VALUING DERIVATIVES IN COMMERCIAL BANKS OF EMERGING MARKETS – APPLICATION TO SLOVENIAN MARKET

Andraž Grum

Faculty of Economics, Ljubljana
Trihed Consulting
Preglov trg 13
SI-1000 Ljubljana, Slovenia
e-mail: grumci@yahoo.com
phone: +386 41 434 210

In emerging market economies there is usually no institutionalised derivative market. Like in every other market-oriented economy, there exists the need for such instruments, especially in the corporate and financial sectors. In practice, the main market or position risk that a corporate sector is exposed to is the exchange rate or currency risk. The shortage of standardized derivatives is partly covered by unstandardized, tailor-made derivatives issued by commercial banks to satisfy the specific needs of clients. Not surprisingly, a large portion of unstandardized derivatives issued by commercial banks comes in the type of forward agreements and / or options, with a foreign currency as the underlying asset. Because those derivatives are "tailor-made," they often have characteristics for which they can be classified as exotic derivatives. To manage efficiently the market risk, the issuer of such derivatives has to address the issue of valuation of those instruments. In practice, the most effective method of valuation of exotic derivatives has been found to be the Monte Carlo simulation based on the parametric model of the underlying asset price dynamics. Using the Monte Carlo simulation for pricing options raises several issues such as measuring the accuracy of simulated prices and determining the number of simulations required for the desired level of accuracy.

1. Introduction

There is no institutionalised derivative market in Slovenia on which it would be possible to trade with standardized derivatives. Like in every modern market-oriented economy, there exists the need for such instruments, especially in the corporate and financial sector, as those instruments are an important part of the hedging and risk management process. The shortage is partly covered by unstandardized, "tailor-made" derivatives issued by commercial banks to satisfy the specific needs of clients.

The main market risk that the corporate sector is exposed to is currency risk. Not surprisingly, a large portion of unstandardized derivatives issued by commercial banks come in the type of forward agreements and / or options, with a foreign currency as the underlying asset as the demand for those instruments has been growing rapidly. One of the reasons can be the increased volatility of exchange rates due to the brakedown of the Bretton Woods system in 1971 and introduction of managed floating exchange rates. Another reason is globalisation, as companies are intensifying the engagement in international trade. Companies are trying to hedge their position in special arrangements with commercial banks which issue unstandardized derivatives, especially forwards and foreign currency options. Those derivatives being "tailor-made," they often have characteristics for which they can be classified as exotic derivatives.

The absence of the derivative market is even a bigger problem for participants in the financial sector, as there are practically no instruments that would enable them to manage the market risk imposed by debt and equity instruments, especially general position risk and interest rate risk. Slovenian commercial banks are limited in issuing unstandardized derivatives, as they can find no counter party to hedge their exposure, especially in the case when the underlying asset is a stock, stock exchange index or interest rate. The main derivative transactions on the stock exchange market are REPO (repurchase) agreements, which are a combination of spot and forward transactions. REPO agreements are in their essence very similar to loans where financial assets bought by a bank in a spot transaction can be seen as a collateral. The situation is better on the currency market. Commercial banks issue derivatives to the corporate sector and then hedge their own open position by the opposite position in standardized derivatives, which can be bought on developed financial markets.

A commercial bank as the issuer of unstandardized derivatives has to address the issue of valuation of those instruments for the purpose of risk management. In this article we will focus on the valuation of exotic foreign currency options. In practice, the most effective method of valuation of exotic derivatives has been found to be the Monte Carlo simulation based on the parametric model of underlying asset price dynamics. The goal of this paper is to present the details of exotic option valuation and to use the programmed model to address the issue of method accuracy.

2. Methodology

2.1. Modelling asset price dynamics

The parametric option-pricing model can be described as a model in which the price dynamics of the underlying asset is specified up to a finite number of parameters. The first aspect of parametric option-pricing focuses on the dynamics of financial asset price, which is usually modelled using Brownian motion based on Wiener process and Ito's lemma. The second aspect focuses on Monte Carlo simulation and its use for option pricing. Monte Carlo simulation is especially appropriate for pricing path-dependent and other exotic derivatives, but it can also be used for pricing plain vanilla options. Using Monte Carlo simulation for pricing options raises several issues such as measuring the accuracy of simulated prices, determining the number of simulations required for the desired level of accuracy, and designing the simulations to make the most economical use of computational resources.

The most frequently used model for asset yield modelling is the discreet time independently and identically distributed (IDD) normal model (Campbell et al., 1997). It should be noted that in practice the actual yields of financial instruments are not normally distributed, the distribution being rather leptokurtic (Poon, Granger, 2002). In addition, recent empiric research indicates that the correlation in volatility is stronger than the correlation in yields (Aydemir, 1999; French, Schwert and Stambaugh, 1987). The IDD model assumes that financial asset yields are independent in time and have a normal distribution as well as that the distribution of yields does not change over time, which in other words means that the yields on financial instruments have the nature of white noise. If we assume that the price of financial instrument is a function of time ($S = S(t)$), then the relative change in the price of the financial instrument for small changes of Δt may be expressed by a discrete version of geometric Brownian motion:

$$\frac{\Delta S}{S} = \mu \Delta t + \sigma \varepsilon \sqrt{\Delta t}\,, \qquad (1)$$

S – price of the financial instrument at time t

ΔS – change in the price of the financial instrument over time Δt

μ – expected daily price growth rate of the financial instrument over time Δt

σ – volatility of daily returns of the financial instrument over time t

ε – random variable with standardized normal distribution $N(0, 1)$.

In practice, for calculating the expected price of a financial instrument after the expiry of Δt different techniques may be used, – mainly the binomial tree models and the Black–Scholes model based on differential equations. As pointed out by Thompson et al. (2003), the binomial tree allows modelling the price movement in both stock and derivatives. More information on the price modelling of financial instruments by means of binomial tree is given in Nelson and Ramaswamy (1990), and more information on the modelling of prices of derivatives can be found in Amin (1995). However, differential equation models (Black –Scholes model) are simpler. In these models the geometric Brownian motion theory is most often used for describing stochastic price movements in financial instruments. They are based on the assumption that relative changes in the prices of financial instruments vary stochastically in accordance with Equation 1.

The Wiener process is the central part of all stochastic models of financial instrument price changes and assumes that the change of any variable Δz in a short interval of Δt may be expressed as

$$\Delta z = \varepsilon \sqrt{\Delta t}\,, \qquad (2)$$

where ε is a random variable from the standardized normal distribution. To apply the Wiener process to the foreign currency price movements means that the currency price reflects all information accessible to the public. Therefore, the future price movement may not be inferred from its historical movement. The price movement is stochastic and follows the Wiener process, i.e. the process of randomly chosen values from standardized normal distribution.

2.2. Option valuation models

Black and Scholes (1973) and Merton (1973) contributed most to the development of theoretical option valuation models, which are based on the law of one price and on the assumption of the absence of arbitrage opportunities. Dybvig and Ross (1989) underline that the concept of the absence of arbitrage opportunities is one of the fundamental theoretical concepts in financial theory, since it can be used as a basis for the linear price function which can be applied for financial asset valuation. Theoretical option valuation models were well accepted by both theoreticians and participants in the financial markets.

Nevertheless, in practice also other, parametric option valuation methods were developed, which are primarily used for the valuation of exotic options. Of course, the quality of a parametric option valuation model greatly depends on the quality of the model of dynamic price movement in the underlying asset. Monte Carlo simulation is mostly used for valuating the path-dependent derivatives. In this way the strike price becomes a stochastic variable, since its value can exactly be determined only at derivative maturity. An example of a path-dependent derivative is the option that gives the option holder the right to buy or sell the underlying asset at its average price or at the extreme price attained during the life of the option. In this case Monte Carlo simulation turned out to be the most efficient among various analytical approaches to derivative valuation. The same method is often used for the valuation of the options whose value depends on a number of different underlying assets and consequently on a number of stochastic variables, but only if the path movement of each stochastic variable is numerically definable at the same time. Although Monte Carlo simulation is primarily used for the valuation of exotic options, it can also be used for valuing plain vanilla options, in which case the strike price is known in advance and therefore is not stochastic.

Option valuation by using Monte Carlo simulation follows the following steps:

- the entire interval of the option's life until expiry (T) is divided into n sub-intervals, so that $\Delta t = \frac{T}{n}$;
- the price of the underlying asset is calculated at the end of each sub-interval according to Equation 1, under the assumption that the ε values have been generated by a random number generator from the standardized normal distribution $N(0, 1)$;
- the calculation of the underlying asset price at the end of interval T and the calculation of the option value at the end of interval T, taking into account the strike price\, which may be stochastic or not. Discounting the calculated values back to the beginning of the interval;
- repeated simulation and calculation of the average option value arrived at on the basis of the entire set of simulations.

There are several problems that have to be addressed. In the first place, they include the problem of how accurate the simulated movements in the prices of underlying assets are and the problem of determining how many simulations are needed to achieve the desired rate of accuracy. In the case of European style options, which can be exercised only at the expiry date, the Monte Carlo method is used for simulating price movements in the underlying asset and calculating the average payoff. The payoff, depending on the strike price and the final price of the underlying asset, can be calculated for every simulation. The option's present value equals the average of the payoff present values reached over the entire set of simulations. The average number of simulations ranges between 10,000 and 150,000, which is computationally demanding and time-consuming. Monte Carlo simulation cannot be used in the case of American style options, which can be exercised any time during the option's life.

2.2.1. Random number generator

The first problem to be solved is the choice of the random number generator, which has to enable the values of the stochastic variable to be drifted from standardized normal distribution. In general, ordinary random number generators cannot be used for this purpose, as they attribute the same probability to all values in the interval from 0 to 1. This problem can be solved by approximation, namely by simultaneously using several random number generators:

$$\varepsilon = \sum_{i=1}^{12} \text{RAND}(\ )_i - 6. \qquad (3)$$

The average distribution value calculated using the sum of 12 random number generators is 6. So 6 is subtracted from the right side of Equation 3, which makes the average distribution value the same as in the case of standardized normal distribution.

2.2.2. Antithetic variable and simulation accuracy

The average payoff at the end of the option's life is calculated via Monte Carlo simulation and at the same time this average, taking into account the values from various simulations, has its variance. The payoff variance decreases as the number of simulations increases, which gives more accurate valuation results. On the other hand, there are methods for reducing the payoff variance and increasing the speed of computing. The antithetic variable technique is one of such methods. The essence of this technique is that in each simulation the price of the underlying asset and the value of the option are calculated twice: the variable change in the Wiener process (Equation 2) is first calculated by using ε and then by using the same value, only this time with a negative sign ($-\varepsilon$). Thus, two path movements of the underlying asset are determined at the same time:

$$\frac{\Delta S}{S} = \mu\Delta t + \sigma\varepsilon\sqrt{\Delta t} \text{ and}$$

$$\frac{\Delta S'}{S'} = \mu\Delta t - \sigma\varepsilon\sqrt{\Delta t} \qquad (4)$$

By using both path movements in the underlying asset price represented by Equation 4, two payoffs are calculated in each simulation and their average is then discounted back to the present value. In this way the average error is eliminated and consequently error variance is reduced, which entails a smaller number of necessary simulations.

3. Data

3.1. Exchange rate regime in Slovenia

From its independence Slovenia has chosen the managed floating exchange rate regime. In textbook economics, the managed floating exchange rate regime is said to be most appropriate for small internationally open economies, but its higher volatility makes it harder for companies to plan their activities and increases their cost of hedging. The Bank of Slovenia is not obligated to publicly announce the official exchange rate, nor has it been, until recently, obligated to express the expectations regarding the future movement of the managed floating exchange rate.

Among foreign currencies, banks in Slovenia have most of their positions denominated in EUR, USD, GBP, CHF and HRK currencies. The structure of the foreign currencies portfolio roughly matches the structure of Slovenian international trade. Those currencies are therefore the ones that are most interesting for the Slovenian corporate sector when hedging its currency risk exposer. In the composition of foreign currency portfolio the EUR fraction is dominant, but the SIT / EUR exchange rate movement is predictable, as the nominal exchange rate tends to linearly depreciate to cover the difference between Slovene and "Euroland" inflation.

Figure 1 shows that the nominal SIT / EUR

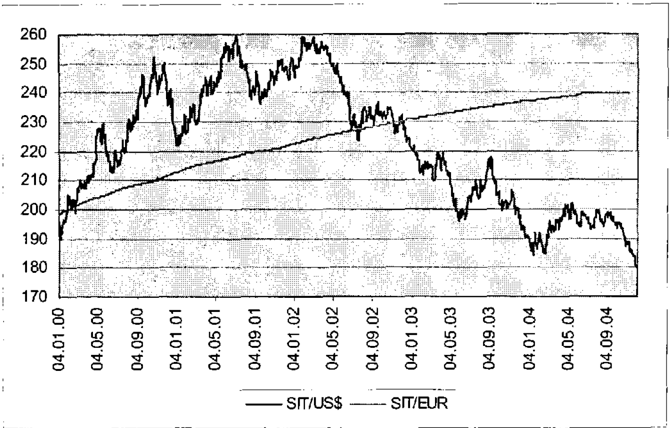

Fig. 1. The SIT / US$ and SIT / EUR middle exchange rate movement

Source: Bank of Slovenia Bulletin, different issues.

exchange rate has been consistently rising to cover the difference between Slovene and "Euroland" inflation. In the last period, the rate of depreciation has fallen, as the Bank of Slovenia has been preparing to join the ERM2 mechanism. At the end of year 2001 the Bank of Slovenia has become more active on thye foreign exchange market to actively manage exchange rate movements. For that purpose the Bank of Slovenia has reached an agreement with Slovenian commercial banks to set the intervention SIT / EUR exchange rate at which the central bank will intervene on the market. As a result, the volatility of SIT / EUR exchange rate has dropped dramatically. The policy measure has significantly lowered the currency risk, and the change in the environment has made it easier to plan business activities from the corporate sector point of view. On the other hand, the discrepancy between the actual and equilibrium exchange rates has not changed as the exchange rate depreciation has still followed the difference between the Slovenian and "Euroland" inflation. In April 2004 the intervention has stopped, but the policy measure is still ready to be used if the exchange rate would not move in the way planned by monetary authorities. After joining the EU, Slovenia has become member of the ERM2 mechanism. If the nominal and real convergence will be successfully accomplished, the government plans to become member of the EMU in the year 2007. In the ERM2 mechanism, the central parity was set to 239.640 SIT / EUR and the nominal exchange rate is allowed to depreciate at the rate of ±15 percent.

The SIT / EUR path of movement is predictable. The Slovenian government has chosen the managed floating exchange rate regime, but the SIT / EUR exchange rate is so important that the SIT currency is "informally pegged" to the EUR currency. On the other hand, the SIT / US$ exchange rate volatility is much higher, as the SIT / US$ exchange rate moves in high correlation with an internationally set EUR / US$ exchange rate. Consequently, the SIT / US$ exchange rate volatility is one of the most important risk factors Slovenian exporters / importers are exposed to. Slovenian companies engaged in international trade are becoming increasingly aware of the effect of exchange rate movements on their business results. Not surprisingly, the demand for derivatives with US$ as the underlying asset has increased. The most important hedging instruments are currency forwards and currency options.

3.2. Exchange rate volatility and expected yield

From the corporate sector hedging point of view, the SIT / US$ exchange rate movement is important, therefore we will focus on the SIT / US$ exchange rate. The foreign currency US$ will be taken as an asset whose SIT price will be modelled using the parametric model of asset price dynamics. There are several sources of data available for the SIT / US$ and SIT / EUR exchange rates. In the analysis, the middle exchange rate of the Bank of Slovenia will be used in the time period from 4th December 2003 to 3rd December 2004. The length of the period is in line with the quantitative requirements for use of internal models in the risk management process defined in the decree of capital adequacy of banks and savings banks legislated by the Bank of Slovenia. The decree charges commercial banks to use a one-year time series of daily market data.

Daily yields for the SIT / US$ exchange rates are calculated as logarithmically continuous yields:

$$r_t = \ln\left(\frac{P_t}{P_{t-1}}\right), \tag{5}$$

r_t – yield on the SIT / US$ exchange rate at time t

P_t – value of the SIT / US$ exchange rate at time t

P_{t-1} – value of the SIT / US$ exchange rate at time t-1.

Daily volatility is calculated as standard deviation (Gujarati, 1995):

$$\sigma = \sqrt{\frac{1}{n-1} \cdot \sum_{t=1}^{n} (r_t - \mu)^2} \tag{6}$$

μ – expected daily return

r_t – daily return at time t.

In the mathematical model, the expected yield from financial asset and the volatility of yields are assumed to be constant. Table 1

Table 1. Descriptive statistics for SIT / EUR and SIT / US$ middle exchange rate based on daily logarithmically continuous yields

Exchange rate	Year	2002	2003	2004*
SIT / EUR	Expected daily yield (%)	0.01575	0.01109	0.00554
	Standard deviation of daily yields (%)	0.00257	0.00043	0.00052
SIT / US$	Expected daily yield (%)	-0.05110	-0.06217	-0.02196
	Standard deviation of daily yields (%)	0.03982	0.04465	0.04303

* The data for year 2004 are not complete and correspond to period from 1. 1. 2004 to 3. 12. 2004.
Source: Our own calculations.

shows that the volatility of SIT / US$ daily yields has constantly been around 0.04%, which is more than 80 times higher than the volatility of the SIT / EUR exchange rate. For the purpose of Monte Carlo simulation we will assume the volatility of SIT / US$ daily exchange rate yields to be the same as in year 2004. The expected daily SIT / US$ yield is still expected to be negative.

The re-election of G. W. Bush has not been good information for the stability of American currency, as analysts are not expecting any significant change in economic policy. There still exist problems of fiscal and trade deficit, which are two important reasons for a more than 30 percent drop of the dollar compared to EUR until February 2002. Analysts seem to be unified in their opinion that the trend of US$ depreciation will continue, but a variety of opinions exist on the exchange rate value at which the lows will be reached. Analysts at Deutsche Bank expect that the low will be reached at 1.40 US$ / EUR, analysts at Goldman Sachs, on the other hand, expect lows to be reached at 1.50 US$ / EUR. They believe the European central bank would intervene on the market if this exchange rate is reached. Based on the analyst opinions, we will assume 7.5 percent depreciation of US$ to the value of EUR in the following year, which correspond to the -0.0203 percent expected daily yield. We will also assume the SIT / EUR exchange rate to remain stable around the parity exchange rate set at the ERMII entering, so US$ is expected to depreciate against SIT with the same rate as against EUR. The expected depreciation of US$ against SIT is especially problematic for Slovenian exporters, which receive payments in US$. They will be trying to hedge their risk by fixing the exchange rate at which they can sell US$ received in the future. They can hedge by buying a put option with US$ as the underlying asset.

4. Results

Results of exotic put option on SIT / US$ exchange rate valuation are based on Monte Carlo simulation in Excel. A precondition is a Visual Basic Macro written for Monte Carlo simulation. The Macro can be provided by the author upon the reader's request. The following example shows the results of an analysis based on a hypothetical example of a 100-day life European put option linked to the movement of the SIT / US$ exchange rate. The option was issued on 3rd December 2004 at a strike price 178 SIT / US$. The following Monte Carlo simulation will evaluate the payoff of the plain vanilla option and the payoff of the options whose strike price is stochastic and equals the maximum and average value of the SIT / US$ exchange rate during the life of the option.

4.1. Option payoffs

The payoff of a put option can be calculated as a maximum of two elements – the value zero and the difference between the strike price (P_S) and the SIT / US$ exchange rate at the end of the option life (P_n):

$$Max\,(0; P_S - P_n). \tag{7}$$

In case the put option is based on the maximum or average SIT / US$ exchange rate reached during the life of the option, its payoff is calculated according to Equation 7 as well, whereas the strike price becomes a stochastic variable, which is determined only on the day the option is exercised.

Table 3 shows option payoffs arrived at on the basis of the average of 1,000 simulations for a plain vanilla put option and the put option based on the maximum and average valu-

*Table 2. **Input data to Monte Carlo simulation***

Δt	Change of time index (days)	1
T	Length of simulation period (days)	100
S	Exchange rate at time t	178 SIT/US$
μ	Expected daily yield	-0.0203%
σ	Volatility of daily returns	0.0430%
	Number of simulations	1,000

Source: Our own calculations.

es of the SIT / US$ exchange rate during a 100-day life of the option. Besides the results obtained by the ordinary Monte Carlo method (one variable), the results of an antithetic variable technique are indicated. As expected, the antithetic variable substantially reduces the standard deviation of the obtained payoffs and therefore increases the accuracy of simulation.

Table 4 shows option payoffs arrived at on the basis of the average of 10,000, 20,000 and 50,000 simulations carried out by using the antithetic variable technique. The values from Table 3 do not differ much from those in Table 3. This means that an increased number of simulations does not lead to better results, in spite of the fact that it is much more time- and computational-resources-consuming. Thus, when interpreting the results, it should be taken into account that the payoffs and consequently the option values depend mainly on the subjectively set inputs into simulation, which are indicated in Table 2. Changes in the

*Table 3. **Option payoffs (in SIT) on the basis of Monte Carlo simulation***

	Plain vanilla put option		**Maximum price put option**		**Average price put option**	
	One variable	Antithetic variable	One variable	Antithetic variable	One variable	Antithetic variable
Try	1000 simulations	1000 simulations	1000 simulations	1000 simulations	1000 simulations	1000 simulations
1	1,730518	1,737632	3,666311	3,659300	1,791252	1,801391
2	1,713197	1,738372	3,618619	3,660730	1,784888	1,801578
3	1,744195	1,738061	3,681264	3,661645	1,809592	1,801560
4	1,779057	1,737988	3,686989	3,660894	1,808001	1,801448
5	1,686457	1,738232	3,628962	3,662905	1,799538	1,801563
6	1,736902	1,738317	3,626851	3,660376	1,813036	1,801545
7	1,765186	1,737734	3,661668	3,661640	1,783121	1,801429
8	1,730246	1,737398	3,658720	3,660878	1,806847	1,801574
9	1,744342	1,737204	3,658484	3,662067	1,800044	1,801495
10	1,756409	1,737659	3,671921	3,659595	1,814468	1,801450
Average	**1,738651**	**1,737860**	**3,655979**	**3,661003**	**1,801079**	**1,801503**
St. dev.	**0,026304**	**0,000397**	**0,023528**	**0,001103**	**0,011356**	**0,000069**

Source: Our own calculations.

Table 4. Effects of increased number of simulations on accuracy

	Plain vanilla put option	**Maximum price put option**	**Average price put option**
No. of simulations	Option payoff (SIT)	Option payoff (SIT)	Option payoff (SIT)
10.000	1,738208	3,659932	1,801500
20.000	1,738046	3,660701	1,801495
50.000	1,738145	3,660412	1,801513

Source: Our own calculations.

expected yield or yield volatility of an underlying asset would lead to different payoffs and consequently option values.

5. Conclusions

The main market risk that the Slovenian corporate sector engaged in international trade is exposed to is exchange rate risk. Due to the high exchange rate volatility, the SIT / US$ exchange rate is the most problematic. The corporate sector is trying to hedge currency risk with unstandardized derivatives issued by the Slovenian Commercial Bank, which in turn has to address the issue of valuation of those derivatives and the issue of its own risk management. In this article, we have represented one of the possible ways of exotic option valuation based on the parametric model of asset price dynamics and Monte Carlo simulation. We address the issue of method accuracy based on the introduction of the antithetic variable and the effect of an increased number of simulations. The application of antithetic variable has significantly lowered the volatility of payoffs and was found to be cost-effective for an increased number of simulation regarding the use of time and computational resources.

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IŠVESTINIŲ PRIEMONIŲ VERTINIMAS BESIVYSTANČIŲ ŠALIŲ KOMERCINIUOSE BANKUOSE: SLOVĖNIJOS RINKOS PAVYZDYS

Andraž Grum

Santrauka

Besivystančiose rinkose paprastai nėra standartizuotos išvestinių priemonių rinkos, nors tokių priemonių poreikis akivaizdus, ypač finansinio šalies sektoriaus bei daugelio veikiančių įmonių lygmeniu. Vykdydamos veiklą įmonės dažnai susiduria su valiutų kursų kitimo rizika, o jai valdyti išvestines priemones galima sėkmingai pritaikyti. Standartizuotų išvestinių priemonių trūkumą iš dalies padengia komercinių bankų kuriamos nestandartinės išvestinės priemonės, specialiai pritaikytos specifiniams klientų poreikiams. Daugiausia dėmesio sulaukia išankstiniai ir pasirinkimo sandoriai, sudaryti pagal pasirinktą valiutą. Kadangi šie sandoriai nestandartizuoti, juos galima priskirti prie egzotinių išvestinių priemonių. Komerciniai bankai, kaip išvestinių priemonių siūlytojai, turi pasirinkti tinkamą šių priemonių įvertinimo metodą. Straipsnyje nagrinėjami egzotiniams valiutų pasirinkimo sandoriams įvertinti tinkantys metodai. Vienas iš veiksmingiausių metodų, tinkančių egzotinių išvestinių priemonėms vertinti, – Monte Karlo imitacinis modeliavimas. Jo pagrindas yra bazinio turto kainos kitimo parametrinis modelis. Straipsnio tikslas – išanalizuoti egzotinių pasirinkimo sandorių vertinimo detales panaudojant programinį modelį naudojamo metodo tikslumui pabrėžti. Tam panaudotas atvirkštinis kintamasis ir daugiau imitacinio modeliavimo variantų. Taikius atvirkštinį kintamąjį sumažino pasirinkimo sandorių išmokų nepastovumas, be to, didesnis modeliavimų skaičius prisidėjo prie išlaidų mažinimo dėl efektyvesnio laiko ir skaičiavimo resursų panaudojimo.

Įteikta 2005 m. liepos mėn