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On the Opportunity Cost of Nontradable Stock Options

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SUMMARY

Firms grant to their employees non-tradable stock options as an incentive device. Is the opportunity cost of issuing these options equal to the amount the company would receive if it sold the same options to outside investors? No, it is not, since the options granted to employees are non tradable, due to the incentive scheme to which they are related, and their value, i.e. the opportunity cost, may be lower or larger than the value of the corresponding tradable option.

Keywords: Employees stock options, opportunity cost, nontradable options

JEL: J33, G13

CONTENTS

1 Introduction

A recent paper (Hall and Murphy, 2000) concentrates on the value and the opportunity cost of options granted to employees. The question arises since it has become widely common for employees, mostly executives, to receive options which are not tradable up to a certain date and for which no action can be taken to hedge against risk, such as short selling the underlying stock. The rationale of these limitations hinges upon the incentive to work that the options are meant to provide as long as they are held by employees. Non tradability implies that the risk contained in the underlying asset and, consequently, in the option, cannot be diversified away.

It is maintained that firms granting non tradable options face an opportunity cost that is larger than the benefit, i.e. the value, employees get. If this gap really existed a deadweight loss should result and inefficiency in the incentive mechanism based on stock options would appear. The gap, supposedly, arises since "the opportunity cost of granting an option to employees is the amount the company could have received if it were to sell the option to an outside investor... who is generally free to trade the option or take action such as short selling" (Hall and Murphy, 2000, p.210). Since employees cannot diversify away the risk, they place on the stock options less value than outside investors. However, through their effort they increase the market price of the stock by an amount that may be larger or smaller than the gap due to the risk premium arising from forbidden trade.

As a matter of fact, tradable options are never given to employees, since firms grant nontradable options whose value may be lower or higher than the value of corresponding tradable options according to the effort stock options are able to stimulate. As a result the incentive mechanism may lead either to a Pareto superior outcome or give rise to a deadweight loss whenever the valuation of granted options differs between employees and shareholders.

We concentrate on a rational employee who provides the effort that increases the value of the stock, without affecting the idiosyncratic risk of the firm, i.e. the risk he is not allowed to diversify away once he has been granted the stock option with limited tradability[1]. We then go through the opportunity cost of stock options according to the effectiveness of the incentive mechanism.

[1] We assume away moral hazard that may arise in the relationship between shareholders and executives.

In the next section we use a binomial model to evaluate the opportunity cost of nontradable options granted to employees. In section 3 we derive some results concerning the incentive scheme embodied in the stock option. In section 4 we consider an example of a non neutral effort. In section 5 conclusions are drawn.

2 The shareholders' opportunity cost in a simple binomial model

Suppose, for instance, that, on January 1, 2001, a company grants its employees, as an incentive device, an option that is tradable only in one year, i.e. from January 1, 2002. This option is the basis of a compensation mechansim to induce "profit-performance"[2]. Therefore, its market value (and the opportunity cost for the writer) is not equal to the value of the corresponding wholly tradable option issued at the same date.

To see why, let us define the value of the wholly tradable option at time zero, when it is issued and sold in the market, as F_0. In a simple two-period framework, the value of the corresponding nontradable option for the writer is given by the "profit-performance" he gets. While for the holder, assuming away for simplicity non option wealth and risk aversion, it is equal to the "expectation" on January 1, 2001 of the value that will take the corresponding tradable option on January 1, 2002, minus the "cost of his effort". In other words, there need to be no coincidence of the return on granted options with respect to the equilibrium return required by outside investors on an equivalent-risk traded stock [3].

The above assertion can be made more precise in a two-period binomial model. To this purpose, let us consider a non dividend-paying asset whose returns, at time one, are:

$$S_0 \begin{array}{ll} \nearrow \; S_1^+ = uS_0 & \text{with probability } q \\ \searrow \; S_1^- = dS_0 & \text{with probability } 1-q \end{array} \tag{1}$$

[2] Using the terminology of Murphy (2001).

[3] According to Johnson and Tian (2000, footnote 2, p.6), when the option doesn't expire before the employees leave the firm, the value of the option is reduced for both the employees and the shareholders "below the costs calculated from the valuation models".

where $u > 1$, $d < 1$, and, to eliminate arbitrage opportunities, $u > 1+r > d$, with r as the riskless rate.

Moreover, let us consider an European call option written on (1). Its value over the period is equal to:

$$F_0 \begin{array}{l} \nearrow \; F_1^+ = \max(S_1^+ - K, 0) = S_1^+ - K, \quad \text{with probability } q \\ \searrow \; F_1^- = \max(S_1^- - K, 0) = 0 \qquad \text{with probability } 1-q \end{array} \tag{2}$$

where F_1^+ and F_1^- are the values of the call option at time one according to whether the asset price has gone up or down, and $K \in [S_1^-, S_1^+]$ is the exercise price.

2.1 Shareholders and outside investors

Consider a shareholder who holds the asset (1), writes the European call (2) with the exercise price K and sells it to an outside investor. His wealth at time zero is:

$$V_0 = S_0 + F_0. \tag{3}$$

where F_0 is the price of the call (2) sold to the outside investor. After one period the shareholder's wealth becomes:

$$V_0 = S_0 + F_0 \begin{array}{l} \nearrow \; V_1^+ = S_1^+ - (S_1^+ - K) + (1+r)F_0 = K + (1+r)F_0 \\ \qquad\qquad \text{with probability } q \\ \searrow \; V_1^- = S_1^- + 0 + (1+r)F_0 = S_1^- + (1+r)F_0 \\ \qquad\qquad \text{with probability } 1-q \end{array} \tag{4}$$

In words: with probability q the asset goes up to $S_1^+ = uS_0$. The option is exercised by the investor and the writer loses $(S_1^+ - K)$. With probability $1-q$ the asset falls to $S_1^- = dS_0$ and the call option is not exercised. Yet, the shareholder gets $(1+r)F_0$ if he has invested in a riskless asset the amount F_0 cashed at time zero. If we assume that the asset S_0 does not pay any dividend, the expected gain from holding V_0 is equal to $\Delta^* \equiv E_0(V_1) - V_0$, or, by substitution,

$$\Delta^* = qK + (1-q)dS_0 + rF_0 - S_0 \tag{5}$$

2.2 Sharedolders and employees

So far we have neglected that shareholders give the stock option to employees as an incentive device. This is why the option must be nontradable for a certain time. While there would be no reason to do so if the option were just an ex post compensation.

In our two-period framework, non tradability implies that employees have no right to sell or exercise before time one. Let's assume, for the sake of simplicity, that the employees' effort increases profits between zero and one, while leaving unchanged the probability distribution of the asset returns at time one[4]. Then, the incentive device can be represented rewriting the shareholders' wealth (4) as:

$$W_0 = S_0 + I_0 \begin{array}{l} \nearrow \quad \begin{array}{c} W_1^+ = S_1^+ - (S_1^+ - K) + I_1 = K + I_1 \\ \text{with probability } q \end{array} \\ \\ \searrow \quad \begin{array}{c} W_1^- = S_1^- + 0 + I_1 = S_1^- + I_1 \\ \text{with probability } 1-q \end{array} \end{array} \tag{6}$$

As the employee gets the option for free the shareholders' wealth at zero is given by the value of the stock plus the "cost of the effort", i.e. the discounted "profit-performance" induced by the incentive $I_0 = \rho I_1$, with $\rho = \frac{1}{1+r}$.

At time one the shareholders receive the increment of profit I_1 plus the realization of S, i.e. with probability q the stock goes up to S_1^+ and the option is exercised, while with probability $1-q$ the stock falls to S_1^- and the option goes underwater[5]. Then, the shareholders' expected gain is:

$$\Delta^{**} = qK + (1-q)dS_0 + rI_0 - S_0 \tag{7}$$

Rational shareholders grant the stock option only if $\Delta^{**} \geq 0$. The opportunity cost of this decision is the value of the best foregone alternative, i.e. Δ^*.

Shareholders may gain or lose by granting a nontradable stock option to employees rather than selling a corresponding tradable option to outside investors, i.e.:

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[4] Again, this implies absence of moral hazard.

[5] It is worth noting that in (6), the "profit-performance" I_1 looks like a dividend paid on the stock at time one to shareholders. This "dividend-like" increment resulting from the employees' effort adds to the value of the stock.

$$\Delta^{**} - \Delta^{*} = r(I_0 - F_0) \tag{8}$$

may be zero, negative or positive.

3 The value of the stock option as an incentive device

Now we go through the sign of the difference $\Delta^{**} - \Delta^{*}$, by evaluating the European call F_0 vis à vis the "profit-performance" value I_0.

Consider first the European call F_0. The shareholder and the outside investor would agree to use the standard methodology (Ingersoll, 1987, ch. 14) for pricing it, by setting up a portfolio composed by the call and short sales of N shares of the asset at the current price S_0, i.e.:

$$\Phi_0 = F_0 - NS_0. \tag{9}$$

After one period the value of the portfolio is:

$$\Phi_0 = F_0 - NS_0 \begin{array}{ll} \nearrow \ \Phi_1^+ = F_1^+ - NS_1^+ & \text{with probability } q \\ \searrow \ \Phi_1^- = F_1^- - NS_1^- & \text{with probability } 1-q \end{array} \tag{10}$$

For the portfolio to provide the same return, regardless of the state, we choose N to satisfy $\Phi_1^+ = \Phi_1^-$. Since this portfolio at time 1 is risk free and the asset does not pay out any dividend, the return from holding it equals the capital gain $\Phi_1 - \Phi_0$, and, to avoid arbitrage, $\Phi_1 - \Phi_0 = r\Phi_0$. Solving for the two unknowns, N and F_0, we obtain:

$$F_0 = \rho p F_1^+ \tag{11}$$

with:

$$p = \frac{(1+r) - d}{u - d} > 0 \tag{12}$$

where p is the "risk-neutralized probability", that would prevail in a risk-neutral environment in which the actual return rate $qu + (1-q)d$ is replaced by a certainty-equivalent or risk-neutral rate $pu + (1-p)d$.

3.1 An example where the compensation mechansim does not change the distribution of S.

If shareholders grant the stock option to employees as an incentive device, the option becomes a compensation to induce employees "profit-performance". In this case a different pricing rule is needed to take into account the trade-off between the stock option received by workers and the related "profit-performance". Recalling that we have assumed away non option wealth and risk aversion, the employees value their opportunity to optimally decide selling (or exercising) the stock option by comparing the intrinsic value of the option with that of the European call, net of the "profit-performance", i.e.:

$$f_0 = \max\left[S_0 - K, F_0 - I_0\right] \tag{13}$$

where, from (2), $F_0 - I$ is given by:

$$F_0 - I_0 \quad \begin{array}{l} \nearrow \quad F_1^+ - I_1 = \max(S_1^+ - K, 0) - I_1 = S_1^+ - K - I_1, \\ \qquad\qquad \text{with probability } q \\ \searrow \quad F_1^- - I_1 = \max(S_1^- - K, 0) - I_1 = -I_1 \\ \qquad\qquad \text{with probability } 1 - q \end{array} \tag{14}$$

In words: if at time one the stock option is exercised the employee pays the strike price plus the "cost of the effort" i.e. $K + I_1$. If the stock option goes unexercised, the employee pays only I_1. With early exercise allowed, equation (14) gives the price of the stock option only if it is larger than $S_0 - K$. Otherwise, the price f_0 is given by the intrinsic value of the option, $S_0 - K$.

Nontradability implies that the employees have no right to sell their option before time one and, therefore, rules out the exercise of (13) at time zero. The employees are constrained to hold the option up to time one and pay $K + I_1$ to exercise it or I_1 to leave it. If employees are to accept this "conditionality", introduced by shareholders to get I_1, it must be[6]:

$$F_0 - I_0 \geq S_0 - K \tag{18}$$

[6] Option nontradability implies nontradable stocks for employees. With simple adaptations of (9) we evaluate nontradability for outside investors. If the company stock cannot be traded, the short position in the above portfolio (9) requires an extra payment. Otherwise no rational investor holds the long position. To go long in the company asset a

or, after substituting (9), we can rewrite (18) in term of I_1 as a function of the strike price K [7]:

$$I_1 \leq p(uS_0 - K) - (1+r)(S_0 - K) \equiv -(1+r-pu)S_0 + (1+r-p)K \quad (19)$$

This is no end of the story. To induce employees to perform I_1 we need a further participation condition, i.e.: $f_0 \geq 0$. Within the admissable interval for the nontradable option expressed by (18), this constraint requires:

$$F_0 - I_0 \equiv \rho[p(S_1^+ - K) - I_1] \geq 0 \quad (20)$$

or rearranging terms[8]:

$$I_1 \leq p(S_1^+ - K) \equiv puS_0 - pK. \quad (21)$$

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risk-adjusted rate of return is required that equals the market expected rate of return, i.e. that of outside investors on an equivalent-risk traded security. The difference between the equilibrium rate of return on a similar financial security and the company asset's actual return is analogous to a (constant) dividend yield rate δ. Since a proportional dividend yield rate provides a portfolio return δNS_0, in a risk neutral world, the asset must yield an expected return equal to $r - \delta$. Hence, equation (11) becomes:

$$\tilde{F}_0 = \rho\tilde{p}F_1^+ \quad (15)$$

where:

$$\tilde{p} = \frac{(1+r-\delta) - d}{u - d} > 0 \quad (16)$$

or:

$$\tilde{F}_0 = \rho pF_1^+ - \rho\frac{\delta}{u-d}F_1^+ = F_0 - \rho\frac{\delta}{u-d}F_1^+ \leq F_0 \quad (17)$$

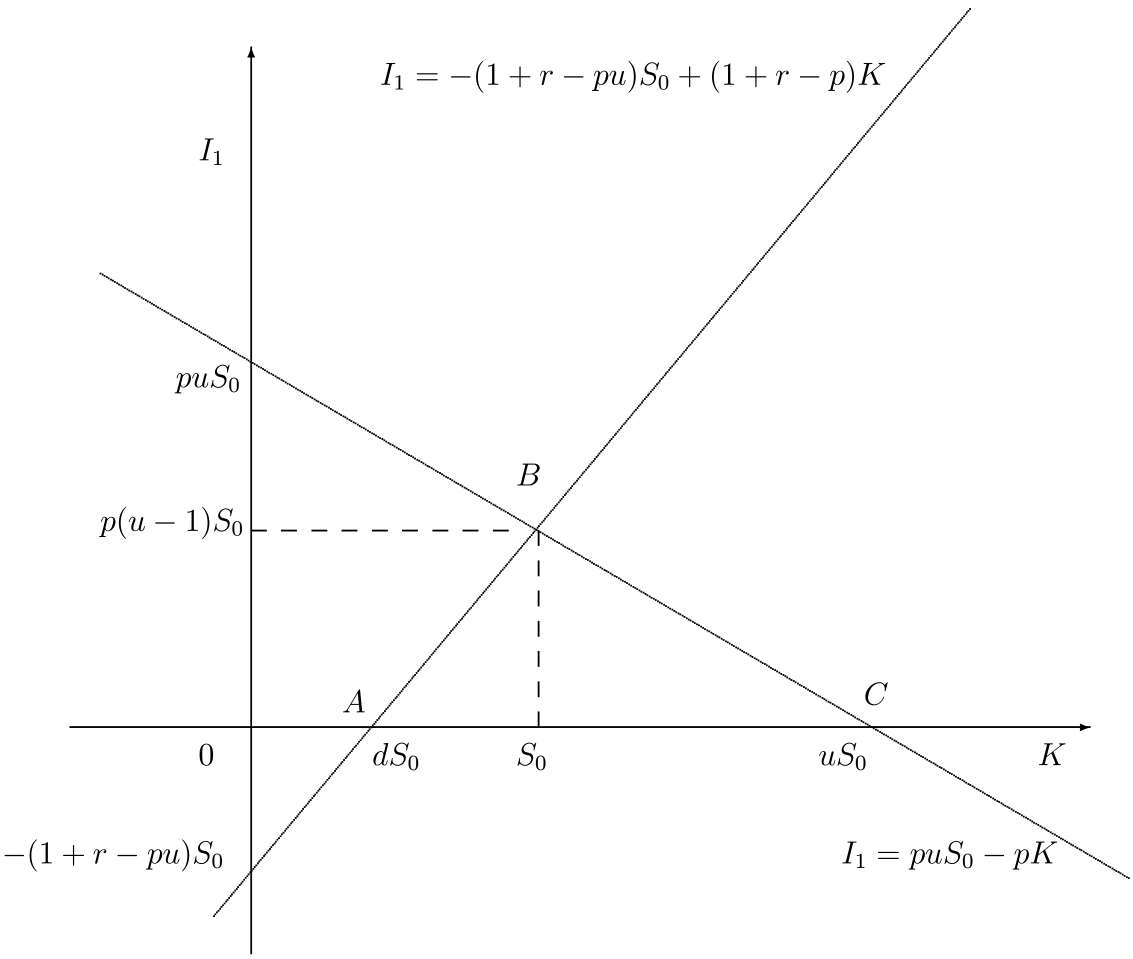
The term on the r.h.s. of (17) is the cost of the asset nontradability (McDonald and Siegel, 1984).

[7]Since $p = \frac{1+r-d}{u-d}$ it is easy to show that $1 + r - pu > 0$

[8]If the risk-free probability p is known, the value of stock option $\frac{F_0}{\rho} = p(S_1^+ - K)$ defines a linear compensation scheme where the exercise price K may be seen as an index of performance which allows the firm to meet the employees' "reservation wage" at the "profit-performance" value I_1 (See Murphy, 2001).

Inequalities (19) and (21) give rise to an admissible region (portrayed in Figure 1 by the area ABC) for (K, I_1) wherein the employees *participate* and *accept* a nontradable option. Notice that, as long as $S_0 - K > 0$ (i.e. the stock option is issued in the money), the biting constraint is (19) and the maximum value of the "profit-performance", the shareholders can obtain, is $I_1 < p(uS_0 - K)$ or, valued at time zero, $I_0 < F_0$. While, if $S_0 - K \leq 0$ (i.e. the stock option is issued out of the money or just at the current price), the biting constraint is (21) and the maximum benefit for shareholders is $I_1 = p(uS_0 - K)$ or, valued at time zero, $I_0 = F_0$.

Figure 1 : Admissable Set



We sum up the above statements in two results. In the first we go through the opportunity cost while in the second we provide a simple rational explanation of why usually stock options are granted either out of money or at the current price.

Result 1 If we rule out risk aversion and non option wealth, the maximum value of the effort-incentive shareholders may get from employees is equal to the value of the European call option sold to outside investors.

In other words, for all $K \in [S_0, uS_0]$ the opportunity cost for shareholders of the stock option is always equal to the best foregone alternative, i.e.: selling to outside investors, or $\Delta^{**} - \Delta^{*} = 0$.

Result 2 If the stock option is granted in the money, the employees' participation constraint requires a lower value of the incentive-effort that goes to shareholders. For all $K \in [dS_0, S_0)$ there is a difference between the opportunity cost and what shareholders get. This difference is negative, i.e. $\Delta^{**} - \Delta^{*} < 0$ (as Hall and Murphy, 2000 maintain).

Finally an additional observation can be added. If we assume employees' risk aversion, the area ABC, where Result 1 holds, shrinks. On the contrary, if we introduce non option wealth the effect of risk aversion is smaller and the area ABC, in which Result 1 holds, gets larger.

3.2 An example where the compensation mechansim changes the distribution of S.

So far we have described an incentive scheme that is neutral for the employees: the value of "profit-performance" I_1 shifts to the left the shareholders' wealth without altering the shape of S. This effect is only partially appriopriable by the employees through the incentive and partecipation constraints. Actual stock option schemes are often designed to let the employees change the distribution of profits and get the additional value as a compensation. In a very simple model we show what happens when the employees are able to change the distribution of S in (1) in the following way:

$$S_0 \begin{array}{ll} \nearrow & S_1'^{+} = u'S_0 \quad \text{with probability } q \\ \searrow & S_1^{-} = dS_0 \quad \text{with probability } 1-q \end{array} \tag{22}$$

where $u' \equiv \alpha u > u > 1$, with $\alpha > 1$. Moreover, to simplify the example, we add $d = \frac{1}{u}$ and $r = 0$. Notice that (22) shows that the employees boost the positive value of the asset, i.e. with probability q the asset may go up to $S_1'^{+} = u'S_0$. Yet in the downturn the asset value is the same as before[9].

[9] If employees affect $u' > u$ they alter the trend of the asset value, without changing probabilities. A similar result may be obtained if we assume that employees are able to influence probability $q' > q$, while leaving unchanged the trend u.

In (22) the downside value of the asset does not change. Then the shareholders' portfolio (6) and (7) do not change. The two constraints for employees, (19) and (21), become:

$$I_1 \leq -(1-p'u')S_0 + (1-p')K \tag{23}$$

and:

$$I_1 \leq p'u'S_0 - p'K. \tag{24}$$

By substituting[10] for p, $1-pu = p$, $p' = p - \Psi(\alpha)$, $1-p'u' = p + d\Psi(\alpha)$, where

$$\Psi(\alpha) \equiv \frac{u^2(\alpha-1)}{(\alpha u^2-1)(u+1)} \in [0,1],$$

we get:

$$\begin{aligned} I_1 &\leq -(1-p'u')S_0 + (1-p')K \equiv \\ &\equiv -pS_0 + (1-p)K + (K-dS_0)\Psi(\alpha) \end{aligned} \tag{25}$$

and:

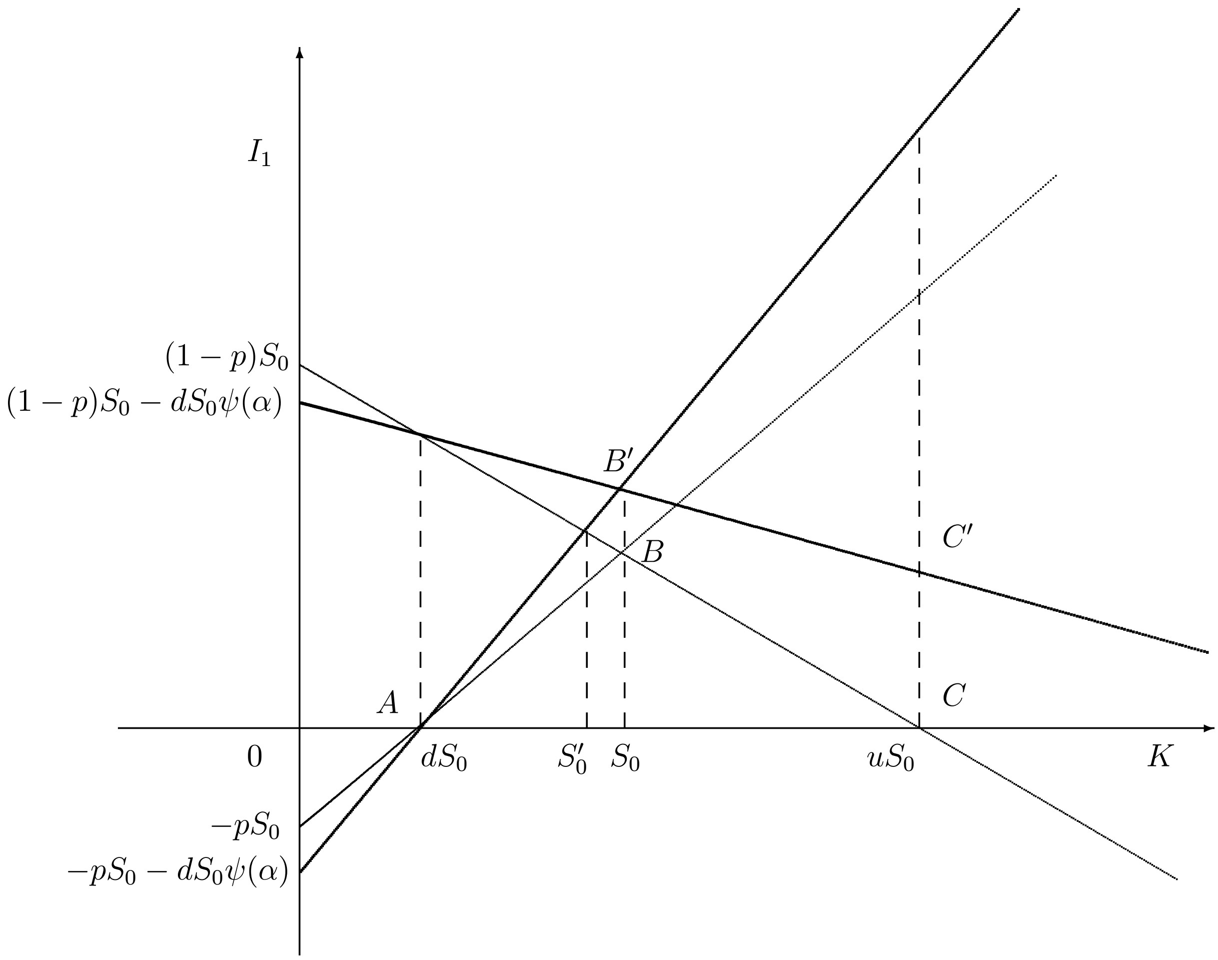
$$\begin{aligned} I_1 &\leq p'u'S_0 - p'K \equiv \\ &\equiv (1-p)S_0 - pK + (K-dS_0)\Psi(\alpha) \end{aligned} \tag{26}$$

[10] It is easy to show that:

1. $p = \frac{1-d}{u-d} = \frac{1-\frac{1}{u}}{u-\frac{1}{u}} = \frac{\frac{u-1}{u}}{\frac{u^2-1}{u}} = \frac{u-1}{u^2-1} = \frac{u-1}{(u-1)(u+1)} = \frac{1}{(u+1)}$
2. $p' = \frac{1-d}{u'-d} = \frac{1-\frac{1}{u}}{\alpha u-\frac{1}{u}} = \frac{\frac{u-1}{u}}{\frac{\alpha u^2-1}{u}} = \frac{u-1}{\alpha u^2-1} = \frac{1}{(u+1)} - \frac{u^2(\alpha-1)}{(\alpha u^2-1)(u+1)} = p - \Psi(\alpha)$ where $\Psi(\alpha) \equiv \frac{u^2(\alpha-1)}{(\alpha u^2-1)(u+1)} \in [0,1]$.
3. $1-pu = 1 - \frac{1-d}{u-d}u = \frac{(u-d)-u+ud}{u-d} = \frac{d(u-1)}{u-d} = \frac{\frac{1}{u}(u-1)}{u-\frac{1}{u}} = \frac{u-1}{u^2-1} = \frac{u-1}{(u-1)(u+1)} = \frac{1}{(u+1)} = p$
4. $1-p'u' = \frac{d(u'-1)}{u'-d} = \frac{\frac{1}{u}(\alpha u-1)}{\alpha u-\frac{1}{u}} = \frac{\frac{1}{u}(\alpha u-1)}{\frac{\alpha u^2-1}{u}} = \frac{\alpha u-1}{\alpha u^2-1} = \frac{1}{(u+1)} + \frac{u(\alpha-1)}{(\alpha u^2-1)(u+1)} = (1-pu) + \frac{\Psi(\alpha)}{u} = p + d\Psi(\alpha)$

As long as the term $(K - dS_0)\Psi(\alpha)$ is positive we are able to substitute the new inequalities (25) and (26) to the old ones. This is done in Figure 2 below.

Figure 2 : Admissable Set: Changes in the Distribution of S



Direct inspection of figure 2 shows that the admissable region where employees *partecipate* and *accept* the nontradable option is now given by the area $AB'C'C$ which is greater than ABC. Therefore, considering the first-oder approximation of the differential $d(\Delta^{**} - \Delta^{*})$ around $r = 0$, we get[11]:

Result 3 In both inequalities (25 and 26) the term $(K - dS_0)\Psi(\alpha) > 0$, goes to zero as $\alpha \to 1$. Therefore:

- if the stock option is granted out of the money or at the current price $K \in [S_0, u'S_0]$, the maximum value of the effort shareholders may obtain from employees is larger than the value of the European call sold to outside investors. In other words, for $dr > 0$, the opportunity cost of granting the option (the value of the best alternative) is lower than the benefit shareholders get, i.e.: $d(\Delta^{**} - \Delta^{*}) > 0$.
- if the stock option is granted in the money, there exists an interval of $K \in (S'_0, S_0)$ where shareholders obtain from employees an effort whose value is larger than the price of the European call sold on the market and then $d(\Delta^{**} - \Delta^{*}) > 0$. While in the remaining part of the interval $K \in [dS, S'_0)$, the opportunity cost is larger than the benefit, i.e.: $d(\Delta^{**} - \Delta^{*}) < 0$ (as Hall and Murphy, 2000 maintain).
- Finally, if $K = S'_0$, we have $d(\Delta^{**} - \Delta^{*}) = 0$

4 Conclusions

We have shown that the opportunity cost of granting non tradable options is not equal to the price of a corresponding tradable option. Non tradability puts a wedge between the option granted to employees and the corresponding option sold to outside investors.

Non tradability of stock option granted to employees finds its rationale in the incentive that options are meant to provide. If we consider the employees' effort we may have that the opportunity cost of non tradable stock options is

[11] Having assumed $r = 0$, we consider the first-oder approximation of the differential of $\Delta^{**} - \Delta^{*}$ around zero, i.e.:

$$d(\Delta^{**} - \Delta^{*}) \mid_{r=0} = (I_0 - F_0)dr - r\frac{\partial F_0}{\partial r}dr = (I_0 - F_0)dr.$$

either larger or smaller than the price of the corresponding tradable option. This adds a rationale to the different exercise prices adopted by firms granting stock options. In particular it explains why options are mostly granted either out of the money or at the current price.

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(xliv) This paper was presented at the International Workshop on "Green National Accounting in Europe: Comparison of Methods and Experiences" organised by the Fondazione Eni Enrico Mattei within the Concerted Action of Environmental Valuation in Europe (EVE), Milan, March 4-7, 2000
(xlv) This paper was presented at the International Workshop on "New Ports and Urban and Regional Development. The Dynamics of Sustainability" organised by the Fondazione Eni Enrico Mattei, Venice, May 5-6, 2000.
(xlvi) This paper was presented at the Sixth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CORE, Université Catholique de Louvain, Louvain-la-Neuve, Belgium, January 26-27, 2001
(xlvii) This paper was presented at the RICAMARE Workshop "Socioeconomic Assessments of Climate Change in the Mediterranean: Impact, Adaptation and Mitigation Co-benefits", organised by the Fondazione Eni Enrico Mattei, Milan, February 9-10, 2001
(xlviii) This paper was presented at the International Workshop "Trade and the Environment in the Perspective of the EU Enlargement ", organised by the Fondazione Eni Enrico Mattei, Milan, May 17-18, 2001
(xlix) This paper was presented at the International Conference "Knowledge as an Economic Good", organised by Fondazione Eni Enrico Mattei and The Beijer International Institute of Environmental Economics, Palermo, April 20-21, 2001
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(li) This paper was presented at the Fourth Toulouse Conference on Environment and Resource Economics on "Property Rights, Institutions and Management of Environmental and Natural Resources", organised by Fondazione Eni Enrico Mattei, IDEI and INRA and sponsored by MATE, Toulouse, May 3-4, 2001
(lii) This paper was presented at the International Conference on "Economic Valuation of Environmental Goods", organised by Fondazione Eni Enrico Mattei in cooperation with CORILA, Venice, May 11, 2001
(liii) This paper was circulated at the International Conference on "Climate Policy – Do We Need a New Approach?", jointly organised by Fondazione Eni Enrico Mattei, Stanford University and Venice International University, Isola di San Servolo, Venice, September 6-8, 2001

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