THE EARLY EXERCISE PREMIUM FOR AMERICAN OPTIONS. EMPIRICAL STUDY ON SIBEX MARKET

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1. Introduction

The early exercise premium is the difference in price between an American option and an otherwise identical European option.

Merton (1973a) has shown that the early exercise will never occur for American call option written on non-dividend paying stocks. In this case, calls could be valuated with Black-Scholes model, as if they were European options. If American call options have a dividend paying stock, early exercise can be optimal just before the ex-dividend instant. For an American put option on the other hand, early exercise may be optimal even if the underlying stock is not paying any dividends. In fact, an American put option should always be exercised before the maturity if it is sufficiently in-the-money.

The possibility of early exercise of American options complicates their valuation. Therefore, several valuation approaches, both analytical approximations and numerical methods, have been developed. Examples of the first category are Roll (1977), Geske (1979) and Whaley (1981) for call options and Geske and Johnson (1984) and MacMillan (1986) for put options. Moreover, Barone-Adesi and Whaley (1987) analysed both call and put options. For American option valuation with numerical methods relevant results are provided by Brennan and Schwartz (1977), Boyle (1977) and Cox et al. (1979).

The estimate of early exercise premium (EEP) is difficult because simultaneous liquid markets for American and European identical options do not exist.

Jorion & Stoughton (1989) have established directly the early exercise premium using European and American options on exchange rate trading at Philadelphia Stock Exchange.

Shastri & Tandon (1986) have calculated EEP for futures options substracting from the price calculated using Geske-Johnson model[1] the price calculated with Black-Scholes model.

Brenner & Galai (1986) proposed the use of the put-call parity relationship to estimate the value of early exercise premium. Their innovation consists in the calculation of an implied risk free interest rate from the put-call parity arbitrage condition, given the observable prices for put options, call options and the underlying stock price

Zivney (1991) considers that the American option pricing models don't value the early exercise premium appropriately and suggests that the value of EEP to be established empirically. Thus, Zivney examines deviations from European put-call parity of the American S&P 100 index options.

Hyun Mo Sung (1995) calculates EEP for American put options. His findings show that the value of EEP for American put options with no dividend is positively related to the moneyness, time to maturity and volatility. The early exercise premium of American put options with dividend is positively related to moneynes and risk-free interest rate.

[1] Geske-Johnson model is an American option pricing model.

Engstrom & Norden (2000) estimates the value of EEP for swedish equity American put options using the deviation of the American put price from the European put-call parity. In addition, they computed a theoretical estimate of the premium, calculating a theoretical value of the American options using Barone-Adesi Whaley model. The results indicate the fact that the EEP obtained by the first method is higher than the theoretical EEP. The EEP also increases with the moneyness and the time to maturity, whyle the effects of the risk-free interest rate and volatility depend on the moneyness.

Doffou (2008) also examines emipirically the value of early exercise premium for American put options. The novelty of his paper is that he is testing the ability of two American options pricing models to estimate EEP for put options on S&P 100 Index. The results obtained using models developed by Barone-Adesi Whaley and Carr Jarrow Myneni indicate that 35% of the market value of early exercise premium is captured by either the BAW model or theCJM model. Hence, the BAW and the CJM American put valuation models do notfully capture the value of early exercise embedded in American put prices.

The put-call parity relationship was first sugested by Stoll (1969), and later extended and modified by Merton (1973a,1973b). Further, many papers have analised the put-call parity: Gould and Galai (1974), Galai (1978), Klemkosky and Resnick (1979), Bhattacharya (1983), Geske and Roll (1984), Evnine and Rudd (1985), Gray (1989), Taylor(1990), Brown and Easton (1992), Easton (1994), Wagner, Ellis and Dubofsky (1996), Broughton, Chance and Smith(1998), Mittnik and Rieken (2000), Brunetti and Torricelli (2005), Weiyu Guo and Tie Su (2006), Hoque, Chan and Manzur (2008), etc.

Hans Stoll (1969) first identified, in his paper *The relationship between put and call option prices,* that exists a relationship between call and put premium of an European option which has the same undurlying asset, the same strike price and the same maturity. Merton (1973) and Gould & Galai (1974) have extended the put-call parity on American options and paying dividends.

Dan Galai (1978) built covered portfolios composed of stocks and options and studied the relation between the theoretical price estimated with the Black-Scholes model and the market price. The study was based on the assumption that the overvalued options are sold while the undervalued ones are bought each day. The results showed that this strategy leads to substantial gains violating the efficient market hypothesis. Yet, when considering transaction costs these gains became null. For transaction costs of only 1%, the gains where particularly annihilated for those brokers confronted to operational costs above 1%. The market makers could deal at costs below 1%, being as such able to take advantage of some arbitrage opportunities. Yet additional costs appeared as the market maker had to give up an alternative activity which diminished „apparent profits”. As a conclusion, the results of Galai's study confirmed that option prices calculated with the Black and Scholes model are very closed to the market prices.

Mihir Bhattacharya (1983) examined the „adherent” of market price to the theoretical lower bounds imposed by non arbitrage contitions. In his paper, Bhattacharya used the transactions prices for options on 58 stocks over a 196-day period between August 1976 and June 1977. First, he examined whether the options satisfied the condition that the price be at least as great as the intrinsic value. More than 86000 option prices were examined and about 1300 were found to violate this condition. In 29% of the cases, the ciolation disappeared by the next trade, indicating that in practice traders would have not been able to take advantage of it. When transactions costs were taking into account, this opportunities disappeared. Secondly, Bhattacharya examined whether options sold for less than the lower bound $S\text{-}D\text{-}Xe^{-rT}$. He found that 7,6% of observations did sell for less than the lower bound. However, when transactions costs were taken into account, these did not give rise to profitable opportunities.

Klemkosky and Resnick (1979) tested put-call parity using data between July 1977 and June 1978. They subjected their data to several tests to determine the likelihood of options being exercised early, and they discarded data for which early exercise were considered probable. Thus, they felt they were justified in treating American options as European. Klemkosky and Resnick identified 540 situations were the call price was too low relative to the put price and 540 situations where the reverse was true. After transactions costs were taken into account, 38 of the first set of situations and 147 of the second set of situations were still profitable. This opportunities persisted 5 or 15 minutes delay between the opportunity being noted and assumed by traders. Klemkosky and Resnick's conclusion was that arbitrage opportunities identified during the examined period were available to some traders, particularly market makers.

Brunetti & Torricelli (2005) tested the efficiency of the Italian index option market in the period 1 sepetember 2002 – 31 december 2002 by checking the validity of the two non arbitrage conditions: the lower boundary conditions and the put-call parity relationship. Brunetti & Torricelli's conclusion is that the market was efficient during the analysed period because the the frequancy of arbitrage opportunities is low to arbitrageurs and much lower for occasional retails. However, in the very few cases of PCP violations, it is possible to implement profitable arbitrage strategy. Moreover, in contrast with ather European markets, the absence of short selling restrictions seems to play an important role in enhancing the market efficiency.

Hoque, Chan & Manzur (2008) have tested the efficiency for major currency options including the Euro, analyzing 5377 daily put–call pairs from January 2001 to March 2006. Their study was structured in two phases: first, the two fundamental no-arbitrage conditions (the lower boundary condition and the put–call parity) condition are examined in a descriptive manner, then they performed an econometric analysis for PCP. The results showed that the put options tend to be more overpriced relative to call options.

2. Put-call parity relationship

First, the relationship put-call parity assumes that the underlying asset does not generate dividend before option maturity:

$$c + Xe^{-rT} = p + S$$

where c and p are European-style call and put option premiums, respectively, S is the current price of the underlying asset, X is the options' strike price, r is the annualized continuously compounded risk-free interest rate of interest, and T is the time to options' maturity.

If the underlying asset pays dividends before the option's maturity, the put-call parity relation can be modified as:

$$c + Xe^{-rT} = p + S - PV(D)$$

where $PV(D)$ is the present value of all expected cash dividend payments generated by the underlying asset to be paid before the option's maturity. For example, if the underlying asset is expected to pay a dividend D at time t $(0 < t < T)$, then $PV(D)=De^{-rt}$. To demonstrate dividend-adjusted put-call parity, we consider that an investor holds the following two portfolios from today until the option's maturity: $c + Xe^{-T}$ and $p+S\text{-}De^{-rt}$. The final value of the first portfolio at time T is $p_T+S_T\text{-}De^{-rt}e^{rt}+De^{r(T-}$

$^{t)}= p_T+S_T$ because the future value of the dividend received at time *t* cancels the future value of *PV(D).*

It's now easy to see that when the options expire, the two portfolios have exactly the same final value $c_T+X=p_T+S_T$. This occurs because if $S_T \geq X$, then $p_T+S_T=S_T$ *and* $c_T+X=S_T$ so that $c_T+X=p_T+S_T$. Alternatively, if $S_T \leq X$, then $p_T+S_T=X$ *and* $c_T+X=X$ so that again $c_T+X=p_T+S_T$.

Because the two portfolios always have the same final value, they must have exactly the same present value in an efficient market. Consequently, we must have $c+ Xe^{-rT}=p+S-PV(D)$.

The put-call parity formula is not identically valid for American options. Yet, the principle of arbitrage is useful in establishing the lower and upper limits for the difference between the price of an American call option and that of a put option. (Weiyu Guo, 2006):

$$c+ Xe^{-rT} \leq p+S \leq c+X$$

The length of the interval, which is the difference between the upper and the lower limit is:

$$(c+X)-(c+ Xe^{-rT})=X(1- e^{-rT})$$

If the underlying asset delivers dividends before maturity than the put-call parity relationship will become:

$$c+ Xe^{-rT} \leq p+S \leq c+X+ PV(D)$$

For proof, we will assume that a single dividend is paid at time t ($0 < t < T$), without loss of generality. We must not omit that European options may be early exercised which is optimum in our approach.

Exercising a call option before maturity may be the consequence of a significant dividend delivered by the underlying asset, of which value exceeds the time value or the speculative remaining value. A put option exercise before maturity appears when the stock's price is sufficiently low in order for the interest on the intrinsic value to be higher than the remaining time value.

The proof of this formula is divided into two relations:

$$c+ Xe^{-rT} \leq p+S$$

$$p+S \leq c+X+ PV(D)$$

These relations will be proved via contradiction. We will firstly assume that the first relation is not valid for all the options and the underlying assets and that there is at least one option satisfying the condition: $c+Xe^{-rT} > p+S$, in which case an arbitrage opportunity emerges.

An arbitrageur buys an American put option and an underlying asset. In the same time, she sales an American call option and a risk free bond of which nominal value equals the option's strike price. The initial cash flow is positive as $(c+Xe^{-rT})-(p+S) >0$. As a consequence, the position $p+S-c-Xe^{-rT}$ is sustained.

As the arbitrageur has sold an American option call, the buyer can choose to exercise the option before maturity in order to cash up a consistent dividend flow on the underlying asset. In the previous situation (when the underlying asset didn't deliver dividend), the owner of the call option could exercise it before maturity paying the strike price for an underlying stock. In this case the arbitrageur loses the underlying asset, while the buyer of the call option obtains the stock and the future dividend.

The value of the arbitrageur's portfolio becomes:

$$P+S_t-S_t+X- Xe^{-r(T-t)} =P+ X- Xe^{-r(T-t)} >0$$

If the dividend is not sufficiently high to induce the exercise of the call option before maturity, the arbitrageur will cash the dividend and will keep the option until its maturity. The value of this portfolio becomes: $p_T+S_T +De^{r(T-t)} -c_T-X= De^{r(T-t)} >0$. As such, it is obvious that the assumption $c+ Xe^{-rT} >p+S$ generates an arbitrage opportunity. In consequence, on an efficient market the inequality $c+ Xe^{-rT} \leq p+S$ must remain valid at any moment for all options.

We will further assume that the second inequality is not valid for all options and underlying assets. There is at least one option which satisfies the condition:

$$p+S > c+X+PV(D).$$

An arbitrage opportunity will also appear in this case. An arbitrageur buys an American call option, buys a risk free bond of which nominal value equals the expected dividend and also buys a risk free bond evaluated at price *X*. In the same time the arbitrageur sells and American put option and short sales an underlying asset. The initial cash-flow is positive as $(p+S)-(c+X+VP(D))>0$. At this moment the arbitrageur holds the $c+X+VP(D)-p-S$ position.

The arbitrageur is responsible for the payment of all dividends generated by the underlying asset as she has short sold it. The term *PV(D)* is meant to neutralize this commitment.

If the owner of the put option decides to exercise it before maturity, the value of she's portfolio is: $c+Xe^{rT}+S_t-X-S_t =c+Xe^{rT}-X>0$. If she doesn't exercise the put option before maturity the arbitrageur holds the portfolio until the option expires. The value of this portfolio becomes:

$$c_T+Xe^{rT}-p_T-S_t=Xe^{rT}-X>0$$

The assumption $p+S>c+X+PV(D)$ generates a new arbitrage opportunity. As such, on an efficient market the inequality $p+S\leq c+X+PV(D)$ must be valid for all the assets.

The put-call parity relationship adjusted for American options implies a larger dimension of the interval $(c+X+VP(D))-(c+ Xe^{-rT})=X-Xe^{-rT}+PV(D)$, due to the uncertainty of exercising the option before the dividend is paid.

As a conclusion, the put-call parity relationships for European and American options adjusted to include dividends are:

- for European options $c+ Xe^{-rT}=p+S-PV(D)$.
- for American options $c+ Xe^{-rT} \leq p+S \leq c+X+ PV(D)$

3. Data and methodology

In this study we have used American put options with futures contracts on SIF5 as underlying asset (common stocks issued by SIF Oltenia S.A.), these being the most liquid options on Sibex. The analysed period is January 2009 - June 2010, and options' maturity is three months. The call premium, the put premium, the exercise price, the price of the futures contract on SIF5 were delivered by Sibex, and for computing the risk free rate we used three month ROBOR. After a first selection the data base was composed of 107 put-call pairs. 51 observations were eliminated as they didn't check the parity relation characteristic to American options[2].

In this study we will try to investigate if the exercise premium EEP of an American put option is dependent on the degree in which the option is in the money, the time to maturity, the risk free rate and the volatility. The following model was used in this sense:

$$EEP_{pi,t}=c_1+c_2{*}M_t+c_3{*}T_t+c_4{*}r_{ft}+c_5{*}\sigma_t+\varepsilon_{i,t},$$

where:

EEP_p – the exercise premium before maturity for the American put option;
M – the degree in which the option is in the money;
T – the time to maturity;
r_f – risk free rate;
σ – volatility;
ε – residual variable.

In order to estimate EEP_p we have subtracted the put premium, calculated with the aid of the PCP relationship for European options, from the market price of the American option:

$EEP_p=P-p$, where:

P- the price of the American put option on Sibex;
$p=c-F+Xe^{-rT}$

The moneyness variable (M) has been calculated as a ratio between the strike price and the price of the underlying asset (X/F). The options for which F<X are in the money, and those for which F>X are out of the money.

[2] *Obs.* The condition was verified without considering dividends. The relation is $c+ Xe^{-rT} \leq p+F \leq c+X$, where F is the price of a futures contract on SIF5.

In order to compute the variable *T* we have applied the YEARFRAC function in Excel which returns the proportion of number of days between the transaction date and the maturity date within a year.

The risk free rate was computed with the following formula:

$$r_{ft}=4*\ln(1+ROBOR_{3mt})$$

The only variable within the model that can not be directly observed is the volatility of the underlying asset's price. We have firstly introduced in the model the historical volatility computed based on the current prices of the futures contract DESIF5. As the volatility is higher when the market is opened compared to when it is closed, we have considered 30 transaction days and not calendaristic days. The formula applied for the standard deviation is:

$$\sigma=\sqrt{\frac{\sum_{i=1}^{n}(u_i-\bar{u})^2}{n-1}}$$, where

$$u_i=\ln\left(\frac{S_i}{S_{i-1}}\right)$$, i=0, 1, ..., n

$$\bar{u}=\frac{1}{n}\sum_{i=1}^{n}u_i$$

n- number of observations

S_i - the price of the underlying asset at time i

An alternative method for computing the volatility consists of inversely running the Black-Scholes function on the option's market price and by determining the volatility for which the theoretical value equals the market price. This approach leads to the *implied volatility* of the option.

4. Descriptive statistics and empirical results

Table 1 presents the descriptive statistics: mean, median, maximum, minimum, standard deviation, skewness, Kurtosis and the Jarque-Bera test for the exercise premium before maturity, the implicit volatility, the moneyness, the risk-free rate, the time to maturity and the historical volatility.

Table 1. **Descriptive Statistics for American Put Options**

	EEP_p	σ_{impl}	M	Rf	T	σ_{ist}
Mean	-0.510893	0.641904	1.028393	4.921964	0.121607	0.473750
Median	-0.490000	0.636700	1.020000	4.960000	0.120000	0.460000
Maximum	-0.050000	2.332000	1.630000	6.310000	0.220000	0.920000
Minimum	-1.120000	0.000000	0.730000	3.410000	0.020000	0.270000
Std. Dev.	0.257945	0.336286	0.159223	0.710844	0.055326	0.146754
Skewness	-0.410123	1.921889	1.714056	0.311667	0.019614	0.832962
Kurtosis	2.363537	13.05799	7.561922	2.998578	2.021196	3.372773
Jarque-Bera	2.515077	270.5214	75.98053	0.906608	2.239059	6.799945
Probability	0.284353	0.000000	0.000000	0.635525	0.326433	0.033374

Source: Authors' processing

The second table presents the results obtained when historical volatility is used. Using historical volatility leads to a surprising result opposite to investors' expectation. Yet, other financial studies (Lee J., Xue M., 2006) using the same type of volatility, have identified the same negative impact of the volatility on the exercise premium.

Table 2. **Modeling EEP for American put options using moneyness, time to maturity, risk free rate and historical volatility as exogenous variables.**

$EEP_p=c_1+c_2*M+c_3*T+c_4*r_f+c_5*\sigma_{is}$ - + + - -	
R^2	0.821648
Adjusted R^2	0.807660
C_1	-0.348376*** (-5.903748)
C_2	0.539612*** (12.70999)
C_3	0.227811** (1.861853)
C_4	-0.009743 (-0.790925)
C_5	-0.152022*** (-2.458741)

Source: Authors' processing

Note: ** significance at a confidence level of 95%;
*** significance at a confidence level of 99%;.

As it was expected, coefficient M (defined as a proportion between X and F) is positive and statistically significant, which means that the EEP increases with M. as M increases and the option is more in the money, it becomes more valuable.

The value of the put option increases with the time to maturity which leads to a more valuable exercise premium before maturity.

The interest rate and volatility effects depend on the degree in which the option is in the money. As shown in table 4, the risk free rate and volatility coefficients are negative. As far as the interest rate is concerned, as it increases the present value of the strike price diminishes leading to the superiority of the current price of the futures contract on the option' strike price. As the interest rate increases, the put option will probably be more out of the money, diminishing the value of the exercise premium.

The majority of the studies is modeling the exercise premium using the implicit volatility under the assumption that the market price equals the theoretical value of the option. The results of these studies are more conclusive, confirming investors' expectations through a positive impact of the volatility on the exercise premium. Table 3 points out the undervaluation of historical volatility in comparison to the implicit volatility through absolute and relative frequencies series:

Table 3. **Historical and implicit volatility distributions**

Quartile	**Historical Volatility**				**Implicit volatility**			
	[0.2,0.4)	[0.4,0.6)	[0.6,0.8)	[0.8,1]	[0,0.5)	[0.5,1)	[1,1.5]	[2,2.5]
Absolute frequency	20	25	9	2	14	38	3	1
Relative frequency	35.71	44.64	16.07	3.57	25.00	67.86	5.36	1.79

Source: Authors' processing

Table 4 presents the results of the econometric model when using the implicit volatility.

Table 4. **Modeling EEP for American put options using moneyness, time to maturity, risk free rate and implicit volatility as exogenous variables.**

$EEP_p=c_1+c_2*M+c_3*T+c_4*r_f+c_5*\sigma_{impl}$ (- + + - +)	
R^2	0.868627
Adjusted R^2	0.858323
C_1	-0.394308*** (-7.732621)
C_2	0.570962*** (15.41261)
C_3	0.527626*** (4.761319)
C_4	-0.041749*** (-5.493082)
C_5	0.097745*** (5.142466)

Source: Authors' processing

Note: ** significance at a confidence level of 95%;
*** significance at a confidence level of 99%;.

Opposite to the previous case, we observe that all coefficients except for the interest rate are positives, confirming the results acknowledged in the financial literature. The estimated coefficients are statistically significant. The coefficient of the implicit volatility indicates that the exercise premium increases with the increase in volatility.

5. Conclusions

Concluding, we may assert that the early exercise premium for short-term American put options is revealing in identifying arbitrage opportunities. The probability of early exercise is positively influenced by the degree in which the option is more in the money. The EEP of a put option is likely to increase with the proportion of the strike price in the price of the underlying asset.

The time to maturity was also expected to have a positive effect on the premium as the owner of a long term option has the same opportunities as the owner of a short term one, plus other opportunities derived from the time excess to maturity.

As far as the interest rate is concerned, an increase will lead to a reduction of the present value of exercising the option. As a result, the opportunity of exercising becomes more attractive, and the EEP is expected to increase with the reduction of the interest rate.

The effect of the implicit volatility confirms what investors might expect: a higher volatility leads to a more consistent exercise premium. The volatility estimation method remains the main challenge in modeling the exercise premium and evaluating the options. This is a controversial issue both in theory and practice. A more rigorous analysis of different volatility estimation methods will make the subject of future research.

The empirical results of our study are in accordance to those obtained by Zivney and Sung pointing out the importance of the exercise premium before maturity in constructing evaluation models for American put options. In this study we have computed the exercise premium for American put options based on the put-call parity. According to some approaches, the exercise premium is estimated based on American options' evaluation models. We consider exciting this alternative and we intend to further develop this methodology in our future research.

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