_{s,t-1}^0\right) \tag{16}$$

where $\check{r}_t^u$ is defined as the unexpected interest rate at time *t*, Δ is defined as the change, m is the number of days in the month and, *t* is the day of the announcement. So, *m-t* is the difference in days between the end of the month and the monetary policy announcement day. $F_{s,t}^0$ is the futures contract yield for a contract with the smallest time to maturity on the day after the announcement is made by the corresponding central bank. The formula above captures a 1-day surprise as it involves differences in the futures implied rate adjusted for the time to expiration of the futures contract after the day of announcement. Given the forward-looking nature of derivatives markets, the proposed measure can be considered as a change in expectations (see Evans and Kuttner (1998), and Kuttner (2001)). Moreover, according to Hamilton (2009), changes in near-term futures prices are an excellent measure for changes in market expectations of near-term FED policy. He also shows that these surprises are well described by a martingale difference sequence and that it is quite reasonable to interpret them as primarily signaling changes in the market's assessment of future changes in US monetary policy.

In the present study, we focus on a time period that considers interest rate targeting announcements in Mexico, even though, this type of announcements started several years before in the US (in the early 1990s). Basically, we are considering the period 2005-2009 since in the earlier days there is no interest rate targeting in Mexico. In addition, during the studied period, we match information of both central banks in terms of interest rate announcements to distinguish between Mexican and US interest rate surprises. During this time frame, there are several events we are going to analyze. Table 1 presents the dates of these events. The first three columns are associated with the Mexican case while the last three relate to the US case. Columns one and four show the specific date of the announcements.[15] Columns two and five show the decision of increase, decrease or no change in the interest rate target. We also present the relevant change in basis points of the corresponding target interest rate.

We start from a time frame of five trading days before and after the announcement. If the announcements by both central banks are relatively close to each other and overlap within these 5-day intervals, we also consider narrower windows in order to control for different profiles of overlapping events from both central banks. As a minimum, we allow the day of the announcement plus/minus a two trading-day window. So, if the announcements by both central banks are separated by less than two trading days, then we eliminate the whole event because in such cases it becomes difficult to isolate the effects of each bank release. For the interpretation of Tables 3-5 we use notation for days before, during and after an announcement. For example, $X_0 - i$, X_0, $X_0 + i$, where X_0, is the day of the announcement, $X_0 - i$ or $X_0 + i$ is the ith day before (-) of after (+) the announcement. Again, this procedure serves to isolate the effect of each central bank announcement and avoid contamination from one central bank decision to the other days when the announcements are very close to each other.

Before the estimation of RNDs, for both techniques we look for possible statistical effects from surprises on changes in the exchange rate. The idea is to find out whether surprises affect statistically the exchange rate movements between the Mexican peso-USD. Therefore, we run a regression of the depreciation rate of the Mexican peso on US monetary policy surprises calculated from FFR futures following the methodology explained above. The regression is stated formally as:

$$\Delta xr_t = \alpha + \beta surprise_t + \mu_t \qquad (17)$$

[15] In Mexico the announcement is made at 9:00 AM Mexico's Central Time (also Central Time US). In US the announcement is made in general at 2:15 PM Eastern time.

where Δxr_t represents the depreciation rate for the Mexican peso-US dollar, $surprise_t$ is a measure of the monetary policy FED surprise on day t, computed from Equation 16, and μ_t represents a zero mean error term that is assumed to be uncorrelated with the surprises. [16] We consider only announcements from the FED given that the time series is considerably larger. As explained earlier, Banco de Mexico started releasing its desired interest rate level until late September 2005. We consider a sample period from January 1996 to June 2009. There are 3,447 daily observations and during that time frame there were 112 monetary policy events. Table 2 shows the results of this regression. They indicate that there is a statistical significant impact of FED surprises on the exchange rate depreciation rate. The *t*-statistic clearly rejects the null of the beta coefficient being equal to zero.

Some insights can be given about the negative sign of the estimated slope coefficient. For example, when a surprise is positive (i.e., a realization is higher than an expectation) we should expect a negative depreciation rate; in other words, a Mexican peso appreciation with respect to the US dollar. A possible explanation is that interest rate increases are usually associated with non-recessionary periods in the US. As we know, the Mexican economy depends considerably on exports to the US (almost 80% of the Mexican exports go to the US). If the US economy is not facing growth concerns, the prospects of growth of the Mexican economy as well as its exports to the US would be more favorable. Therefore an appreciation of the Mexican currency is consistent with this intuition. On the other hand, if the surprise is negative (i.e., a target rate lower than expected) we could relate it to a period of slow (or negative) grown in the US, when the target interest rate may have been cut more than the market expected in order to stimulate the economy. Under this scenario, the Mexican peso may be expected to depreciate (given the negative coefficient sign) because a weak US economy is likely to be associated with a lower demand for Mexican products in the US. We are aware that these arguments can depend on other economic interactions which analysis is beyond the aim of this paper. We only highlight the empirical result here and leave its theoretical discussion for future work.

[16] Note that surprises are zero on non-announcement days.

4.2. Analysis of volatility function technique vs. generalized extreme value

Central measures and exchange rate analysis

There is a clear trend towards more extreme upward movements in the Mexican Peso-US dollar exchange rate for the period under study, especially around the 2008 financial crisis. This can be observed in Figure 1 that illustrates the behavior of this time series from 1995 (when the Mexican peso started floating with respect to the US dollar) to 2009. The 2008 financial crisis caused a significant depreciation of the exchange rate of about 55%. During our revised period, the highest value was 15.37 pesos per dollar (recorded in March 2009) compared to the smallest one of about 9.92 pesos per dollar (recorded in August 2008). The difference between these values suggests a depreciation of about 55%. As we are going to show, the pattern of upward extreme movements in the exchange rate can be captured differently by the RNDs methods analyzed here.

To examine the behavior of these methods on monetary policy event-days, we first look at the results on the center of the distribution. Table 3 presents the correlation between central measures estimated from both GEV and VFT densities. As shown in this table, scenarios for downward, upward and no changes in interest rates are considered. Given these scenarios correlation coefficients are estimated for positive, negative and no surprises measured from Kuttner (2001) methodology, as mentioned above. The first column presents the period in days before or after the announcement, i.e. five days before $(X_0 - 5)$ the announcement day and up to five days $(X_0 + 5)$ after the announcement day, controlling for the overlapping of events, as explained earlier. The results suggest that the correlation between central measures is relatively high, indicating that the central measures extracted from the two estimated RNDs show similar dynamics at the center of the distribution on the analyzed event days.

Right-hand tail analysis

We claim that the main differences between both methods are noticeable at the tails. In order to make a comparable analysis about the extremes of the distributions, we fit the tails of the VFT method using extreme value distributional theory (just as applied to the GEV method). We estimate the tail parameter associated with the VFT results. The parameter that characterizes the shape of the tail under the GEV methodology is labeled as epsilon (ε) and the equivalent tail parameter for the VFT methodology as xi (ξ). It can be observed in Table 4 the relevant results for the right tail of the distribution that characterizes the extreme upward movements observed in Figure 1. In this table, as in the other ones we present, we show separately the results for two types of events: 1) A monetary policy decision by Banco de Mexico, and 2) A monetary policy decision by the FED. The first column presents the number of observations for these interest rate cases. The second column shows whether we have a situation of a decrease, an increase, or no change in the interest rate target considering an announcement of each central bank. The third (and ninth) column describes which method implies heavier tails; i.e., which of the tail parameters were larger in magnitude. For example, in the third column, for the case of Mexico, ε was larger 89% of the times (see seventh column). The fourth column shows how the results are classified based on the bias (skewness) of the distribution and the sign of the tail estimators. Columns 5 and 6 show the results under this classification for the GEV and VFT methods, respectively. Thus, once the bias is observed, the comparison of the two methods in terms of the tail parameters is presented next. For example, when Banco de Mexico's strategy is to lower the interest rate target, the GEV method shows a heavier right tail than VFT 89% of the cases (see seventh column). Of this proportion, 92% occurred when the bias is positive (seventh column) and, in this context, in 100% of the cases the GEV method suggests heavier tails than those of the normal distribution (ε is positive), as it can be observed in the fifth column.[17] The ξ parameter suggests fat tails 82% of the cases.

When we analyze the right-hand tail of the distribution (Table 4), we can observe that, when the pareto parameter from the GEV method is greater than the relevant parameter from the VFT (this occurs most of the times); i.e., GEV has heavier tails than VFT, the skewness of the implicit distribution is positive (a bias to the right). In addition, this behavior occurs when the tail-parameters are positive (i.e., when they indicate heavier tails than those of the normal distribution). It is important to point out that the ε is always positive. The implication here is that when the market puts more weight on an increase in the exchange rate (a depreciation of the Mexican peso), the GEV method will adjust better. On the other hand, when the pareto parameter from the VFT method is higher than the relevant one of the GEV method, the skewness and the

[17] Recall from subsection 2.1.2 that when the tail parameter is positive we have the Frechet case that has heavier tails than the normal distribution.

sign of the parameters are negative (a Weibull distribution case). This implies that when there are expectations that the exchange rate is going to decline (an appreciation for the Mexican peso), both methods can accurately capture this type of behavior given that they show the right-hand tails less heavier than those of the normal distribution.[18] As an analogy to the positive skewness case, the ε is always negative when the distribution is negatively skewed. Thus, the GEV method shows a right-hand tail less heavier than that of the VFT method since the GEV has a more negative parameter (ε smaller than ξ). This behavior seems desirable given that in such situations the market gives more weight to an appreciation of the Mexican currency and right tail events may be less likely. This type of behavior is qualitatively similar if we classify the results based on the direction of monetary policy surprises, as it is documented in Table 5. [19]

Robustness checks

Finally, we conduct two robustness checks. First, we estimate regressions in the spirit of Birru and Figlewski (2010). The idea is to examine the sensitivity of the tails suggested by each method to unexpected changes in the underlying asset. The larger the sensitivity of the extreme quantiles, the more adjustment a method will require. Thus, we run some regressions of changes in the distribution quantiles on changes in the forward exchange rate. Specifically, for a given level of α, we compute the corresponding quantile for each day of the sample. The daily quantile changes are projected on the corresponding changes of forward exchange rates. These results can be observed in Table 8 and Figures 2-3. We focus on the higher quantiles of the right skewed distribution and on the lower quantiles of the left skewed distribution. The results suggest that the GEV shows greater stability for the tails of the distribution given changes in the forward

[18] The normal distribution is associated with a pareto parameter equal to zero.

[19] For the case of the left-hand tail we observe qualitatively similar results (Tables 6 and 7 in the appendix). The parameter ε is always negative. Given that the GEV parameter is smaller, i.e. more negative than the relevant VFT parameter, the former presents less heavier tails than the VFT. For this reason it captures more accurately the dynamics of the data (see Figure 1). Furthermore, this type of behavior is also consistent with that based on surprises from futures data (Table 7). The ε parameter is most of the times smaller than the ξ parameter and it is always negative. We could interpret these results as saying that when the probabilities of higher exchange rates are large (skewness>0), then the GEV method adapts better to the second moment. However, when the probabilities of decreases in the exchange rate are larger (skewness<0) then GEV method is still more attractive given that the relevant parameter is located to the left of VFT method parameter, i.e., ε is smaller than ξ, which again it is in line with the observed data.

exchange rate (see shaded areas in Table 8). This is because the magnitude of the coefficients for GEV is smaller and overall more stable. For the case of positive skewness, the estimated parameters look ‘better-behaved’ compared to the VFT parameters. Figures 2 and 3 show that GEV curves have less deviations from its trend if compared with the VFT curve. Again, this is an indication of greater stability for the GEV method. The interpretation is that the distribution under GEV does not have to change or to move drastically given its shape on the previous day, once the new information is incorporated. The same results and conclusions are obtained for the case of negative skewness (see lower panel of Table 8). The second robustness check consists on estimating correlation coefficients between the change in implied volatilities and the change in the GEV and VFT shape parameters on the day of the announcement, respectively. The idea is to observe the sign and magnitude of the correlation between these series. It is expected that increases in implied volatility should be accompanied by increases in the value of the shape parameters. We compute these correlations for the samples of both FED and Banxico announcement days. The results for FED events suggest that, while under the GEV method this correlation is 82%, under the VFT method the correlation is only 62%. For Banxico announcement days, the correlations suggested by the two methods are basically equal (48% and 50%, respectively). Hence, from the FED data the GEV method appears to adjust the tails in a more consistent way given the behavior of volatility. The evidence from Banxico data is not conclusive.

Overall, the GEV method is more consistent than the VFT because, if we analyze the right tail, when the GEV parameter is greater and the skewness is positive, the GEV tail parameter is always positive. This is the most relevant case since the data show a clear pattern of more frequent upward extreme movements in the exchange rate (see Figure 1). We do not observe the same type of consistency for the VFT method. For the left-hand tail, the GEV parameter most of the times is smaller than the VFT and the former is always negative showing the case of a Weibull distribution that has tails (with a finite endpoint) smaller than those of the normal distribution. This fits better our analyzed exchange rate data.

5. Summary and Conclusions

The on-going debate regarding which is the most accurate model to estimate RNDs of prices of financial assets has led to a substantial amount of research. Many have compared parametric vs. non parametric methods and there is still no consensus on a unique superior methodology. In the present paper, we try to contribute to the existing literature by analyzing and comparing two known methods used to extract RNDs from option prices. We based our study on both a non-parametric and a parametric approach for modeling exchange rate expectations. Our results are relevant for the time period from September 2005 to June 2009. The non-parametric method we used is the volatility function technique (VFT) proposed by Malz (1997). The parametric method is the novel methodology of Figlewski (2009) that applies Generalized Extreme Value theory (GEV) to basically fit the tails of a known parametric distribution (as used for Black-Scholes pricing). We used a monetary policy event-study to compare these methods. In particular, we analyze monetary policy events that correspond to the dates in which the Central Bank of Mexico and the FED announce their target interest rate. We incorporate the surprise component of each central bank release by incorporating data on interest rate futures contracts. The similarities and differences between VFT and GEV are documented. This paper presents an approach that is new for Mexican financial data including the measurement (from market information) of the surprise component of monetary policy announcements.

According to our results, we can observe that there are important similarities in the center of the distribution. However, we find that the GEV method shows a better behavior in the tails of the distribution, regardless of whether the Central Bank of Mexico or the FED makes the announcement about the interest rate target. The same results are found when we control for the surprise component of the monetary policy news, which is measured by obtaining expectations from interest rate futures contracts. The results presented here are promising regarding the accuracy of methodologies to fit the tails of the RNDs on days of intense market activity where important economic information is released to the market. This is considered important given that Value-at-Risk is estimated from the tails of a distribution, which are assumed to be stable. Our results should be interpreted in the context of monetary policy announcement days. In that regard, we do not make a general case in terms of which method should be used in other situations. We leave that for future research.

References

Aït-Sahalia, Y., and Lo, A. (1998). Nonparametric Estimation of State-Price Densities Implicit in Financial Asset Prices. Journal of Finance, 53, 499-547.

Andersen T. G., and Bollerslev T. (1998). Deutsche Mark-Dollar Volatility: Intraday Activity Patterns, Macroeconomics Announcements, and Longer Run Dependencies. Journal of Finance, 53, 219-265.

Andersen T. G., Bollerslev T., Diebold F. X. and Vega C. (2003). Effects of Macro Announcements: Real-time Price Discovery In Foreign Exchange. American Economic Review, 93, 38-62.

Bahra, B. (1997). Implied Risk Neutral Probability Density Functions from Options Prices: Theory and Application. Bank of England. Working Paper No. 66.

Bates, D. S., (1991). The Crash of '87: Was It Expected? The Evidence from Options Markets. Journal of Finance, 46, 1009-44.

Benavides, G. and Capistrán, C. (2009). Forecasting Exchange Rate Volatility: The Superior Performance of Conditional Combinations of Time Series and Option Implied Forecasts. Banco de México. Documento de Investigación No. 2009-01.

Benavides, G., and Mora F. I. (2008). Parametric vs. Non-Parametric Methods for Estimating Option Implied Risk-Neutral Densities: The Case of the Exchange Rate Mexican Peso - US Dollar. Ensayos, 27, 33-52.

Bernanke, B. S., and Kuttner K. (2005). What Explains the Stock Market's Reaction to Federal Reserve Policy? Journal of Finance, 60, 1221-1257.

Birru, J. and Figlewski, S. (2010). Anatomy of a Meltdown: The Risk Neutral Density for the S&P 500 in the Fall of 2008. Working Paper NYU. Revised Feb. 2010.

Black, F. and Scholes, M. S. (1973). The Pricing of Options and Corporate Liabilities. Journal of Political Economy, 81, 637-654.

Bliss, R., and Panigirtzoglou, N. (2002). Testing the Stability of Implied Probability Density Functions. Journal of Banking and Finance, 26 , 381-422.

Bomfim, A. N. (2003). Pre-announcement Effects, News Effects, and Volatility: Monetary Policy and the Stock Market. Journal of Banking and Finance, 27, 133-151.

Breeden, D., and Litzenberger, R. (1978). Prices of State-Contingent Claims Implicit in Option Prices. Journal of Business, 51, 621-651.

Castrén, O. (2005). Estimating and Analyzing Currency Options Implied Risk-Neutral Density Functions for the Largest New EU Member Status. European Central Bank. Working Paper No. 440.

Cooper, N., and Talbot, J. (1999). The Yen/Dollar Exchange Rate in 1998: Views from Options Markets. Bank of England. Working Paper.

Díaz de León, A., and Casanova, M. E. (2004). Expectativas del Mercado Implícitas en los Precios de Instrumentos Derivados: Aplicaciones al Mercado Cambiario y Petrolero. Banco de México. Documento de investigación No. 2004 01.

Evans, C.L., and Kuttner, K.N., (1998). Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market. Journal of Monetary Economics, 47, 523-544.

Figlewski, S. (2009). Estimating the Implied Risk-Neutral Density for the U.S. Market Portfolio. Volatility and Time Series Econometrics: Essays in Honor of Robert F. Engle (Eds. Tim Bollerslev, Jeffrey Rusell and Mark Watson). Oxford, UK: Oxford University Press.

Flannery, M., and Protopapadakis A. (2002). Macroeconomic Factors Do Influence Aggregate Stock Returns. Review of Financial Studies, 15, 751-782.

Fleming M. J., and Remolona E. M. (1999). Price Formation and Liquidity in the U.S. Treasury Market: The Response to Public Information. Journal of Finance, 54, 1901-1915.

Garman, M. B., and Kohlhagen, S. W. (1983). Foreign Currency Option Values. Journal of International Money and Finance, 2, 231-37.

Guarkaynak, R., Sack B., and Swanson E. (2005). The Sensitivity of Long-Term Interest Rates to Economic News: Evidence and Implications for Macroeconomic Models. American Economic Review, 95, 425-436.

Hamilton, J. D. (2009). Daily Changes in Fed Funds Futures Prices. Journal of Money, Credit and Banking, 41, No. 4.

Jackwerth, J. C. (2004). Option-Implied Risk-Neutral Distributions and Risk Aversion. Charlotteville: Research Foundation of AIMR.

Jones, C., Lamont O., and Lumsdaine R. (1998). Macroeconomic News and Bond Market Volatility. Journal of Financial Economics, 47, 315-337.

Kuttner, K. N. (2001). Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market. Journal of Monetary Economics, 47, 523-44.

Malz, A. M. (1997). Estimating the Probability Distribution of the Future Exchange Rate from Option Prices. Journal of Derivatives, 5, 18-36.

McManus, D. J. (1999). The Information Content of Interest Rate Futures Options. Bank of Canada. Working Paper No. 99-15.

McNeil, A. J., Frey, R. and Embrechts, P. (2005) Quantitative Risk Management. Concepts Techniques Tools. Princeton Series in Finance.

Melick, W. and Thomas C. (1997). Recovering an Asset's Implied PDF from Option Prices: an Application to Crude Oil During the Gulf Crisis. Journal of Financial and Quantitative Analysis, 32, 91-115.

Micu, M. (2004). Extracting Expectations from Currency Option Prices: A Comparison of Methods. Bank of International Settlements. Working Paper. September.

Newey, W. K., and West K. D. (1987). A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix. Econometrica, 55, 703-70.

Rangel, J.G. (2009). Macroeconomic News, Announcements, and Stock Market Jump Intensity Dynamics. Journal of Banking and Finance. *Forthcoming*.

Rubinstein, M. (1994). Implied Binomial Trees. Journal of Finance, 49, 771-818.

Shimko D., (1993). Bounds of probability. Risk Magazine, 6, 33-37.

Soderlind, P. (2000). Market Expectations in the UK Before and after the ERM Crisis. Economica, 67.

Taylor, S. J. (2005). Asset Price Dynamics, Volatility, and Prediction. Princeton University Press.

Table 1

Monetary policy interest rate announcements by Banco de Mexico and the Federal Reserve System.

Banco de Mexico			Federal Reserve System		
Date	Announcement	Basis points	Date	Announcement	Basis points
September 23, 2005	Interest rate decrease	25	September 20, 2005	Interest rate increase	25
October 28, 2005	Interest rate decrease	25	November 1, 2005	Interest rate increase	25
November 25, 2005	Interest rate decrease	25	December 12, 2005	Interest rate increase	25
December 09, 2005	Interest rate decrease	50			
January 27, 2006	Interest rate decrease	50	January 31, 2006	Interest rate increase	25
February 24, 2006	Interest rate decrease	25	March 28, 2006	Interest rate increase	25
March 24, 2006	Interest rate decrease	25	May 10, 2006	Interest rate increase	25
April 21, 2006	Interest rate decrease	25	June 29, 2006	Interest rate increase	25
May 26, 2006	Interest rate unchanged		August 08, 2006	Interest rate increase	25
June 23, 2006	Interest rate unchanged		September 20, 2006	Interest rate unchanged	
July 28, 2006	Interest rate unchanged		October 25, 2006	Interest rate unchanged	
August 25, 2006	Interest rate unchanged		December 12, 2006	Interest rate unchanged	
September 22, 2006	Interest rate unchanged				
October 27, 2006	Interest rate unchanged				
November 24, 2006	Interest rate unchanged				
December 08, 2006	Interest rate unchanged				
January 26, 2007	Interest rate unchanged		January 31, 2007	Interest rate unchanged	
February 23, 2007	Interest rate unchanged		March 21, 2007	Interest rate unchanged	
March 23, 2007	Interest rate unchanged		May 09, 2007	Interest rate unchanged	
April 27, 2007	Interest rate increase	25	June 28, 2007	Interest rate unchanged	
May 25, 2007	Interest rate unchanged		August 07, 2007	Interest rate unchanged	
June 22, 2007	Interest rate unchanged		September 18, 2007	Interest rate decrease	50
July 27, 2007	Interest rate unchanged		October 31, 2007	Interest rate decrease	25
August 24, 2007	Interest rate unchanged		December 11, 2007	Interest rate decrease	25
September 21, 2007	Interest rate unchanged				
October 26, 2007	Interest rate increase	25			
November 23, 2007	Interest rate unchanged				
December 07, 2007	Interest rate unchanged				
January 18, 2008	Interest rate unchanged		January 22, 2008	Interest rate decrease	75
February 15, 2008	Interest rate unchanged		January 30, 2008	Interest rate decrease	50
March 14, 2008	Interest rate unchanged		March 18, 2008	Interest rate decrease	75
April 18, 2008	Interest rate unchanged		April 30, 2008	Interest rate decrease	25
May 16, 2008	Interest rate unchanged		June 25, 2008	Interest rate unchanged	
June 20, 2008	Interest rate increase	25	August 05, 2008	Interest rate unchanged	
July 18, 2008	Interest rate increase	25	September 16, 2008	Interest rate unchanged	
August 15, 2008	Interest rate increase	25	October 08, 2008	Interest rate decrease	50
September 19, 2008	Interest rate unchanged		October 29, 2008	Interest rate decrease	50
October 17, 2008	Interest rate unchanged		December 16, 2008	Interest rate decrease	75
November 28, 2008	Interest rate unchanged				
January 16, 2009	Interest rate decrease	50	January 28, 2009	Interest rate unchanged	
February 20, 2009	Interest rate decrease	25	March 18, 2009	Interest rate unchanged	
March 20, 2009	Interest rate decrease	75	April 29, 2009	Interest rate unchanged	
April 17, 2009	Interest rate decrease	75			
May 15, 2009	Interest rate decrease	75			
June 19, 2009	Interest rate decrease	50			

Notes: This table shows announcement dates of monetary policy events, which correspond to variations in the target (objective) interest rates by Banco de México and the U.S. Federal Reserve from September 2005 to June 2009. Blanks in the column that corresponds to the FED are due to the time intervals between announcements. These are usually longer than those of Banco de México. There are no missing data.

Table 2
Regression of the Mexican Peso-US dollar depreciation rate vs. surprises

β coefficient	t-statistic	N=3,447
-0.0058	-2.98	Events=112

Notes: This table shows the relevant coefficient of the regression of the Mexican peso-US dollar depreciation rate vs. monetary policy surprises calculated following the methodology proposed by Kuttner (2001) using futures prices of FED Funds contracts and robust standard errors according to Newey & West (1987) methodology. *N* represents the number of observations.

Table 3
Correlations between central measures

	Interest rate			Futures Surprises		
	Down	Up	No	Positive	Negative	No
Mexico						
[-5 a -1]	100%	50%	100%	75%	100%	100%
[-1 a 2]	67%	67%	100%	100%	100%	67%
[2 a 5]	67%	100%	100%	100%	67%	100%
FED						
[-5 a -1]	100%	100%	75%	100%	75%	100%
[-1 a 2]	33%	33%	67%	100%	100%	100%
[2 a 5]	100%	67%	33%	100%	100%	33%

Notes: This table presents correlation coefficients estimates between both methodologies. Three monetary policy scenarios are considered: downward movement, upward movement and no changes in the interest rate target. Surprises are computed from futures contracts (Kuttner (2001) methodology). The correlation is also estimated for positive, negative and no surprises. We define surprise as the difference between a realization and an expectation; i.e., y-$\hat{y}$; where y is the realization and $\hat{y}$ is the expectation (see Andersen et al. (2003)). The sample period is from September 2005 to June 2009.

Table 4
Right side tail and interest rate strategy

Mexico							FED					
1	2	3	4	5	6	7	8	9	10	11	12	13
N		Tail Parameter	Bias	ε	ξ		N	Tail Parameter	Bias	ε	ξ	
55	Down						39					
		ε > ξ				89%		ε > ξ				77%
			negative			8%			negative			37%
			-	75%	100%				-	-	100%	
			+	25%	-				+	100%	-	
			Positive			92%			positive			63%
			-	0%	18%				-	-	5%	
			+	100%	82%				+	100%	95%	
		ξ > ε				11%		ξ > ε				23%
			negative			100%			negative			67%
			-	100%	100%				-	100%	33%	
			+	-	-				+	-	67%	
			positive			-			positive			33%
			-	-	-				-	100%	-	
			+	-	-				+	-	100%	
21	Up						43					
		ε > ξ				67%		ε > ξ				93%
			negative			-			negative			13%
			-	-	-				-	20%	100%	
			+	-	-				+	80%	-	
			positive			100%			positive			88%
			-	-	7%				-	-	80%	
			+	100%	93%				+	100%	20%	
		ξ > ε				33%		ξ > ε				7%
			negative			100%			negative			100%
			-	100%	86%				-	100%	100%	
			+	-	14%				+	-	-	
			positive			-			positive			-
			-	-	-				-	-	-	
			+	-	-				+	-	-	
113	No						52					
		ε > ξ				42%		ε > ξ				71%
			negative			64%			negative			27%
			-	13%	57%				-	60%	80%	
			+	87%	43%				+	40%	20%	
			positive			36%			positive			73%
			-	-	6%				-	-	37%	
			+	100%	94%				+	100%	63%	
		ξ > ε				58%		ξ > ε				29%
			negative			91%			negative			100%
			-	100%	80%				-	100%	100%	
			+	-	20%				+	-	-	
			positive			9%			positive			-
			-	100%	-				-	-	-	
			+	-	100%				+	-	-	

Notes: Column 1 refers to the number of observations. Column 2 indicates the direction of the interest rate target changes. Column 3 specifies which parameter is larger in magnitude. The column 4 (Bias) indicates when the implied distribution shows either a positive or a negative bias (positive or negative skewness). Elements in this column refer to the sign of the parameters in the following two columns. For example, when Banco de Mexico's strategy is to lower the interest rate target (see column 2), 89% of the times $\varepsilon > \xi$ (see column 7); i.e., the GEV method shows a heavier right tail than the VFT method. Of this proportion, 92% occurs when the bias is positive. In this context, as shown in column 5, in 100% of cases the method of GEV has a heavier tail than the normal distribution ($\varepsilon > 0$ or positive), and in 82% of the cases, the VFT method suggests heavier tails than the normal case (see column 6). For this event-study analysis, in the case there is overlapping of the announcement days within a window of five trading days, the window used to include an event is narrowed. Specifically, we only rule out an event when it is separated by less than two trading days from another event. The time frame is from September 2005 to June 2009.

Table 5
Right side tail and futures surprise

Mexico							FED					
1	2	3	4	5	6	7	8	9	10	11	12	13
N		Tail Parameter	Bias	ε	ξ		N	Tail Parameter	Bias	ε	ξ	
71	Positive						17					
		$\varepsilon > \xi$				59%		$\varepsilon > \xi$				65%
			negative			19%			negative			-
			-	38%	100%				-	-	-	
			+	63%	0				+	-	-	
			positive			81%			positive			100%
			-	-	15%				-	-	100%	
			+	100%	85%				+	100%	-	
		$\xi > \varepsilon$				41%		$\xi > \varepsilon$				35%
			negative			83%			negative			100%
			-	100%	92%				-	100%	100%	
			+	-	0.08				+	-	-	
			positive			0.17			positive			-
			-	1	-				-	-	-	
			+	-	1				+	-	-	
77	Negative						56					
		$\varepsilon > \xi$				74%		$\varepsilon > \xi$				79%
			negative			0.26			negative			23%
			-	0.27	0.73				-	10%	80%	
			+	0.73	0.27				+	90%	0.2	
			positive			74%			positive			77%
			-	-	12%				-	-	26%	
			+	100%	88%				+	100%	74%	
		$\xi > \varepsilon$				26%		$\xi > \varepsilon$				21%
			negative			95%			negative			75%
			-	100%	79%				-	100%	56%	
			+	-	21%				+	-	0.44	
			positive			0.05			positive			0.25
			-	1	-				-	1	-	
			+	-	1				+	-	1	
41	No						61					
		$\varepsilon > \xi$				27%		$\varepsilon > \xi$				85%
			negative			100%			negative			31%
			-	-	18%				-	38%	100%	
			+	100%	82%				+	63%	-	
			positive			-			positive			69%
			-	-	-				-	-	53%	
			+	-	-				+	100%	47%	
		$\xi > \varepsilon$				73%		$\xi > \varepsilon$				15%
			negative			100%			negative			100%
			-	100%	77%				-	100%	100%	
			+	-	23%				+	-	-	
			positive			-			positive			-
			-	-	-				-	-	-	
			+	-	-				+	-	-	

Notes: Same as Table 4. We perform the analysis for cases of futures surprises defined in Table 3.

Table 8

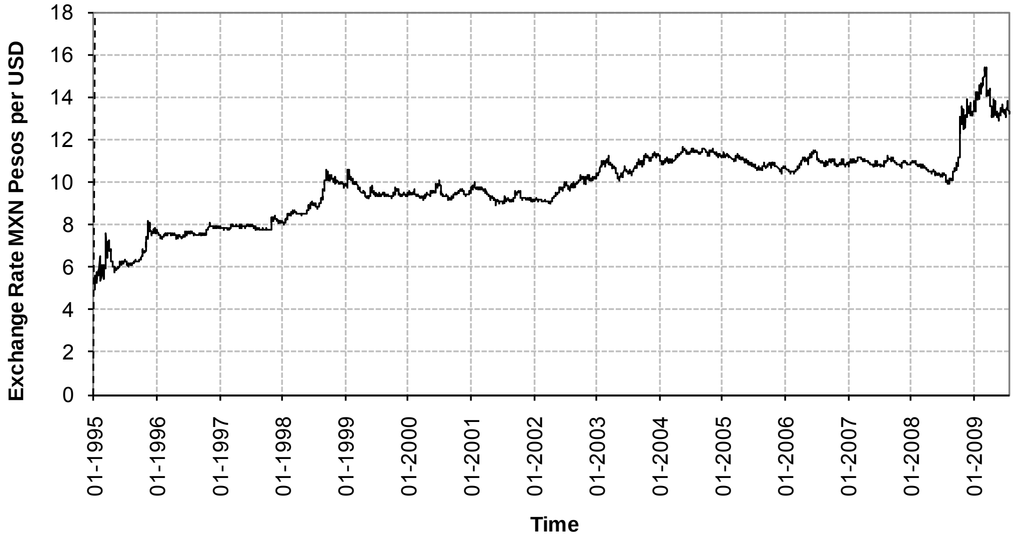
Regression estimates of changes in the forward exchange rate (*F*) on the change in the distributions quantiles (*Q*).

Positive Skewness															
	1%	2%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%
GEV															
coef.	0.207	0.27	0.402	0.557	0.75	0.891	1.008	1.12	1.232	1.368	1.528	1.735	1.845	1.806	1.994
std. err.	0.07	0.07	0.06	0.05	0.03	0.02	0.01	0.01	0.02	0.03	0.05	0.08	0.11	0.15	0.15
t-stat.	3.0	4.0	6.6	11.8	25.8	51.9	93.4	80.0	55.2	40.5	30.8	22.6	16.9	12.0	13.3
VFT															
coef	0.29	0.38	0.46	0.57	0.69	0.80	0.91	1.01	1.12	1.28	1.47	1.78	2.10	2.47	2.72
std err	0.07	0.07	0.06	0.05	0.03	0.02	0.02	0.01	0.01	0.02	0.04	0.07	0.10	0.14	0.17
t-stat	4.0	5.6	8.1	12.3	20.4	34.6	62.2	113	85.0	52.6	33.5	24.1	20.5	18.0	16.4

Negative Skewness															
	1%	2%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%
GEV															
coef.	0.63	0.65	0.73	0.86	0.98	1.04	1.07	1.10	1.11	1.12	1.10	1.15	1.23	1.44	1.77
std. err.	0.04	0.04	0.04	0.03	0.03	0.02	0.01	0.01	0.01	0.03	0.05	0.10	0.15	0.20	0.21
t-stat.	15.5	15.8	19.1	25.8	39.6	56.4	79.8	107	85.4	42.7	21.0	11.5	8.3	7.3	8.4
VFT															
coef.	0.829	0.902	0.878	0.921	0.94	0.961	1.02	1.055	1.094	1.169	1.247	1.393	1.524	1.684	1.844
std. err.	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.02	0.02	0.02	0.03	0.05	0.07	0.09	0.11
t-stat.	10.6	12.5	14.6	17.9	23.4	33.0	42.1	60.0	63.4	57.2	41.4	29.0	22.8	18.2	17.2

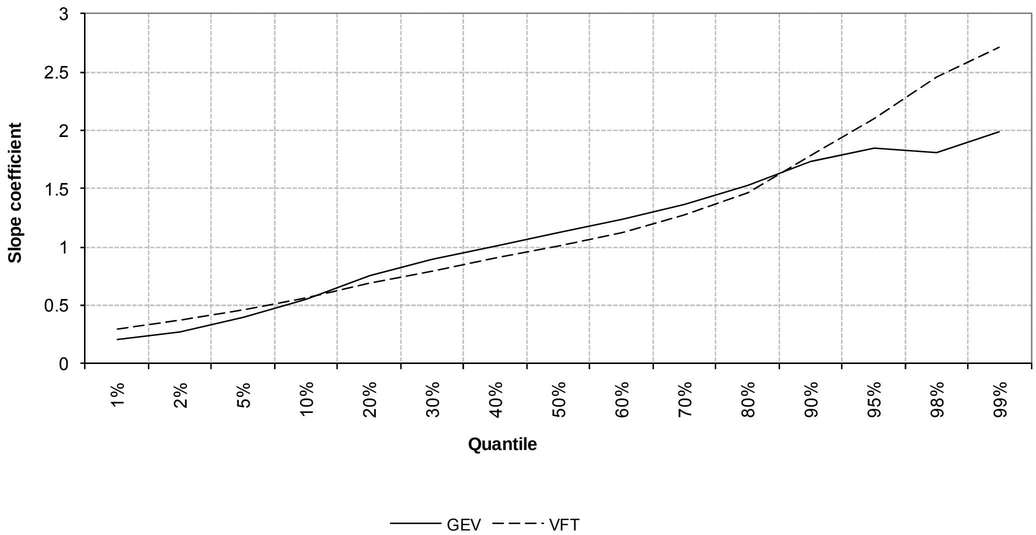
Notes: This table reports regression estimates of changes in the distribution quantiles (*Q*) on changes in the forward exchange rate (*F*). Quantiles are expressed horizontally as a percentage (first row underneath the positive/negative skewness title). The first column details the methods used (GEV vs. VFT) and in the following order the estimates: coefficient, standard error and *t*-statistic. The sample period under analysis is from September 2005 until June 2009. The number of observations is 903.

Figure 1
Exchange rate Mexican pesos per US dollar



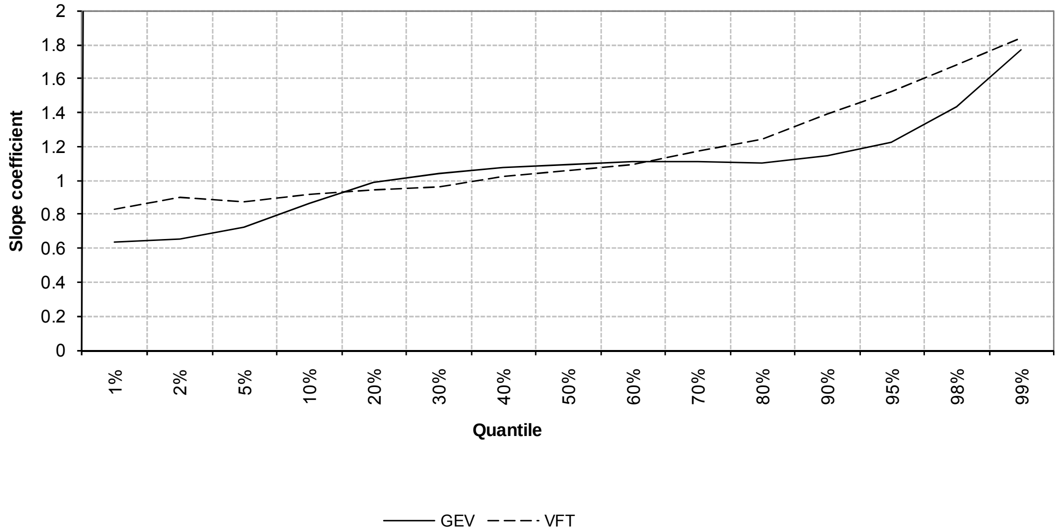
Source: Banco de México.
Notes: The exchange rate used is the one called FIX, which is published by Banco de México every working day at the Mexican Official Gazette (Diario Oficial de la Federación). This exchange rate represents a weighted average of the exchange rate for transactions in US dollar by major Mexican banks.

Figure 2
Regressions of change in quantile vs. change in forward exchange rate (cases for positive skewness)



Notes: This figure shows the relevant coefficient estimates according to the quantile for cases of positive skewness. The estimates can be observed in Table 8.

Figure 3
Regressions of change in quantile vs. change in forward exchange rate (cases for negative skewness)



Notes: This figure shows the relevant coefficient estimates according to the quantile for cases of negative skewness. The estimates can be observed in Table 8.

Appendix

Table 6

Left side tail and interest rate strategy

Mexico							FED					
1	2	3	4	5	6	7	8	9	10	11	12	13
N		Tail Parameter	Bias	ε	ξ		N	Tail Parameter	Bias	ε	ξ	
55	Down						39					
		ε > ξ				13%		ε > ξ				8%
			negative			-			negative			100%
			-	-	-				-	-	100%	
			+	-	-				+	100%	-	
			positive			100%			positive			-
			-	-	14%				-	-	-	
			+	100%	86%				+	-	-	
		ξ > ε				87%		ξ > ε				92%
			negative			21%			negative			39%
			-	100%	100%				-	100%	86%	
			+	-	-				+	-	14%	
			positive			79%			positive			61%
			-	100%	79%				-	100%	95%	
			+	-	21%				+	-	5%	
21	Up						43					
		ε > ξ				14%		ε > ξ				-
			negative			-			negative			
			-	-	-				-	-	-	
			+	-	-				+	-	-	
			positive			100%			positive			
			-	-	100%				-	-	-	
			+	100%	-				+	-	-	
		ξ > ε				86%		ξ > ε				100%
			negative			39%			negative			19%
			-	100%	100%				-	100%	100%	
			+	-	-				+	-	-	
			positive			61%			positive			81%
			-	100%	100%				-	100%	100%	
			+	-	-				+	-	-	
113	No						52					
		ε > ξ				6%		ε > ξ				8%
			negative			100%			negative			-
			-	-	100%				-	-	-	
			+	100%	-				+	-	-	
			positive			-			positive			100%
			-	-	-				-	-	100%	
			+	-	-				+	100%	-	
		ξ > ε				94%		ξ > ε				92%
			negative			78%			negative			52%
			-	100%	93%				-	100%	100%	
			+	-	7%				+	-	-	
			positive			22%			positive			48%
			-	100%	91%				-	100%	78%	
			+	-	9%				+	-	22%	

Notes: Same as Table 4.

Table 7
Left side tail and futures surprise

Mexico							FED					
1	2	3	4	5	6	7	8	9	10	11	12	13
N		Tail Parameter	Bias	ε	ξ		N	Tail Parameter	Bias	ε	ξ	
71	Positive						17					
		ε > ξ				8%		ε > ξ				-
			negative			-			negative			
			-	-	-				-	-	-	
			+	-	-				+	-	-	
			positive			100%			positive			
			-	-	50%				-	-	-	
			+	100%	50%				+	-	-	
		ξ > ε				92%		ξ > ε				100%
			negative			49%			negative			35%
			-	100%	100%				-	100%	100%	
			+	-	-				+	-	-	
			positive			51%			positive			65%
			-	100%	91%				-	100%	100%	
			+	-	9%				+	-	-	
77	Negative						56					
		ε > ξ				5%		ε > ξ				5%
			negative			-			negative			100%
			-	-	-				-	-	1	
			+	-	-				+	100%	0%	
			positive			100%			positive			-
			-	-	25%				-	-	-	
			+	100%	75%				+	-	-	
		ξ > ε				95%		ξ > ε				95%
			negative			47%			negative			30%
			-	100%	100%				-	100%	88%	
			+	-	-				+	-	13%	
			positive			53%			positive			70%
			-	100%	82%				-	100%	97%	
			+	-	18%				+	-	3%	
41	No						61					
		ε > ξ				17%		ε > ξ				7%
			negative			100%			negative			-
			-	-	-				-	-	-	
			+	100%	100%				+	-	-	
			positive			-			positive			100%
			-	-	-				-	-	100%	
			+	-	-				+	100%	-	
		ξ > ε				83%		ξ > ε				93%
			negative			100%			negative			44%
			-	100%	74%				-	100%	100%	
			+	-	26%				+	-	-	
			positive			-			positive			56%
			-	-	-				-	100%	84%	
			+	-	-				+	-	16%	

Notes: Same as Table 4. We perform the analysis for cases of futures surprises defined in Table 3.