Power Options  
in Executive Compensation

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Abstract

Tian [2013] shows that firms are better off linking incentive pay to average stock prices. This paper proposes a new type of executive stock option contract that improves upon Tian [2013]’s Asian executive option. This contract is a type of power option and its price has a simple closed-form expression under standard Black-Scholes assumptions. Numerical results show that the new contract is on average four percent cheaper than Tian’s. Holding constant the company’s cost of option issuance, the power option is more valuable to executives and has superior incentive properties compared to Tian’s Asian executive option and to the standard call option.

Key-words: Executive compensation, Cost-efficiency, Asian options, Optimal contracting, Incentive effects.

JEL classifications: G13, G30, J33, M52.

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1 Introduction

Stock options are an important component of executive compensation in many companies. This paper shows how to design a new type of executive stock option that has advantages over the Asian options introduced by Tian [2013]. Our paper contributes to the existing literature on the design of executive options and is similar in spirit to Johnson and Tian [2000b] who analyze a range of different executive option designs.

Tian [2013] has shown that Asian options have advantages over traditional call options as a form of executive compensation Using a principal-agent analysis he concludes that firms are better off basing executive options on average stock prices than basing them on stock prices at maturity. In general, the use of averaging is found to be more cost-effective and incentive-effective than the use of traditional stock options. This means that for a given cost of the option grant, risk-averse executives benefit from a higher subjective value of the Asian option than the European one. On the other hand, incentive-effective means that Asian-style options provide executives with stronger incentives to increase the stock price than standard ones.

Our main contribution is to design a new type of executive option (a power option) that dominates an Asian executive option in several respects. While an Asian option payoff is based on the average path of the stock price, the power option payoff is essentially based on a power of the terminal stock price. The power option has the same ex ante distribution as the Asian option but it is cheaper. It is constructed using the concept of cost-efficiency, which was introduced by Dybvig [1988a] and then extended by Bernard et al. [2014].

We compare the properties of the proposed power options with Asian options and standard call options. We show that the power option is on average 4% cheaper than Tian’s [2013] Asian option. We also show that for the same option cost, the subjective value of the power option is strictly higher than that of the Asian. We demonstrate that the power option dominates the Asian option in the case of two out of three incentive measures. The power option is superior in terms of incentives related to manipulating the stock price and volatility but not in terms of reducing dividends. We argue that this is not an issue given the reluctance of companies to reduce dividends even under adverse conditions.

The rest of this paper is organized as follows. Section 2 sets out our framework and reviews Tian [2013]’s design. This section explains cost-efficiency through an example. Section 3 describes our new design. Section 4 compares the properties of our proposed contract with Tian’s Asian option and with a standard call option. In Section 5 we discuss a number of important extensions and limitations of the analysis. Appendix A contains some expressions that are required to compute pay for performance sensitivities. All proofs are presented in Appendix B. To make the paper more readable, some of the longer tables are placed in Appendix C.
2 Framework

This section lays out our framework. We explain certain concepts that are needed in the paper. Specifically, we start with the valuation of executive options, and then recall the concept of cost-efficiency.

In the context of executive options, we can distinguish between the cost to the company and the value to the executive. The cost to the company is generally market-based. In technical terms, this market-based approach is the risk-neutral expectation of the discounted payoff of the executive option. The value to the executive is referred to as the subjective value of the contract. These concepts are explained more fully in Lambert et al. [1991]. Similarly to Tian [2013], we assume that the executive’s total wealth comprises of a fixed salary and stock options, and use the certainty equivalent of the total wealth to derive the subjective value of the option. Let \( W_0 \) be the initial wealth and \( \lambda \) be the fraction of the executive’s initial wealth in the form of stock options. Let \( n \) be the number of options issued in the compensation package such that \( n = \frac{\lambda W_0}{c(V_T)} \) where \( c(V_T) \) is the initial cost of one option with payoff \( V_T \) to the company. The final wealth \( W_T \) at maturity \( T \) is given by

\[
W_T = (1 - \lambda)W_0 e^{rT} + nV_T
\]

where \( V_T \) denotes the payoff of a single option.

The certainty equivalent (CE) is defined as the amount of cash that an executive with utility function \( u(\cdot) \) would view as equivalent in value to the stock options. In other words, the executive is indifferent (same expected utility level) between the amount of cash CE and the random payoff associated with the compensation in options, \( nV_T \). We assume an increasing utility function \( u \).

\[
\begin{align*}
    & u \left(((1 - \lambda)W_0 + nCE)e^{rT}\right) = E_P \left(u(W_T)\right) \\
\end{align*}
\]

where the expectation is under the agent’s subjective probability measure \( P \). Without loss of generality,\(^1\) we get

\[
\begin{align*}
    & u \left(1 - \lambda + \lambda \frac{CE}{c(V_T)} \right) = E_P \left[u \left(1 - \lambda + \lambda \frac{V_T}{c(V_T)} e^{-rT}\right)\right] \\
\end{align*}
\]

The subjective value of a particular option is defined as the fraction of the certainty equivalent CE of the option with respect to its risk-neutral value \( c(V_T) \) i.e. \( \frac{CE}{c(V_T)} \).

To obtain a cheaper form of option compensation, we use the concept of “cost-efficiency”. This concept was introduced by Dybvig [1988a, 1988b] and Cox and Leland [2000],\(^2\) and

\(^1\)But with a slight abuse of where we replace \( x \mapsto u(W_0 e^{rT} x) \) with \( x \mapsto u(x) \)

\(^2\)The original Cox and Leland paper was written in 1982 but not published until 2000 in Cox and Leland [2000].
recently extended by Bernard et al. [2014]. Cost-efficiency refers to achieving a given probability distribution at the lowest possible cost. We use a two-period numerical example to illustrate the basic idea. A more formal treatment can be found in the literature cited above.

2.1 Numerical example to illustrate cost-efficiency

Consider a two-period discrete time model in the Cox, Ross and Rubinstein [1979] framework. Let \( p = \frac{1}{2} \) be the physical (real-world) probability of an up jump at each node. Suppose the initial stock price is 16. At the end of the second period, the stock price can take three distinct values (4, 16 or 64) and the associated (physical) probabilities over the two periods are \( \frac{1}{4}, \frac{1}{2} \) or \( \frac{1}{4} \) respectively:

\[
\begin{align*}
S_0 &= 16, & S_1 &= 8, & S_2 &= 4, \\
\mathbb{P}(S_2 = 64) &= \frac{1}{4}, & \mathbb{P}(S_2 = 16) &= \frac{1}{2}, & \mathbb{P}(S_2 = 4) &= \frac{1}{4}.
\end{align*}
\]

Let \( V_2 \) be the payoff at the end of the second period:

\[
V_2 = \begin{cases} 
1 & \text{if } S_2 = 64, \\
2 & \text{if } S_2 = 16, \\
3 & \text{if } S_2 = 4.
\end{cases}
\] (2)

The expected utility of this payoff can be calculated as \( E_p[u(V_2)] = \frac{u(1)}{4} + \frac{u(3)}{4} + \frac{u(2)}{2} \).

When the interest rate is ten per cent per period, the corresponding risk-neutral probability of an up jump is \( q = \frac{2}{5} \). Thus the risk-neutral probabilities that \( S_2 = 64, S_2 = 16 \) or \( S_2 = 4 \) are respectively equal to \( \frac{4}{25}, \frac{12}{25} \) and \( \frac{9}{25} \). We denote by \( c(V_T) \) the cost of an executive option with terminal payoff \( V_T \) computed as the risk-neutral expectation of the discounted payoff. The time zero cost of the payoff \( V_2 \) is given by

\[
c(V_2) = \frac{Q(S_2 = 64)}{(1 + r)^2} \times 1 + \frac{Q(S_2 = 16)}{(1 + r)^2} \times 2 + \frac{Q(S_2 = 4)}{(1 + r)^2} \times 3 \approx 1.82.
\]

Consider another payoff given by

\[
V_2^* = \begin{cases} 
3 & \text{if } S_2 = 64, \\
2 & \text{if } S_2 = 16, \\
1 & \text{if } S_2 = 4.
\end{cases}
\]
The key observation is that the expected utility of the second payoff, \( E_\phi[u(V^*_2)] \), is equal to the expected utility of \( V_2 \) whereas its cost, \( c(V^*_2) \), is now strictly lower:

\[
c(V^*_2) = \frac{Q(S_2 = 64)}{(1 + r)^2} \times 3 + \frac{Q(S_2 = 16)}{(1 + r)^2} \times 2 + \frac{Q(S_2 = 4)}{(1 + r)^2} \times 1 \approx 1.49 < c(V_2).
\]

In fact, the payoff \( V^*_2 \) is cost-efficient, i.e. it is the cheapest way to get the same distribution as the payoff of \( V_2 \) under the physical measure because its outcomes are in reverse order to the price of each state.\(^3\) Observe that \( V^*_2 \) is non-decreasing with respect to \( S_2 \). In the Black-Scholes model, Bernard et al. [2014] show that when \( \mu_S > r \), a payoff is cost-efficient if and only if it is non-decreasing with respect to \( S_T \). This characterization leads to an explicit representation of cost-efficient payoffs that will be useful to construct a better executive option than the Asian executive option proposed by Tian [2013].

### 2.2 Asian Executive Option

We now briefly describe the payoff of the Asian executive option introduced by Tian [2013].\(^4\) This option has a payoff

\[
A_T = (S_T^{\text{avg}} - K)^+ \tag{3}
\]

where \( S_T^{\text{avg}} \) denotes the geometric average of the stock price from time 0 to time \( T \) and \( K \) is the strike. If the stock price is observed at discrete dates \( t_1, t_2, \ldots, t_n \), then the geometric average can be computed as

\[
(S_{t_1} S_{t_2} \cdots S_{t_n})^{\frac{1}{n}}. \tag{4}
\]

For convenience, we will use the limiting case where the stock is observed at all times and the geometric average is defined as

\[
S_T^{\text{avg}} = \exp\left\{ \frac{1}{T} \int_0^T \ln S_t dt \right\}. \tag{5}
\]

\(^3\) It follows from Theorem 1 of Dybvig [1988a], which states that in a complete discrete-time market model where all states are equally probable, “the cheapest way to achieve a lottery assigns outcomes of the lottery to the states in reverse order of the state-price density.” The state-price process at time \( t \), \( t \in \{0, 1, 2\} \) is the ratio of probabilities under the risk-neutral measure and the physical measure discounted at the risk-free rate. Bernard et al. [2014] extend this result to a general discrete-time or continuous-time market.

\(^4\) Tian [2013] also studied indexing. But Dittmann et al. [2013] investigated the impact of indexing executive options by calibrating the standard principal-agent model to a large sample of US CEO contracts. They find that the benefits from indexing executive options are small and actually increase the compensation costs by 50% for most firms in their sample. They conclude also that the overall benefit of indexing options is ambiguous, which could explain why indexing is rarely used in practice (e.g. Hall and Murphy [2003], Murphy [1999]). For this reason, we will focus on the Asian executive option without indexing.
From the discussion above, cost-efficient payoffs must be non-decreasing in the final stock price. Thus the Asian option may not be cost-efficient. In this case, we can construct a new option payoff, say $P_T$ with the same probability distribution as $A_T$ under the real-world probability $\mathbb{P}$ but at a strictly smaller cost. Observe that for any utility function $u$, $A_T$ and $P_T$ have the same expected utility since they have the same probability distribution (that is, $E_\mathbb{P}[u(A_T)] = E_\mathbb{P}[u(P_T)]$). The rest of the paper will illustrate how to use cost-efficiency to improve CEO compensation schemes. Interestingly, this improvement will not be only in terms of cost of issuance to the company but will also provide a higher subjective value (for a given cost) and better incentives to the executive. The next section discusses this strict Pareto improvement in more detail.

3 The Power Executive Option

In this section we construct a power option as an alternative to the Asian executive option proposed by Tian [2013]. We use the same notations as Tian [2013]. In this setting, our new option has an explicit expression. Assume a constant risk-free rate $r$. The stock price process (under the physical measure $\mathbb{P}$) is given by

$$\frac{dS_t}{S_t} = (\mu_S - q_S)dt + \sigma_S dZ_t$$

(6)

where $\mu_S > r$ and $q_S$ are respectively the expected rate of return and dividend yield, $\sigma_S$ is the volatility and $Z_t$ is a standard Brownian motion. At time $T$, the stock price can be written as

$$S_T = S_0 \exp \left\{ \left( \mu_S - q_S - \frac{\sigma_S^2}{2} \right) T + \sigma_S Z_T \right\}.$$  

(7)

Here, the cost of a payoff $V_T$ paid at time $T$ is given by $c(V_T) = E_\mathbb{Q}[e^{-rT}V_T]$. Our main result is presented in the next proposition. We give explicit expressions for the power option that dominates the Asian option.

**Proposition 1.** Consider the following power option

$$P_T = \psi \left( S_T^\varphi - \frac{K}{\psi} \right)^+$$

(8)

where $\varphi = \frac{1}{\sqrt{3}}$ and $\psi = S_0^{1-\varphi} \exp \left\{ (\frac{1}{2} - \varphi) \left( \mu_S - q_S - \frac{\sigma_S^2}{2} \right) T \right\}$. It has several important properties.

- First, the power option with payoff $P_T$ above has the same distribution as the Asian executive option $A_T$ in (3).
Second, the power option with payoff $P_T$ is cheaper than Tian’s option with payoff $A_T$. Specifically, the costs of the Asian option $A_T$ and the power option $P_T$ at time zero are given by

\[
c(A_T) = \text{BSCall}[S_0, K, r, T, \varphi S, q_{S^\text{avg}}]
\]

\[
c(P_T) = \text{BSCall}
\begin{array}{c}
S_0, K, r, T, 
\varphi S, q_{S^\text{avg}} + 
\left(\varphi - \frac{1}{2}\right)(\mu_S - r)
\end{array}
\]

where $\text{BSCall}[S_0, K, r, T, \sigma, q]$ is the usual Black-Scholes\(^5\) price of a call option (with initial underlying price $S_0$, strike $K$, risk-free rate $r$, maturity $T$, volatility $\sigma$ and dividend yield $q$), and where $\varphi = \frac{1}{\sqrt{3}}$, $q_{S^\text{avg}} = \frac{1}{2} \left( r + q_S + \frac{\sigma^2}{6} \right)$ and $\varphi - \frac{1}{2} \approx 0.0774$.

For any non-decreasing utility function $u$, the subjective value of the power option accounting for the cost of issuing the option is always higher than the subjective value of the Asian executive option

\[
\frac{CE_{\text{Power}}}{c(P_T)} > \frac{CE_{\text{Asian}}}{c(A_T)}.
\]

At first sight this proposition may look complicated but the power option payoff is based on the ending stock price and it has a simple design. By construction its cost of issuance to the company is lower. It could be argued that cost-effectiveness of executive options should not be measured by the cost of issuance but by the subjective value to CEOs. However, it turns out that the power option is not only cheaper to the company to issue but it also has a larger subjective value to the executives if we assume the same dollar expenditure by the company. Tian [2013] shows that the Asian option is generally more cost-effective than traditional executive call options. His conclusion is based on the ratio between the certainty equivalent and the cost of issuing the option. Here, we show that the power option always has a larger subjective value. The numerical analysis in Section 4 will quantify the magnitude of this gain and compare it directly with some of the numerical experiments of Tian [2013].

We now give some intuition about the ideas behind the proof of Proposition 1. More details can be found in Appendix B. To apply the idea of “cost-efficiency,” we need to construct an option that has the same distribution as Tian [2013]’s Asian executive option but that is non-decreasing in the terminal stock price. The structure of the power option (8) can be explained as follows. The two terms, $\psi$ and $\varphi$, are needed to adjust the terminal stock price, $S_T$, so that it mimics the distribution of the underlying Asian option, $S^\text{avg}_T$. Kemna and Vorst [1990] showed that the price (geometric) average $S^\text{avg}_T$ has a lognormal

\[\text{BSCall}[S_0, K, r, T, \sigma, q] = S_0 e^{-qT} N(d_1) - K e^{-rT} N(d_2)\]

where $d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + (r - q + \frac{\sigma^2}{2})T}{\sigma \sqrt{T}}$ and $d_2 = d_1 - \frac{\sigma \sqrt{T}}{2}$.
distribution. It is the same distribution as the distribution of $S_T$, after adjusting the drift and volatility terms with $\psi$ and $\varphi$:

$$\psi S_T \sim S_T^{\text{avg}}$$

where $\sim$ denotes equality in distribution. This removes the geometric averaging component, but preserves the distribution of the average since the presence of $\varphi$ reduces the stock price volatility.

Note also that the cost of the power option, $c(P_T)$, and the cost of the Asian option, $c(A_T)$, share a similar expression (9) based on the Black-Scholes formula. They can therefore be readily compared. The only difference between the two expressions is in the term that takes the place of the dividend yield that is used in the Black-Scholes formula. Given that $\mu_S > r$, the power option price is computed with a higher dividend yield than the Asian option. It is thus cheaper because a call option price is decreasing in the dividend yield.

### 3.1 Comparison with the Asian option

We now provide some additional discussion of the main features of the power option and also how it compares with the Asian option. First, we discuss a numerical example that illustrates how it operates. Then, we compare the payoffs of the power option, $P_T$, and of the Asian option, $A_T$, under a few stock price paths. Finally, we compare the performance of these two options during the last ten years for a particular stock.

The payoff of the power executive option is given by

$$P_T = (\psi S_T^\varphi - K)^+.$$  \hspace{1cm} (10)

There is a threshold stock price above which the power option is in-the-money and below which it is out-of-the-money. We use that as a reference point in our comparison and we denote it by $\hat{H}$.

$$\hat{H} = \frac{K^{\frac{1}{\varphi}}}{\psi^\varphi}.$$  \hspace{1cm} (11)

We now find the values of $\hat{H}$ for some specimen parameters. For our base case we assume that

$$S_0 = 100, K = 100, \sigma = .35, T = 5, r = .04, \mu_S = .08, q_S = 0.$$  \hspace{1cm} (12)

For this case we find that $\hat{H} = 101.26$. Table 1 illustrates that $\hat{H}$ is an increasing function of $\mu$ and a decreasing function of $\sigma$.

Although the payoff of the power option is designed to have the same distribution as the Asian option, it will not necessarily have the same cash-flows. We illustrate this idea
Table 1: Sensitivity of $\hat{H}$ to $\mu_S$ and $\sigma$. Other parameters are given by (12).

<table>
<thead>
<tr>
<th>$\mu_S$</th>
<th>$\sigma$</th>
<th>$\hat{H}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.08</td>
<td>0.35</td>
<td>101.26</td>
</tr>
<tr>
<td>0.10</td>
<td>0.35</td>
<td>102.63</td>
</tr>
<tr>
<td>0.08</td>
<td>0.50</td>
<td>97.03</td>
</tr>
</tbody>
</table>

Figure 1: Time series plot of daily Legg Mason closing prices from July 1, 1998 to July 1, 2013. Historical prices are extracted from Yahoo finance.

with an actual stock: Legg Mason Inc (NYSE:LM). This is an asset management company based in Baltimore, Maryland.

We issue five year at-the-money and in-the-money options of both types\(^6\) on July 1, 2003 and also on July 1, 2008. For each option, we use five years of prior data to estimate the various parameters using maximum likelihood estimation. $S_T^{\text{avg}}$ is estimated using the geometric average of daily closing prices (as in (4)). Figure 1 depicts Legg Mason’s stock price over these two periods.

During the first period (2003-2008) the average is quite high because the price rose and fell. However during the second period (2008-2013) the opposite happened. This is confirmed by the payoffs of the power option and Asian option that are given in the last two periods.

\(^6\)These correspond to the geometric Asian option and our proposed power option.
columns of Table 2. The Asian option and the power option have different cash-flows at maturity on an ex post basis even if they share the same ex ante probability distributions. Different orderings are possible on an ex post basis. For instance, it is possible to have a positive payoff for the Asian option and a worthless power option (this is the case of the two option issued on July 1, 2003). This is essentially driven by the fact that the average price is higher but the terminal stock price is lower than the initial stock price at the date of issuance. The opposite situation in which the Asian option expires worthless and the power option has a positive payoff is possible as can be seen from the payoffs of the two in-the-money options issued on July 1, 2008. Both options can also expire worthless (see the two at-the-money options issued on July 1, 2008). We observe from Figure 1 that at the end of the period, the stock price is low but the average is relatively high. From the company’s perspective, it may not be a good decision to pay large option payoffs given that the stock price is low, which support the power option against the Asian option.

<table>
<thead>
<tr>
<th>Issue</th>
<th>$\mu_S - q_S$</th>
<th>$\sigma_S$</th>
<th>$K$</th>
<th>$S_T$</th>
<th>$\bar{H}$</th>
<th>$S_{avg}^T$</th>
<th>Payoff $A_T$</th>
<th>Payoff $P_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 1, 2003, ATM</td>
<td>0.262</td>
<td>0.444</td>
<td>44.63</td>
<td>41.25</td>
<td>49.78</td>
<td>77.94</td>
<td>33.31</td>
<td>0.00</td>
</tr>
<tr>
<td>July 1, 2003, ITM</td>
<td>0.262</td>
<td>0.444</td>
<td>30</td>
<td>41.25</td>
<td>49.78</td>
<td>77.94</td>
<td>47.94</td>
<td>0.00</td>
</tr>
<tr>
<td>July 1, 2008, ATM</td>
<td>0.053</td>
<td>0.322</td>
<td>41.25</td>
<td>31.31</td>
<td>41.28</td>
<td>27.54</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>July 1, 2008, ITM</td>
<td>0.053</td>
<td>0.322</td>
<td>30</td>
<td>31.31</td>
<td>41.28</td>
<td>27.54</td>
<td>0.00</td>
<td>5.16</td>
</tr>
</tbody>
</table>

Table 2: The Asian and Power options are issued on July 1, 2003 and July 1, 2008 and at-the-money (ATM) and in-the-money (ITM) respectively. $\mu_S - q_S$ and $\sigma_S$ are estimated using the MLE of five years of prior data.

4 Comparison of Executive Options

This section contains a comparison of three executive options (the power option proposed in this paper, the Asian option proposed by Tian [2013] and a standard European call option). We first base our discussion on cost-effectiveness (costs and subjective values) and then on the incentive measures used by Tian [2013]. Specifically, we compare these options on the basis of cost (risk-neutral value and subjective value) and of incentives to increase share price and volatility, and reduce share dividends.

Table 3 displays ranges for each parameter needed for our comparison. We assume that these parameters are uniformly distributed within their respective ranges and are independent of each other. The sample of parameters used is constructed by randomly drawing sets of option parameters from these distributions. We only consider parameters that produce a cost for the Asian executive option $c(A_T)$ of at least 5, which represents
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial share price</td>
<td>$S_0$</td>
<td>100</td>
</tr>
<tr>
<td>Strike price</td>
<td>$K$</td>
<td>[50, 150]</td>
</tr>
<tr>
<td>Volatility</td>
<td>$\sigma_S$</td>
<td>[0.20, 0.60]</td>
</tr>
<tr>
<td>Interest rate</td>
<td>$r$</td>
<td>[0.03, 0.06]</td>
</tr>
<tr>
<td>Expected return</td>
<td>$\mu_S$</td>
<td>$r + [0.01, 0.05]$</td>
</tr>
<tr>
<td>Term</td>
<td>$T$</td>
<td>[3, 10]</td>
</tr>
<tr>
<td>Dividend yield</td>
<td>$q_S$</td>
<td>[0, 0.02]</td>
</tr>
</tbody>
</table>

Table 3: Range of values for each parameter. Each set of parameters is sampled uniformly and independently from the above ranges provided that $c(A_T) > 5$. This process is repeated until a sample of 10,000 valid option prices is attained.

five per cent of the initial wealth $W_0$ that is set to 100. We use a sample of size 10,000. This method is standard and was used for instance by Broadie and Detemple [1996].

### 4.1 Comparison of costs and subjective values

Here we compare costs and subjective values. This set of results confirm our theoretical findings: the power option $P_T$ is strictly cheaper than the Asian option but provides a higher subjective value to executives holding option expenditure constant. Let us recall the notation for the payoff of the power option, $P_T$, the payoff of the Asian option, $A_T$, and let us denote by $C_T$ the payoff $(S_T - K)^+$ of a traditional call option with the same strike as the Asian option. It is then known that

$$c(P_T) < c(A_T) < c(C_T).$$

The first inequality follows from the fact that by construction, the power option is cost-efficient and thus cheaper (Proposition 1). The second part is a well-known inequality between the price of an Asian call and a traditional call with the same strike.

We sample 10,000 parameters from Table 3 and compute option costs for each of these parameters. They are provided in Table 4.

The “Mean” and “RMSE” columns are the average and root mean square error respectively. Observe that even though the RMSE is relatively large across the board, it does not imply the conclusions drawn are less valid. It means that the sample used is comprehensive enough to capture a wide range of option values, thus allowing the average scores to be more conclusive.

Based on the same sample of 10,000 parameters, we compute the relative efficiency loss of the Asian executive option over the corresponding power option. It is defined as follows
Based on a comparison of the cost \( c(A_T) \) of the Asian payoff \( A_T \) and the cost \( c(P_T) \) of the power option payoff \( P_T \):

\[
\frac{c(A_T) - c(P_T)}{c(A_T)} = 1 - \frac{\text{BSCall}\left[S_0, K, r, T, \varphi \sigma_S, q S_{\text{avg}} + \left(\varphi - \frac{1}{2}\right) (\mu_S - r)\right]}{\text{BSCall}\left[S_0, K, r, T, \varphi \sigma_S, q S_{\text{avg}}\right]}
\]

This quantity measures the extra amount of money spent on the Asian executive option to achieve essentially the same distribution as its cost-efficient alternative (the power option), relative to the cost of the Asian executive option itself. The numerical results are reported in Table 5.

### Table 4: Summary statistics of sample of 10,000 option costs. Payoffs are sorted in decreasing order of the average score.

<table>
<thead>
<tr>
<th>Option prices</th>
<th>Mean</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power option ( c(P_T) )</td>
<td>20.0306</td>
<td>9.4294</td>
</tr>
<tr>
<td>Asian option ( c(A_T) )</td>
<td>20.7628</td>
<td>9.6145</td>
</tr>
<tr>
<td>Standard call ( c(C_T) )</td>
<td>44.7951</td>
<td>12.5801</td>
</tr>
</tbody>
</table>

On average, the relative efficiency loss is 3.90% and ranges from a minimum of 0.57% to a maximum of 14.70%. Replacing the Asian option by a power option reduces the option cost. To be precise, the power option is cheaper than the Asian executive option provided that the expected return \( \mu_S \) is greater than the risk-free rate \( r \) as can be seen clearly from (13). If both parameters \( \mu_S \) and \( r \) are equal, then the efficiency loss is zero.

We next turn to the executive’s subjective value of the option. We assume that the executive maximizes the expected utility of wealth at some date \( T \) and that she has a CRRA utility function

\[
u(w) = \frac{w^{1-\gamma}}{1-\gamma}
\]

where \( w \) is the level of wealth and \( \gamma \geq 0 \) is the coefficient of relative risk aversion. It corresponds to log utility when \( \gamma = 1 \).

In addition to the parameters from Table 3, we need two more parameters to compute the subjective values for each of the three options. These additional parameters are the
fraction of wealth represented by the executive option ($\lambda$) and the relative risk aversion parameter ($\gamma$). Both parameters are also sampled uniformly $\lambda \in [0.05, 0.95]$ and $\gamma \in [0.50, 5]$ in order to cover a wide range of parameters. Based on 10,000 sets of parameters, we compute the subjective values for each option payoff. We then assign a score to each payoff based on the rank of its subjective value in increasing order. The smallest subjective value is assigned a score of 1 and the largest one is assigned a score of 3. Results are reported in Table 6. Note that in each simulation, the cost spent by the company is the same so that the comparison among the three options is fair.

<table>
<thead>
<tr>
<th>Subjective values</th>
<th>Mean</th>
<th>RMSE</th>
<th>Avg Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power option $P_T$</td>
<td>0.4520</td>
<td>0.3503</td>
<td>2.59</td>
</tr>
<tr>
<td>Standard call $C_T$</td>
<td>0.4155</td>
<td>0.3332</td>
<td>1.73</td>
</tr>
<tr>
<td>Asian option $A_T$</td>
<td>0.4406</td>
<td>0.3364</td>
<td>1.69</td>
</tr>
</tbody>
</table>

Table 6: Summary statistics of the subjective values for our sample of 10,000 options. Payoffs are sorted in decreasing order of the average score.

Note that if we were to compare the power option and the Asian option only, then the power option would always have a higher subjective value in all the simulations. In Table 6, the standard call can outperform the power option for some of the simulations explaining a score of 2.59 instead of 3 for the power option. For convenience, we reproduce Table 2 of Tian [2013] in Appendix C (see Table 11). In this table, we have added the corresponding results for the power options. The power option has a consistently higher subjective value than the Asian option.

### 4.2 Incentives Effectiveness

In this section, we compare the incentive properties of the three executive options (the Asian option, the power option and the standard call option). To standardize the comparison we assume that the initial company’s cost is the same for the three options. Similarly to Tian [2013], our measures of performance correspond to the pay-performance sensitivity (PPS) measure used by Jensen and Murphy [1990]. The total certainty equivalent value (TCE) of the executive’s portfolio invested in the risk-free asset and the options is

$$\text{TCE} = (1 - \lambda)W_0 + n\text{CE}$$

(15)

Recall that

$$u \left( 1 - \lambda + \frac{\text{CE}}{c(V_T)} \right) = E_p \left[ u \left( 1 - \lambda + \frac{V_T}{c(V_T)} e^{-rT} \right) \right]$$

(16)

where $V_T$ refers to any of the terminal payoffs considered ($A_T$, $P_T$ or $C_T$), and $c(V_T)$ is its corresponding risk-neutral price (respectively $c(A_T)$, $c(P_T)$ and $c(C_T)$). The various
incentive measures all arise from a combination of (15) and taking partial derivatives of both sides of (16) with respect to the parameter of interest.

The incentives to increase stock price, volatility, and dividends are measured by their respective sensitivities defined as the ratio of the percentage change in the executive’s total wealth to the percentage change in the stock price (PPS), volatility (VS), and dividend (DS). Their expressions are given in Tian [2013] and recalled in Appendix A for completeness.

We first consider the incentive to increase the stock price. We use the rescaled pay-performance sensitivity (PPS) measure defined in (17) (Appendix A) as proposed by Tian [2013]. Based on the same sample of 10,000 sets of parameters, we compute the pay-performance sensitivity for each of the three options. Then, for each of the 10,000 sets of pay-performance sensitivities, we compute the score of each payoff as the rank of its pay-performance sensitivity in increasing order, the smallest one being assigned a score of 1 and the largest one being assigned a score of 3. Results are given in Table 7. The vanilla call option produces the least incentive to increase share price. Separately, the Asian executive option and the power option already deliver high incentives to increase share price (with an average score of 2.17 and 2.83 respectively).

<table>
<thead>
<tr>
<th>Pay-performance sensitivity (PPS)</th>
<th>Mean</th>
<th>RMSE</th>
<th>Avg Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power option $P_T$</td>
<td>0.6744</td>
<td>0.6055</td>
<td>2.83</td>
</tr>
<tr>
<td>Asian option $A_T$</td>
<td>0.6657</td>
<td>0.5973</td>
<td>2.17</td>
</tr>
<tr>
<td>Standard call $C_T$</td>
<td>0.3934</td>
<td>0.3628</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 7: Summary statistics of the pay performance sensitivities values calculated for our sample of 10,000 option costs. Payoffs are sorted in decreasing order of the average score.

For convenience, we reproduce Table 3 in Tian [2013] in Appendix C (see Table 12) and compare his results with the power option. While there is no clear dominance for the Asian option and the standard call, the power option outperforms the Asian executive option on the basis of pay performance sensitivities across all sets of parameters investigated by Tian [2013]. Note that even though Table 7 is presented in a compact form it covers a wide range of possible parameter values. It is clear from this analysis that the power option is better than the Asian option.

We next consider the incentive to increase volatility. A positive value of the volatility sensitivity means that the particular option incentivizes the executive to increase share volatility, a presumably undesirable effect. Hence, the smaller the value of volatility sensitivity, the better it is. We compute the score of each payoff as the rank of its volatility sensitivity in decreasing order, the largest one being assigned a score of 1 and the smallest one being assigned a score of 3. This way, the more desirable property of having a negative
volatility sensitivity is assigned a higher score. From Table 8, the power option clearly 
dominates the Asian executive option and the standard call option. In fact, the volatility 
sensitivity for the power option is much smaller than all of the other options across all 
parameters.

<table>
<thead>
<tr>
<th>Volatility Sensitivity (VS)</th>
<th>Mean</th>
<th>RMSE</th>
<th>Avg Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power option ( P_T )</td>
<td>-2.9675</td>
<td>3.5158</td>
<td>2.84</td>
</tr>
<tr>
<td>Standard call ( C_T )</td>
<td>-0.1990</td>
<td>0.2146</td>
<td>1.68</td>
</tr>
<tr>
<td>Asian option ( A_T )</td>
<td>-0.1904</td>
<td>0.2631</td>
<td>1.49</td>
</tr>
</tbody>
</table>

Table 8: Summary statistics of the volatility sensitivities values calculated for our sample of 10,000 options. Payoffs are sorted in decreasing order of the average score.

As a last comparison criteria, Tian [2013] also examines the incentive to reduce dividend 
payments. Johnson and Tian [2000a] point out that since most executive options are not 
protected against dividends that would reduce terminal stock price, there is an incentive 
for executives to reduce dividend payments in order to increase their dividend option 
payoffs. As a practical matter, this may not be an important property because it is well-
known that corporations show extreme reluctance to reduce dividends, even under adverse 
financial conditions.

We examine the average scores of the dividend sensitivity calculated using the same set 
of parameters sampled from Table 3. For each of the 10,000 samples, we compute the score 
of each payoff as the rank of its dividend sensitivity in increasing order, the smallest one 
being assigned a score of 1 and the largest one being assigned a score of 3. Table 9 gives 
the results. It shows that along this dimension the power option provides the strongest 
incentive to reduce dividends: the average score of the power option is almost identically 1, 
the lowest possible score. Out of the sample of 10,000 sets of parameters, the power option 
received a score of 1 (lowest value of dividend sensitivity) in 9,968 of them. As explained 
above we do not regard this as a critical disadvantage of the power option.

<table>
<thead>
<tr>
<th>DS</th>
<th>Mean</th>
<th>RMSE</th>
<th>Avg Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian option ( A_T )</td>
<td>-0.0207</td>
<td>0.0248</td>
<td>2.89</td>
</tr>
<tr>
<td>Standard call ( C_T )</td>
<td>-0.0243</td>
<td>0.0297</td>
<td>2.11</td>
</tr>
<tr>
<td>Power option ( P_T )</td>
<td>-0.2954</td>
<td>0.3508</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 9: Summary statistics of the dividend sensitivities values calculated for our sample of 10,000 options. Payoffs are sorted in decreasing order of the average score.

For convenience, Table 10 below reproduces the scores calculated, as well as the ag-
gregate score for all criteria which is just the straight average. If we were to omit the
sensitivity to dividend payments, the results would be even more striking.

<table>
<thead>
<tr>
<th>Payoff</th>
<th>Cost</th>
<th>Subjective Value</th>
<th>Pay Performance Sensitivity</th>
<th>Volatility Sensitivity</th>
<th>Dividend Sensitivity</th>
<th>Aggregate Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power option $P_T$</td>
<td>3.00</td>
<td>2.59</td>
<td>2.83</td>
<td>2.84</td>
<td>1.00</td>
<td>2.45</td>
</tr>
<tr>
<td>Asian option $A_T$</td>
<td>2.00</td>
<td>1.69</td>
<td>2.17</td>
<td>1.49</td>
<td>2.89</td>
<td>2.05</td>
</tr>
<tr>
<td>Standard call $C_T$</td>
<td>1.00</td>
<td>1.73</td>
<td>1.00</td>
<td>1.68</td>
<td>2.11</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Table 10: Average score of each option across different criteria, sorted in decreasing order by the aggregate score.

5 Conclusions

This paper proposed a new form of executive stock option that has appealing properties. This new contract is a power option. It has advantages over Tian [2013]’s Asian option and over a traditional call option. The new power option is cheaper than the Asian option to the company. For a given issuance cost to the company, the power option has superior subjective value and incentive properties compared to the Asian option. The comparison is based on the firm’s cost of issuance, subjective values to executives, and incentives to increase share price, volatility, and dividends. This comparison is comprehensive and uses a wide range of sampled parameters.

The power option is actually not very complicated. Given that it is cheaper to the company and that for a given cost at issuance, it has also a larger subjective value to executives, it is clear that this efficiency gain can be used to improve the welfare of both parties, the company and the executive.

It is also appropriate to mention some extensions and limitations. We have used the geometric average Asian option as our benchmark because in this case both the Asian option and its power option counterpart have simple closed from solutions. The same analysis goes though if we were to use the arithmetic Asian option as a benchmark but in this case neither the Asian option nor its cost efficient counterpart have closed form solutions. We use the Black-Scholes market model but results can be extended to more realistic models using numerical techniques. Finally, we have focused on European options only for convenience. It would be possible to extend the analysis incorporate early exercise and use for instance the study of Miao et al. [2014].

7However, results would be approximately the same as the distribution of the arithmetic average is close to that of the geometric average.

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Asian options are quite common in financial markets and well understood by market participants. For example, many defined benefit pension plans base the pension on the average salary of the last few years. The new power options may not be as easy to understand and may be viewed as more abstract and complicated. Although our proposed power options have the same ex ante distribution as the benchmark Asian option, there will be scenarios when one of them is the money and the other is out of the money. The Legg Mason example in Section 3 provides an example. So these two options are not equivalent on an ex post basis and this might be a source of concern to some executives when the Asian option outperforms the power option if they hold the power options. The power option requires an estimate of the stock’s expected return. The expected return is difficult to estimate, so pricing these new options is more challenging than pricing a standard call or an Asian option. Despite these limitations, we think that the proposed power options merit consideration as an alternative to standard call options and Asian options in the structure of executive compensation.

References


A Expressions of Sensitivities

The expression of the pay-performance sensitivity (PPS) is also given in (17) of Tian [2013], and the volatility sensitivity appears in (20) of Tian [2013].

\[
PPS = \frac{\partial (TCE)}{\partial S_0} = E_P \left[ u' \left( (1 - \lambda) + \lambda \frac{V_T}{c(V_T)} e^{-rT} \right) \frac{\partial V_T}{\partial S_0} \right] \frac{\lambda S_0 e^{-rT}}{(1 - \lambda)c(V_T) + \lambda CE} \tag{17}
\]

\[
VS = \frac{\partial (TCE)}{\partial \sigma_S} = E_P \left[ u' \left( (1 - \lambda) + \lambda \frac{V_T}{c(V_T)} e^{-rT} \right) \frac{\partial V_T}{\partial \sigma_S} \right] \frac{\lambda \sigma_S e^{-rT}}{(1 - \lambda)c(V_T) + \lambda CE} \tag{18}
\]

\[
DS = \frac{\partial (TCE)}{\partial q_S} = E_P \left[ u' \left( (1 - \lambda) + \lambda \frac{V_T}{c(V_T)} e^{-rT} \right) \frac{\partial V_T}{\partial q_S} \right] \frac{\lambda q_S e^{-rT}}{(1 - \lambda)c(V_T) + \lambda CE} \tag{19}
\]

B Proof of Proposition 1

This proposition consists of two parts. The first part is based on the results in Bernard et al. [2014], they show that in the Black-Scholes setting, when \( \mu_S \geq r \), for any cumulative distribution function (cdf) \( F \), the unique\(^8\) cost-efficient payoff with cdf \( F \) is given by

\[
V_T^* = F^{-1}(F_S(S_T)) \tag{20}
\]

where the pseudo inverse of \( F \) is defined as \( F^{-1}(y) = \min \{ x \mid F(x) \geq y \} \). In other words, let \( V_T \) be any other executive compensation with the same cdf \( F \), \( c(V_T^*) \leq c(V) \). The expression of \( P_T \) follows applying formula (20) to the Asian executive compensation \( A_T \) that is defined in (3). We omit the derivations as it is a straightforward extension to include a dividend yield in the example of the cost-efficient alternative to a Geometric Asian option derived by Bernard et al. [2014].

The second part of Proposition 1 requires a proof. For the cost-efficient alternative \( P_T \) (with certainty equivalent \( CE_{Power} \) and cost \( c(P_T) \)) compared to the proposed Asian compensation \( A_T \) (with certainty equivalent \( CE_{Asian} \) and cost \( c(A_T) \)), observe that

\[
\begin{align*}
\left( 1 - \lambda + \lambda \frac{CE_{Power}}{c(P_T)} \right) & = E_P \left[ u \left( 1 - \lambda + \lambda \frac{P_T}{c(P_T)} e^{-rT} \right) \right] \\
\left( 1 - \lambda + \lambda \frac{CE_{Asian}}{c(A_T)} \right) & = E_P \left[ u \left( 1 - \lambda + \lambda \frac{A_T}{c(A_T)} e^{-rT} \right) \right]
\end{align*}
\tag{21, 22}
\]

\(^8\)Uniqueness is only almost surely: it means that any payoff equal to \( V_T^* \) everywhere except on a set with probability measure zero would also be cost-efficient.
From the increasing property of the utility function and the fact that \( c(P_T) < c(A_T) \),

\[
E_P \left[ u \left( 1 - \lambda + \frac{P_T}{c(P_T)} e^{-rT} \right) \right] > E_P \left[ u \left( 1 - \lambda + \frac{P_T}{c(A_T)} e^{-rT} \right) \right]
\]

\[= E_P \left[ u \left( 1 - \lambda + \frac{A_T}{c(A_T)} e^{-rT} \right) \right] \]

The last equality comes from the fact that \( P_T \) and \( A_T \) have the same probability distribution. Using (21) and (22), we have that

\[ u \left( 1 - \lambda + \frac{\text{CE}_{\text{power}}}{c(P_T)} \right) > u \left( 1 - \lambda + \frac{\text{CE}_{\text{Asian}}}{c(A_T)} \right) \]

Finally, as \( u \) is increasing, the result is proved. \( \square \)

### C Appendix: Numerical Exhibits

This Appendix reproduces several of the Tables in Tian [2013]'s paper with the addition of the power option.
<table>
<thead>
<tr>
<th>Risk aversion $\gamma$</th>
<th>Weight in options $\lambda$</th>
<th>Subjective value as a fraction of risk-neutral value (%)</th>
<th>Call $C_T$</th>
<th>Power $P_T$</th>
<th>Asian $A_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.90</td>
<td>11.07 11.18</td>
<td>11.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
<td>25.75 26.67</td>
<td>26.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.50</td>
<td>51.56 54.42</td>
<td>52.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.25</td>
<td>87.28 92.20</td>
<td>87.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.90</td>
<td>5.30 5.25</td>
<td>5.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.75</td>
<td>14.20 14.37</td>
<td>14.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.50</td>
<td>33.62 35.02</td>
<td>34.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.25</td>
<td>66.29 70.33</td>
<td>67.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.90</td>
<td>14.68 18.56</td>
<td>18.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
<td>32.01 39.39</td>
<td>38.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.50</td>
<td>59.41 69.91</td>
<td>67.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.25</td>
<td>94.32 104.55</td>
<td>99.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.90</td>
<td>7.02 8.59</td>
<td>8.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.75</td>
<td>18.14 22.22</td>
<td>21.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.50</td>
<td>40.32 48.57</td>
<td>47.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.25</td>
<td>74.17 85.34</td>
<td>81.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.90</td>
<td>8.63 7.09</td>
<td>7.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
<td>21.11 18.24</td>
<td>17.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.50</td>
<td>44.74 41.15</td>
<td>39.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.25</td>
<td>80.39 78.16</td>
<td>74.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.90</td>
<td>4.16 3.39</td>
<td>3.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.75</td>
<td>11.45 9.62</td>
<td>9.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.50</td>
<td>28.28 25.03</td>
<td>24.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.25</td>
<td>59.14 55.86</td>
<td>53.89</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11: Table 2 of Tian [2013]. Parameters used: $T = 10$, $K \in [80, 120]$, $r = 4\%$, $q_S = 2\%$, $\mu_S = 8\%$, $\sigma_S = 30\%$. The relative risk aversion is 2 or 3 and the weight in options varies from 25% to 90%.
<table>
<thead>
<tr>
<th>Weight in options $\lambda$</th>
<th>Strike price $K$</th>
<th>Pay-to-Performance Sensitivity (PPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$C_T$</td>
<td>$P_T$</td>
</tr>
<tr>
<td><strong>Panel A: Moderate level of risk aversion ($\gamma = 2$)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td>50</td>
<td>0.3075</td>
</tr>
<tr>
<td>0.25</td>
<td>75</td>
<td>0.3229</td>
</tr>
<tr>
<td>0.25</td>
<td>100</td>
<td>0.3255</td>
</tr>
<tr>
<td>0.25</td>
<td>125</td>
<td>0.3201</td>
</tr>
<tr>
<td>0.50</td>
<td>50</td>
<td>0.5271</td>
</tr>
<tr>
<td>0.50</td>
<td>75</td>
<td>0.5285</td>
</tr>
<tr>
<td>0.50</td>
<td>100</td>
<td>0.5067</td>
</tr>
<tr>
<td>0.50</td>
<td>125</td>
<td>0.4745</td>
</tr>
<tr>
<td>0.75</td>
<td>50</td>
<td>0.7908</td>
</tr>
<tr>
<td>0.75</td>
<td>75</td>
<td>0.7479</td>
</tr>
<tr>
<td>0.75</td>
<td>100</td>
<td>0.6799</td>
</tr>
<tr>
<td>0.75</td>
<td>125</td>
<td>0.6086</td>
</tr>
<tr>
<td>0.90</td>
<td>50</td>
<td>1.0558</td>
</tr>
<tr>
<td>0.90</td>
<td>75</td>
<td>0.9348</td>
</tr>
<tr>
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<td>100</td>
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<tr>
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<tr>
<td><strong>Panel B: High level of risk aversion ($\gamma = 3$)</strong></td>
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</tr>
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</table>

Table 12: Table 3 of Tian [2013]. Parameters used: $T = 10$, $K \in [50,125]$, $r = 4\%$, $q_S = 2\%$, $\mu_S = 8\%$, $\sigma_S = 30\%$. The relative risk aversion is 2 or 3 and the weight in options varies from 25\% to 90\%.