The effect of market sentiment and information asymmetry on option pricing

Imen Zghal[1], Salah Ben Hamad[2] , Hichem Eleuch[3] , and Haitham Nobanee [4]

Paper Link: https://www.sciencedirect.com/science/article/abs/pii/S1062940820301327

Citation:

Zghal, I., Hamad, S.B., Eleuch, H. and Nobanee, H., 2020. The effect of market sentiment and information asymmetry on option pricing. The North American Journal of Economics and Finance, 54, November, p.101235.

Abstract

This work addresses the impact of imperfections, such as information asymmetry and market sentiment, on the performance of option pricing models. More precisely, this work compares the option pricing model of Black and Scholes and the same model in the presence of imperfections. This study is based on S&P 500 options that cover the period between 17/03/2000 and 14/06/2013. The achieved results show that, in general, in the presence of imperfections, the model is more effective than the Black and Scholes model. This research appears to be promising for the incorporation of imperfections into the assessment of options.

Keywords: option pricing, market imperfections, information asymmetry, market sentiment, put-call parity.

JEL Classification: G13; G14

1 Imen Zghal: University of Sfax, Faculté des Sciences Economiques et de Gestion, GFC Laboratory, Route de l'Aérodrome km 04 Sfax 3018, Tunisia. Email: imenzghal@yahoo.fr.

[2] Salah Ben Hamad: University of Sfax, Institut des Hautes Etudes Commerciales, MODEOR Laboratory, Route Sidi Mansour Km 10, Sidi Mansour 3061 Sfax, Tunisia. Email: benhamad_salah@yahoo.fr.

[3] Hichem Eleuch: Institute for Quantum Science and Engineering, Texas A&M University, College Station, TX 77843, USA; Department of Applied Sciences and Mathematics, College of Arts and Sciences, Abu Dhabi University, Abu Dhabi, UAE.

[4] Haitham Nobanee: College of Business, Abu Dhabi University, P.O. Box 59911, Abu Dhabi, United Arab Emirates. E-mail: haitham.nobanee@adu.ac.ae; Tel: +971 2 5015709; Fax: +971 2 5860184; Oxford Center for Islamic Studies, The University of Oxford, Marston Road, Oxford OX3 0EE, U.K. Tel: +44 1865 618541; Fax: +44 1865 248942; Email: haitham.nobanee@oxcis.ac.uk; The University of Liverpool Management School, The University of Liverpool, Chatham Building, Chatham Street, Liverpool, L69 7ZH, U.K. Tel: +44 (0)151 795 3610, Email: haitham.nobanee@online.liverpool.ac.uk

Introduction

The most significant financial derivatives are options, which are mostly used for their flexible and nonstandard character. Options can be used to speculate in the market for profit, earn income to enhance investment returns, protect against a temporary decline in a stock’s value, or to hedge an entire portfolio against market risk. The role of options is very important for developing the financial system and generating economic growth.

Options are instruments that are derived from some other financial instruments, which makes them more complicated, on the one hand, and riskier, on the other hand.

In 1973, Fischer Black, Myron Scholes and Robert Merton made their major contribution to financial theory by developing a valuation formula for a European equity option, and this contribution was made through the transposition of a formula into economics that is well known in physics, the formula for "heat transfer". This discovery led the authors to be awarded the Nobel Prize in economics in 1997.

This contribution has had an enormous impact, not only at the theoretical level but also at the practical level, since the Black and Scholes model and its variants are widely used by professionals to evaluate various types of options, including stock options, stock index options, currency options, etc.

The Black and Scholes model is an arbitrage-based valuation model. Under the assumptions that they stated to be "ideal conditions", it is possible to build a hedge portfolio by taking a long position on a stock and a short position on a call issued on this stock. As the price of the stock is subject to variations, the maintenance of a hedged position implies a continuous readjustment of the proportions of the stocks and the calls in the portfolio.

Market Efficiency, which is the main assumption in the Black-Scholes model, is based on two pillars. On the one hand, the model assumes that economic agents are perfectly rational. On the other hand, the model assumes a lack of imperfections in financial markets. This circumstance implies that the Asset prices respond instantaneously to the arrival of new information and that they reflect any available information (Fama 1991). Such a market presents two important characteristics.

The first characteristic is that competition will quickly eliminate any opportunity for profitable arbitrage, making it impossible to beat the market. The second characteristic is to assume that the prices are fair, in the sense that each asset price on the market is equal to its fundamental value, which is defined as the present value of the expected amount of its future cash flows.

Two methods for research in this area involve the hypothesis of market efficiency.

On the one hand, market imperfections can lead to evaluation errors. Indeed, multiple factors are responsible for these imperfections; we can cite, for example, the presence of transaction and information costs (Jensen 1978; Grossman and Stiglitz 1980; Gu et al 2012; Longjin et al 2016), the presence of information asymmetry (Leland and Pyle 1977; Allen and Gorton 1993; Kashefi Pour 2016), and restrictions on short selling (Harrison and Kreps 1978; Duffie et al. 2002; Scheinkman and Xiong (2003); Feng and Chan 2016; Bohl et al 2016 and references therein).

These imperfections make arbitrage operations unprofitable in eliminating evaluation errors.

On the other hand, behavioral finance studies show how psychology influences the decisions made by investors, causing inefficient market behavior. Consequently, this second research path, which derives from behavioral finance, postulates that investors' rationality is unrealistic. Indeed, multiple studies show that errors of valuation can result when rational investors are confronted with other investors who are irrational, for example, investors qualified as noise traders, as in De Long and al. (1990.a) and Ramiah et al (2015), or investors with over-confidence, as in Daniel and al. (2002) and Abreu and Brunnermeier (2003).

A common measure of market behavior is sentiment. Compared with other psychological biases, market sentiment, which is quantitatively measured, can be a better search angle.

By abandoning the hypothesis of investors' rationality, this research attempts to explain how market sentiment, as well as information asymmetry, can influence European options pricing.

By taking an exploratory point of view on this largely untapped field of study, we were interested in analyzing the influence of the introduction of information asymmetry and market sentiment together to the Black and Scholes option pricing model.

In particular, this work aims to answer the following questions:

- What is the impact of the introduction of economic agents’ behavior in options pricing?
- Does the modified Black and Scholes model (1973) reduce the estimation errors caused by the Black and Scholes (1973) model, in other words, reduce undervaluation and overvaluation bias and move closer to market prices?

Therefore, in this study, the economic agents' behavior, information asymmetry, and market sentiment are introduced to be utilized to enhance the Black-Scholes model.

1- European option pricing in the presence of information asymmetry and market sentiment

1-1- Literature

In the present work, a different angle of analysis is explored: the idea is to rely on the sentimental behavior of investors and information asymmetry in the market concerning option pricing.

Indeed, the link between informed trade and option prices has been widely studied. For example, Cremers and Weinbaum (2010), Wen et al (2012) and Yigit (2014) used the difference between the implied volatility of a call and put with the same exercise price and the same maturity (IV spread) as a proxy for the informed investor's presence.

While the basic Black and Scholes model assumes that this difference must be zero, this later work shows that this assumption is not true in reality. For example, they found that when an investor obtains positive (negative) information about an event, the demand for call (put) options increases relative to that of put (call) options, which results in a deviation of the IV spread of zero.

According to Easley et al (1998), several studies assume that the presence of informed investors in the options market causes a deviation of the call-put parity relation in the direction of private information (Cremers and Weinbaum (2010), An et al (2014), Govindaraj et al (2015), Xing et al (2010), Jin et al (2012) and Goncalves et al (2016)).

On the other hand, some empirical results show that the market sentiment measures extracted from the options market and the underlying rate have a systematic effect on the options pricing. Han (2008) found that the option price can be affected by the underlying market sentiment of 'stock sentiment'. Three sentiment measures were used in the Han (2008) empirical test: the investors’ intelligence index, the trading volume of future S&P 500 contracts, and the valuation error index of the S&P 500 of Sharpe (2002). This author found that these sentiment measures were significantly correlated with the performance of the S&P 500 index options.

Other research has found that the option price can be affected by the sentiment of the options market. For example, Schmitz et al. (2009) derived a measure of sentiment from warrants and found that sentiment has a positive impact on future returns.

On the other hand, Sheu and Wei (2011) used future volatility, the ARMS index, the volatility option index, the put-call transaction volume ratio and the put-call open interest ratio as sentiment measures to study how sentiment can impact options prices as well as volatility.

However, the existing literature focuses on how sentiment can affect option prices but does not offer a theoretical model of options-based sentiment (Han 2008, Mahani and Poteshman 2008, Bauer and al. 2009 and Sung and Jun 2015).

In this article, these two market and investor anomalies are combined (information asymmetry and market sentiment) and are incorporated into the Black and Scholes (1973) options pricing model.

In traditional options pricing models, the investor is supposed to be rational and neutral in the face of risk. Under these conditions, the expected growth rate of the underlying rate and the discount rate are assumed to be equal to the risk-free rate. Examples are Black and Scholes (1973), Bick (1987), He and Leland (1993), Ricardo (2002), Faria and Correia-da-Silva (2014) and Guo and Yuan (2014).

However, abundant literature shows that investors are irrational and risk-averse in options markets. A part of the literature shows the irrationality of investors in options markets, for example, Poteshman (2001), Poteshman and Serbin (2003), Bauer et al. (2009), Mahani and Poteshman (2008) and Siddiqi (2011). Another part of the literature provides evidence of investors' aversions to risk in options markets, such as the work of Jackwerth and Rubinstein (1996) and Jackwerth (2000).

In this work, a different angle of analysis is explored: the presence of informed investors in the face of other sentimentalists (as guided by market sentiment).

1-2- Derivation of the model in the presence of imperfections

<u>The actual discount rate in the presence of imperfections: asymmetry of information and market sentiment</u>

The traditional assumptions of the Black and Sholes basic model give no role to investors' sentiment, which negotiates in the context of an efficient market in the informational sense.

Within this framework of analysis, rational investment decisions push prices closer to their fundamental values (Friedman 1953).

However, this argument is not adopted by behavioral finance, which asserts that prices can be affected by sentiment. For example, De long et al. (1990.b) and Lee et al. (1991) found that irrational investors (noise traders) can drive prices away from their equilibrium prices, reinforcing the error of valuation in an environment where limits to arbitrage exist.

Much research, such as Brown and Cliff (2004), Kangar and Lee (2006), Baker and Wurgler (2006), Lemmon and Portniaguina (2006), Yang and Zhang (2013) and Yang et al (2016), has shown that sentiment has a systematic impact on the expected return of an asset.

Traditional option pricing models, which assume that investors are risk-neutral, assume that the expected rate of return on any investment is the risk-free rate.

However, some economic and neuroeconomic research shows that the discount rate can be affected by subjective, psychological and sentimental opinions.

Thaler (1981) estimated the individual discount rate of survey results and found that the discount rates were smaller for losses than for gains.

Warner and Pleeter (2001) estimated discount rates to range from 0 to 30% and found that they were influenced by education, age, race, gender, qualifying examinations, salary, and other personal characteristics.

Lawrence et al. (2007) found that investor sentiment influences the expected discount rate. Indeed, for an investor with a high sentiment for future performance, the discount rate is low.

Yang et al (2016) introduced the concept of the sentiment discount rate, and they found that an investor with the highest sentiment level had the lowest sentiment discount rate.

A large amount of research has shown that the individual discount rate is affected by sentiment factors.

To develop the options pricing model in the presence of information asymmetry and market sentiment, we adopt the same assumptions as those of Black and Scholes, except for market efficiency.

Leaving the market efficiency hypothesis, we derive a formula for evaluating options while accounting for information asymmetry and market sentiment.

"When investors move from a risk-neutral world to a risk-averse world, two things happen: the expected growth rate in the stock price changes and the discount rate that must be used for any pay-off from the derivative changes." (John Hull 2008).

Consequently, in the context of information asymmetry and sentiment, the expected growth rate of the underlying rate and discount rate are assumed to be equal to the risk-free rates plus the costs generated by these anomalies.

If we find ourselves in a market where there are informed investors (who hold private information) against uninformed but rational investors (in the sense that they do not account for market sentiment), the impact of information asymmetry is similar to the application of an additional discount rate (Merton 1987; Bellalah and Jaquillat 1995; Ben Hamad and Eleuch 2008). We have

$\boldsymbol{r_1} = \boldsymbol{r} +$ the costs associated with information asymmetry (1)

where

- r_1 : Means the effective risk-free interest rate;
- r: Refers to the real risk-free interest rate.

On the other hand, several studies have shown the significant role that market sentiment plays in the evaluation of options (Han 2008; Mahani and Poteshman 2008; Lemmon and Xi 2008; Bauer et al. 2009; and Thirukumaran and Koteswararao 2009; Frijns et al 2011; Yang et al. 2016).

As a result, if we account for market sentiment, the potential gain or loss from private information will be different.

Indeed, if private information is positive and market sentiment is bullish, sentimentalists (investors who react according to market sentiment) will help the informed (investors who own private information) to conceal their transactions (Sung and Jun 2015; An et al. 2013).

On the other hand, if private information is negative and market sentiment is bullish, the information will not be incorporated immediately. Indeed, pessimistic views are not reflected instantaneously during periods of rising markets (Yu and Yuan 2011; Stambaugh et al 2012).

Consequently, during high sentiment periods, informed traders become less willing to leverage their information advantages, which diminishes the derivative markets' leading informational role and contributions to price discovery (Lin et al. 2018).

As a result, the presence of sentimentalists modifies the profit of the gain or loss relative to private information.

To incorporate the impact of sentiment, the costs associated with information asymmetry and modified with sentiment are defined as follows:

$$r_1 = r + \lambda w(l) \tag{2}$$

where

- λ: is the amplitude of information asymmetry, and

- $w(l) = 1 - e^{-\alpha l}$ (3)

designates the function of imperfections, which verifies:

$$\begin{cases} w(0) = 0 \\ \lim\limits_{l \to +\infty} w(l) = 1 \\ \lim\limits_{l \to -\infty} w(l) = -\infty \end{cases}$$

<u>Study of the imperfections function: the contribution of the introduction of the sentiment on the gain or loss related to the information asymmetry</u>

The imperfection function w (l) is defined as follows:

$$w:]-\infty, +\infty[\rightarrow]-\infty, +\infty]$$
$$l \rightarrow 1 - e^{-\alpha l} \quad , \quad (4)$$

where

α: is the market sentiment coefficient;

l: is the advantage or disadvantage of the information.

The derivative of w (l) with respect to 'l' is given by the following formula:

$$w'(l) = \alpha e^{-\alpha l} > 0 \quad (5)$$

where $w(l)$ is strictly increasing on ℝ.

where $\begin{cases} \lim\limits_{l \to -\infty} w(l) = -\infty \\ \lim\limits_{l \to +\infty} w(l) = 1 \end{cases}$

	$-\infty$	**0**	$+\infty$
$w'(l)$	+		+
(l)	$-\infty$ ↗	0 ↗	1

<u>Table 1: Table of variations in the imperfections function</u>

As shown in the variation table of the imperfections function, *w (l)* strictly increases on ℝ. In other words, if the information advantage increases, *w (l)* increases, but the growth rate of *w (l)* depends on the coefficient of sentiment α.

Indeed, if the market sentiment increases, *w (l)* grows faster. The sentiment multiplies; therefore, the private information has an impact.

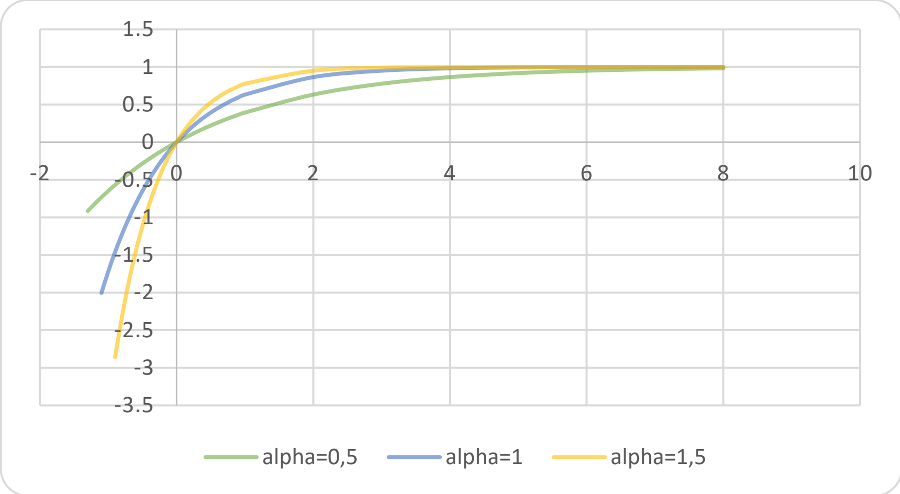

Figure 1: Evolution of the imperfections function w (l)

From Figure 1, we note that the function of imperfections increases when '*l*' increases and tends to 1, regardless of the value of the market sentiment coefficient α. However, the rate of change of w (l) varies according to the value of α. Indeed, w (l) approaches 1 faster when α increases.

We can see that the value of w (l) for a given level of 'l' increases as a function of α.

However, regardless of the value of α, if the asymmetry of information vanishes, l = 0, the function of imperfections w (l) vanishes also, and thus, we find ourselves in an efficient market. In the context of market efficiency, there is no private information. As a result, any available information is perfectly incorporated into the price, and therefore, there is no place for market sentiment. We are then in the Black and Scholes assumptions, and therefore, we have the same formula as that of Black and Scholes (1973).

Derivation of the option pricing model in the presence of imperfections

According to Black and Scholes (1973), it is possible to create a hedged position that consists of selling $\frac{1}{\frac{\partial C(S,T)}{\partial S}}$ options against the purchase of a stock.

Indeed, taking the same approach as Black and Scholes (1973), while accounting for information asymmetry and sentiment, we can deduce that the small variation of δS in the share price generates a variation in the option value $\frac{\partial C(S,T)}{\partial S}\delta S$, and therefore, the change in the long position on the stock is approximately compensated by the $\frac{1}{\frac{\partial C(S,T)}{\partial S}}$ options variation.

Next, consider what occurs at any time for a portfolio that consists of a stock and $\frac{1}{\frac{\partial C(S,T)}{\partial S}}$ options.

At the initial instant, the position value is $S - \frac{1}{\frac{\partial C(S,T)}{\partial S}} C(S,T)$ (6)

During an infinitesimal interval δt, the position variation is given by

$$\delta S-\frac{1}{\frac{\partial C(S,T)}{\partial S}}\delta C(S,T) \tag{7}$$

where

$$\delta C(S,T)=C(S+\delta S,T+\delta T) \tag{8}$$

The price evolution is governed by geometric Brownian motion:

$$dS=\mu Sdt+\sigma Sdt \tag{9}$$

where - μ: is the instantaneous expected rate of return of the underlying rate;

- σ : is the standard deviation of the instantaneous rate of return of the underlying rate;
- dz: is a standard Wiener process. dz is therefore distributed according to a normal distribution of a mean of zero and of variance equal to dt.

Using stochastic calculus and the Itô lemma, we obtain

$$\Delta C=\frac{\partial C}{\partial t}\Delta S+\frac{\partial C}{\partial t}dt+\frac{1}{2}\sigma^2S^2\frac{\partial^2 C}{\partial S^2}dt \tag{10}$$

Since the rate of return of a hedged position must be equal to the effective risk-free interest rates r_1, we obtain

$$\Rightarrow\left(-\frac{\partial C}{\partial t}-\frac{1}{2}\frac{\partial^2 C}{\partial S^2}\sigma^2S^2\right)dt=r_1\left(-C+\frac{\partial C}{\partial S}S\right)dt \tag{11}$$

$$\Rightarrow\frac{\partial C}{\partial t}+\frac{1}{2}\frac{\partial^2 C}{\partial S^2}\sigma^2S^2+r_1\frac{\partial C}{\partial S}S-r_1C=0 : \text{PDE} \tag{12}$$

This equation is a partial differential equation in the presence of imperfections: information asymmetry and market sentiment.

Here,

$$r_1=r+\lambda w(l) \tag{13}$$

where - r: denotes the real risk-free interest rate;

- λ: represents the information asymmetry amplitude;
- $w(l)$=$1-e^{-\alpha l}$: designates the imperfections function.

where: - 'l': represents the advantage or disadvantage of the information;

- α: is the market sentiment coefficient.

To deduce the option value, it is sufficient to apply the following approach:

1. Assume that the underlying return is equal to the effective risk-free rate in the presence of information and sentiment asymmetry, i.e., $\mu=r_1$

$$\Rightarrow E(S)=Se^{r_1T} \tag{14}$$

2. Calculate the expected payoff of the derivative asset at maturity:

$$E[max(S-K);0]=\int_K^{+\infty}(S-K)g(S)\,dS \tag{15}$$

where - $g(S)$: is the probability density function of S

- K: is the exercise price

We find that $E[max(S-K);0] = Se^{r_1 T}N(d_1') - KN(d_2')$

(16)

3. Discounting this expectation at the effective risk-free interest rate r_1 in the presence of imperfections, we find

$$\Rightarrow C = e^{-r_1 T}\left[Se^{r_1 T}N(d_1') - KN(d_2')\right] \quad (17)$$

$$\Rightarrow C = SN(d_1') - Ke^{-r_1 T}N(d_2') \quad (18)$$

We find then the new formula of the European options pricing of Black and Scholes modified in the presence of information asymmetry and market sentiment.

where $d_1' = \frac{\ln\frac{S}{K} + \left(r_1 + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}$ (19)

and $d_2' = d_1' - \sigma\sqrt{T}$ (20)

where - S : the underlying spot price;

- K : the strike price;
- σ : the underlying volatility;
- T : time to maturity;
- N(x) : the distribution function of the normal centered reduced law N (0,1);
- $r_1 = r + \lambda w(l)$

where - r : refers to the real risk-free interest rate;

- λ : represents the information asymmetry amplitude;
- $w(l)$=$1 - e^{-\alpha l}$: refers to the market imperfections function;
- α : represents market sentiment;
- 'l': represents the advantage or disadvantage of information.

The new Put-Call parity in the presence of information asymmetry and market sentiment

The put-call parity that accounts for information asymmetry and market sentiment can be written as follows:

$$C - P = S - Ke^{-r_1 T} \quad (21)$$

where - C: call price;

- P: put price;
- r_1 : refers to the effective risk-free interest rate;
- T: time to maturity

We can then deduce the value of a European put in the presence of imperfections from the parity relation. We have

$$\begin{cases} C - P = S - Ke^{-r_1 T} \\ C = SN(d_1') - Ke^{-r_1 T}N(d_2') \end{cases}$$

Thus, we can write

$$SN(d_1') - Ke^{-r_1 T}N(d_2') - P = S - Ke^{-r_1 T} \tag{22}$$

$$\Rightarrow P = Ke^{-r_1 T}\left(1 - N(d_2')\right) - S\left(1 - N(d_1')\right) \tag{23}$$

as $\quad N(d) + N(-d) = 1 \qquad (25)$

We then find the new formula for the put pricing of Black and Scholes modified in the presence of information asymmetry and sentiment:

$$P = Ke^{-r_1 T}N(-d_2') - SN(-d_1') \tag{26}$$

1-3- The sensitivity of the option price to the new variables

We study the sensitivity of the option price to the newly introduced variables. The sensitivities are, therefore, measured by the partial derivatives of the option price, concerning these variables.

1-4-1- Sensitivity of the option price to *'l'*: advantage or disadvantage of information

The aspect considered here is the sensitivity of the option price to the variation in the advantage or disadvantage of information.

For a call, we have

$$\frac{\partial C}{\partial l} = \frac{\partial C}{\partial r_1}\frac{\partial r_1}{\partial l} \tag{27}$$

$$= \frac{\partial\left(SN(d_1') - Ke^{-r_1 T}N(d_2')\right)}{\partial r_1}\frac{\partial\left(\mathrm{r} + \lambda\left(1 - \mathrm{e}^{-\alpha\, l}\right)\right)}{\partial l} \tag{28}$$

$$= TKe^{r_1 T}N(d_2')\,\alpha\lambda e^{-\alpha l} > 0 \tag{29}$$

Hence, $\frac{\partial C}{\partial l} > 0$, i.e., the increase in 'l' implies an increase in the call price. Indeed, if an investor has positive private information about the underlying rate, the call price is increased.

For a put, we have

$$\frac{\partial P}{\partial l} = \frac{\partial P}{\partial r_1}\frac{\partial r_1}{\partial l} \tag{30}$$

$$= \frac{\partial\left(Ke^{-r_1 T}N(-d_2') - SN(-d_1')\right)}{\partial r_1}\frac{\partial\left(\mathrm{r} + \lambda\left(1 - \mathrm{e}^{-\alpha\, l}\right)\right)}{\partial l} \tag{31}$$

$$= -TKe^{r_1 T}N(-d_2')\,\alpha\lambda e^{-\alpha l} < 0 \tag{32}$$

Unlike the call option, $\frac{\partial P}{\partial l} < 0$, i.e., the increase in *'l'* implies a decrease in the put price. Indeed, if an investor has positive private information about the underlying rate, the put price is pushed down.

1-4-2- Sensitivity of the option price to 'α': market sentiment

We will study the sensitivity of the option price to the variation of 'α': market sentiment.

For a call, we have

$$\frac{\partial C}{\partial \alpha} = \frac{\partial C}{\partial r_1}\frac{\partial r_1}{\partial \alpha} \tag{33}$$

$$= \frac{\partial\left(SN(d_1^{'})-Ke^{-r_1T}N(d_2^{'})\right)}{\partial r_1}\frac{\partial\left(\mathrm{r}+\lambda(1-\mathrm{e}^{-\alpha\, l})\right)}{\partial \alpha} \tag{34}$$

$$= TKe^{r_1T}N\left(d_2^{'}\right)\lambda\, l\, e^{-\alpha l} \tag{35}$$

The sign of $\frac{\partial C}{\partial \alpha}$ depends on the sign of *'l'*.

If 'l'> 0, private information is positive; then, the increase in market sentiment 'α' leads to an increase in the call price. Indeed, if the market sentiment is increasing (α increases), in the same sense as the private information (l> 0), then the transactions of the informed (those who own the private information), as well as the sentimentalists (those who follow the market sentiment), go in the same direction, which pushes the price of the call to increase faster.

In contrast, if *l* <0, i.e., the private information is negative, then the increase in market sentiment 'α' does not increase the price of the call.

Indeed, if the sentiment of the market is increasing (α increases) in the direction opposite to the private information (*l* <0), then the sentimentalist's transactions go in the opposite direction of the informed transactions, which increases the loss in value of the call option.

Hence, the increase in α results in a decrease in the value of the call.

For a put, we have

$$\frac{\partial P}{\partial \alpha} = \frac{\partial P}{\partial r_1}\frac{\partial r_1}{\partial \alpha} \tag{36}$$

$$= \frac{\partial\left(Ke^{-r_1T}N(-d_2^{'})-SN(-d_1^{'})\right)}{\partial r_1}\frac{\partial\left(\mathrm{r}+\lambda(1-\mathrm{e}^{-\alpha\, l})\right)}{\partial \alpha} \tag{37}$$

$$= -TKe^{r_1T}N\left(-d_2^{'}\right)\lambda\, l\, e^{-\alpha l} \tag{38}$$

As in the case of the call, the sign of $\frac{\partial P}{\partial \alpha}$ depends on that of *'l'*.

If the private information is positive, *l*> 0, then $\frac{\partial P}{\partial \alpha} < 0$, i.e., if the increase in α multiplies the effect of the positive information, then it reduces the put price.

On the other hand, if l <0, i.e., if private information is negative, then $\frac{\partial P}{\partial \alpha} > 0$, which means that an increase in market sentiment 'α' leads to an increase in the price of the put. Indeed, if the market sentiment is increasing (α increases) in the opposite direction of the private information (l <0), then the sentimentalists' transactions go in the opposite direction of the informed transactions, which increases the gain in the put price.

Hence, an increase in α leads to an increase in the value of the put.

1-4-3- Sensitivity of the option price to 'λ': information asymmetry amplitude

We study the sensitivity of the option price to the variation in 'λ': the amplitude of information asymmetry.

For a call, we have

$$\frac{\partial C}{\partial \lambda} = \frac{\partial C}{\partial r_1}\frac{\partial r_1}{\partial \lambda} \tag{39}$$

$$= \frac{\partial\left(SN(d_1')-Ke^{-r_1T}N(d_2')\right)}{\partial r_1}\frac{\partial\left(\mathrm{r}+\lambda\left(1-\mathrm{e}^{-\alpha\, l}\right)\right)}{\partial \lambda} \tag{40}$$

$$= TKe^{r_1T}N(d_2)(1-e^{-\alpha l}) \tag{41}$$

As in the case of market sentiment, the sign of $\frac{\partial C}{\partial \lambda}$ depends on the sign of 'l'.

If l> 0, in other words, if the private information is positive, $\frac{\partial C}{\partial \lambda} > 0$, then the increase in 'λ', the amplitude of information asymmetry, leads to an increase in the price of the call. Indeed, if the amplitude of information asymmetry increases, the gain relative to the positive private information increases, which generates an increase in the call value.

However, if l <0, i.e., if the private information is negative, the sensitivity of the call price is $\frac{\partial C}{\partial \lambda} < 0$, then the increase in 'λ' does not increase the call price, but there is a decrease in its value.

Indeed, the loss relative to negative private information, (l <0), multiplies if the amplitude of the information asymmetry increases, which results in a decrease in the call value.

For a put, we have

$$\frac{\partial P}{\partial \lambda} = \frac{\partial P}{\partial r_1}\frac{\partial r_1}{\partial \lambda} \tag{42}$$

$$= \frac{\partial\left(Ke^{-r_1T}N(-d_2')-SN(-d_1')\right)}{\partial r_1}\frac{\partial\left(\mathrm{r}+\lambda\left(1-\mathrm{e}^{-\alpha\, l}\right)\right)}{\partial \lambda} \tag{43}$$

$$= -TKe^{r_1T}N(-d_2)(1-e^{-\alpha l}) \tag{44}$$

Similarly, the sign of $\frac{\partial C}{\partial \lambda}$ depends on the sign of 'l'.

If l> 0, i.e., if the private information is positive, $\frac{\partial c}{\partial \lambda} < 0$, then the increase in 'λ', the amplitude of information asymmetry, results in a decrease in the put price.

Indeed, if the information asymmetry amplitude increases, the loss relative to the positive private information (concerning the underlying rate) increases, which leads to a decrease in the call value.

However, if l <0, i.e., if the private information is negative, the price sensitivity of the put is $\frac{\partial c}{\partial \lambda} > 0$, then the increase in 'λ' increases the put price.

Indeed, the gain relative to the negative private information (l <0) multiplies if the amplitude of information asymmetry increases, which gives rise to an increase in the value of the call option.

2- The contribution of the imperfections introduction: information asymmetry and market sentiment in the option evaluation model: Empirical validation

Several studies have focused on the proposal of new models based on the criticism of the different hypotheses of Black and Scholes (1973) to improve the options price estimated by these models. According to these studies, we propose the extension of the Black-Scholes model in the presence of imperfections: information asymmetry and market sentiment.

The objective of this section is to empirically test the capacity of the new model to approximate the market price better than the Black-Scholes model. This section is structured around three parts:

- The first part presents the measurements of the new variables used in the model.
- The second part presents the methodology adopted to test the model performance.
- The third part presents an analysis component that consists of testing the performance of the model by comparing the evaluation gaps of the new model with the classical model.

2-1- Procedure for calculating the European option price by the options pricing model in the presence of imperfections

To present the procedure for calculating the European option price by the options pricing model in the presence of imperfections, we first present the measures used for the new variables.

2-1-1- New variables measurement

Three new variables have been introduced in the option pricing model in the presence of imperfections, namely, market sentiment 'α', the information asymmetry amplitude 'λ' and the advantages or the disadvantages of information '*l*'. We then present their measurements below.

i.Measurement of 'α': market sentiment

The literature offers a multitude of measures of market sentiment. However, empirical studies of these measures have shown that they are correlated with one another.

This aspect is an element that increases the credibility of the different measurement methods. However, this finding shows that it is not useful to multiply them to ensure the quantification of sentiment. Indeed, each additional measure will provide some of the information already given.

The put-call trading volume or the put-call ratio is often used as a sentiment indicator, as in Simon & Wiggins III (2001), Lee & Song (2003), and Thirukumaran & Koteswararao (2009).

The put-call trading volume or put-call ratio is a measure of market sentiment that is equal to the trading volume of put options divided by the trading volume of call options. When the market is bearish, people buy more put options either to hedge their spot positions or to speculate bearishly.

Therefore, the trading volume of the put options becomes large in relation to the trading volume of the call options and the put call ratio goes up, and vice versa. Thus, an increase in the put-call ratio is an indication of bearish sentiments and a decrease is an indication of bullish sentiments.

On the other hand, Wang et al. (2006) modified the put-call ratio by replacing the transaction volume with open interest to calculate the put-call ratio.

They argue that this ratio could be a preferred measure of market sentiment since the open interest is the final image of sentiment at the end of the day or week, which could, therefore, have predictive power for the future volatility.

The trading volume and open interest have been used in the literature as proxies for speculative activities and market depth, respectively (Bessembinder & Seguin, 1992, 1993; Fung & Patterson, 2001). Trading volume is a flow measure, and market depth is a stock measure; these two measures might be correlated (Chan et al, 2015). By dividing the trading volume by open interest, this issue is resolved (Chan et al, 2018).

Instead, we utilize the speculative ratio, which utilizes the ratio of daily volume to opening interests, as outlined in Chan et al. (2013, 2015), as a proxy to measure excessive speculative activities in SPX option markets.

In other words, 'α' is calculated by the following formula: $\alpha = \frac{V\ Call/OICall}{V\ Put/OIPut}$

(45)

If α> 1, then $V\ Call/OICall > V\ Put/OIPut$: the market sentiment is bullish for the underlying price.

Indeed, the volume to opening interests ratio for call options ($V\ Call/OICall$) measures the excessive speculative activities of investors who believe that the underlying price will rise. On the other hand, the volume to opening interests ratio for put options (V Put/OIPut) measure the excessive speculative activities of investors who believe that the underlying price will decline. As a result, if V Call/OICall>V Put/OIPut, market sentiment is bullish for the underlying price. As a result, market sentiment is bullish for the call options and bearish for the put options.
On the other hand, when α <1, the result is that V Call/OICall < V Put/OIPut: market sentiment is bearish for the underlying price. As a result, market sentiment is bearish for the call options and bullish for the put options.

Indeed, when market sentiment is bullish (bearish), investors are demanding more hedge by call (put) options. In this context, calls (puts) become more expensive in relation to puts (calls), since when the market maker issues more calls (puts), it will be confronted with higher hedging costs. Due to aversion to risk, an investor increases the premium when the number of calls (puts) issued increases (Bollen and Whaley 2004).

Nevertheless, if private information is positive, an increase in the value of 'α' means an improvement in market sentiment, which pushes the price of a call (put) to increase (decrease). On the other hand, a decrease in the value of 'α' means a deterioration in market sentiment, which pushes the value of a call (put) to decrease (increase).

ii.Measurement of 'λ': the information asymmetry amplitude

The impact of private information varies depending on the nature of the information (positive or negative). Many studies have examined the extent of the impact of information depending on the nature of the news (good or bad).

Chan (2003) suggests that investors react more slowly to bad news, which confirms the existence of a more pronounced subreaction when announcing bad news.

According to Swaminathan and Lee (2000), Hong et al. (2000), and Kirchler (2009), the bad news is reflected in stock prices more slowly than good news. In this framework of analysis, the amplitude 'λ' is lower for bad private information than that for good private information.

Among the aforementioned information asymmetry measurements, we chose the IV spread, which is given by the following formula: $\lambda = \frac{IVCall}{IVPut}$ (46)

If the information is positive (negative), then λ> 1 (λ <1). Indeed, the implied volatility of the calls is higher (lower) than that of the puts when the prices of the calls are pushed by informed investors with positive (negative) information who choose to trade on the options market in the first place (Cremers and Weinbaum (2010).

iii. Measurement of 'l': the advantages or disadvantages of information

As detailed above, the deviation from the parity relation is a measure of market information asymmetry. We propose, therefore, to implicitly calculate 'l' from the parity relation.

Brenner and Galai (1986), who were the first to implicitly estimate the risk-free rate from the parity relation, have been followed by other researchers, such as Brenner, Subrahmanyam, and Uno (1990), Liu, Longsta, Mandell (2006), Feldhütter and Lando (2008), Naranjo (2009).

Following the same approach of Brenner and Galai (1986), we propose to measure '*l*', the advantages or the disadvantages of information, implicitly from the parity relation, but this time, we propose to account for imperfections. The calculation is as follows:

The parity relation that accounts for imperfections is given by the following formula:

$$C - P = S - Ke^{-r_1 t} \qquad (47)$$

We then find that $r_{1implicite} = \frac{ln(K) - ln(S+P-C)}{t}$

(48)

where $r_{1implicite}$ is the risk-free rate in the presence of imperfections, which is implicitly calculated from the parity relation.

Given that

$$r_1 = r + \lambda(1 - e^{-\alpha l}) \qquad (49)$$

then 'l' is given by the following formula:

$$l = \frac{-ln\left(1 - \frac{r_{1implicite} - r}{\lambda}\right)}{\alpha} \qquad (50)$$

If *l*> 0, the private information is positive for the underlying price. Therefore, the private information is positive for a call and negative for a put. On the other hand, if *l* <0, the private information is negative for the underlying price. Therefore, private information is negative for a call and positive for a put.

2-2- Study of the model performance

One of the most important reasons why researchers develop new models lies in the fact that the Black and Scholes model (1973) does not correctly evaluate option prices. In other words, researchers and practitioners note a significant difference between the prices of the Black and Scholes model (1973) and those of the market.

In this work, we study the evaluation errors and the correlation coefficient between theoretical and market prices as performance indicators.

Our approach is to test empirically the Black-Scholes option model (1973) modified in the presence of information asymmetry and market sentiment.

This approach involves testing the proposed model and using daily data from European call and put options and from the S&P 500 index from the CBOE for a study period from 17/03/2000 until 14/06/2013.

Particularly, our problem is formulated as follows:

The modified Black and Scholes model (1973) makes it possible to reduce the estimation errors caused by the Black and Scholes model (1973), in other words, to reduce the biases of undervaluation and overestimation and to approximate the prices observed in the market.

In other words, does the introduction of the economic agents' behavior into the market have an impact on the evaluation of options?

The objective of our empirical approach is to determine whether the model with imperfections provides a better approximation of the market price of a European option than that obtained using the Black and Scholes 1973 model.

To answer our problem and to reach our objective, our empirical study is organized in the following way: First, we define the null hypothesis. Then, we perform the null hypothesis test. Finally, we comment on the results obtained.

The null hypothesis

To test the performance of the models, we have defined the following hypothesis:

H0: The model in the presence of imperfections makes it possible to approach as closely as possible the market value of the option compared with that of the basic model of Black and Scholes.

Note: - C_{BS}, P_{BS} are the prices of a European call and put option, respectively, calculated using the Black and Scholes formula (1973)

- $C_{imperfections}$, $P_{imperfections}$ are the prices of a European call and put option, respectively, calculated using the model in the presence of imperfections

- C_M, P_M are the prices of a European call and put option, respectively, quoted on the market.

We define:
$$\begin{cases} ECBS = C_{BS} - C_M & (51) \\ EPBS = P_{BS} - P_M & (52) \end{cases}$$

We define ECBS (EPBS) as the difference between the call (put) price calculated by the theoretical model of Black and Scholes (1973) and the call (put) market price.

In addition, we have

$$ECI = C_{imperfections} - C_M \tag{53}$$

$$EPI = P_{imperfections} - P_M \tag{54}$$

ECI (EPI): The difference between the call (put) price calculated by the model in the presence of imperfections and the call (put) market price.

If the difference is positive (negative), then the option is overvalued (undervalued). In other words, the theoretical models use overvalued or overestimated (undervalued or underestimated) market prices. These differences are calculated for each option and each day of the sample to calculate the average evaluation error for each option of the sample.

By calculating the mean square error MSE for the whole sample of the options, we obtain the following:

$$MSE_{CBS} = \frac{1}{n}\sum(C_{BS} - C_M)^2 \tag{55}$$

$$MSE_{PBS} = \frac{1}{n}\sum(P_{BS} - P_M)^2 \tag{56}$$

The mean square error for the Black and Sholes model (1973) for the call and put options is obtained

$$MSE_{CI} = \frac{1}{n}\sum\left(C_{imperfections} - C_M\right)^2 \tag{57}$$

$$MSE_{PI} = \frac{1}{n}\sum\left(P_{imperfections} - P_M\right)^2 \tag{58}$$

The mean square error for the model in the presence of imperfections for the call and put options is obtained.

Another measure of the model efficiency is the correlation of the prices calculated by the two models with those of the market. We then define the following:

- $\boldsymbol{\rho_{C_{BS}/C_M}}$, $\boldsymbol{\rho_{P_{BS}/P_M}}$: the correlation coefficients of the options prices calculated by the models of Black and Sholes with those of the market.
- $\boldsymbol{\rho_{C_{imperfections}/C_M}}$, $\boldsymbol{\rho_{P_{imperfections}/P_M}}$: the correlation coefficients of the option prices calculated by the models in the presence of imperfections with those of the market.

To argue that the model in the presence of imperfections constitutes, on average, a better approximation of the market values of options compared with those obtained using the Black-Scholes model (1973) amounts to testing the following null hypothesis:

Ho: $\begin{cases} MSE_{CI} - MSE_{CBS} < 0, \text{ and } \rho_{C_{imperfections}/C_M} - \rho_{C_{BS}/C_M} > 0 \\ MSE_{PI} - MSE_{PBS} < 0, \text{ and } \rho_{P_{imperfections}/P_M} - \rho_{P_{BS}/P_M} > 0 \end{cases}$

Results

The database used in this work is the S&P 500 call and put options traded on the Chicago Board Options Exchange (CBOE), whose daily observations (recorded at market close) are between March 17, 2000, and June 17, 2013, which corresponds to 3457 observations. The observation data are the index value, the strike price, the current date, the maturity date, the option value, the transaction volume and the open position.

In terms of the dividend adjustment, we use the daily dividend distribution rate of the S & P 500 index reported by Datastream as it is approved by NASDAQ OMX.

Three-month daily US Treasury Bill Rates data are used as a risk-free rate estimator. Hull (2009) assumes that such a rate is a correct estimator of the risk-free rate.

Two filters were applied to this sample. First, the options do not respect the arbitration condition (Merton (1973)); in other words, $C \geq S - Ke^{-r\tau}$ for the call options and $P \geq Ke^{-r\tau} - S$ for the put options are excluded from the sample to calculate the implied volatilities. Second, following the Bakshi and Kapadia (2003) approach, days with missing observations, or with implied volatilities less than 1% or more than 100%, are eliminated. Indeed, these volatilities can be due to a synchronization bias.

The deviations MSECI, MSECBS, MSEPI, and MSEPBS, as well as the correlation coefficients$\rho_{C_{imperfections}/C_M}$, ρ_{C_{BS}/C_M}, $\rho_{P_{imperfections}/P_M}$ and ρ_{P_{BS}/P_M}, defined above, are calculated for the whole sample.

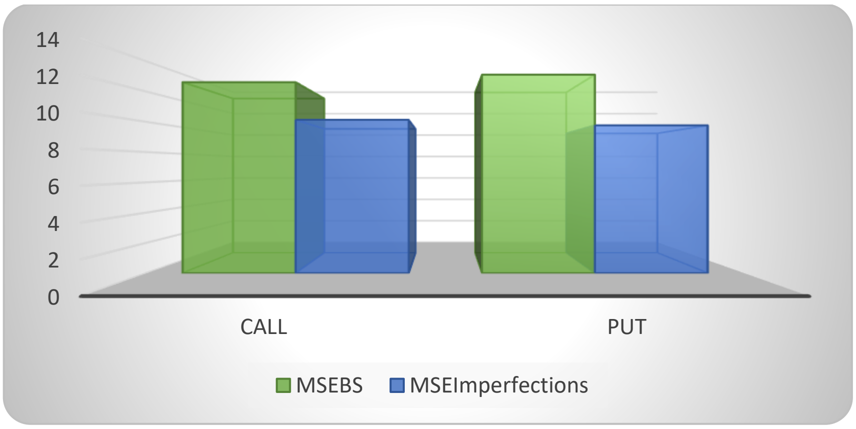

Figure 2: Mean square error of the Black and Scholes model and the model in the presence of imperfections

Throughout the study period, from 17/03/2000 to 14/06/2013, for the basic model of Black and Scholes, the mean square error MSE_{BS} is approximately 12.611 for the call options and

13.109 for the put options. The correlation coefficient $\rho_{BS/M}$ is in the range of 0.942 for the call options and 0.937 for the put options.

Considering the information asymmetry and market sentiment, the two efficiency criteria, **MSE$_{\text{Imperfections}}$** and $\boldsymbol{\rho_{Imperfections/M}}$, have values of 12.611 and 0.967, respectively, for the call options and 13.109 and 0.937 for the put options.

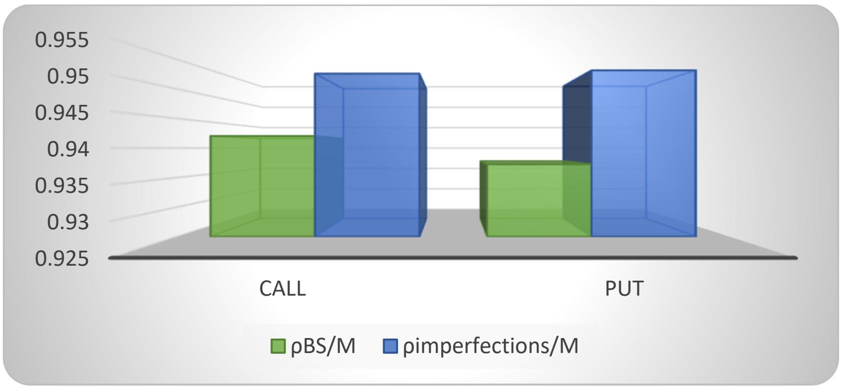

Figure 3: Correlation coefficient of theoretical prices calculated from the two models studied and the market prices

From Figures 2 and 3, we can see the improvements in the values taken by these two criteria. Indeed, in Table 1, we can see that the MSE decreased by 5.398, i.e., a relative variation of -42.80%, for the calls, and 6.384, i.e., a relative variation of -48.70%, for the puts.

Table 1: MSE of the two models, the variation of MSE and the relative variation of MSE[5]

	CALL	PUT
MSE$_{BS}$	12.611	13.109
MSE$_{\text{Imperfections}}$	7.213	6.725
MSE variation	-5.398	-6.384
MSE relative variation (%)	-42.80%	-48.70%

From Table 2, we noted a strong correlation between the prices given by the two theoretical models and their corresponding market values. However, the correlation is improved by the introduction of market imperfections and the irrational behavior of the market participants

[5] **The relative variation of MSE is calculated as**

$$\frac{(MSEImperfections - MSEBS)}{MSEBS}$$

to the option valuation model. The correlation coefficient increased from 0.942 to 0.967, a relative variation of 2.61%, for the calls, and from 0.937 to 0.968, and a relative variation of 3.32%, for the puts.

Table 2: Correlation coefficient of the theoretical prices calculated from the two models studied and the market prices

A

	CALL	**PUT**
$\boldsymbol{\rho_{BS/M}}$	0.942	0.937
$\boldsymbol{\rho_{Imperfections/M}}$	0.967	0.968
$\boldsymbol{\rho}$ **variation**	0.024	0.031
$\boldsymbol{\rho}$ **relative variation (%)**	2.61%	3.32%

It is clear that the model with imperfections performs better for the S&P 500 index puts and calls. For the whole sample, we find

$$\begin{cases} MSE_{CI} - MSE_{CBS} < 0, \text{ and } \rho_{C_{imperfections}/C_M} - \rho_{C_{BS}/C_M} > 0 \\ MSE_{PI} - MSE_{PBS} < 0, \text{ and } \rho_{P_{imperfections}/P_M} - \rho_{P_{BS}/P_M} > 0 \end{cases}$$

Thus, the hypothesis Ho is confirmed.

In this way, we can confirm that the model in the presence of imperfections (market imperfection: information asymmetry, the imperfection of investor behavior: sentiment) provides an approximation of the market value of the calls and puts better than that calculated by the Black-Scholes model (1973).

In other words, accounting for these two imperfections together in the option evaluation model helped to reduce the evaluation errors and hence improve the quality of the evaluation.

Conclusions

In this work, we studied the impact of the introduction of imperfections, namely, information asymmetry and market sentiment, in the evaluation of options. To accomplish this goal, we presented the explanation, the derivation of the model in the presence of imperfections, and the sensitivity of the price of the options to the new variables. Empirically, we tested the introduction of imperfections to the option evaluation model.

Our study of the value of the S&P 500 call and put options from 17/03/2000 to 14/06/2013 (13 years) shows that the introduction of information asymmetry and sentiment into the Black-Scholes option model (parametric model) improves the evaluation performance of the model.

Indeed, in a market with asymmetric information and in which investors are irrational, prices can be affected by the presence of informed investors (who have positive or negative private information about the future evolution of the underlying price).

This deviation of the prices from their core values varies according to the market sentiment. Indeed, irrational investors can drive prices away from their equilibrium prices, thus reinforcing the evaluation error in an environment where information is asymmetric.

However, under the traditional assumptions of the Black-Scholes (1973) base model, which does not play any role in investors' sentiment and which assumes that the market is efficient in the informational sense, investors are assumed to be neutral in the face of risk, and the expected rate of return, as well as the discount rate, are assumed to be equal to the risk-free rate.

However, economic and neuroeconomic research shows that the discount rate can be affected by subjective, psychological and sentimental opinions, as well as by information asymmetry.

To account for these anomalies, we proposed an effective discount rate that supports these two anomalies: the real risk-free rate increased by the costs generated by these anomalies.

Indeed, the impact of private information on the option price depends on the nature of the price (positive or negative information on the future evolution of the underlying). If the private information is positive ('l'> 0), the price of a call option will increase, while that of a put option will decrease.

The magnitude of this variation is asymmetric, depending on the nature of the information (good or bad news). Indeed, many studies have found that investors react slowly to bad news compared to good news (Swaminathan and Lee 2000; Hong et al. 2000; Chan 2003; Kirchler 2009).

As a result, the amplitude of information asymmetry λ has values greater than 1 if the information is positive, which amplifies the impact of the favorable information, and has values less than 1 if the information is negative, which reduces the impact on adverse information.

However, the presence of irrational investors (the sentimentalists) modifies the impact of private information. If, for example, the information is positive ('l> 0) and market sentiment is positive (α> 1), i.e., along the same lines of private information, then the transactions of the informed, as well as the sentimentalists, go in the same direction, which pushes the price of the call to increase and the put to decrease faster (Sung Won Seo and Jun Sik Kim (2015), An et al. (2013)).

On the other hand, if the information is positive ('l> 0) and market sentiment is negative (α <1), then sentimentalist transactions go in the opposite direction to those of the informed, which will slow the increase in the call and decrease the put (Yu and Yuan 2011; Stambaugh et al 2012).

As a result, the introduction of imperfections into the option pricing formula leads to more accurate theoretical prices since these anomalies are included in the option market price.

When these imperfections are introduced in the basic model, they have the potential to explain some of the biases observed in the basic model of Black and Scholes (1973).

Bibliographies

Abreu,D. & Brunnermeier, M. K. (2003). Bubbles and Crashes. Econometrica, 71(1), 173–204.

Alain, F. (2011). Le sentiment de marché : mesure et intérêt pour la gestion d'actifs. Thèse de doctorat, Université d'Auvergne - Clermont-Ferrand I.

Allen, F. & Gorton, G. (1993).Churning bubbles. Review of Economic Studies, 60, 813– 36.

An, B., Ang, A., Bali; T.G. & Cakici, N. (2014). The joint cross section of stocks and options. The Journal of Finance, 69, 2279-2337.

Ansi, A. & Ben Ouda, O. (2009). How option markets affect price discovery on the spot markets: a survey of the empirical literature and synthesis. International Journal of Business and Management, 4, 155–169.

Augustin, P., Menachem, B. & Marti, S. (2015). Informed options trading prior to M&A announcements: insider trading. Retrieved January 3, 2016 from http://ssrn.com/abstract=2441606.

Austin, M., Bates, G., Dempster, M., Leemans, V. & Williams, S. (2004). Adaptive systems for foreign exchange trading. Quantitative Finance, 4(4), 37-45.

Baker, M. & Stein, J. C. (2004). Market liquidity as a sentiment indicator. Journal of Financial Markets, 7(3), 271–299.

Baker, M. & Wurgler J. (2006). Investor sentiment and the cross-section of stock returns. The Journal of Finance, 61(4), 1645–1680.

Bali Turan, G., & Hovakimian, A. (2009). Volatility spreads and expected stock returns. Management Science 55, 1797–1812.

Bauer, R. (1994). Genetic Algorithms and Investment Strategies. John Wiley & Sons, Inc. New York, NY, USA.

Bauer, R., Cosemans, M., & Eichholtz, P. (2009). Option trading and individual investor performance. Journal of Banking and Finance, 33(4), 731–746.

Bellalah, M. & Jacquillat, B. (1995). Option valuation with information costs: Theory and Tests, The Financial Review, 30(3), 617–635.

Bellalah, M. & Mahfoudh, S. (2004, March). Option pricing under stochastic volatility with incomplete information, Wilmott Magazine, 50-58.

Bellalah, M. (2004). Options, Contrats à terme et Gestion des risques : Analyses, évaluation et stratégies, Edition Economica.

Ben Hamad, S. & Eleuch, H. (2008). Options Assessment and Risk Management in Presence of the Imperfections (delay effect). Journal of International Finance and Economics, 8(2), 77-95.

Ben Hamad, S. & Eleuch, H. (2008). Options Assessment and Risk Management in Presence of Dynamical Imperfections. China Review International, 2(2), 121-156.

Bessembinder, H. and P.J. Seguin, 1992. Futures-trading activities and stock price volatility, Journal of Finance, 47, 2015–2034.

Bessembinder, H. and P.J. Seguin, 1993. Price volatility, trading volume, and market depth: Evidence from futures markets, Journal of Financial and Quantitative Analysis, 28, 21–39.

Bick, A. (1987). On the consistency of the Black–Scholes model with a general equilibrium framework. Journal of Financial and Quantitative Analysis, 22(9), 59–276.

Black, F. (1975). Fact and Fantasy in the Use of Option. Financial Analysts Journal, 31 (4), 36 – 41.

Black, F., Derman, E. & Toy, W. (1990). A One-Factor Model of Interest Rates and Its Application to Treasury Bond Options. Financial Analysts Journal, 46(1), 33–39.

Black, F., Scholes, M. (1972). The valuation of Option Contracts and a test of Market Efficiency. Journal of Finance, 27(2), 399 – 417.

Black, F., Scholes, M. (1973). The pricing of Option and corporate Liabilities. The Journal of Political Economy, 81(3), 637-654.

Bohl, M. T., Reher, G., Wilfling, B. (2016). Short selling constraints and stock returns volatility: Empirical evidence from the German stock market. Economic Modelling, 58, 159-166.

Bollen, N.P.B. & Whaley, R. (2004). Does Net Buying Pressure Affect the Shape of Implied Volatility Functions?. Journal of Finance, LIX (2), 711-753

Brenner, M. & Galai, D. (1986). Implied Interest Rates. The Journal of Business, 59(3), 493-507.

Brenner, M., Subrahmanyam, M. G. & Uno, J. (1990). Arbitrage Opportunities in the Japanese Stock and Futures Markets. Financial Analyste Journal, 46 (2), 14-24.

Brown, G. W. & Cliff, M. T. (2004). Investor sentiment and the near-term stock market. Journal of Empirical Finance, 11(1), 1-27.

Brown, G. W. & Cliff, M. T. (2005). Investor sentiment and asset valuation. Journal of Business, 78 (2), 405-440.

Buraschi, A. & Jiltsov, A. (2006). Model Uncertainty and Options Markets with Heterogeneous Beliefs. The Journal of Finance, Cambridge, 61(6), 2841.

Canina, L. & Figlewski, S. (1993). The information content of implied volatility. The Review of Financial Studies, 6(3), 659–681.

Chan, L. & Lien, D. (2006). Are options redundant? Further evidence from currency futures markets. International Review of Financial Analysis, Greenwich: 15(2), 179-188.

Chan, L., Chi M. Nguyen, and Kam. Chan, 2015. A new approach to measure the impacts of excessive speculation and some policy implications, Energy Policy, 86, 133-141

Chan, L., Chi M. Nguyen, and Kam. Chan, 2018. Forecasting oil futures market volatility in a financialized world: Why speculative activities matter, North America Journal of Economics and Finance, https://doi.org/10.1016/j.najef.2018.10.009

Chan, W. (2003). Stock price reaction to news and no-news: drift and reversal after headlines. Journal of Financial Economics, 70(2), 223-260.

Christensen, B.J. & Prabhala,, N.R. (1998). The relation between implied and realized volatility. Journal of Financial Economics, 50(2), 125-150.

Cox, J. & Ross, S. (1976). The Valuation of Options for Alternative Stochastic Processes. Journal of Financial Economics, 3(1), 145-166.

Cremers, M. & Weinbaum, D. (2010). Deviations from Put-call Parity and Stock Return Predictability. Journal of Financial and Quantitative Analysis, 45(2), 335-367.

Daniel, K., Hirshleifer, D. & Teoh, S. H. (2002). Investor psychology in capital markets: evidence and policy implications. Journal of Monetary Economics, 49(1), 139–209.

De Long, J.B., Shleifer, A., Summers, L. H. & Waldmann, R.J. (1990.b). Positive Feedback Investment Strategies And Destabilizing Rational Speculation. Journal of Finance, 45(2), 374-3957.

De Long, J.B., Shleifer, A., Summers, L.H. & Waldmann, R. J. (1990.a). Noise trader risk in financial markets. Journal of Political Economy, 98(4), 703—738.

Duffie, D., Garleanu, N. & Pedersen, L. H. (2002). Securities lending, shorting, and pricing. Journal of Financial Economics, 66, 307–339.

Easley, D., O'Hara, M., & Srinivas, P. S. (1998). Option volume and stock prices: evidence on where informed traders trade. Journal of Finance, 53(2), 431–465.

Fama, E. F. (1991). Efficient Capital Markets: II. Journal of Finance, 46(5), 1575-1617.

Faria, G., & Correia-da-Silva, J. (2014). A closed-form solution for options with ambiguity about stochastic volatility. Review of Derivatives Research, 17(2), 125–159.

Feldhütter, P. & Lando, D. (2008). Decomposing Swap Spreads. Journal of Financial Economics, 88 (2), 375-405.

Feng, X. & Chan, K. C., (2016). Information advantage, short sales, and stock returns: Evidence from short selling reform in China. Economic Modelling, 59, Pages 131-142.

Frieder, L. & Subrahmanyam, A. (2004). Nonsecular regularities in returns and volume. Financial Analysts Journal, 60(4), 29-34.

Friedman, M. (1953). The case for flexible exchange rates. Essays in positive economics: University of Chicago Press.

Frijns, B., Lehnert, T. & Zwinkels, R. (2012). Sentiment Trades and Option Prices. Retrieved January 30, 2014, from https://ideas.repec.org/p/crf/wpaper/12-9.html.

Galai, D. (1977). Tests of Market Efficiency of the Chicago Board option Exchange. Journal of Business, 50(2), 167-97.

Goncalves-Pinto, L., Grundy, B. D., Hameed, A., Heijden, T. V. D. & Zhu, Y. (2016). Informed Trading in Options or Price Pressure in Stocks? Connecting the DOTS in Option-Based Return Predictability. Retrieved November 7, 2016, from http://bizfaculty.nus.edu/media_rp/publications/pk8co1448187766.pdf.

Govindaraj, S., Li, Y. & Zhao, C. (2015). The Effect of Option Transaction Costs on Informed Trading in the Option Market around Earnings Announcements. Retrieved August 21, 2015, from https://acfr.aut.ac.nz/__data/assets/pdf_file/0004/29731/562865-Y-Li-Transaction-Cost-Paper.pdf

Grossman, S. J. &. Stiglitz J. E (1980). On the impossibility of informationally efficient markets, American Economic Review, 70(3), 393-408.

Gu, H., Liang, J.R. & Zhang, Y.X. (2012). Time-changed geometric fractional Brownian motion and option pricing with transaction costs. Physica A: Statistical Mechanics and its Applications, 391(15), 3971–3977.

Guo, Z., & Yuan, H. (2014). Pricing European option under the time-changed mixed Brownian-fractional Brownian model. Physica A: Statistical Mechanics and its Applications, 406, 73-79.

Han, B. (2008). Investor Sentiment and Option Prices. The Review of Financial Studies. 21(1), 387-414.

Harrison, H., Scheinkman, J., & Xiong, W. (2006). Asset Float and Speculative Bubbles. Journal Of Finance, 61(3), 1073–1117.

Harrison, M. & Kreps, D. (1978). Speculative Investor Behavior in a Stock Market with Heterogeneous Expectations. Quarterly Journal of Economics, 42, 323–336.

Harvey, C. R. & Whaley, R. E. (1992). Dividends and S&P 100 index option valuation. Journal of Futures Markets, 12(2), 123–137.

Hong, H. & Stein, J. C. (1999). A unified theory of under reaction, momentum trading and overreaction in asset markets. Journal of Finance, 54(6), 2143–2184.

Hong, H., Lim T. &Stein, J. C. (2000). Bad news travels slowly: Size, analyst coverage and the profitability of momentum strategies. Journal of Finance, 55(1), 265–295.

Hull, J. (2008). Options, futures, and other derivative securities (7th ed.). Upper Saddle River, NJ: Pearson Prentice-Hall.

Jackwerth, J. C. & Rubinstein, M. (1996). Recovering probability distributions from option prices. The Journal of Finance, 51(5), 1611–1631.

Jackwerth, J. C. (2000). Recovering risk aversion from option prices and realized returns. The Review of Financial Studies, 13(2), 433–451.

Jensen, M. C. (1978). Some Anomalous Evidence Regarding Market Efficiency. Journal of Financial Economics, 6(2-3), 95-101.

Jin, W., Livnat, J.W. J. & Zhang, Y. (2012).Option Prices Leading Equity Prices: Do Option Traders Have an Information Advantage?. Journal of Accounting Research, 50(2), 401-432.

Jorion, P. (1995). Predicting Volatility in the Foreign Exchange Market. Journal Of Finance, 50(2), 507-528.

Kashefi Pour, E., (2016). Entering the public bond market during the financial crisis: Underinvestment and asymmetric information costs. Research in International Business and Finance, 39(A), 102-114.

Kirchler, M. (2009). Under reaction to fundamental information and asymmetry in mispricing between bullish and bearish markets. An experimental study. Journal of Economic Dynamics & Control, 33(2), 491–506.

Kumar, A., & Lee, C. (2006). Retail investor sentiment and return comovements. Journal of Finance, 61(5), 2451–2486.

Lawrence, E. R., McCake, G. & Prakash, A. J. (2007). Answering financial anomalies: Sentiment-based stock pricing. The Journal of Behavioral Finance, 8(3), 161–171.

Lee, C., Shleifer A. & Thaler, R. (1991). Investor sentiment and the closed end fund puzzle. Journal of Finance, 46(1), 75–109.

Leland, H. & Pyle, D. (1977). Informational asymmetries, financial structure, and financial intermediation. Journal of Finance, 32(2), 371-387.

Leland, H. E. (1985). Option pricing and replication with transaction Cost. Journal of Finance, 40(5), 1283 – 1301.

Lemmon, M. & Ni, S. X. (2008). The Effects of Investor Sentiment on Speculative Trading and Prices of Stock and Index Options. Retrieved Jun 21, 2013, from https://ssrn.com/abstract=1572427.

Lemmon, M. & Portniaguina, E. (2006). Consumer confidence and asset prices: Some empirical evidence. The Review of Financial Studies, 19(4), 1499–1529.

Lin C., Chou R. K. &Wang G. H.K. (2018). Investor sentiment and price discovery: Evidence from the pricing dynamics between the futures and spot markets. Journal of Banking & Finance, 90, 17-31.

Liu, J., Longstaff, F. & Mandell, R. (2006). The market price of risk in interest rate swaps: the roles of default and liquidity risks. Journal of Business, 79 (5), 2337–2359.

Longjin, L., Jianbin, X., Liangzhong, F. & Fuyao, R., (2016). Correlated continuous time random walk and option pricing. Physica A: Statistical Mechanics and its Applications, 447(C), 100-107.

Mahani, R. S. & Poteshman, A. M. (2008). Overreaction to stock market news and misevaluation of stock prices by unsophisticated investors: Evidence from the option market. Journal of Empirical Finance, 15(4), 635–655.

Merton, R. (1987). A Simple Model of Capital Market Equilibrium with Incomplete Information. Journal of Finance, 42(3), 483–510.

Naranjo, L. (2009). Implied Interest Rates in a Market with Frictions. Retrieved March 18, 2015, from https://ssrn.com/abstract=1308908.

Ofek, E., Richardson, M. & Whitelaw R. (2004). Limited arbitrage and short sales restrictions: Evidence from the options markets. Journal of Financial Economics, 74(2), 305-342.

Poteshman, A. & Serbin, V. (2003). Clearly irrational financial market behavior: Evidence from the early exercise of exchange traded stock options. Journal of Finance, 58(1), 37–70.

Poteshman, A. (2001). Underreaction overreaction and increasing misreaction to information in the options market. Journal of Finance, 56(3), 851–876.

Ramiah, V., Xu, X. & Moosa, I. A. (2015). Neoclassical finance, behavioral finance and noise traders: A review and assessment of the literature. International Review of Financial Analysis, 41, 89-100.

Ricardo, J. (2002). Lognormal option pricing for arbitrary underlying assets: A synthesis. The Quarterly Review of Economics and Finance, 42(3), 577–586.

Roll, R., Schwartz, E. & Subrahmanyam, A. (2010). O/S: The relative trading activity in options and stock. Journal of Financial Economics, 96(1), 1–17.

Scheinkman, J. & Xiong, W. (2003). Overconfidence and Speculative Bubbles. Journal of Political Economy, 111(6), 1183-1219.

Schmitz, P., Glaser, M., & Weber, M., (2009). Individual investor sentiment and stock returns – What do we learn from warrant traders?. Retrieved December 28, 2015, from https://ssrn.com/abstract=923526.

Sharpe, S. (2002). Reexaming Stock Valuation and Inflation: The Implication of Analysts Earnings Forecasts. Review of Economics and Statistics, 84(4), 632–48.

Sheu, H. J. & Wei, Y. C. (2011). Effective options trading strategies based on volatility forecasting recruiting investor sentiment. Expert Systems with Applications, 38(1), 585-596 ·

Stambaugh, R.F., Yu, J. & Yuan, Y. (2012). The short of it: Investor sentiment and anomalies. Journal of Financial Economics, 104(2), 288–302.

Sung, W. S. & Jun S. K. (2015).The information content of option-implied information for volatility forecasting with investor sentiment. Journal of Banking & Finance, 50, 106-120.

Sung, W. S. & Jun, S. K. (2015). The information content of option-implied information for volatility forecasting with investor sentiment. Journal of Banking & Finance, 50(C), 106-120

Swaminathan, B. & Lee, C. M. C., (2000). Do stock prices overreact to earnings news?. Retrieved September 13, 2015, from https://www.researchgate.net/publication/245966842.

Swaminathan, B. & Lee, C.M.C. (2000). Price momentum and trading. Journal of Finance, 55(5), 2017-2069.

Thaler, R. H. (1981). Some empirical evidence on dynamic inconsistency. Economics Letters, 8(3), 201–207.

Thirukumaran, N. & Koteswararao, M. (2009). Effects of Market Sentiment in Index Option Pricing: A Study of CNX Nifty Index Option. Retrieved September 13, 2015, from http://ssrn.com/abstract=1490758.

Wang, Y. H., Keswani, A. & Taylor, S. J. (2006). The relationships between sentiment, returns and volatility. International Journal of Forecasting, 22(1), 109-123.

Warner, T. & Pleeter, S. (2001). The personal discount rate: Evidence from military downsizing programs. American Economic Review, 91(1), 33–53.

Xing, Y., Zhang, X. & Zhao, R. (2010). What does the individual option volatility smirk tell us about future equity returns?, Journal of Financial and Quantitative Analysis, 45(3), 641–662.

Yang, C. & Zhang, R. (2013). Sentiment asset pricing model with consumption. Economic Modelling, 30, 462–467.

Yang, C., Gao, B. & Yang, J. (2016).Option pricing model with sentiment. Review of Derivatives Research, 19(2), 147–164.

Yang, F., Li, M., Huang, A. & Li, J. (2014). Forecasting time series with genetic programming based on least square method. Journal of Systems Science and Complexity, 27(1), 117-129.

Yigit, A. (2014).Volatility spreads and earnings announcement returns. Journal of Banking & Finance, 38, 205-215.

Yu, J. & Yuan, Y. (2011). Investor sentiment and the mean–variance relation. Journal of Financial Economics, 100(2), 367-381.