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Central Bank Foreign Exchange Market Intervention and Option Contract Specification: The Case of Colombia

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Abstract

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This paper aims to identify appropriate option contract specifications for effective central bank exchange market intervention. Option contract specifications determine the impact of options on the underlying asset or currency, and hence their actual effect on asset price or currency volatility and are therefore key to determining the effectiveness of option-based intervention. The paper reviews the experience of the systematic option-based foreign exchange market intervention of the Central Bank of Colombia and finds that its contract has only been moderately successful at abating exchange rate volatility, which is attributed here to sub-optimal contract specifications.

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I. INTRODUCTION

The Central Bank of Colombia pioneered the use of systematic option-based foreign exchange market intervention to reduce excessive currency volatility. The introduction of options in securities and exchange markets has often been associated with a decrease in volatility of the underlying asset or currency because of associated hedging operations related to the risk management of option portfolios (Conrad, 1989; Klemkosky and Maness, 1980; Whiteside et. al, 1983). Yet, option contract specifications determine the impact of options on the underlying asset or currency and hence their actual effect on asset price or currency volatility and are therefore key to determining the effectiveness of option-based intervention. The increasing adoption of floating exchange rate regimes and prevailing concerns about excessive currency volatility by central banks suggests that central banks will need to address more and more the effectiveness of their foreign exchange market interventions.

This paper aims to identify appropriate option contract specifications for effective central bank exchange market intervention to reduce currency volatility. While there have been some contributions to the literature on the use of options by central banks for foreign exchange intervention (Breuer, 1999; Clavijo, 2003; Hong Kong Monetary Authority, 2000; Werner and Milo, 1998), little attention has been paid to the importance of option contract specifications (Wiseman, 1999). The second part of the paper reviews the contracts issued by the Central Bank of Colombia and uses an event study and an analysis-of-variance model to test the effect of the options on exchange rate volatility. The results show that the contract has only been moderately successful at abating currency volatility in a sustained fashion. The third part describes basic aspects of contract specifications and the main features of option-related hedging, and summarizes desirable option contract specifications for central bank option-based foreign exchange intervention. The last part offers some conclusions.

II. USE OF OPTIONS BY THE CENTRAL BANK OF COLOMBIA

The Central Bank of Colombia introduced in November 1999 a series of option contracts as part of a comprehensive scheme of option-based exchange market intervention. The main features of the contracts have been adopted from the Central Bank of Mexico that first introduced the systematic use of writing options for foreign exchange market intervention in 1996. The central banks of Mexico and Colombia are believed to be the only central banks to have used options in a systematic fashion to intervene in the foreign exchange market, and the Central Bank of Colombia is currently the only central bank to maintain such a scheme.²

² The Central Bank of Mexico in May 2001, in light of the significant accumulation of reserves achieved under the option scheme, decided to suspend the contract. The Hong Kong Monetary Authority (Hong Kong Monetary Authority, 2000), has recently rejected the use of options for exchange market intervention as it believes that there are sufficient hedging operations in the Hong Kong dollar market. However, the Hong Kong dollar market operates within the constraints of a currency board.

Both central banks introduced option-based foreign exchange market intervention with the adoption of floating exchange rate arrangements.

The Central Bank of Colombia maintains four contracts, two to accumulate or decumulate international reserves and two to mitigate excessive exchange rate volatility (Appendix):

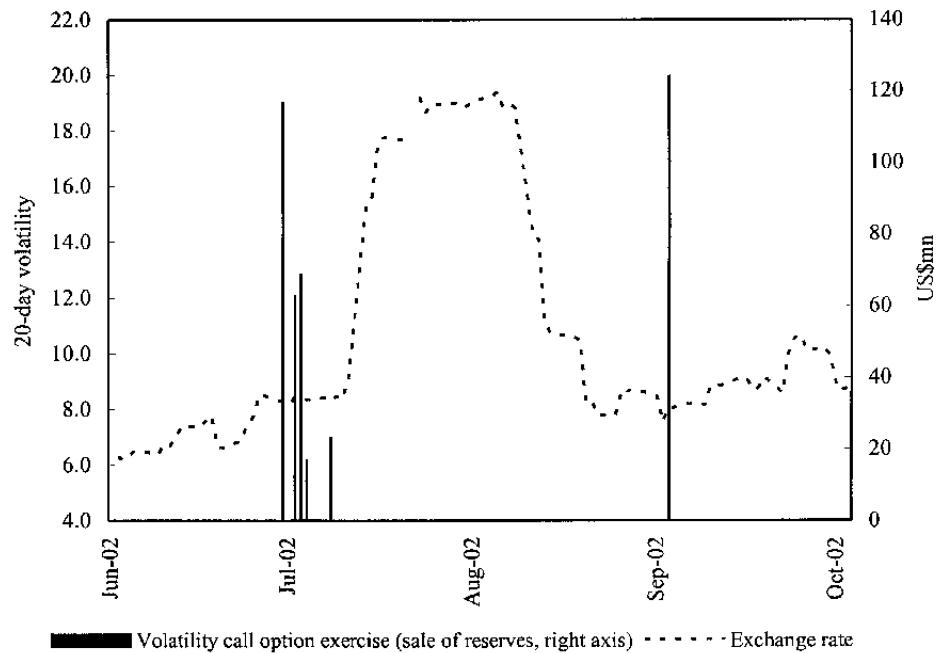
- *Options to accumulate (decumulate) international reserves*: Put (call) options with a maturity of 30 days that are auctioned each month giving the bearer the right to sell (buy) U.S. dollars from (to) the central bank. The options can be exercised whenever the current exchange rate is more appreciated (depreciated) than the 20-day arithmetic moving average of the past daily currency fixes. The amount to be auctioned is determined at the end of each month for the following month.
- *“Volatility” options*: Put (call) options with a maturity of 30 days that are auctioned in an amount of US\$180 million whenever the exchange rate is more than 4 percent depreciated (appreciated) than its 20-day arithmetic moving average. Calls and puts can be exercised at any time whenever the exchange rate is more than 4 percent depreciated (appreciated) than its 20-day arithmetic moving average until maturity. The intervention amount is significant as the average daily volume of the exchange market during the first six months of 2002 was US\$300 million. To date only call volatility options were auctioned.

The adoption of a symmetric intervention mechanism allows the central bank to signal forcefully its commitment to mitigate excessive exchange rate volatility while providing a transparent rule-based intervention mechanism. The use of options to accumulate international reserves has allowed the Central Bank of Colombia to increase international reserves by US\$1,400 million since inception. In February 2003, the central bank initiated the use of call options to decumulate international reserves.

The volatility call option contract has been adopted to mitigate significant deviations from trend of the currency. Volatility call options were auctioned for the first time in July 2002 followed by another two auctions in August and October of 2002. The paper recognizes that standard time series techniques may not be suited to study the impact of interventions on the exchange rate. To analyze the impact of the option-based intervention on the spot exchange rate therefore, an event study and a simple analysis-of-variance model are used.³

³ The use of implied volatilities of the currency option prices is discarded due to the small sample. See Bonser-Neal and Tanner (1996) for the use of implied volatilities of currency options to test the effect of central bank foreign exchange market interventions. The use of GARCH models was rejected due to the small number of interventions. See Edison et al (2003) for an application of GARCH models to test for changes in exchange rate volatility.

Figure 1. Colombia: U.S. Dollar Volatility Call Options



Event studies rest on the actual observation of asset prices over relatively short time periods and are being used increasingly to analyze exchange rate behavior (Edison et al, 2003).⁴ The event refers here to the auction of volatility call options by the central bank of Colombia and the event window is set as pre- and post-event windows of two, five, and ten days, respectively. Where the period of no intervention was shorter than three days, the event would be identified as one. A successful event is defined as one where the intervention can be associated with a decline in the average level of volatility of the spot exchange rate during the post-event window compared with the pre-event window as measured by the standard deviation annualized of interday exchange rate movements over a 20-day period. The results suggest that the contract has been at best moderately successful in reducing the volatility of the underlying exchange rate (Table 1).

⁴ See Fatum (2000) for a detailed description of event studies to test central bank foreign exchange market interventions.

Table 1. Success of Call Volatility Option Auctions

Auction*	Level of volatility before event (percent)			Level of volatility after event (percent)			Success
	2 days	5 days	10 days	2 days	5 days	10 days	
29 Jul 02	8.5	8.3	Moderate
1 Aug 02	8.3	7.8	7.5	8.4	8.5	11.7	No
1 Oct 02	8.0	8.5	8.3	8.1	8.4	8.6	Moderate

* US\$180 million per auction.

Analysis-of-variance models are useful to study the behavior of the exchange rate around interventions as they allow to capture some attributes that are essentially qualitative in nature. Let $Y_i = \alpha + \beta D_i + u_i$, where Y is the level of volatility of the spot exchange rate as measured by the standard deviation annualized of interday exchange rate movements over a 20-day period, D is a dummy with $D = 1$ if options are auctioned on a certain day and $D = 1$ for the subsequent 3 and 10 days after the options are auctioned, and u is a stochastic error term. The model allows to find out whether the auction of options makes any difference in the volatility of the exchange rate during the 3 and 10 days following the auction, that is the short-term and medium-term impact of the option auction. Assuming that the disturbances satisfy the usual assumptions of the classical linear regression model, we obtain the mean volatility from $E(Y_i|D_i = 0) = \alpha$ and the mean volatility upon and 3 or 10 subsequent days after an option auction from $E(Y_i|D_i = 1) = \alpha + \beta$. The null hypothesis is tested that an option auction does not alter the volatility of the exchange rate. A 5 percent level of significance is chosen and standard errors, t -, and F -tests are provided.

The impact of the volatility call options is tested using daily data for the Colombian peso between July and October 2002. The results for the short-term impact (3 days) show that the dummy and the overall regression are statistically significant, that is, volatility declines upon and shortly after the auction of a volatility option; average volatility is 11.06 percent and the volatility the day and subsequent 3 days after an option auction is 8.26 percent (Equation 1).⁵ The results for the medium-term impact (10 days) of the volatility call options are not statistically significant, suggesting that the impact of the option is more limited as time elapses (Equation 2).

⁵ The low R^2 can be attributed to the nature of analysis of variance models that result in a regression function that is a step function for which the average fit is poor.

Equation 1:	$Y_i =$	11.06	-2.80D		
		(0.48)	(1.37)		
	$t =$	(23.06)	(-2.04)	$R^2 = 0.05$	$F = 4.17$
Equation 2:	$Y_i =$	11.08	-1.30D		
		(0.54)	(1.02)		
	$t =$	(20.66)	(-1.27)	$R^2 = 0.02$	$F = 1.63$

The statistical results suggest that the option contracts have only been moderately successful at reducing volatility of the underlying exchange rate in a sustained fashion. This may at least in part be attributable to the option contract specifications that may not be designed to address exchange rate volatility effectively.

III. OPTION CONTRACT SPECIFICATIONS AND HEADING

The attractiveness of using options arises mostly from the associated hedging operations related to the risk management of option portfolios. The bearer of an option aims at neutralizing or hedging his or her exposure to an option to minimize possible losses by buying or selling the underlying asset or currency. This may have a stabilizing impact on the underlying asset price or currency. The hedging operations in turn are determined by the susceptibility of the options to movements in the underlying asset price or currency that depend on option contract specifications and the type of risks that affect the valuation of an option.

Options are financial derivatives that convey the right but not the obligation to buy (call option) or sell (put option) an underlying asset during a fixed period at a predetermined exercise or strike price. The hedging operations related to an options portfolio against possible losses depend on the user's position vis-à-vis the underlying:

- *Long position:* The option user is said to be long options if he or she holds an option to buy or sell an underlying for a premium. The premium represents the maximum loss a long option position may incur. The buyer will try to minimize this loss through hedging by taking positions in the underlying. The upside from exercising an option is unlimited.
- *Short position:* The option user is said to be short options if he or she writes or sells an option for a premium. The premium represents the maximum upside for an option writer or seller. The writer or seller will aim at minimizing this loss through hedging by taking positions in the underlying. Option writers are exposed to unlimited losses.

The hedging operations themselves are a function of specific risks. Options are affected by anything that increases or decreases uncertainty as an increase in uncertainty reduces the

predictability of an option's payoff. Such uncertainty is related to spot risk, curvature risk, time decay, and volatility risk:⁶

- *Spot risk (delta)*: The largest risk for options is price risk. To hedge a price risk, the bearer takes an equivalent position in the underlying asset. The amount of the underlying the hedger buys (in the case of calls) or sells (in the case of puts) is determined by the option's delta that marks the sensitivity of an option price to movements in the underlying. Buyers of options will periodically buy or sell the underlying as conditions in the underlying continuously change the option's delta (dynamic hedging).⁷
- *Curvature risk (gamma)*: Gamma is the rate of change of an option's delta with regard to a change in the underlying and shows how quickly an option becomes inappropriately hedged. Large price movements in the underlying may cause the bearer of an option to be hugely over- or under-hedged and hence to lose money. If gamma is small, delta changes slowly and adjustments to keep an option delta neutral are relatively infrequent. A large gamma, in contrast, implies a delta highly sensitive to movements in the underlying and requires frequent adjustments.
- *Time decay (theta)*: The maturity date of an option determines the time left for an underlying asset to move sufficiently in favor of the option bearer. Options will lose value even if the underlying asset price and volatility have not changed due to the time decay of an option. All things being equal, an option's price tends to decrease with time; a longer-dated option has more time value than a short-dated one.
- *Volatility risk (vega)*: Option values are determined not only by the price level of the underlying but also by its volatility. Volatility reflects the uncertainty associated with the price of an underlying. Vega is the risk of an option position changing in value as a result of changes in the underlying's volatility. Vega is always positive for long option positions as the option value increases with a rise in the volatility of the underlying. Volatility risk is more relevant for longer-dated options as changes in volatility are more likely over the longer term.⁸

⁶ For a more detailed discussion, see Chew (1996) and Hull (1999).

⁷ Delta changes rapidly when the option is near or at-the-money and is close to expiry and also when market moves are large. An option that is deep in-the-money has a high delta and an option that is deep out-of-the money has a low delta.

⁸ Volatility represents one of the key determinants of an option's price, and option valuation depends critically on the estimation of volatility during the life of the option. The estimation of volatility affects the price of the option and hence its delta and gamma. Option writers estimate future volatility on the basis of historical volatilities and personal judgment.

Continuous changes in the underlying and hence changes in the risk exposure of the option bearer induce periodic hedging operations in particular against price and curvature risks. This rebalancing of long option positions should lead to a reduction in volatility of the underlying.⁹ However, option contract specifications determine the actual sensitivity of the option to the different kinds of risk.

Option contract specifications include exercise style and strike price determination. They determine the sensitivity of an option to movements in the underlying, that is, the moneyness of an option. Option specifications thus allow to tailor options to specific needs or objectives of the option buyer or seller.

Exercise styles determine the timing of the exercise and comprise:

- *American*: Option can be exercised at any time during their life.
- *Bermudan*: Option can be exercised at predetermined times during their life.
- *European*: Option can be exercised only at expiration.

The determination of the strike price establishes the strike price relative to its path:

- *Path independent options*: Standard or plain vanilla options are path independent options as their payoffs are not affected by the path by which the strike prices are reached. They may exhibit volatile payoffs and may expire worthless even if the options could have been exercised most of the time.
- *Path dependent options*: Options where the payoff depends on the path followed by the price of the underlying asset. Asian options are a special kind of path dependent options whose strike price is based on the average price of the underlying asset during a certain period of time. Averages can be arithmetic or geometric and the exercise price can be a fixed-strike (if the exercise price is a constant) or floating strike (if the exercise price is a current observation). Asian options reduce the significance of the closing price at maturity, minimizing possible price manipulations of the underlying asset at maturity making payoffs less volatile than those of plain vanilla options.

The relationship between the underlying asset price and the exercise price determines the option's moneyness and hence the option's payoff:

- *At-the-money*: An option is at-the-money if its cash flow would be zero if it were exercised, that is the exercise price equals the price of the underlying. Options are

⁹ To reduce transaction costs, option bearers make qualitative assessments on how often hedge ratios should be adjusted but the more infrequently a hedge ratio is adjusted, the greater the prospects of missing an important market move.

usually close to the money when they are issued. With time to maturity elapsing, they often become either deep-in-the money or deep-out-of-the money.¹⁰

- *In-the-money*: An option is in-the-money if its cash flow would be greater than zero if it were exercised. An option will be exercised when it is in-the-money. The intrinsic value of an option is the in-the-money portion of an option's price.
- *Out-of-the-money*: An option is out-of-the-money if its cash flow would be negative if it were exercised. The only value a deep out-of-the-money option has is time value.

Options are usually close to the money when they are issued and exhibit high gammas. With time to maturity elapsing, they often become either deep-in-the money or deep-out-of-the money with their gammas becoming relatively small and inconsequential (gamma decay). In contrast, for an at-the-money option, gamma increases with time to maturity. The most challenging situation for a holder of long call positions is a high gamma through to maturity, implying that the option remains very close at-the-money and requires intensive hedging.

The contract specifications of the options used by the Central Bank of Colombia do not seem conducive to sustained hedging:¹¹

- *Exercise price determination*: The exercise price as a function of the moving average implies that the value of the option changes every day through to maturity as a smoothed function of prior interday price movements. The Asian features of the contracts (average strike) are effective in reducing the volatility of the payoff, but this also limits the need for hedging as only significant movements in the underlying are likely to affect the value of the option. The 4 percent threshold of the volatility option of Colombia may cause the option to go quickly out-of-the-money once the moving average moved away from a near-exercise level, which causes sharp declines in delta and gamma. Low delta and gamma reduce hedging needs and may therefore limit stabilizing hedging operations.
- *Exercise-style*: The American feature implies that options can be exercised immediately after the auction date, also undermining the need for sustained hedging.

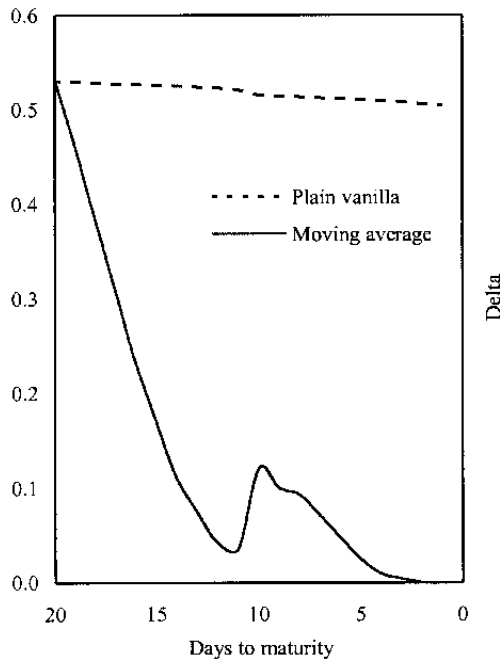
The statistical results affirm the above descriptions of the contract specifications. The results for the Colombian volatility option contract show a rapid decline in delta and gamma

¹⁰ The relation between maturity and gamma implies that an option that is near at-the-money and close to maturity has a higher gamma than one with a longer remaining life because the further from maturity, the less sensitive options' deltas are to changes in the underlying.

¹¹ The adoption of the contract specifications by the Central Bank of Colombia seems to have been motivated at least in part by the fact that the specifications of the contract allows the central bank to intervene in the exchange market without being perceived as targeting a certain exchange rate level as the actual market intervention is market determined by the option bearer (Werner and Milo, 1998).

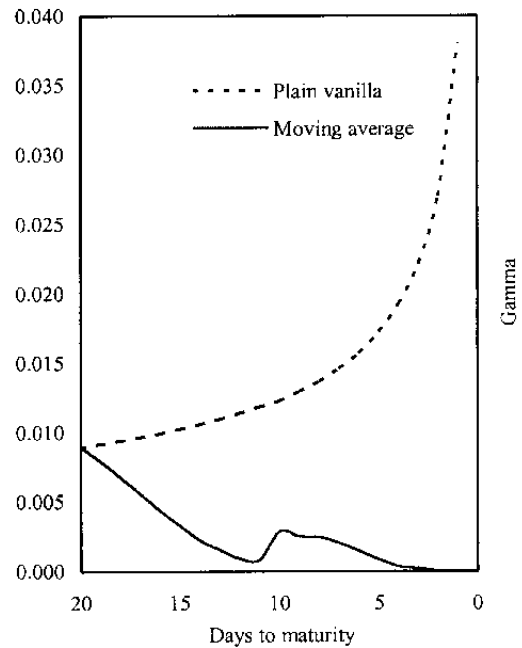
eliminating the need for sustained hedging operations consistent with the insignificance of a medium-term reduction in volatility. The rapid delta and gamma decays that the volatility call options suffer can be illustrated graphically compared with a hypothetical plain vanilla option (Figures 2 and 3).¹²

Figure 2. Colombia: Estimated Deltas



Source: Author's calculation.
Note: Volatility call options auctioned on July 29, 2002.

Figure 3. Colombia: Estimated Gammas



Source: Author's calculation.
Note: Volatility call options auctioned on July 29, 2002.

The review of Colombia's option contracts suggests that central banks should design option contracts that maximize the sensitivity of options to movements in the underlying while avoiding undue volatility in payoffs.¹³

¹² The simulation is based on an approximation using European call options.

¹³ The impact of options on the underlying assets also depends on exogenous factors such as the composition of option market participants and the presence of other currency derivatives. The net effect will be determined by the option positions of hedgers, speculators, and arbitrageurs. The first will seek to minimize outright exposure while the second will use leverage associated with options to make bets on the direction of the underlying. Arbitrageurs will aim at entering simultaneous transactions to benefit from small pricing differences in

- *Exercise price determination:* Exercise prices as a function of an underlying average is effective in reducing price manipulation and allows option writers to refrain from determining an exercise price up-front. Asian options generally provide for a “stickier” exercise path that reduce the need for hedging operations and could result in a prolonged gamma exposure but may also imply more rapid and permanent gamma decay (Kemma and Vorst, 1990; Turnbull and Wakeman, 1991). However, the calculation of the average is essential in determining the exercise path. Shorter-term and fixed-term averages should provide for greater sensitivity to movements in the underlying while mitigating the possibility of exercise price manipulation. Some barrier features may be effective, e.g., as a percent of the price of the underlying, as it may force hedging activities to be more concentrated in a narrower price range. Barrier options pay only in the event the underlying reaches a certain price or nothing otherwise (e.g., knockout options).
- *Style:* European-style and Bermudan-style options provide for a more predictable effect on the underlying than American-style options as the time path of exercise is predetermined and hedging needs preserved through to maturity if the option remains close to being at-the-money. Delayed exercise may also prevent price manipulation to affect the moneyness of the option at any given point in time.
- *Maturity:* Longer-dated options are susceptible to greater volatility risk and less to time decay. This increases the need to hedge the option over a longer time period, increasing the probability of sustained hedging operations.
- *Short volatility risk:* To limit exposure to unlimited losses for a central bank, the use of some binary elements, that is, the payment of only a fixed amount in the event of exercise, may be considered. Binary options exhibit a discontinuous payoff that only pay a given fixed amount in the event the underlying reaches a certain level and nothing if otherwise (e.g., cash-or-nothing options). Central banks are assumed to abstain from hedging their short option positions which implies potential significant losses and should be taken into account when determining option-based intervention rules. Prudential regulation and reporting standards may have to be adjusted to account for potential contingent liabilities and preserve appropriate central bank accounting.

different instruments. The efficiency of option-based market intervention may be constrained by the lack of complementary market instruments. In many emerging markets, only a limited set of capital market instruments is available which may reduce the possibilities to adopt effective hedging strategies and operations and hence reduce the impact of options-based intervention.

IV. CONCLUSION

The increasing adoption of floating exchange rate regimes and prevailing concerns about excessive currency volatility by central banks suggests that central banks will need to address more and more the effectiveness of their foreign exchange market interventions. In that regard, the use of options represents potentially an efficient intervention instrument and an attractive alternative to spot interventions.

The attractiveness of using options arises mostly from the associated hedging operations related to the risk management of option portfolios that may exert a stabilizing impact on the spot exchange rate. The effectiveness of option-based intervention rests on the sensitivity of options to movements in the underlying as established by exercise price determination, style, and maturity of an option. The closer option contract specifications are to spot price intervention, the less intrinsic benefits of option-based interventions are exploited. The paper discussed the relationship between option contract specifications and the effectiveness of option-based intervention and found that the option contracts used by the Central Bank of Colombia are not optimal to mitigate excessive currency volatility.

The option contract specifications that induce sustained hedging operation exhibit a high gamma, that is, a high sensitivity of the hedge on the price of the underlying. This can be achieved by longer-dated European or Bermudan-style path dependent options based on shorter-term and fixed-term averages while being less susceptible to price manipulations. To safeguard central banks from losses resulting from issuing options, some binary elements, such as fixed payouts, may be considered.

The paper has not discussed the advantages and disadvantages of exchange market interventions by central banks and the use of options does not alter their limitations. Under a floating exchange rate regime, foreign exchange intervention should be directed at temporary imbalances in the foreign exchange market. As such, intervention may complement but should not substitute the central bank's monetary policy instruments. Option contracts that address fundamental foreign exchange market imbalances may undermine the central bank's perceived commitment to a floating exchange rate regime and give rise to undue speculation. Prevailing monetary conditions and the option volume are therefore important determinants of the effectiveness of option-based intervention. The former refers to concerns that an accommodative monetary policy stance effectively sterilizes any intervention thus reducing their effectiveness. The latter is directed at high issuance volumes of options relative to the average foreign exchange market turnover that may unduly influence the exchange rate path.

CENTRAL BANK OF COLOMBIA OPTION CONTRACTS

Contract Specifications†

	Action	Auction amount	Auction trigger	Strike	Maturity	Amounts to date‡
Call options	Right to buy dollars from central bank	To be determined by the board**	Occasional auction based on policy directive	Official close of peso (TRM)* when TRM* more depreciated than its 20-day simple moving average (incl. TRM* of the day)	First to last day of month following month in which auction took place	Auctioned US\$400 million; exercised US\$145 million
Put options	Right to sell dollars to central bank	To be determined by the board for each month**	Regular monthly auction (average auction volume to date was US\$80 million)	Official close of peso (TRM)* when TRM* appreciated than its 20-day simple moving average (incl. TRM* of the day)	First to last day of month following month in which auction took place	Auctioned US\$2,600 million; exercised US\$1,199 million
Volatility control call options	Right to buy dollars from central bank	US\$180 million	If current official peso rate is 4% or more depreciated than its 20-day moving average and no other volatility call option is open***	Official close of peso (TRM)* when TRM* more depreciated by 4% or more than its 20-day simple moving average (incl. TRM* of the day)	30 days from and including the auction date	Auctioned US\$360 million; exercised US\$289 million
Volatility control put options	Right to sell dollars to central bank	US\$180 million	If current official peso rate is 4% or more appreciated than its 20-day moving average and no other volatility put option is open	Official close of peso (TRM)* when TRM* more appreciated by 4% or more than its 20-day simple moving average (incl. TRM* of the day)	30 days from and including the auction date	None

Source: Central Bank of Colombia.

† Options are in U.S. dollars and exchange rate refers to the peso/dollar rate.

‡ Through end-March 2003.

* Official exchange rate close for the day (Tasa Representativa de Mercado) based on previous day.

** If all options have been exercised, a new auction may be authorized by the board of the central bank.

*** As per central bank board decision of August 1, 2002, another auction can be held if the open contracts are less than US\$180 million.

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