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Evaluation of efficiency of hedging strategies with option portfolios for buyers of the currency US dollar/Colombian peso

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Article Info

ABSTRACT

This paper evaluates the efficiency to mitigate the exchange rate risk of nine hedging strategies with financial options. Strategies to hedging the purchase of US dollar Colombian peso (USDCOP) by importers in Colombia were raised. In this way, the traditional strategy with call options and eight strategies with investment portfolios were evaluated. These portfolios of options for hedge are offered by financial entities in Colombia. These nine hedged scenarios were compared with the unhedged scenario that corresponds to the foreign exchange risk exposure of importers. The USDCOP currencies were modeled with a mean reversion with jumps models, option premiums were valued with the black-scholes method and the best hedging strategy was determined through a Monte Carlo simulation. According to the results obtained, the nine hedging strategies manage to mitigate risk, but the most efficient was the option portfolio called collar.

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1. INTRODUCTION

Since Modigliani and Miller classic financial theory [1], companies have covered their risks by diversifying their portfolios. Despite this, authors such as Ahmed *et al.* [2], Allayannis and Weston [3] assure that the coverage contributes to the creation of value in the company and its financial development. Also, for companies that have operations in foreign currency they reduce the factors of exposure to the exchange rate [4]. As mentioned by Smith and Stulz [5] there are several reasons for companies to have hedging practices, the most common being the use of financial derivatives that are usually taken by risk-averse entrepreneurs to reduce the variability of cash flows, which leads to a decrease in the volatility of their profits and in turn decreases the expected costs of financial difficulties. As a result, the value of the company increases, since it simultaneously increases the company's debt capacity, which implies an increase in value for shareholders [6]. In addition, companies apply coverage strategies in order to attract strategic allies such as suppliers, shareholders, among others. According to Smith and Stulz [5], this is because it is not possible to diversify all the risk, which makes them reluctant and increases costs because they need greater compensation to assume them, but through hedging they manage to mitigate them, which decreases these costs and increases the value for the company.

For Dobson and Soenen [7], corporate risk coverage is justified in that agency costs can be reduced based primarily on three reasons. First, uncertainty is reduced by smoothing the cash flow stream, which leads to a reduction in the cost of corporate debt. Second, with debt financing, underinvestment problems will tend to be reduced, due to the adjustment of the average cash flow of the hedge. Finally, there is a reduction in the probability of financial difficulties, which increases the duration of contractual relations between

shareholders. Bartram *et al.* [8], included from 6,888 non-financial companies from 47 countries that the use of financial derivatives managed to reduce the company's risk, this is positively associated with the company's value and according to Ahmed *et al.* [2] it excels in those that are more exposed to interest rate, exchange rate and commodity price risks. This is why companies that conduct operations in foreign currencies should identify the exchange rate risk to which they are exposed and thus opt for hedging strategies that mitigate it or bring it to a level where the company can bear it [9].

When referring to currency risk, one has to consider that a company can earn more if it does not hedge because the currency in which it operates can have a decrease, which means greater profits when acquiring products at a lower price, but taking into account the volatility of exchange rates, especially the dollar, one cannot trust that these fluctuations will play in favor of the entrepreneur, since the objective is not to compare the profit it had with the one it could have had, but to implement hedging strategies, in this case with financial derivatives, it is possible to have a price where the company is not affected, in addition, to eliminate the uncertainty of the future, allowing to have more certainty about future cash flows [9]. In the literature there are several authors who have used coverage for different purposes obtaining positive results. For example, Martinez [10] analyzed how hedges help preserve public budgets and increase a country's foreign currency reserves, in this case Mexico. Choi *et al.* [11] studied the relationship between coverage and dividend payments in Korean companies listed on the Korean stock exchange by finding the effect of liability insurance coverage on a company's dividend decisions. Also, research has been done on the companies that use coverage and their relationship with employees, finding that those companies that have significant sales abroad and use coverage to mitigate currency risk tend to include employee benefits within their coverage policies when retention of human talent is costly [12]. On the other hand, [13] they carried out an empirical analysis to determine the best hedging strategy with financial options with the criterion that investors obtain a better profit. These authors use the following strategies: call, put and collar [9] analyzed the exchange rate risk of an export company from different alternatives to mitigate it, including financial derivatives, since companies that carry out foreign trade activities are exposed to exchange rate risk. According to Ochoa *et al.* [14], they found gains by minimizing the volatility of investment portfolios through hedges that mitigated the foreign exchange risk for the stock portfolio of a Mexican and a Colombian investor.

Velmurugan [15] studied 18 large Indian companies, which use hedging with financial derivatives to avoid risks such as interest rate volatility, variability in commodity prices and foreign exchange rates. It was found that the main reasons for these companies to use hedging are total assets and underinvestment, which showed that only large Indian companies are able to pay for these derivatives. Similar results were found in Spanish financial companies Palenzuela and Esteban [16] as it was the larger companies and those with more debt that most chose to have hedging strategies to mitigate foreign exchange risk and currently the likelihood of companies choosing to implement these strategies has increased. Géczy *et al.* [17], in studying 372 industrial companies, state that they use hedging in order to reduce the variation of cash flows, because if the flows are much lower than expected, the company can be prevented from making investments, which leads to the loss of opportunities for development and growth. Therefore, it is felt that the companies most likely to hedge with currency derivatives are those with financial limitations and high growth. Also, those exposed to the exchange rate and economies of scale have a high probability of using financial derivatives. Also Laing *et al.* [18] analyzed the effectiveness of financial hedging in oil and gas companies in the United States, where it was found that these companies were exposed to the volatility of commodity prices, but using financial hedging had a significant impact. On the other hand, Bodnar and Marston [19] state that the companies that are more exposed to exchange risk are those whose revenues or costs are not balanced, that is, they do not have an equal proportion in foreign currency, and therefore require the use of financial hedges that allow them to mitigate exchange risk. But it is required to establish strategies that favor the company according to its type of need, either by ensuring the value of a commodity, a future exchange rate, a financing cost, among others.

This paper will present hedging strategies with option portfolios, where the best coverage strategy will be chosen by means of the leapfrog reversion model. The cost of the strategies will be determined using the black-scholes and merton method and the currency will be modeled using the Wiener process. The objective is to mitigate the foreign exchange risk of importers in Colombia, the time series of the textile reinforced mortar (TRM) will be extracted from the Banco de la República. The methodology is presented below, followed by the results of the strategies and conclusions.

2. METHOD

Nine hedging strategies will be carried out with financial options offered by the Colombian over the counter market (OTC) for importers, since they must support the exchange risk derived from the volatility in the price of the currency. Additionally, it is taken into account that the hedging strategy used by importers is equivalent to the hedging of buyers. Data from March 16, 2017 to September 30, 2020 will be used, obtaining 1,001 prices and 1,000 yields. The most recent price is $3878.94. The Figure 1 shows the historical

price of the US dollar (USD)/Colombian peso (COP) currency and the yields of the prices with limits. Having for the upper limit to define upward jumps a deviation of 0.728% per day and for the lower limit to define downward jumps a deviation of -0.728%. The price of the exchange rate has an upward trend with short periods of time with abrupt changes called jumps, these jumps are identified because they exceed the limits.
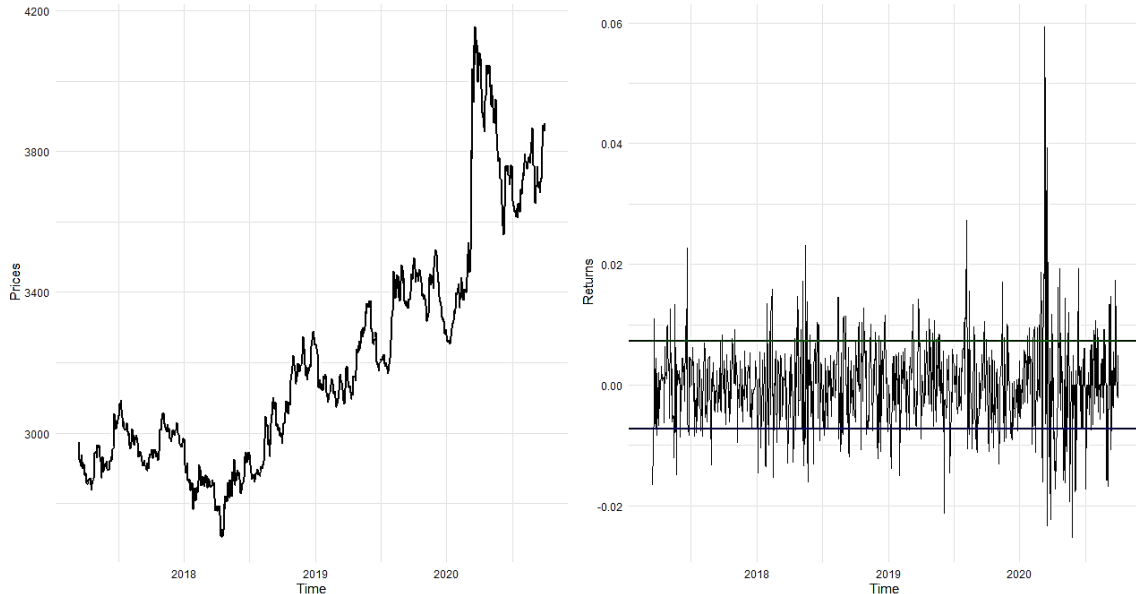

Figure 1. USD/COP currency history (left) and yields with limits (right)

The Figure 2 shows the histogram of the jumps is displayed, with a total number of upward jumps of 124 and 118 downward jumps. The graph on the left shows the histogram of the jumps up (positive) and the one on the right the jumps down (negative). Three strike prices (k_i) were used for the hedging strategies, where $k_2 = \$3878,94$ which corresponds to the initial spot price for at the money ATM options, k_1 and k_3 are equivalent to a \$50 change from k_2, down and up, respectively, where $k_1 = \$3828,94$ and $k_2 = \$3928,94$. The Figure 3 shows the payoff of the first strategy, in which you take a long position in call options. The horizontal line indicates that the option is not exercised, and the sloping line shows the zone in which the option is exercised and the higher the spot price, the greater the profit.
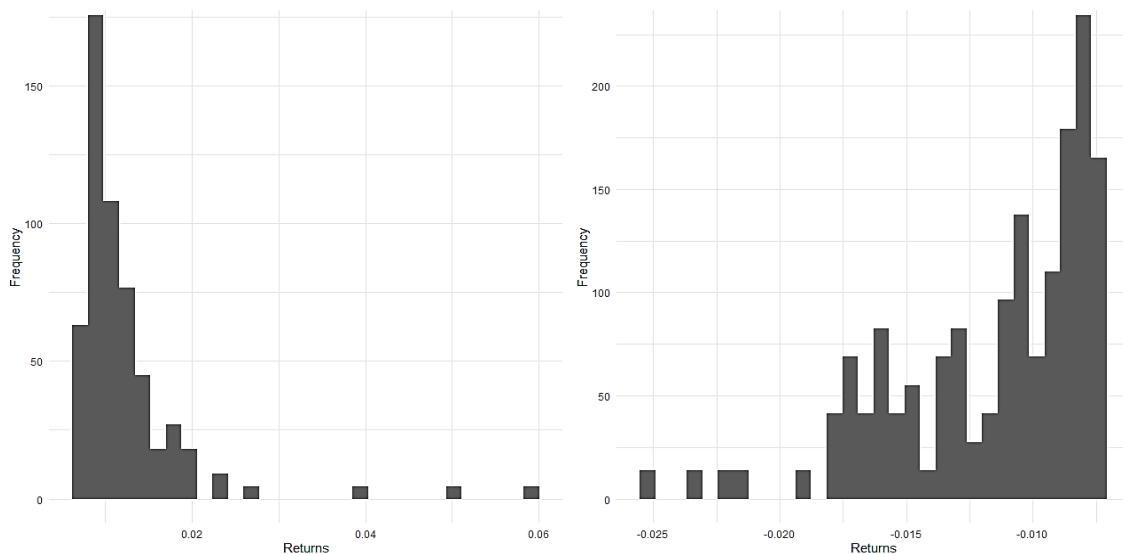

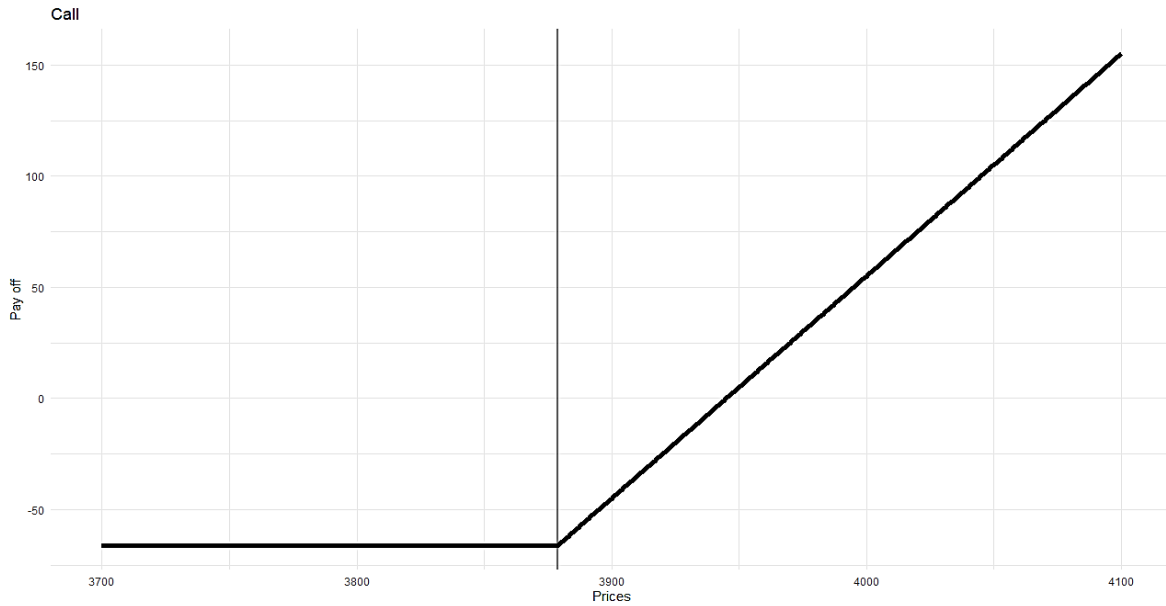Figure 2. Histogram of upward jumps (left) and downward jumps (right)

Figure 3. Traditional hedging strategy with financial options

With option portfolios, four coverage strategies for importers are applied, which consist of the combination of the four positions in the financial options: long call, long put, short call and short put. The Figure 4 shows eight coverage strategies with option portfolios. Each strategy has an associated name and its own combination of options. Some strategies have options with the same strike price and others with different strikes price levels. In addition, a local risk-free rate in effect for one month of 1.749% Annual. and a foreign risk-free rate in effect for one month of 0.14825% nominal is used.
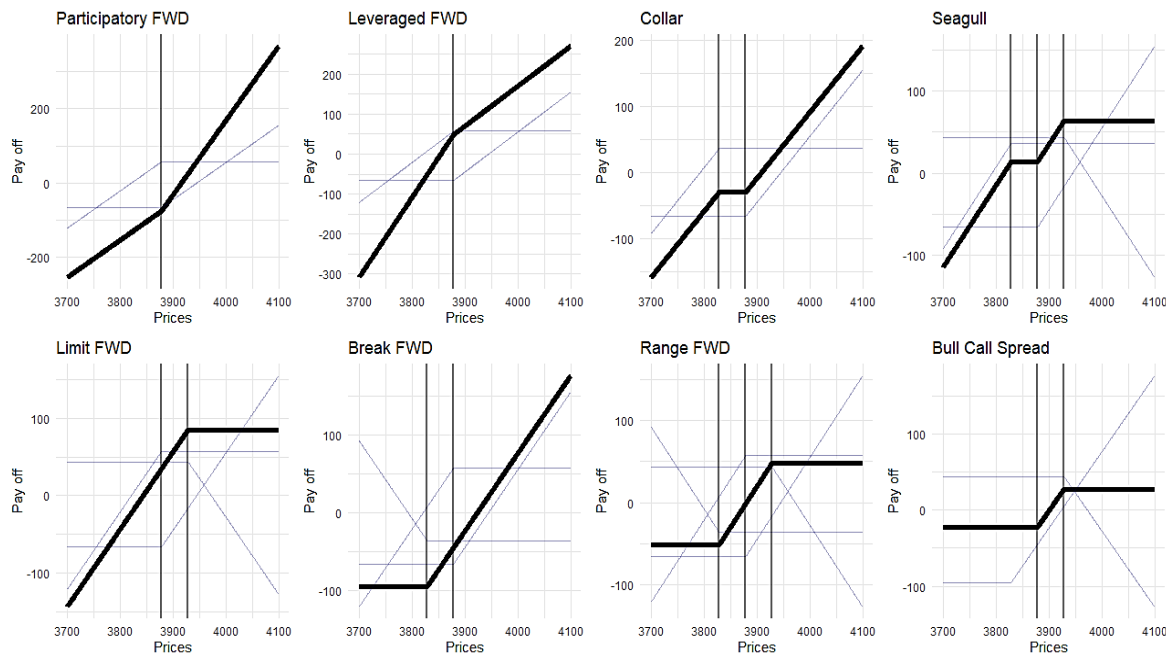

Figure 4. Hedge strategies with financial option portfolios

Next, the equations of the coverage strategies that will be used in the realization of the paper will be presented, for which the following notation will be used:

S_t: spot price of the currency modeled with the geometric Brownian motion (GBM) with jumps for t period
k_2: initial spot price (ATM options)
k_3: strike price $> k_2$
k_1: strike price $< k_2$
c: premium *call* option
p: premium *put* option
PCC: buyer hedge price
FWD: forward
lev: leverage
part: Participatory

- Traditional call:

$$PCCCall = |-St + Max[St - K1; 0] - c1| \qquad (1)$$

- Participatory Forward:

$$PCCFWD\ Part. = |-St + (Max[St - K1; 0] - c1) * 2 + Min[St - K1; 0] + p1| \qquad (2)$$

- Leveraged forward:

$$PCCFWD\ lev. = |-St + Max[St - K1; 0] - c1 + (Min[St - K1; 0] + p1) * 2| \qquad (3)$$

- Collar:

$$PCCCollar = |-St + Max[St - K2; 0] - c2 + Min[St - K3; 0] + p3| \qquad (4)$$

- Spreads:

$$PCCSpreads = |-St + Max[St - K3; 0] - c3 + Min[K2 - St; 0] + c2| \qquad (5)$$

Strategies with three or four financial options are now shown, where each financial option has a different strike price:

- Gull:

$$PCCGull = |-St + Min[St - K3; 0] + p3 + Max[St - K1; 0] - c1 + Mín[K2 - St; 0] + c2| \qquad (6)$$

- Forward limit:

$$PCCFWD\ limit = |-St + Min[St - K3; 0] + p3 + Max[St - K3; 0] - c3 + Mín[K2 - St; 0] + c2| \qquad (7)$$

- Break forward:

$$PCCFWD\ Break = |-St + Min[St - K2; 0] + p2 + Max[K1 - St; 0] - c1 + Max[St - K2; 0] - c2| \qquad (8)$$

- Forward range:

$$PCCFWD\ Range = |-St + Min[St - K1; 0] + p1 + Max[K3 - St; 0] - p3 + Max[St - K1; 0] - c1 + Min[K2 - St; 0] + c2| \qquad (9)$$

2.1. Currency modeling

The currency USDCOP (S_T) will be modeled with the stochastic process of reversion to the average with jumps for a period of one month, because this has been widely used to model the price of an asset, assuming that the percentage changes are independent and are distributed identically [19]. The Figure 1 above mentioned shows the daily behavior of the currency for the last three years. It shows an upward trend and has small random movements. This random behavior can be replicated with the geometric brownian motion (GBM). The spot price of the TRM is $3,774 for May 22, 2020, with the daily prices of three years,

we obtain a daily volatility of 0.8564438% and an average yield of 0.03545416%. Thus, K_1 will equal $3,774, K2 greater than K_1 by $100 and K_3 less than K_1 by $50.

　　　Stochastic processes are those that show the evolution of a random variable in time, are classified as:
- Discrete variable: only certain discrete values can be taken.
- Continuous variable: it can take any real value.
- Discrete time: the value can only change at certain moments of time.
- Continuous time: the value can change at any instant of time.

　　　A stochastic process of continuous time is the wiener process, where the variations in the prices are distributed lognormally and its main characteristics are:
- It is a Markovian process, that is, the probability distribution of future values only depends on their current value, has a mean equal to zero and a variance equal to 1.
- Changes in a given time interval are independent of changes in another time interval.
- The variations in a Δt are distributed normally and their variance increases linearly [20], [21].

　　　Also, it is true that:

$$\Delta z = \varepsilon_t * \Delta t \tag{10}$$

where, ε_t a non-self-correlated random variable of the type $\Phi(0.1)$, Δz the variations that are independent of each other and Δt the time intervals. In the long term the variance tends to be infinite and if $\Delta t \to 0$, the increase of dz in continuous time is

$$dz = \varepsilon_t * dt \tag{11}$$

generalizing this equation, we have

$$dx = a * dt + b * dz \tag{12}$$

where a and b are constant and

$$dz = \varepsilon_t * \sqrt{dt} \tag{13}$$

　　　The weiner process is defined as a brownian movement with a trend or drift, whose expected trend is sometimes the elapsed time and noise from the second component of the equation. This noise is sometimes a Wiener dz process and in the case of very small time intervals the Δx, are given by the following equation $\Delta x = a\Delta t + b\varepsilon_t * \sqrt{\Delta t}$ (14), then $\Delta x \sim N(a\Delta t, b^2 \Delta t)$ [20]. To simulate the price of an S share it is assumed that logarithmic price changes follow a normal distribution and from there the logarithm of the price is modeled with the Wiener process using the following equation in a time interval Δt for a stock that does not pay dividends:

$$\frac{\Delta S}{S} = \mu\Delta t + \sigma\varepsilon\Delta t \tag{15}$$

Considering that:
- $\frac{\Delta S}{S}$ is distributed normally, with mean $\mu\Delta t$ and variance $2\Delta t$
- μ expected performance of the action
- σ share volatility

　　　When deriving this equation using Ito's Lemma, which fulfills the same function as the rule of the chain in stochastic processes, we have that the equation for the geometric brownian movement, where the price of a share can be modeled in time t, is given by the following expression:

$$S_t = S_0 e^{[(\mu - \frac{\sigma^2}{2})\Delta t + \sigma\varepsilon\Delta t]} \tag{16}$$

where, the expected value of the share price is $S_0 e^{\mu t}$ and the variance is given by $S_0 e^{2\mu t}(e^{\sigma^2 t} - 1)$ [22]. Additionally, the value of an asset tends to return to an average price in the long term, for which mean reversion models are used. Also, models with jumps are used that allow the modeling of sudden changes. In this paper we will use the modeling of mean reversion with jumps, where the jumps are distributed exponentially and will occur every few years for very short periods. The formula for this model is defined by the following stochastic differential equation:

$$dx = \eta(\bar{x} - x)dt + \sigma dz + dq \tag{17}$$

When there are jumps, either up ϕ_u or down ϕ_d it is necessary to add the dq distribution of the size of the jumps. Also, it should be defined that the Brownian process dz and the Poisson process dq are not correlated and to guarantee that dx is independent of the jumps, λk is subtracted, where λ corresponds to the sum of the frequency of the jumps

$$(\lambda = \lambda_u + \lambda_d) \tag{18}$$

Obtaining (19):

$$dx = [\eta(\bar{x} - x) - \lambda k]dt + \sigma dz + dq \tag{19}$$

Finally, you have that the value of the asset at time t is given by (20) [23]:

$$S_t = e^{\left(x_t - \left(1 - e^{-2\eta\Delta t}\right)\frac{\sigma^2 + \lambda Var(\phi)}{4\eta}\right)} \tag{20}$$

where x_t is:

$$x_t = \log(S_{t-1})\, e^{-\eta\Delta t} + \log(\bar{S} + \lambda k\eta)\,(1 - e^{-\eta\Delta t}) + \sigma\sqrt{\frac{1 - e^{-2\eta\Delta t}}{2\eta}}\, dz + dq \tag{21}$$

2.2. Financial option valuation method

The Black-Scholes and Merton method, created in 1973 by Fischer Black and Myron Scholes, and later modified by Robert C. Merton, is used for the valuation of financial options. Although it serves as the basis for pricing almost all financial derivatives, the markets do not use this methodology, but rather prices are based on supply and demand [24]. In this method it is assumed that the stock price follows a geometric Brownian motion and that Ito's Lemma was used to describe the behavior of the option price, [25] additionally, a series of assumptions are made [26], [27]: i) stock returns are normally distributed and independent over time, ii) the volatility of returns is known, iii) no dividends are paid and if paid, they are known future dividends, iv) the short-term risk-free interest rate is constant and there are no risk-free arbitrage opportunities, v) there are no transaction costs or taxes, and vi) trading in securities is continuous.

The equations for calculating the prices of European call and put options are given by

$$c = S_0 e^{-r_f t} N(d1) - k e^{-rt} N(d2) \tag{22}$$

and

$$p = k e^{-rt} N(-d2) - S_0 e^{-r_f t} N(-d1) \tag{23}$$

where

$$d1 = \frac{\ln\left(\frac{S_0}{k}\right) + \left(r - r_f + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}} \tag{24}$$

and

$$d2 = \frac{\ln\left(\frac{S_0}{k}\right) + \left(r - r_f - \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}} \tag{25}$$

$N(x)$ corresponds to the cumulative probability function for a normal variable with a mean of zero and standard deviation 1, S_0 is the stock price, k is the strike price, r is the risk-free rate, r_f is the foreign risk-free rate, t is the time to expiration and σ is the stock price volatility. There will be 10 scenarios, one unhedged and 9 with hedging strategies for importers present in the over-the-counter (OTC) market, the cost of each strategy will be given by the black-scholes and merton method, the USDCOP currency will be modeled for one month and thousands of iterations will be performed for each of the scenarios by means of the reversion to the mean with jumps model and the 5% percentile that will represent the VaR for each of the scenarios will be calculated and based on the lowest VaR the best hedging strategy will be chosen.

3. RESULTS AND DISCUSSION

The simulation of the unhedged scenario was carried out in addition to the evaluation of the nine hedging strategies for buyers. Additionally, Table 1 shows the value of the premiums used for each strategy. For call options the highest strike price corresponds to k_1, because in this case the options are in the money (ITM), that is, they have a lower price than the spot price and lower for k_3 where the options are out the money (OTM), because the strike price is higher than the spot price. The opposite occurs with put options, since for a price higher than the spot price the options are OTM and for a lower one they are ITM, which is evidenced by the values of k_3 and k_1. Table 2 shows that there are strategies where there is a cost; that is, those whose value is negative, with call being the one where a higher premium must be paid, followed by break forward (FWD) and collar. But there are others where money is received in advance; that is, those with a positive sign, being leveraged FWD the one that receives the highest premium, in second position is limit FWD and then seagull.

The Figure 5 shows in gray the empirical distribution of the scenario without coverage and in blue the empirical distribution of the strategies with hedged. Also, two vertical lines representing the 95% percentile are added to each graph both when there is coverage and when there is no coverage. It was found that hedging strategies manage to mitigate exchange rate risk, since the buyer has the risk of buying at high prices and all the blue lines are further to the left than the gray lines, which means that under the worst-case scenario one could buy at lower prices. The call, participatory FWD, collar and break FWD strategies are the ones that manage to mitigate it the most, and there are others like bull call spread and range FWD where there is a very similar behavior to the unhedged scenario as shown in Table 3.

Table 1. Individual premium value for each strike price

Option	k_1	k_2	k_3
Call	$94.91946	$66.07437	$43.60025
Put	$36.38879	$57.42831	$84.8388

Table 2. Value of premiums for each coverage strategy

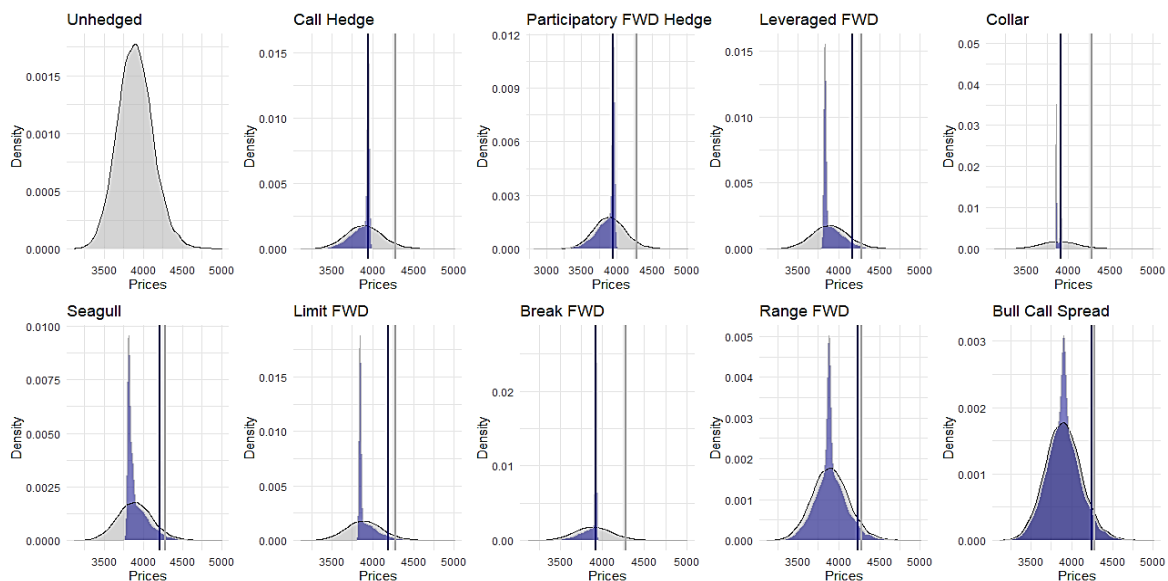| Strategy	Premium (+receipt, -pay)
Call	-$ 66.07437
Participatory FWD	-$ 8.646062
Leveraged FWD	+$ 48.78225
Collar	-$ 29.68558
Seagull	+$ 13.91467
Limit FWD	+$ 34.95419
Break FWD	-$ 45.03485
Range FWD	-$ 1.434602
Bull Call Spread	-$ 22.47412

Figure 5. Empirical distributions of the strategy simulations

Table 3. Results simulation of coverage strategies

Strategy	Mean	Standard deviation	VaR5%
Unhedged	$ 3899.414	$ 226.87815	$ 4280.212
Call	$ 3865.478	$ 120.60878	$ 3945.014
Participatory FWD	**$ 3853.649**	$ 144.97074	$ 3953.660
Leveraged FWD	$ 3909.695	$ 120.60878	$ 4172.148
Collar	$ 3887.149	**$ 24.01892**	**$ 3908.626**
Seagull	$ 3919.463	$ 142.59847	$ 4216.297
Limit FWD	$ 3919.900	$ 128.43799	$ 4195.258
Break FWD	$ 3865.915	$ 103.23313	$ 3923.975
Range FWD	$ 3898.229	$ 189.65636	$ 4231.647
Bull Call Spread	$ 3897.792	$ 207.65364	$ 4252.686

The mean, standard deviation, and value at risk (VaR) are presented for the nine coverage strategies and for the unhedged scenario. Analyzing the standard deviation, the unhedged scenario has the highest value, which means that all the strategies manage to mitigate the exchange rate risk, since the empirical distributions of each strategy are less volatile, the strategy that most manages to reduce this measure is collar, where there is a very noticeable difference compared to the others and coincides with what is shown in Figure 5. Continuing with the analysis, the average is the expected value that the buyer expects to pay, so it is expected to have the least value possible, since the risk of a buyer is to pay high prices, therefore, the participatory FWD strategy is the best in this aspect and in the leveraged FWD, seagull and limit FWD strategies the average of the prices is higher compared to the scenario without coverage. Also, the VaR of 5%, where the best scenario of all possible scenarios is sought, is observed that the collar strategy has the lowest measure, so it guarantees the importer that in the face of the worst scenario he can buy at a lower price. Finally, the best hedging strategy is collar, since it has a much smaller standard deviation than the others and is the one with the lowest price in the calculation of the 5% VaR. On the other hand, the worst hedging strategy is the bull call spread, since it is the most volatile of all strategies, and is also the one that in the worst scenario would make the importer pay a higher price.

4. CONCLUSION

Nine hedging strategies were evaluated to mitigate the exchange rate risk to which the buyers are subject, one of which was the traditional call and the remaining eight correspond to financial option investment portfolios. To obtain the results, an R simulation was carried out, with thousands of iterations for each of the scenarios. Evidence was found of hedging strategies that succeed in mitigating foreign exchange risk for importers, taking as a reference a scenario where there was unhedged. The variables that support that evidence are first the standard deviation, taking into account that this measure is associated with the risk, it was possible to obtain lower values indicating a lower volatility. The second is the VaR, where in the worst possible scenario lower prices were obtained. In conclusion, analyzing all the possible scenarios when hedging strategies were used, the importer can buy at a lower price than without hedging; even in the worst-case scenario, in addition, having a lower volatility, so it can be shown that by using currency hedges buyers are less exposed to risk and therefore can have more profits or greater certainty of their future cash flows.

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