International Review of Accounting, Banking and Finance

Vol 15, No. 2, Summer, 2023, Pages 1-21

IRABF

Executive Stock Options, Investment Decisions, and Agency Costs

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Accepted July 2023

A B S T R A C T

If corporate executives are responsible for investment decision-making, their executive stock options (ESOs) payoffs shall be contingent on decision-making results. This study proposes a new valuation model for ESOs correlated with investment and financial decisions. Our findings suggest that their investment choices and financial policies determine corporate executives' payoffs generated from their holdings of ESO contracts. In particular, if a firm's executives are more responsible for their investment behavior, they receive more ESO payouts. Our mode reinforces corporate executives on behalf of shareholders' interests through ESO's payoffs directly connected with their attitude of responsibility for investment policies.

Keywords: agency cost, credit risk, executive stock options, investment risk

JEL classification codes: G11, G13, G30, G35

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1. Introduction

A firm's executives are responsible for managing corporate investment and financial affairs to create value for corporate shareholders and repay enough interest for debtholders. To inspire executives to make better efforts in their business, the firm issues executive stock options (ESOs) to the executives to promote their incentives of making efforts and taking risks. Most of the research has centered on the valuations and incentives effects of ESOs with various contract designs (e.g., Johnson and Tian 2000a, b; Brisley 2006). Although academics have developed well-done models of ESOs contingent on the stock price, it is worth noting that firm executives manage corporate affairs for the firm's investment and financing policies involving investment value and asset value, not directly correlated to the stock price. A firm's stock prices present themselves as reflecting the results of investment and financing policies.

In practice, the results of a firm executive's investment and financing decisions are identified to affect its capacity to pay out its outside liabilities, shareholders, and ESOs holders. Suppose the corporate executives are diligent in making their investment projects and financial management decisions with earnest efforts to make successful decisions; in that case, the ESO holders will likely gain more payoffs. Thus, we suggest that the valuations of ESO contracts should directly link to a firm's investment projects and financing policy, not only to a firm's stock price.

This study proposes a valuation model for executive stock options correlated to investment value and firm value generated from corporate executives' decision-making in financial and investment policies. If an executive fails in his investment or financial policies, ESO holders receive fewer payoffs upon maturity since the failure is more likely to pull down a firm's stock price. Thus, the payouts of ESOs are intimately connected with firm executives' performance of decision-making for their investment and financial policies. Precisely, a worse performance lowers the firm's asset values and stock prices, leading to few payoffs from ESOs.

This study discusses three main issues. First, we examine how ESO values vary with a firm's investment and financial policies. It is common knowledge that the values of ESO contracts are contingent on underlying stock prices. However, firms' stock prices are correlated to their values or performances of investment policies. An ESO with superior contract designs shall reflect the firm executives' investment performances. Second, we analyze how a firm's financial management affects ESOs' values by a firm's capacity to pay toward outside liabilities, inside salary compensation, and ESO payoffs. In addition, the firm's investment risk also potentially impacts the financial profitability and asset values. Third, we discuss the role of agency costs in pricing ESO contracts. The ESO holders may receive fewer stock option payoffs if they do not act with better responsibility for shareholders. The executives or ESO holders receive contract payoffs contingent on their results of how responsible they are in making those decisions, resulting in the agency cost. Consequently, the valuations of ESO contracts involve several issues regarding corporate executives' investment decisions, financial management, and responsible attitudes.

Many earlier studies have valued the executive stock option by considering various characteristics themselves. For instance, Johnson and Tian (2000b) developed the indexed ESOs to evaluate stock options values in which underlying stock price shall exceed a reference benchmark index. Brisley (2006) suggested a valuation of ESOs with a progressive performance vesting to allow issuing firms to be more efficient in rebalancing executives' risk-taking incentives. Brenner *et al.* (1999) examined a resetting in contract terms for previously-issued executive stock options. Pointedly, Johnson and Tian (2000a) compared and evaluated six nontraditional ESOs and examined executive incentive effects. Still, there is a lot of growing literature on the importance of valuations considering ESO contract' designs to satisfy certain practical characteristics.

Our study differs from the previous studies in three ways. First, we focus on how corporate executives' decisions regarding investment policy derive ESO values. Moreover, compared to stock prices and firm values, a firm's investment value is expected to affect the ESO values in our model. Our pricing models of ESOs encompass considerations of the firm values, investment value, and underlying stock price. Second, the study also offers how investment, default, and exercisable risks impact ESO values. Besides the investment decision, the executives' financial decisions change the firm's values and default risk. Third, the study also points out the agency problem's role in pricing ESOs, which includes the agency cost in our models. If firm executives are more responsible for their policy of investment in projects, they may be more likely to profit from the ESO contracts. Given our model, the agency problem is mitigated as firm executives hold ESO contracts. Although the literature on executive stock options valuation is plentiful, our study's issues are unique. Specifically, the study does not extend or improve one or some previous works that are directly correlated with ours; however, the study is reasonably developed by observing common facts in practice.

We examine, answer, or discuss specific issues using the research process. We first develop a pricing model of ESO contracts under credit risks, investment risks, and exercisable risks. For this task, in our study, ESO's value is contingent on three underlying asset stochastic dynamics: a firm's stock price, asset value, and investment value. Second, we examine premium characteristics by adjusting contract parameters and stock price features in a comparative state analysis. Third, the study analyzes how credit risk generated from the firm's asset value is insufficient to pay liabilities, salary payments, and option payoffs impacts ESOs values. Fourth, we specifically alter characteristics of investment projects to discuss the effects of a firm executive's investment decisions on the ESOs values. Fifth, the investment risk, credit risk, and agency cost are analyzed in our research. Finally, to see the robustness of results for our Monte Carlo simulation procedures, we offer an accuracy test for ESO values.

This study is composed of five parts. The following section provides brief reviews of studies in the literature. Our pricing model for ESO contracts is described in Section 3. Section 4 offers numerical evidence for analyzing price dynamics based on the abovementioned viewpoints. Section 5 concludes our study with a brief discussion.

2. Literature Review

Executive stock options are used to inspire corporate executives to be on behalf of shareholders' interests. Stock option holders, also corporate executives, expect to receive payoffs as a firm's stock price exceeds the strike price. Under some conditions, however, a firm's executives do not always receive payoffs in full, even if stock prices exceed the strike price upon maturity. Previous studies specifically focus on the firm's credit risk generated from inadequate firm asset values to pay ESO holders. Except for stock options' exercisable risk, a valuation of executive stock options involves whether option writers can pay (Klein 1996; Klein and Inglis 2001; Li and Zhang 2019; Niu *et al.* 2020; Kim *et al.* 2022).

To date, the literature on the valuation of executive stock option contracts has specifically focused on and discussed default risks and incentive effects (see Klein, 1996; Johnson and Stulz, 1987; Hull and White, 1995; Jarrow and Turnbull, 1995; Carpenter, 1998; Carr and Linetsky, 2000; Johnson and Tian, 2000; Klein and Inglis 2001; Colwell *et al*., 2005; Klein and Yang, 2010; Fard 2015; Lu *et al*., 2017; Klein 2018; Mazur and Salganik-Shoshan, 2019; Wang *et al*., 2022; Kim *et al*., 2022). For example, Johnson and Tian (2000a) analyze the value and incentive effects of ESOs and find a more substantial incentive effect for ESO contracts given various scenarios. Klein (1996) examines a default condition on option pricing in which option writers' outside liabilities lower the values of options. Colwell *et al.* (2015) and Kimura (2010) utilize various methods to value ESOs. Lu *et al*. (2017) propose a valuation model of ESOs and discuss incentive effects. They find that executives have incentives to promote ESO values by increasing their efforts or risk-taking. Klein (2018) develops a model for pricing ESO contracts with two sources of early exercise. Many studies have valued ESO contracts by employing various methods and considering multiple views, including default risk or incentive effects. Previous studies solving the question of ESO values have concerned stock prices and asset values, which involve ESO contracts' exercisable risk and credit risk, respectively.

More recent studies of executive stock options also involve more complicated designs in contracts or underlying assets' characteristics. Lu *et al*. (2023) develop an ESO valuation considering a positive relationship between the value of compensation contracts with the convex payoff and the firm's option-implied riskiness through second-order stochastic dominance.

To our best knowledge, the present study is one of the first research concerning how the executives' investment results influence their ESO payoffs. Specifically, ESO payoffs are correlated to the potential performances of investment value, asset value, and stock price; even some relevant researchers have examined ESO payoffs associated with asset value and stock price (e.g., Klein 1996).

3. Valuation Model

Our pricing model of executive stock options contracts considers stochastic processes for a firm's investment project, asset value, and stock price. We assume there is a representative firm for which the dynamic processes of investment value (I), firm value (V), and stock price (S) follow a three-variable geometric *Brownian* motion (*GBM*) process. We herein give some basic notation for the *GBM* items we shall deal with throughout this study, which are framed in a complete probability space (Ω,Θ,P) with natural filtration $\{\Theta_t, t \geqq 0\}$, as follows:

$$dI(t) = (r + \beta - \gamma)I(t)dt + \kappa I(t)dY(t) \tag{1}$$

$$dV(t) = (r + \mu - \delta)V(t)dt + \theta V(t)dZ(t) \tag{2}$$

and

$$dS(t) = (r + \alpha - q)S(t)dt + \sigma S(t)dW(t) \tag{3}$$

The stochastic processes Y, Z, and W follow the *Wiener processes*. The r denotes a risk-free rate of interest, the symbols β, μ, and α are the instantaneous excess growth rates, and κ, θ, and σ are the instantaneous return volatility rates of the investment value, firm value, and stock price, respectively. Along with this, γ denotes a loss percentage[1] on the investment value, δ represent continuous depreciation rates of asset value, and q is the dividend payout rate. In addition, the stochastic processes have their correlations, namely, E($dYdZ$) = ηdt, E($dYdW$) = πdt, and E($dWdZ$) = ρdt. In this sense, the level of the stock price is reciprocally correlated to the firm's asset value and investment value. Under a real-world $\mathbb{P}$-measure[2], by using *Ito*'s lemma, the logarithms of three underlying assets for the contracts can be written as:

$$lnV(T) = lnV(t) + \left(r + \mu - \delta - \frac{\theta^2}{2}\right)dt + \theta dZ^{\mathbb{P}}(T) \tag{4}$$

[1] The loss percentage (γ) expresses a continuous decay in investment values, throughout the process of investing. As a similar meaning in asset values and stock prices, a firm's asset value may be depreciated over time and a firm's stock price may decline due to the dividend payouts.

[2] Refer to Joshi (2005), in Chapter 6.

$$lnS(T) = lnS(t) + \left(r + \alpha - q - \frac{\sigma^2}{2}\right)dt + \sigma dW^{\mathbb{P}}(T) \quad (5)$$

$$lnI(T) = lnI(t) + \left(r + \beta - \gamma - \frac{\kappa^2}{2}\right)dt + \kappa dY^{\mathbb{P}}(T) \quad (6)$$

The preliminary assumptions are consistent with the previous works of Black and Scholes (1973), Johnson and Stulz (1987), Klein (1996), Klein and Inglis (2001), and Lu *et al.* (2013). The stock option is assumed to be the style of a European call option for clearly capturing the main features of our theoretical results. The ESO value (*C*) is calculated by stock option holders' possible payoffs from the ESO writers. Pointedly, an ESO contract's values are contingent on the firm's stock price (*S*), asset value (*V*), and investment value (*I*), where ESO holders suffer from exercisable risk, credit risk, and investment risk. The exercisable risk denotes a stock option's possibility to be exercised when the underlying stock is over the strike price (*K*). The credit risks reflect whether the firm's financial asset value is adequate to be distributed among debt holders, employees, and option holders. The investment risk reflects an executive's performance in investment projects.

On the expiry *T*, the ESO holder may receive payoffs of $S_T - K$, depending on whether the stock price is over the strike price, the firm's asset value is over the financial liabilities, and the investment value is over its investment installation cost (*H*). The ESO holder receives fewer payoffs upon maturity (*T*) if the firm asset value is inadequate to make payments to outside bondholders, the firm's employees, and option holders, reflecting an executive's decision-making of financial asset management. In detail, debt holders and employees prioritize executives regarding the firm's asset values. In this fashion, ESO holders have a credit risk generated from the ESO writer's ability to pay out of payoffs. In addition, for the investment risk, the executives shall be responsible for their investment projects. As a project does not generate adequate value for the firm, the executives undertake possible costs for the investment project they have decided upon and implemented. The executives lose ESO's payoffs depending on their degrees of responsibility for the investment project. Considering credit risk, investment risk, and exercisable risk, we express the ESO value (*C*) at time *T* is outlined as follows:

$$C_T = \begin{cases} S_T - K, \; if \;\; S_T \geq K, V_T \geq B + mV_T + S_T - K, I_T \geq H \\ (1-f)(S_T - K), \; if \;\; S_T \geq K, V_T \geq B + mV_T + S_T - K, I_T < H \\ (S_T - K)\frac{(1-e)(V_T - B - mV_T)}{S_T - K + B + mV_T}, if \;\; S_T \geq K, V_T < B + mV_T + S_T - K, I_T \geq H \\ (1-f)(S_T - K)\frac{(1-e)(V_T - B - mV_T)}{S_T - K + B + mV_T}, if \;\; S_T \geq K, V_T < B + mV_T + S_T - K, I_T < H \\ 0, \; otherwise \end{cases} \quad (7)$$

the symbol *H* denotes a constant installation cost of the investment project, and the symbol *B* denotes a fixed face value of the firm's outside debt (see Klein 1996; Johnson and Stulz 1987; Lu *et al.* 2017). A symbol *e* is a deadweight cost rate when a firm fails to pay total payoffs to ESOs holders due to the occurrence of the firm's credit risk. A symbol *f* is an agency cost rate generated from an investment plan's failure, in which a firm's executives are required to be responsible for the investment plan if the terminal investment value is not over the installation cost (*H*). A greater value *f* means that executives are required to be more responsible for their investment decision, meaning that the agency cost is higher. A symbol *m* represents a percentage of salary cost over the asset values, which the salary is paid to the firm's employees. In detail, for a simplified setting, a firm with a greater scale is susceptible to paying more for firm employees, so we assume that salary payment positively correlates to the firm asset value. An executive's ability to make financial decisions is reflected in salary management and outside liability payments to let the firm be free of credit risk.

In equation (7), the determination of ESO values is based on which of five possible results appears. The first line of this equation witnesses an expected outcome of payoffs ($S_T - K$) for the ESO options on the stock prices, where the stock price is over the strike price, the firm's asset value is sufficient to pay the employees, bondholders, and option holders, and the investment value is over its installation cost. That is, the executive stock option is exercisable, with no financial defaults and no investment failures. In the second line, the ESO holders, i.e., the executives, receive a portion of the total payoff when their investment projects fail to create value for the firm, even though the stock option is still exercisable and the firm's asset value is adequate. The executives are responsible for their decision failure in the investment plan and thus receive fewer payouts due to agency costs with a percentage f from the total payouts $S_T- K$. In the third line, the option writer does not fully pay off the option holders because the firm's asset value is lower, and the firm must make its promised debt payouts and pay the salaries of its employees. A firm fails in its financial management, resulting in the financial default to paying total payoffs, even if the stock price is over the strike price and the investment value is over its installation cost. Peculiarly, the ESO holders receive a portion of the net firm value (i.e., $(1- e)(V - B - mV)$) concerning the total amount of necessary liabilities (i.e., $S - K + B + mV$). Here, the dividend payouts are not considered in the total promised required payments before the firm pays external debts, stock option payoffs, and salary payments. In the fourth line, the ESO holder receives an even lesser portion of the total payoffs as the firm fails in its investment plan and fails to pay the necessary liabilities. In other words, corporate executives' payoffs are deducted from the agency cost of the investment failure and the deadweight loss of the firm's default. In the fifth line equation (7), stock option holders receive nothing since the ESO contract is not exercisable.

Accordingly, under this setting, the valuation of executive stock options involves the stock option's exercisable risk, the firm asset's credit risk, and the investment risk. The executives, i.e., the holders of executive stock options, are responsible for their investment plans succeeding and ensuring their financial assets avoid defaulting.

It is difficult to derive the value (C_t) of ESOs with exercisable, credit, and investment risk[3], so we utilize the *Monte Carlo* simulation method to find its numerical solutions. In this process of calculating, the ESO is valued in a risk-neutral world, in which the risk-free interest rate is used to discount the expected terminal payoff (7) of ESO options. The Cholesky decomposition technique is utilized in considering three correlated random sequences. To calculate stock options prices more correctly, we simulate 1,000,000 forecasts (N = 1,000,000) and average them for each ESO value.

Under these settings, the executive stock option value is determined by a firm's stock price, asset value, and investment value, in which the option holder suffers from the exercisable risk, credit risk, and investment risk. Moreover, the firm's investment project characteristics potentially affect the ESO values. This model reveals how the investment choices of the return volatility (κ) and loss percentage rate (γ) affect the ESO valuation. In addition, a firm's financial policies also have considerable impacts on ESO valuations. Regarding financial policies[4], the stock option payoffs may be changed by employee salaries, dividend payouts, and debt financing. Regarding an agency problem, the agency cost rate (f) reflects the degree to which a firm's executive would like to be on behalf of shareholders' interests in the investment decision-

[3] The terminal payoff (C) of executive stock options has no closed-form solutions, referring to the works of Klein and Inglis (2001), in the second paragraph of page 1000.

[4] Although the parameter (q) of dividend policy does not appear in the ESO formula (C_t), it shifts the ESO values by a firm's stock price (S), as noted in equation (3).

making process. A greater rate (f) of agency cost means a bigger agency problem, deriving greater punishments for corporate executives.

We examine and discuss the following issues using a Monte Carlo simulation method, in which we change the parameters of stock price, asset value, investment value, and contract designs to examine the changes in ESO values. First, this study analyzes how the stock option's values (C_t) change with its underlying: stock price (S_t), firm asset value (V_t), and investment project value (I_t). Second, this study evaluates the role of choices of investment policy and financial management on ESO values. Third, we examine how the investment, credit, and exercisable risks change the ESO values. Fourth, this study also discusses how a degree of agency problem impacts ESO values. Finally, the accuracy of results for the ESO values is evaluated, in which the mean, standard deviation, confidence intervals, and t–statistics are calculated and analyzed by running a series of results simulations.

4. Numerical Calibration

This subsection examines, analyzes, and evaluates executive stock options' values using several numerical calibrations. We concern ourselves with how investment policy, financial management, and agency cost change the ESOs' values since the ESO's terminal payouts directly correlate to the executives' decision-making results under our model's circumstances. The baseline example of numerical analysis has the following settings of parameters. The investment project's initial value (I_t) is assumed to be \$1,000. The firm asset's initial value (V_t) is considered \$5,000. The initial stock price (S_t) and strike price (K) are \$100. The stock price's excess growth rate (α) and return volatility (σ) are assumed to be 2% and 30%, respectively. The investment's installation cost (H) is \$1,000, its excess growth rate (β) is 3%, its value loss rate (γ) is 1%, and return volatility (κ) is 20%. The firm has liabilities with a face value (B) of \$4,500. The firm's asset value has an excess growth rate (μ) of 2%, a depreciation rate (δ) of 1%, and a return volatility (θ) of 10%. The underlying stock has an excess growth rate (α) of 2%, a dividend yield rate (q) of 1%, and a return volatility (σ) of 30%. As well as the firm's salary percentage (m) is 20%. A risk-free interest rate (r) is assumed as 1%. The time to maturity (T–t) for debt and stock options is one year. Next, the coefficient (η) of correlation for investment value and investment value is set as 0.2; the coefficient (ρ) of correlation for the firm value and stock price is 0.3; and the coefficient (π) of correlation for investment value and stock price is assumed to be 0.4. A deadweight cost rate (e) and an agency cost rate (f) are considered to be 10%. In the *Monte Carlo* simulation procedure, the time step (n) is 12, and the simulation number (N) is 100,000. The setting of parameters is consistent with previous ESO studies in the financial literature, such as the ones by Klein (1996), Johnson and Stulz (1987), and Lu *et al.* (201). Our numerical results are generated using MATLAB software in the R2022a version.

4.1 Executive stock options values

Executive stock options' values vary with underlying stock characteristics and contract designs. We first demonstrate the ESO values' changes over time to maturity (T-t), the strike price (K), return volatility (σ) of stock price, and the excess growth rate (α) of stock price, presenting them in Table 1 and summarizing the main findings as follows. First, as the ESO contract's strike price (K) gradually rises, the price (C_t) tends to be lower, given the time-to-expiry ($\tau = T$–t), as you can see in Panel A of Table 1. A higher strike price causes a lower possibility of exercising the contract. Second, the ESO value is greater if the stock price's return volatility (σ) increases (Panel B). It means that executives gain from the stock's high risks. Third, the numerical evidence reveals that stock option contracts with a higher excess growth rate (α) of underlying stock are valuable (Panel C). Fourth, the ESO contract with a long life (T–t) is more valuable. Figure 1 also shows similar results as Table 1. In Panel A of Figure 1, the value positively correlates with the stock price and the time-to-maturity. In Panel B, we also discover that the return volatility positively impacts ESO values.

To sum up, even though an executive stock options contract is correlated to a firm's credit risks, exercisable risks, and investment risks, a more complicated content in the agreements, the elementary characteristics of options values remain similar to those of the valuations of plain vanilla call options without credit risk and investment risk. The trends in an ESO contract's values concerning its contract factors (K and $T–t$) and underlying stock price (S, α, and σ) are alike as the changes for plain vanilla call options.

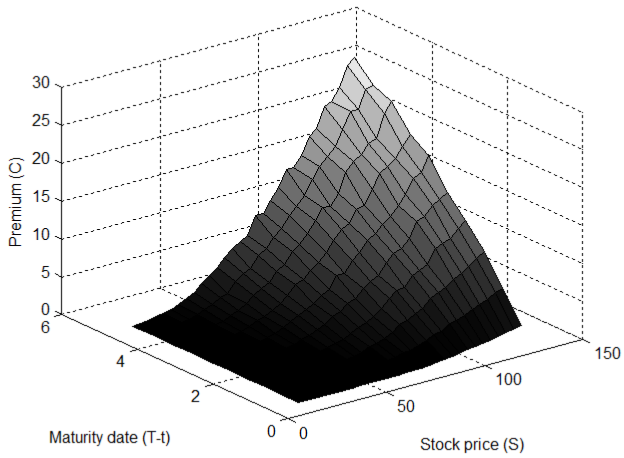
Table 1. Executive Stock Option Values

	Panel A: Exercise price (K)				
Time ($\tau = T–t$)	\$80	\$90	\$100	\$110	\$120
0.5	\$1.7626	1.2182	0.8711	0.5354	0.3331
1.0	5.0795	3.9804	2.9441	2.3040	1.6668
1.5	7.7440	6.3805	4.8160	4.4699	2.9606
	Panel B: Return volatility (σ)				
	5%	10%	15%	20%	25%
0.5	0.1874	0.3581	0.4977	0.6423	0.8415
1.0	0.7264	1.1697	1.6259	2.2175	2.5540
1.5	1.2709	2.0251	2.8378	3.7594	4.3740
	Panel C: Excess growth rate (α) of stock price				
	0%	2%	4%	6%	8%
0.5	0.8439	0.9038	0.9728	0.9882	0.9838
1.0	2.9672	3.0785	3.2460	3.3828	3.7566
1.5	4.2995	5.3496	5.7149	5.7020	6.9226

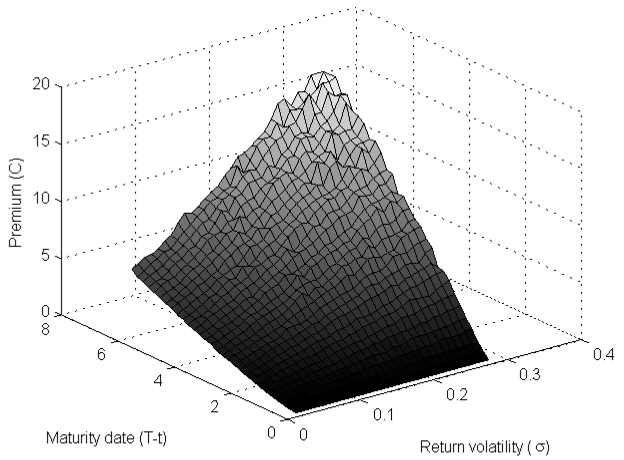
The table reports executive stock options values varying with stock price's feature (α and σ) and contract design (K and T). Parameters are given as follows: initial value of investment project of I_t = \$1,000, investment's installation cost of H = \$1,000, excess growth rate of investment project value of β = 3%, loss rate of investment value of γ = 1%, return volatility of investment project of κ = 20%, firm asset value of V_t = \$5,000, firm debt threshold of B = \$4,500, excess growth rate of asset value of μ = 2%, depreciation rate of firm asset value of δ = 1%, return volatility of firm value of θ = 10%, initial stock price of S_t = \$100, strike price of K = \$100, stock excess growth rate of α = 2%, dividend yield rate of q = 1%, return volatility of stock price of σ = 30%, salary percentage of m = 20%, risk-free interest rate of r = 1%, time to maturity of $T–t$ = 1 year, coefficient of correlation for investment value and investment value of η = 0.2, coefficient of correlation for firm value and stock price of ρ = 0.3, coefficient of correlation for investment value and stock price of π = 0.4, deadweight cost rate of e = 10%, agency cost percentage of f = 10%, time steps of n = 12, and simulation numbers of N = 100,000.

4.2 Investment value, asset value, and ESO values

In a superior design of executive stock options contracts, the ESO holders' payoffs shall directly reflect the firm executives' performances of the investment plan and a level of asset value. This study thus examines how stock options values correlate with a firm's investment and asset values. In Table 2, we change the ranges of the initial investment value from \$500 to \$2,500, the content of the asset value from \$3,500 to \$5,500, and the stock price range from \$80 to \$120, to evaluate the changes in ESO values.



Panel A: Varying with stock prices



Panel B: Varying with return volatilities

Figure 1. Stock Option Values

The figure displays executive stock options values varying with the stock price, volatility rate, and time to maturity. The initial values of the parameters are given in Table 1.

As mentioned in the above descriptions, ESO values (C_t) rise with the underlying stock price, given both investment and asset values. Next, the firm's asset values also positively affect the ESO values. For example, given a low initial investment value (I_t = \$500) and a low initial stock price (S_t = \$80), as the initial firm asset value (V_t) gradually varies from \$3,500 to \$5,500, the ESO value changes from \$0.0000 to 2.2082 sequentially, with a growth trend, as indicated in the upper-left corner of Table 2. We also discover a growth trend of ESO values over the investment value (I_t). Given both stock price and asset value, the ESO values correlate positively to a firm's investment values, meaning that the ESO is more valuable if the initial investment's value is more remarkable.

Table 2. ESO Values, Investment Value, Asset Value, and Stock Price

Investment value (I_t)	Asset value (V_t)	Stock price (S_t) $80	$90	$100	$110	$120
$500	$3500	$0.0000	0.0000	0.0000	0.0000	0.0000
	$4000	0.0059	0.0202	0.0009	0.0131	0.0168
	$4500	0.1911	0.3224	0.4600	0.5445	0.5689
	$5000	1.0498	1.7909	2.8081	3.8699	5.0111
	$5500	2.2082	4.2742	7.0516	10.3133	13.2906
$1000	$3500	0.0000	0.0000	0.0000	0.0000	0.0000
	$4000	0.0054	0.0067	0.0278	0.0099	0.0120
	$4500	0.1778	0.3281	0.4017	0.5937	0.7140
	$5000	1.0565	1.9080	2.5976	3.9363	5.5564
	$5500	2.3782	4.6743	7.8150	10.8900	14.8735
$1500	$3500	0.0000	0.0000	0.0000	0.0000	0.0000
	$4000	0.0073	0.0135	0.0014	0.0241	0.0247
	$4500	0.2391	0.3177	0.4812	0.5759	0.7902
	$5000	1.0255	2.1856	2.9627	4.5012	5.4664
	$5500	2.5439	4.9826	7.8244	11.7019	15.0847
$2000	$3500	0.0000	0.0000	0.0000	0.0000	0.0000
	$4000	0.0061	0.0177	0.0036	0.0152	0.0503
	$4500	0.2190	0.2701	0.4709	0.6059	0.8204
	$5000	1.1136	1.9851	3.0301	4.2442	5.4405
	$5500	2.6301	4.8349	8.0404	11.6584	15.1892
$2500	$3500	0.0000	0.0000	0.0000	0.0000	0.0000
	$4000	0.0088	0.0123	0.0135	0.0081	0.0200
	$4500	0.1965	0.3199	0.4679	0.7175	0.7773
	$5000	1.2070	1.9398	3.0200	4.2282	5.8722
	$5500	2.6208	5.0370	7.7781	11.0095	15.0198

The table reports stock options values varying with investment, firm asset, and stock price. The initial values of the parameters are given in Table 1.

The results support that a higher value of investment projects, or a prosperous firm with presumably sound financial management with a greater value of a firm asset, tends to guarantee a benefit for the ESO contracts. These findings suggest that ESO holders are beneficial from issuers with a larger investment value and a larger asset value. The reason is that the investment project is more likely to succeed, and the asset value is more likely to be adequate to pay for a firm's stakeholders, as a firm's investment value and asset value are larger.

This numerical evidence is based on the analysis based on positive correlations between stock price, asset value, and project value. The positive correlations are appropriate for these values and stock price since executive stock options' three underlying assets (i.e., I, V, and S) shall move together with the same trends.

4.3 Investment policy and stock options values

We discuss a firm's investment policy's impacts on ESO values. Table 3 indicates that relevant factors of investment policy slightly affect the values. As shown in Panel A, as the firm chooses an investment project with a higher excess growth rate (β), the ESO value (C_t) runs to be greater. Although the variance of option values is also slight, seen as an overall trend, the ESO values still perform an increasing path with investment value volatility (κ) (Panel B). Firm executives' investment policy choices can influence ESO contracts' values. An investment project with a greater return growth rate or greater volatility rate of project value is more likely to generate considerable interest for the ESO holders. In Panel C, we find that an investment project's lower installation cost (H) has a greater possibility of promoting ESO values (C_t). The ESO holders receive more payoffs from the option writers since their performances in the investment project are inclined to be better as an investment project's installation cost is lower. Finally, numerical evidence shows that the ESO values drop with the investment project's loss percentage rate (γ) in Panel D). As corporate executives carry out a project with a higher loss percentage in investment values, the ESO values may decline.

Based on these results, a firm's decisions regarding investment projects determine the valuation of ESO contracts. Concretely, as executives prefer to oversee investment projects with a higher growth rate, higher volatility rate, lower installation cost, or lower loss cost percentage, ESO contracts have a tendency to be priced at a higher premium.

Table 3. Investment Policy and Stock Options Values

	Panel A: Project excess growth rate (β)				
Time ($\tau = T–t$)	1%	2%	3%	4%	5%
0.5	\$0.9096	0.9161	0.9341	0.9137	0.9175
1.0	3.0696	2.9990	2.9921	2.9826	3.0862
1.5	5.1510	5.1281	5.2234	5.2014	5.3046
	Panel B: Project volatility (κ)				
	5%	10%	15%	20%	25%
0.5	0.8818	0.9088	0.9041	0.9149	0.9265
1.0	3.1943	3.0217	3.4820	3.3624	3.3655
1.5	5.2438	5.2331	5.3937	5.2825	5.3682
	Panel C: Project installation cost (H)				
	\$1000	\$2000	\$3000	\$4000	\$5000
0.5	0.8468	0.7726	0.7404	0.7671	0.6889
1.0	2.7660	2.7874	2.6661	2.5641	2.5960
1.5	5.1049	4.7599	4.6468	4.5386	4.2209
	Panel D: Project loss rate (γ)				
	0.2%	0.4%	0.6%	0.8%	1.0%
0.5	1.8159	1.7101	1.5463	1.2015	1.2310
1.0	3.5637	3.4685	3.2533	3.0671	3.0873
1.5	7.4530	6.2208	5.9587	4.6839	4.3951

The table reports stock options values varying with a firm investment project's factors. The initial values of the parameters are given in Table 1.

4.4 Financial management and ESO values

We further examine how a firm's financial management changes the ESO's prices. Varying with the parameters of financial policies, we discover that stock option values change, as listed in our results in Table 4. First, the excess growth rates (μ) of firm asset values positively impact the ESO values (Panel A), suggesting that firm executives are recommended to hold those assets with a higher growth rate; having a high-growth asset is beneficial for ESO holders. Second, higher asset value volatilities also create higher ESO values (C_t) (Panel B). Simply put, firm executives are encouraged to put more capital into those assets with a higher risk. To promote the values of ESO contracts, executives may adopt high-risk and high-growth policies in their capital budgeting process. Third, a firm's outside liabilities have hurt the ESO values (Panel C), supporting conservative financing management for corporate executives in debt financing. A more incredible amount (B) of outside liabilities tends to destroy ESO values. Fourth, the asset value's depreciation rate (δ) weakens ESO values (Panel D). Fifth, as that of a plain vanilla call option, the dividend policy (q) tends to lower the ESO values (Panel E). Even though the dividend payout rate does not appear in the valuation model of ESO contracts, it changes the ESO values by depressing the stock price. Sixth, the ESO value (C) negatively correlates with the salary rate (m). The ESO values are lower as firms expand their salary payments to employees.

Table 4. Financial Management and Stock Options Values

	Panel A: Excess growth rate (μ) of firm asset value				
Time ($\tau = T–t$)	1%	2%	3%	4%	5%
0.5	$0.8159	0.9101	1.0463	1.2015	1.2910
1.0	2.5637	3.0685	3.5533	3.8671	4.3873
1.5	4.4530	5.2208	5.9587	6.6839	7.3951
	Panel B: Return volatility (θ) of firm asset value				
	5%	10%	15%	20%	25%
0.5	0.0152	0.8831	2.0138	2.7485	3.2627
1.0	0.5108	2.9549	4.3984	5.2849	5.6367
1.5	1.6611	5.2063	6.5202	7.2413	7.5215
	Panel C: Firm face value (B) of debt financing				
	$4000	$5000	$6000	$7000	$8000
0.5	5.8451	0.0209	0.0000	0.0000	0.0000
1.0	8.6923	0.4649	0.0013	0.0000	0.0000
1.5	11.0892	1.4771	0.0360	0.0000	0.0000
	Panel D: Firm value depreciation (δ)				
	0.2%	0.4%	0.6%	0.8%	1.0%
0.5	0.8121	0.6092	0.4670	0.3430	0.2552
1.0	2.6575	1.9559	1.4077	0.9575	0.6600
1.5	4.5846	3.1918	2.1700	1.4181	0.9136
	Panel E: Firm dividend policy (q)				
	1%	2%	3%	4%	5%
0.5	0.9190	0.8988	0.8398	0.8254	0.8340
1.0	3.0408	2.9060	2.8558	2.6899	2.5782
1.5	5.1662	4.9499	4.7117	4.3328	4.1935
	Panel F: Salary policy (m)				
	0%	5%	10%	15%	20%
0.5	8.4585	7.7347	5.8997	3.1209	0.9100
1.0	11.7766	10.7509	8.7175	5.8500	3.0215
1.5	14.4513	13.1321	10.9396	8.1952	5.1606

The table reports how a firm’s financial management changes the ESO values. The initial values of the parameters are given in Table 1.

In sum, a firm’s financial management can affect the valuation of ESOs. The results of how stock option holders, the firm’s executives, manage their financial affairs can be reflected in the values of ESO contracts.

4.5 Credit risk, investment risk, exercisable risk, and ESO values

We examine how credit, investment, and exercisable risks change ESO values and list numerical results in Table 5. To measure the relative degree of risks, we adopt the option moneyness at stock price (S_t/K) to represent an exercisable risk, the option moneyness (I_t/H) at investment value to represent an investment risk, and option moneyness (V_t/B) at asset value to represent a credit risk. A lower value of S_t/K, I_t/H, or V_t/B means that the exercisable, investment, or credit risks are relatively higher for corporate executives, respectively. Thus, a firm with lower values of I_t/H shows that they shoulder a greater risk of failure as executives invest in the projects; a firm with lower values of V_t/B tends to have a greater risk of defaulting on its debt repayments.

Table 5. Risks and ESO Values

Investment Risk	Credit Risk	Exercisable Risk $S_t/K = 0.8$	$S_t/K = 1.0$	$S_t/K = 1.2$
High ($I_t/H = 0.8$)	High ($V_t/B = 0.8$)	0.0000	0.0000	0.0000
	Mid ($V_t/B = 1.0$)	0.1885	0.3900	0.6389
	Low ($V_t/B = 1.2$)	2.2715	6.3949	12.1120
Mid ($I_t/H = 1.0$)	High ($V_t/B = 0.8$)	0.0000	0.0000	0.0000
	Mid ($V_t/B = 1.0$)	0.2144	0.4770	0.7717
	Low ($V_t/B = 1.2$)	2.2419	6.5626	13.2359
Low ($I_t/H = 1.2$)	High ($V_t/B = 0.8$)	0.0000	0.0000	0.0000
	Mid ($V_t/B = 1.0$)	0.1983	0.4529	0.7805
	Low ($V_t/B = 1.2$)	2.3447	6.7996	14.0458

The table reports ESOs' values varying with a firm's investment, exercisable, and credit risk, expressed in three moneyness. The initial values of the parameters are given in Table 1.

The ESO values run to be greater as firms have lower investment risks. Although some random errors disturb our numerical results in *Monte Carlo* simulations, ESO values (C_t) are inclined to display a consistent tendency in their variance trends. Given the credit and exercisable risks, ESO values rise with the moneyness I_t/H level. As you can see in Table 5, for example, as the option moneyness at asset value is kept in-the-money level ($V_t/B = 1.2$) and the option moneyness at stock price is kept in-the-money ($S_t/K = 1.2$), the option values expand from \$12.1120 to \$14.0458 if the I_t/H level rises from 0.8 to 1.2, i.e., the investment risk decreases.

Besides, higher credit risk is prone to cause low ESO values. The values (C_t) gradually increase from \$0.0000, \$0.1885, to \$2.2715 as the credit risk subsides from a high, mid, and low level, given the values of investment risk and exercisable risk. We have also found the same results in other examples, as indicated in Table 5. Next, our numerical evidence shows that firm executives holding ESO contracts gain from their low investment risk and credit risk policies. If firm CEOs are conservative toward investment projects and debt financing, they benefit from increased ESO values.

Concretely, to explore how credit risk changes the ESO values, we evaluate the option values in various models: our study, the Johnson and Stulz (1987) type model, and the Black and Scholes (1973) type model[5]. Framing in our model of ESO contracts, the coefficients (π and η) of correlation are set to be zero. The ESO value generated from Johnson and Stulz's type model is created, in which stock price and asset value are not correlated to the firm's investment value. For the Black and Scholes model, the correlations' coefficients (π, ρ, and η) are assumed to be zero in our model. Put, neither investment nor asset value affects the stock price, nor do they affect each other.

We summarize the main results, which are listed in Table 6, as follows. First, the credit risk's degree represented in V_t/B in three models depresses three ESO values. A lower value of V_t/B, which means firms have a high possibility of defaulting to pay payoffs for ESO contracts on expiry, brings about a lower premium (C_t). Second, the ESO values tend to be greater, with

[5] Johnson and Stulz type model and Black and Scholes type model are not the same as the original Johnson and Stulz (1987) and Black and Scholes (1973) model since some factors of asset value and investment value still affect the stock options values. However, in our study, the Johnson and Stulz type model is free of investment risk and the Black and Scholes type model is free of investment risk and credit risk.

more risk sources appearing in valuation models. While this is so, the option values of ESO contracts framed in the Black and Scholes type model are susceptible to be lower than those of the other two models. The results imply that ESOs are undervalued if we ignore the firm's investment project and asset value risks. Third, the effect of credit risk is weakened as we ignore the firm's asset values and investment projects. The rate of changes for option values is more prominent for the evident valuations model. The percentage of changes for executive option values is less pronounced for the Black and Scholes type model.

Table 6. Credit Risk and ESO Pricing Models

	Credit risk	Premium		
		This study	Johnson and Stulz type	Black and Scholes type
$S_t/K = 0.9$	$V_t/B = 0.9$	\$0.0401	0.0347	0.0035
	$V_t/B = 1.0$	0.3497	0.2759	0.1514
	$V_t/B = 1.1$	1.6679	1.6176	0.9332
	$V_t/B = 1.2$	3.8919	3.2645	2.8593
$S_t/K = 1.0$	$V_t/B = 0.9$	0.0396	0.0373	0.0180
	$V_t/B = 1.0$	0.4847	0.4379	0.1844
	$V_t/B = 1.1$	2.5740	2.4652	1.3704
	$V_t/B = 1.2$	6.8276	6.7437	4.5659
$S_t/K = 1.1$	$V_t/B = 0.9$	0.0324	0.0509	0.0410
	$V_t/B = 1.0$	0.6188	0.6101	0.3201
	$V_t/B = 1.1$	3.5647	3.5483	2.2842
	$V_t/B = 1.2$	9.4596	9.2286	6.5686

The table reports three stock option values varying with credit and exercisable risks. Parameters are given as follows: initial value of investment project of I_t = \$1,000, investment's installation cost of H = \$1,000, excess growth rate of investment project value of β = 3%, loss rate of investment value of γ = 1%, return volatility of investment project of κ = 20%, firm asset value of V_t = \$5,000, firm debt threshold of B = \$4,500, excess growth rate of asset value of μ = 2%, depreciation rate of firm asset value of δ = 1%, return volatility of firm value of θ = 10%, initial stock price of S_t = \$100, strike price of K = \$100, stock excess growth rate of α = 2%, dividend yield rate of q = 1%, return volatility of stock price of σ = 30%, salary percentage of m = 20%, risk-free interest rate of r = 1%, time to maturity of $T–t$ = 1 year, coefficient of correlation for investment value and investment value of η = 0.2, coefficient of correlation for firm value and stock price of ρ = 0.3, coefficient of correlation for investment value and stock price of π = 0.4, deadweight cost rate of e = 10%, agency cost rate of f = 10%, time steps of n = 12, and simulation numbers of N = 100,000.

4.6 Agency cost and ESO contract

Firm CEOs, who are also the holders of ESO contracts, have a duty to diligently and scrupulously choose, implement, and oversee investment projects. We adopt the agency cost (f) to reflect the degree of corporate executives' responsibility for these investment projects, where a greater cost represents a greater punishment for corporate executives with less responsibility regarding investment projects. These results are outlined in Table 7 and Figure 2. Our evidence witnesses that as the agency cost increases, the ESO values are lower. In Table 7, the values (C_t) decrease with the agency cost (f), given a deadweight cost (e). That means the executives receive more ESO payoffs if they want to be responsible for corporate investment plans.

Table 7. ESO Values and Agency Cost

Deadweight cost (*e*)	Agency cost (*f*)	Premium
0.00	0.00	$3.3628
	0.25	2.8476
	0.50	2.3336
	0.75	1.8790
	1.00	1.6219
0.10	0.00	3.2611
	0.25	2.8299
	0.50	2.2110
	0.75	1.8411
	1.00	1.4994
0.20	0.00	3.1512
	0.25	2.7609
	0.50	2.1599
	0.75	1.8451
	1.00	1.4959
0.30	0.00	3.0796
	0.25	2.7671
	0.50	2.1476
	0.75	1.7822
	1.00	1.3677

The table reports ESOs' values varying with agency cost and deadweight loss rate. The initial values of the parameters are given in Table 1.

Along with this, the deadweight cost also lowers the stock option values. As a firm defaults on the ESO contract, a higher deadweight loss reduces ESO values (C_t). Figure 2 displays the dynamics of the executive's stock option values over both agency cost (*f*) and investment installation cost (*H*). Numerical evidence shows that option values (C_t) demonstrate a declining trend over agency cost. As noted in the descriptions mentioned above, a higher cost (*H*) of investment projects has a deleterious effect on the values of ESO contracts.

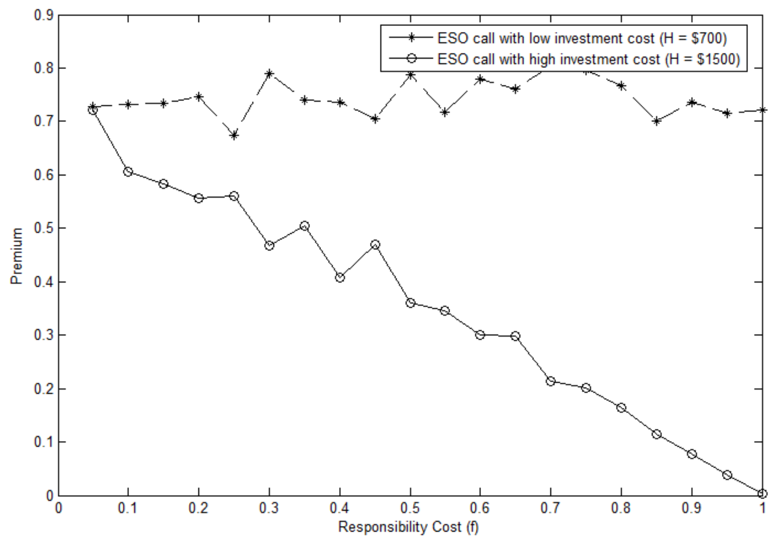


Figure 2. Stock Option Values and Agency Cost

The figure displays ESOs values varying with CEO's responsibility cost related to the agency problem in investment projects. The initial values of the parameters are given in Table 1.

An ESO contract is an effective tool for inspiring executives to do their best and to act in the firm's best interests. They are adding a design of agency cost in the ESO contracts benefits, strengthening executives' responsibility for the business operations. If a firm's executives have less responsibility for the decision-making of investment projects, they run to be punished more and receive less payoffs from ESO contracts.

4.7 Black-Scholes call options and executive stock options

To clarify the differences in values for the ESO contracts and Black and Scholes's (1973) plain vanilla options, we plot a series of premium dynamics in Figures 3 and 4. Over a stock price, the values are gradually increasing for whichever type the stock options are, as described in Figure 3. As well as, the changes in stock options values are more moderate for ESO contracts and more salient for plain vanilla calls. The potential reason for the result is that ESO contracts correlate with the firm's asset and investment project values, not only with the underlying stock price.

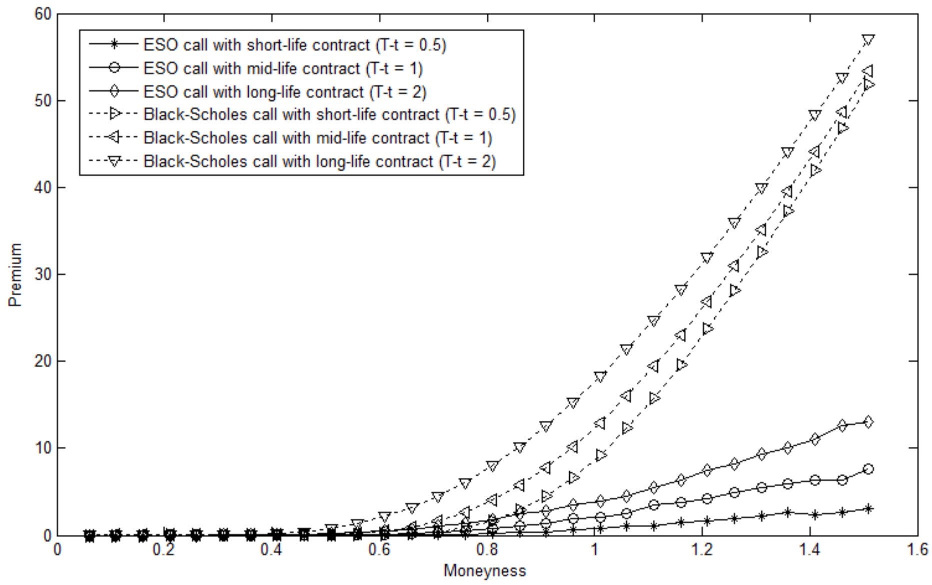


Figure 3. Stock Option Values and Option Moneyness

The figure displays executive stock option values and the Black-Scholes model's values varying with the moneyness at a stock price and time to maturity. The initial values of the parameters are given in Table 1.

Specifically, a firm's asset value does not affect the values of Black and Scholes's plain vanilla call options but changes the values of ESO contracts. In Figure 4, the values of plain vanilla calls remain constant concerning firm asset value (V_t). However, our ESO contract's values (C_t) rise with a firm's asset values, especially on the intervals of at-the-money nearby. As the asset value is around the debt threshold (B = \$4,500), the values significantly rise with the asset values. Far from the debt threshold, the ESO values change over asset values slightly. In addition, as the time closes upon the expiry date, the ESO values readily adjust as the stock price stays near the interval of at-the-money. The changes in option values are more moderate for ESO contracts with longer life.

4.8 Accuracy analysis

The estimated values of stock options show their slightly random variances by the *Monte Carlo* simulation procedure. To identify the accuracy of our numerical results for ESO prices, this study evaluates the effects of simulation numbers (N) on the option values. In Table 8, we calculate and assess the means (C_{Mean}), standard deviations (SD), confidence intervals (CI), and t–statistics (t–value) of option values over underlying stock prices as we vary the number (N) of simulations with 1,000, 10,000, and 100,000 in the simulation process.

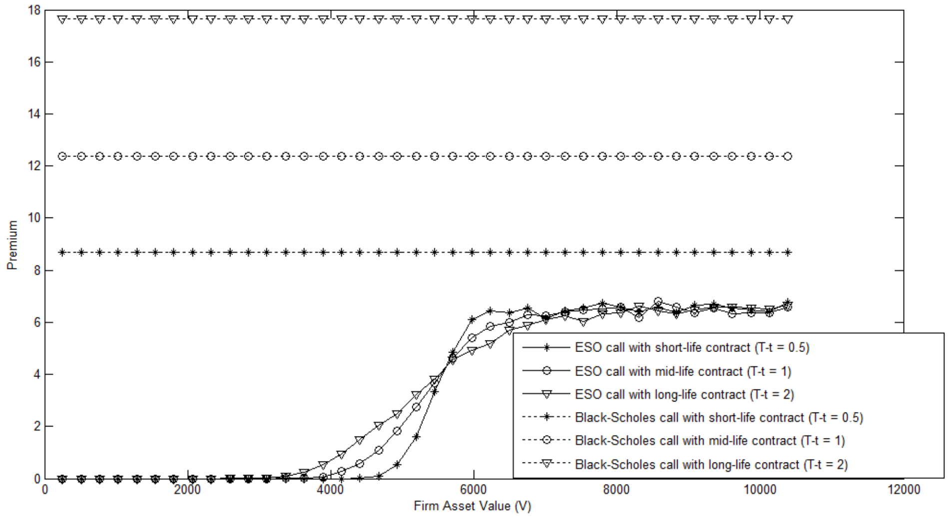


Figure 4. Option Values Vary with Stock Prices and Firm Asset Value

This figure shows how executive stock option values and the Black-Scholes calls vary with firm asset value. The initial values of the parameters are given in Table 1.

The results listed in Table 8 show that our numerical results of ESO values are stable and credible as we increase the simulation numbers. The confidence intervals tend to be minor, and the t–values are prone to be greater as we implement greater numbers of simulations. The mean value of option values based on our simulation procedures displays a convergence trend.

We visually diagram a dynamic of ESO values over the number of simulations and present it in Figure 5. In this simulation case, the initial price of the underlying stock is assumed to be \$100, and we varied the number[6] (N) of simulations from 11 to 297,360. When we implement fewer simulations, the stock option values' variance is more considerable, and the value is unstable. Otherwise, when we implement more numbers (N) of simulations, the stock option values (C_t) change is negligible and stable, with the option price approaching a value of around 3.0034. Specifically, as the number of simulations exceeds 50,000, the option price remains stable. As a result, although option values appear randomly, their performance is stable and shows convergence if the number of simulations is large enough. That is to say, our estimation results for the ESO values are sound and credible.

[6] The number of simulations is set as 10+2.^(i/11), where i = 1:1:200. the range of index i is from 1 to 200 with an increment of one time. The number of simulations changes from 11 to 297,360.

Table 8. Accuracy of Estimations

Simulation Number (N)	Stock Price (S_t)	Values			
		Mean (C_{Mean})	Standard Deviation (SD)	Confidence Intervals (CI at 95%)	t-statistics (t-value)
N = 1,000	\$60	0.0715*	1.4833	(-0.0206, 0.1635)	1.5234
	\$80	1.0499***	6.0155	(0.6766, 1.4232)	5.5193
	\$100	3.2045***	13.7552	(2.3509, 4.0581)	7.3671
	\$120	4.7613***	18.1344	(3.6360, 5.8866)	8.3028
	\$140	7.9007***	24.7482	(6.3649, 9.4364)	10.0953
N = 10,000	\$60	0.2328***	2.7427	(0.1790, 0.2865)	8.4866
	\$80	1.1989***	7.0410	(1.0609, 1.3369)	17.0271
	\$100	3.0588***	12.4173	(2.8154, 3.3022)	24.6334
	\$120	5.3261***	19.3380	(4.9668, 5.6854)	29.0554
	\$140	7.7459***	24.5700	(7.2643, 8.2275)	31.5258
N = 100,000	\$60	0.1933***	2.3900	(0.1785, 0.0280)	25.5721
	\$80	1.1333***	6.6544	(1.0921, 1.1746)	53.8408
	\$100	3.0034***	12.2240	(2.9277, 3.0792)	77.6977
	\$120	5.4324***	18.5978	(5.3171, 5.5476)	92.3693
	\$140	7.9125***	24.7975	(7.7588, 8.0662)	100.9036

The table reports the accuracy of ESO values varying with stock price and simulation numbers. Parameters are given as follows: initial value of investment project of I_t = \$1,000, investment's installation cost of H = \$1,000, excess growth rate of investment project value of β = 3%, loss rate of investment value of γ = 1%, return volatility of investment project of κ = 20%, firm asset value of V_t = \$5,000, firm debt threshold of B = \$4,500, excess growth rate of asset value of μ = 2%, depreciation rate of firm asset value of δ = 1%, return volatility of firm value of θ = 10%, initial stock price of S_t = \$100, strike price of K = \$100, stock excess growth rate of α = 2%, dividend yield rate of q = 1%, return volatility of stock price of σ = 30%, salary percentage of m = 20%, risk-free interest rate of r = 1%, time to maturity of $T–t$ = 1 year, coefficient of correlation for investment value and investment value of η = 0.2, coefficient of correlation for firm value and stock price of ρ = 0.3, coefficient of correlation for investment value and stock price of π = 0.4, deadweight cost rate of e = 10%, agency cost rate of f = 10%, time steps of n = 12, and simulation numbers of N = 100,000. CI denotes confidence interval, where *, **, and *** indicate the significance at the 10%, 5%, and 1% levels, respectively.

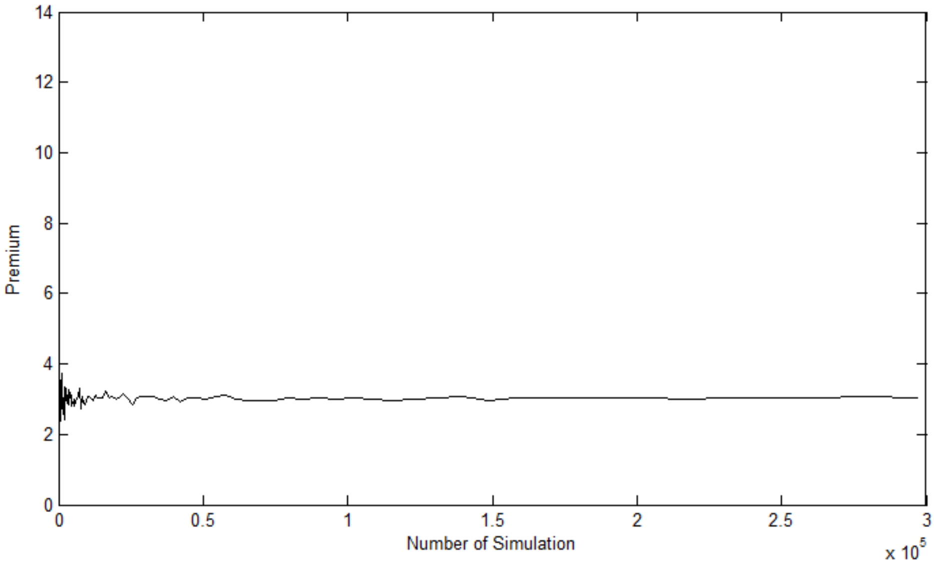


Figure 5. ESO Values and Number of Simulations

This figure demonstrates that estimated results of ESO values vary with the number of *Monte Carlo* simulations. The initial values of the parameters are given in Table 1.

5. Concluding Remarks

This study proposes a structural model of executive stock options for evaluating how a firm's executives making decisions on investment and financial management sway the firm value, shareholder interests, and ESO values. In practice, a failure or success in investment projects or an unbalance in financial management, as decided upon by corporate executives, is identified to disturb the firm values. Based on this stylish observation in practice, this study thus evaluates how corporate investment risk and default risk change stock option contracts' values. If corporate executives are required to be responsible for making investment and financial decisions, their ESO payoffs are contingent on decision-making results.

Our pricing model is more explanatory than those pricing ESO contracts without considering investment and credit risks. Characteristic factors in corporate investment projects can alter ESO values. We suggest that how corporate executives manage asset values, salary payments, dividend payouts, depreciation yield, and debt financing affects the firm's likelihood of defaulting on ESO contracts, resulting in changes in ESO values. Specifically, a higher cost of agency, which implies a more irresponsible attitude regarding investment projects for corporate executives, lowers ESO values. Simply put, corporate executives with an attitude of more vital responsibility strive to see investment projects succeed and have a higher potential to enjoy a higher payoff from ESO contracts. Our models offer analysis regarding investment risk, credit risk, and agency cost, suggesting new insights into executive stock options issues.

A further study may examine a non-constant agency cost for the agency problem issues between a firm's executives and shareholders and how to change the ESO values. Another potential issue is to derive a closed-form solution of formulas by developing a feasible and straightforward ESO model and leaving it to future work.

References

Black, F. and M. Scholes, (1973). The valuation of options and corporate liabilities, *Journal of Political Economy* 81:3, 637–659.

Brenner, M., R. K. Sundaram, and D. Yermack, (1999). We are altering the terms of executive stock options. *Journal of Financial Economics* 57:1, 103–128.

Carpenter, J., (1998). The exercise and valuation of executive stock options, *Journal of Financial Economics* 48:1, 127–158.

Carr, P. and V. Linetsky, (2000). The valuation of executive stock options in an intensity-based framework, *European Finance Review* 4, 211–230.

Colwell, D., D. Feldman, and W. Hu, (2005). Non-transferable non-hedgeable executive stock option pricing, *Journal of Economic Dynamics & Control* 53:1, 161–191.

Fard, F. A. (2015). Analytical pricing of vulnerable options under a generalized jump-diffusion model, *Insurance: Mathematics & Economics*, 60:1, 19–28.

Hull, J. and A. White, (1995). The impact of default risk on the prices of options and other derivative securities, *Journal of Banking & Finance* 19:2, 299–322.

Jarrow, R. and S. Turnbull, (1995). Pricing derivatives on financial securities subject to credit risk, *Journal of Finance* 50:1, 53–85.

Johnson, H. and R. Stulz, (1987). The pricing of options with default risk, *Journal of Finance*, 42:2, 267–280.

Johnson, S. and Y. Tian, (2000a). The value and incentive effects of nontraditional executive stock option plans, *Journal of Financial Economics* 57:1, 3–34.

Johnson, S. and Y. Tian, (2000b). Index executive stock options, *Journal of Financial Economics* 57:1, 35–64.

Kim, D., G. Kim, and J. Yoon, (2022). Pricing of vulnerable exchange options with early counterparty credit risk, *The North American Journal of Economics and Finance* 59, 101624.

Kimura, T., (2010). Valuing executive stock options: A quadratic approximation, *European Journal of Operational Research*, 207, 1368–1379.

Klein, P., (1996). Pricing Black-Scholes options with correlated credit risk, *Journal of Banking & Finance*, 20:7, 1211–1129.

Klein, P., and Inglis, M., (2001). Pricing vulnerable European options when the option's payoff can increase the risk of financial distress, *Journal of Banking & Finance*, 25:5 993–1012.

Klein, P. and J. Yang, (2010). Vulnerable American Options, *Managerial Finance* 36:5, 2010, 414–430.

Klein, D. (2018). Executive turnover and the valuation of stock options, *Journal of Corporate Finance* 48, 76–93.

Li, G. and C. Kang, (2019). Counterparty credit risk and derivatives pricing, *Journal of Financial Economics* 134, 647–668.

Lu, C., C. Shen, P. Shih, and W. Tsai, (2023). Option implied riskiness and risk-taking incentives of executive compensation, *Review of Quantitative Finance and Accounting* 60, 1143–1160.

Lu, J., Y. Chen, C. Hwang, and Y. Ting, (2013) Valuing seller-defaultable options, *Journal of Futures Markets* 33:2, 129–157.

Lu, J., C. Lin, and C. Hwang, (2017). The valuation and incentive effects of executive stock options under the consideration of firm default, *Journal of Management & Systems* 24:1, 1–28.

Mazur, M. and G. Salganik-Shoshan, (2019). The effect executive stock option delta and vega on the spin-off decision, *Quarterly Review of Economics and Finance* 72, 132–144.

Niu, H., Y. Xing, and Y. Zhao, (2020). Pricing vulnerable European options with dynamic correlation between market risk and credit risk, *Journal of Management Science and Engineering* 5, 125–145.

Wang, H., J. Zhang, and K. Zhou, (2022). On pricing of vulnerable barrier options and vulnerable double barrier options, *Finance Research Letters* 44, 102100.

Declaration of Competing Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.