

Simulation of Exchange Hedges with Financial Options to Mitigate Foreign Exchange Risk

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Abstract: The main objective of this research is to cover the exchange risk in an exporting company through coverage with futures on the TRM in Colombia and financial options on the currency. For this, the monthly data of the TRM is used from April 2013-March 2018. Monte Carlo Simulation of the scenario without coverage and the scenarios with coverage with the geometric Brownian motion the price of the TRM are modeled and with the Monte Carlo Simulation all possible values are obtained and then the average value is calculated. The results show that the financial options manage to reduce the exchange risk. The expected value with coverage is approximate to the expected value without coverage but the 5% percentile with coverage is greater than without coverage. The foregoing indicates that in the worst scenarios the exporting companies will obtain better prices for the sale of the currencies if they cover.

Key words: Foreign exchange risk, financial options, geometrical Brownian motion, hedge, data, value

INTRODUCTION

The cash flows of the exporting and importing companies are affected by the movement of the price of Foreign currencies this is known as exposure to the risk of exchange rates. From the point of view of the valuation of companies, the economic value of these companies depends on the exchange rates and the exchange hedges minimize the impact on the cash flows of the changes in the currencies (Hagelin 2003; Solomon and Joseph, 2000). Therefore, the management of Foreign exchange risk is important for organizations (Addae-Dapaah and Hwee, 2009).

Modigliani and Miller's proposals on capital structure and dividend policy argue that in the absence of imperfections in the capital market, hedging does not increase the value of the company, given that there are no reasons for companies to protect themselves. However, the existence of imperfections as factors related to financial difficulties, tax shields and under investments, leads to coverage increases value the economic value of companies (Smith and Stulz, 1985). This is why risk management systems are carried out through financial derivatives for hedging purposes to reduce the impact generated by changes in currencies, interest rates and commodities. In this way, the volatility of the expected cash flows is reduced which leads to a lower variance in the value of the company and a lower probability of obtaining low values.

Because financial difficulties are expensive, companies have incentives to reduce the likelihood of default by obtaining lower financing costs, greater debt capacity and greater benefits of tax shields in interest deduction (Sprcic *et al.*, 2008). In other words, the coverage reduces the variability of the value of the company before taxes, reducing the expected fiscal liability and in turn, the cost of the debt as long as the cost of the coverage is not too great (Fok *et al.*, 1997). Consequently with the coverage a lower cost of capital is obtained by means of the reduction of the cost of the debt and thus increase the value of the company.

Likewise, the increase in leverage increases the value of companies through the tax advantage of the debt, although it pressures the company with interest payments and installments of debt capital. Likewise, employees have a legal right over wages. As a result if the obligations are not met, the company may find itself in financial difficulties and ultimately, bankrupt. In perfect capital markets, bankruptcy leads to the renegotiation without cost of the assets of the company (Aretz *et al.*, 2007). However, with the existence of imperfections in the market, the probability of bankruptcy in the future creates costs for the company that negatively impacts the value of the company.

On the other hand, the decrease in the volatility of cash flows improves the probability of having sufficient internal funds for the planned investments and eliminates

the need to cut profitable projects or support the transaction costs to obtain external financing (Froot *et al.*, 1993). Companies with higher levels of financial leverage, therefore, less financial flexibility, face a greater probability of facing the costs of market imperfections. In addition, companies with substantial growth opportunities and high costs in raising funds under financial difficulties will have an incentive to cover their exposure to risk.

Another effect of the hedge is to reduce the problems of underinvestment. Cash flow is important for the investment process but is affected by movements of external factors such as exchange rates, interest rates and the price of raw materials which compromises the company's ability to invest (Sprcic *et al.*, 2008). If the company's internal cash flows are not sufficient to finance the investment projects, the value of the company is not maximized, due to the opportunity costs caused by the rejection of some profitable investment projects or because of the associated costs to external financing which is more expensive due to the imperfections of the capital market which leads to an increase in the cost of capital. Graham and Rogers (2002) argues that hedging policies mitigate investment problems because the value of debt becomes less sensitive to incremental investment decisions.

The financing by means of debt and the investment in projects that contribute greater risk to the company, increases the value of the patrimony at the expense of the creditors. This is due to the fact that the residual claims of the shareholders can be interpreted as a purchase option on the assets of the company. The value of the purchase option will increase as the volatility of the underlying asset increases. In this way, management, acting in the interest of shareholders, will have to prefer investment projects with volatile cash flows (Sprcic *et al.*, 2008).

In general, imperfections in the capital market are used to argue the relevance of the corporate risk management function. With corporate coverage, the value of the company is increased by reducing the volatility of the expected cash flow and making it possible to face a lower probability of default and therefore, lower bankruptcy costs and financial difficulties without sacrificing tax advantages for debt financing. In this way, companies maintain optimal investment and financing plans to take advantage of attractive investment opportunities, using more internal financing than external financing, since, the latter is more expensive due to market imperfections. For this reason, hedges increase the value of the company with the decrease in the cost of debt, a component of the discount rate of expected cash flows.

On the other hand in the scientific literature there are studies that show the benefits of coverages on companies. Joseph (2000) focused on UK companies identifying that hedging operations have a limited set of techniques to cover risk. Judge (2006) determined that companies with predominant sales abroad carry out exchange hedges but only when they have expectations of a financial crisis. Tai (2008) concluded that half of the industries and most of the banks in the United States have exposure to exchange risk. Finally, the investigation by Dominguez and Tesar (2006) studied the exposure to Foreign exchange risk and its effect on the value of the company through the analysis of exports and the multinational state of the companies.

The main objective of this research is to cover the exchange risk in an exporting company through coverage with futures on the TRM in Colombia and financial options on the currency. For this, the monthly data of the TRM is used from April 2013-March 2018. Monte Carlo Simulation of the scenario without coverage and the scenarios with coverage with the geometric Brownian motion the price of the TRM are modeled and with the Monte Carlo Simulation all possible values are obtained and then the average value is calculated.

MATERIALS AND METHODS

Exchange coverage was made for an exporting company in general from Colombia. Exports are made in US dollars and the company exchanged dollars in Colombian pesos. The coverage is made from the point of view of the exchange of dollars to pesos. Because the profits of the exporting company are negatively affected when the exchange rate decreases this is due to the fact that at the moment of receiving the Foreign exchange for exports, the conversion to Colombian pesos may be less than expected. As a result, the company's dollar position for 6 months was projected starting in April 2018 through September 2018.

The exchange rate of Colombia is measured by the TRM (Representative Market Rate), representing the amount of Colombian pesos for an American dollar. It was considered the assumption that the TRM is the value with which the exporting company sells a dollar. In other words, the TRM corresponds to the value of the dollar in the cash market. With the Brownian geometric motion the TRM was projected for each month of projection and by means of Monte Carlo Simulation the average value of the TRM was estimated in each month.

For financial hedging currency options were used. The 6 months projection was covered with financial options on European-type currency with a strike price of

\$2,780.47 for each month, this value corresponds to the last value of the historical TRM. In the compensation of the options in each month, the price paid for the premium, calculated with the Black-Scholes method for currency options was taken into account.

Finally with the modeling of prices and the Monte Carlo Simulation, the effect of the exchange hedging with options on the exporting company was determined, this by means of the unit price estimate to which the dollars in the scenario without coverage were changed and scenario with coverage.

Financial options: Financial options are derivative instruments in which the buyer of the option must pay a premium at the initial moment to have the right of the option, instead, the seller of the option will receive the premium and will have an obligation. There are two types of options, call options (put options) and put options (put options). The buyer of the buying position in call options, has the right to buy the underlying asset at the strike price of the option, on the contrary, the policy holder of the selling position in the call has the obligation to sell the asset at the strike price. In the put options, the buyer of the option has the right to sell the asset at the strike price and the seller has the obligation to buy it at the same price (Jimenez *et al.*, 2016; McDonald, 2013).

There are European-type options in which the right can only be exercised on the expiration date of the option and the American-type options in which the option can be exercised at any time until the expiration date. European-type options can be evaluated by the binomial tree method and Black-Scholes, the American-type options the Black-Scholes method does not consider the possibility of exercising before the expiration date what the binomial tree method does allows (McDonald, 2013).

Assessment of European options with Black-Scholes:

The Black-Scholes formula starts from the valuation of options with the binominal method, calculating the price of the premium or the price of the option when the step number in the binomial trees tends to infinity. Changing the number of steps changes the price of the option but when the number of steps is large enough, the price approaches a limit value for the price (Kumbaroglu *et al.*, 2008).

The Black-Scholes formula for a European call option (c) and European put option (p) in an action that does not pay dividends is as follows (Eq. 1-4):

$$c = S_0N(d_1) - Ke^{-rt}N(d_2) \tag{1}$$

$$p = Ke^{-rt}N(-d_2) - S_0N(-d_1) \tag{2}$$

Where:

$$d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \tag{3}$$

$$d_2 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T} \tag{4}$$

Where:

- S_0 = The current price of the share
- K = Exercise price or strike price of the option
- σ = Volatility of the action
- r = Risk-free rate with a continuous composition
- T = Time to expiration of the option

The functions $N(d_1)$, $N(d_2)$, $N(-d_1)$, $N(-d_2)$ is the cumulative normal distribution. The entries of K and T describe the characteristics of the option contract, however, S_0 and σ , describe the action and r is the discount rate for a risk-free investment.

When the underlying asset is a currency then the Black-Scholes formula adds the risk-free rate of the currency country (r_f) and S_0 is the current exchange rate, therefore, the formula changes to the following (Eq. 5-8):

$$c = S_0e^{-r_f t}N(d_1) - Ke^{-rt}N(d_2) \tag{5}$$

$$p = Ke^{-rt}N(-d_2) - S_0e^{-r_f t}N(-d_1) \tag{6}$$

$$d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r - r_f + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \tag{7}$$

$$d_2 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r - r_f + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T} \tag{8}$$

Consequently, the values of c and p correspond to the values of the premiums of the options.

Lognormal pricing model: The change in price from the period t to the period $t+dt$, dS_t where d_t is very small ($d_t \ll 1$) is given by Eq. 9:

$$dS_t = \mu S_t dt + \sigma S_t dz_t \tag{9}$$

Where:

- S = Spot price or spot price
- t = Observation time

μ = Average of changes or drift
 σ = Volatility of the changes
 dz = Random stochastic variable

The change in the price over time d_t has two components, the first is the drift or deterministic term $\mu S_t d_t$. The second component is the stochastic or random, contribution to the change in the spot price, $\sigma S_t dz$.

The drift and the stochastic term are proportional to the spot price in period t . The big change in the price is in the expected change in the price and in the random part. The random component contains the variable dz which is a random variable distributed normally with zero mean and standard deviation that grows with the square root of time d_t (Pilipovic, 2007).

Differential Eq. 9 solves the spot price according to the parameters of the model, including the stochastic variable dz and also to know about the behavior of the spot price under the assumption that spot prices have lognormal behavior. So, a variable transformation is performed where a new variable x_t is defined, being the natural logarithm of the price as shown in Eq. 10 (Pilipovic, 2007):

$$x_t = \ln(S_t) \tag{10}$$

Applying the Itô Lemma to the new variable it is found that it is normally distributed (Eq. 11):

$$dx_t = \left(\frac{\mu - \sigma^2}{2} \right) dt + \sigma dz \tag{11}$$

This allows us to solve the new variable x_t first and from this solution we can derive the solution for the spot price in the contingent period T over the spot price in period t (Eq. 12):

$$S_{Tt} = S_t e^{\left(\mu - \frac{\sigma^2}{2} \right) (T-t) + \sigma dz_{t,T}} \tag{12}$$

where, S_{Tt} is the spot price in the contingent period T over the price the spot price in period t . Taking the expected value of the sides of the Eq. 12, we obtain Eq. 13, the solution for the expected spot price in period T as observed in period t (Pilipovic, 2007) (Eq. 13):

$$E_t [S_T] = S_t e^{\mu(T-t)} \tag{13}$$

As observed in the previous derivation, in a lognormal model, the expected value of the spot price grows exponentially through time with an expected rate of yield given by μ . It is emphasized that the randomness in

the wreck through time is always exponential, guaranteeing that the price is always positive. If the random variable, z , takes very negative values, the spot price approaches zero but never negative values (Pilipovic, 2007).

RESULTS AND DISCUSSION

Assuming the TRM as the spot value of each dollar in the market, the modeling of the price was made with the geometric Brownian motion and the monte carlo Simulation with 10,000 iterations. Taking data from the monthly TRM of the last 5 years, an average of 0.7101% monthly and standard deviation of 4.199% monthly was obtained, the previous of the logarithmic changes of the TRM the last data of the TRM was \$2,780.47, this corresponds to S_0 . With the above data, Fig. 1 shows the average of the simulations for each month of projection of the TRM and the percentiles of 5 and 95%. This corresponds to the scenario without coverage where dollars from exports are sold at the simulation average.

Figure 1 shows the result of the simulation for the spot price, trend is bullish for the case of the exporting company this trend indicates that the dollars will be sold at a higher price, however, the 5th percentile indicates that there is a probability of 0.05 that the price of the dollar has lower values and with a downward trend. The above means that there are scenarios of negative impact for the company due to the decreases in the TRM. In this way, it is convenient for the company to make a hedge that mitigates the risk to which it is exposed when the TRM decreases, so that, exchange hedges were made with financial options on the TRM for each projection month.

Coverage will change with financial options on currencies: In this scenario, the projection months were covered with options on the European-type TRM with maturities for each month and strike price of \$2,780.47 as

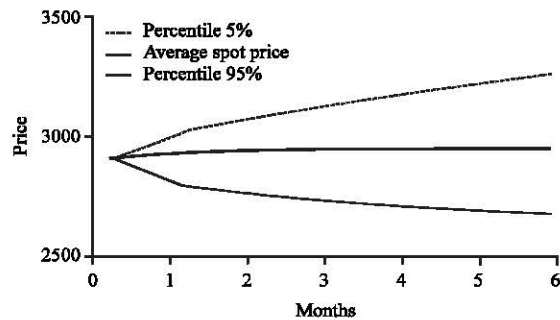


Fig. 1: Spot price projection

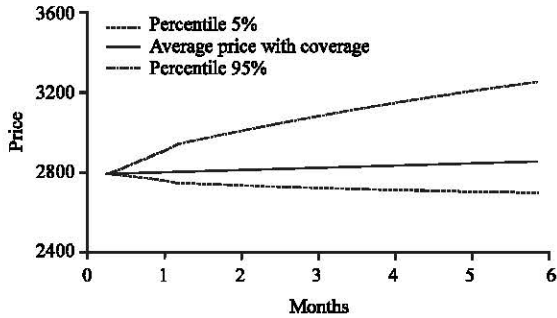


Fig. 2: Unit price with coverage with options

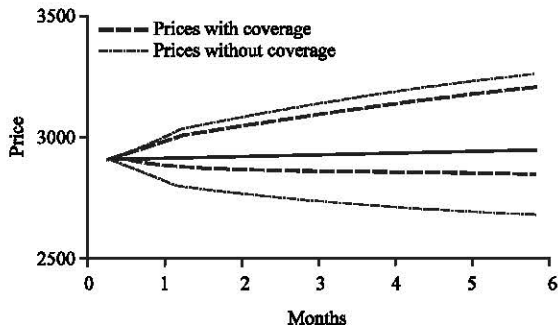


Fig. 3: Results scenario without coverage and scenarios

Table 1: Value of put options

Months	Prices
April	\$43.38
May	\$59.66
June	\$71.65
July	\$81.44
August	\$89.91
September	\$97.48

well as the initial spot price. It was considered to subtract the price of the put option in each month, obtaining that in the coverage the option is compensated by exercising or not and subtracting the value of the premium, Table 1 shows the value of the put options prices for each dollar for each month. It is evident that the options with greater term have greater value.

The result of hedges with currency options for each month is shown in Fig. 2. The unitary price with coverage obtained by the exporting company is closer to the 5% percentile than to the 95% percentile. In other words, the expected price will be located in the worst scenarios. It is also observed that over time the results have greater variability. Figure 2 is not symmetric as it is in Fig. 1.

If the results without coverage are compared with the results with coverage, the benefits of the coverage with options are evident. The thick lines of Fig. 3 are the results of the price with coverage with options and the thin lines of the prices without coverage. The expected prices of the two scenarios are almost the same except in the last months where the scenario with coverage is lower. However, the percentiles of the scenario with coverage

are less dispersed than the scenario without coverage, this indicates that the risk was mitigated. The greater risk that the exporter has is to obtain low prices for the sale of dollars, if he covers the expected value is the same as without coverage but the worst scenarios are higher with coverage than without coverage. The above shows that the percentile of 5% of the scenario with coverage is greater than the percentile of 5% of the scenario without coverage.

CONCLUSION

The financial options on the American dollar are applied to mitigate the exchange risk that the exporting companies have from Colombia. Financial options are valued by the Black-Scholes method. The Brownian geometric motion is used to model the spot price of the currency and by means of Monte Carlo Simulation, the possible values for the scenario without coverage and for the scenario with coverage with put options are obtained.

In the scenario without coverage it is determined that the dollar will have an upward trend, so that, the profits of the exporting company are positively affected because more Colombian pesos will be obtained per dollar, however, there is a 0.05 probability that the opposite will occur. In this way, exchange hedges are important for the company.

In the scenario with coverage, the expected prices are approximate to the price of the scenario without coverage. However, the results in the scenario with coverage are less dispersed. The range between the 5 and 95% percentiles is lower in the scenario with coverage. The benefit of making coverage with financial options is demonstrated in that the risk was mitigated by obtaining the highest adverse scenarios if coverage is not made.

RECOMMENDATIONS

As future research it is proposed to carry out exchange hedging with financial futures on the currency. This could be done because the Colombian stock exchange offers this derivative instrument. With the implementation of the futures, one could compare and determine which of the two derivative instruments best mitigate the Foreign exchange risk.

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