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Non-marketability and the value of employee stock options

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ABSTRACT

We adapt the Benninga et al. (2005) framework to value employee stock options (ESOs). The model quantifies non-diversification effects, is computationally simple, and provides an endogenous explanation of ESO early-exercise. Using a proprietary dataset of ESO exercise events we measure the non-marketability ESO discount. We find that the ESO value on the grant date is approximately 45% of a similar plain vanilla Black–Scholes value. The model is aligned with empirical findings of ESOs, gives an exercise boundary of ESOs and can serve as an approximation to the fair value estimation of share-based employee and executive compensation. Using the model we give a numerical measure of non-diversification in an imperfect market.

1. Introduction

This paper introduces a valuation model for employee stock options (ESOs) that takes accounts for market imperfections and empirically estimates the value of these market imperfections. The advantage of the valuation model, based on a paper by Benninga et al. (BHS, 2005), is that it directly incorporates non-marketability into asset valuation and is easy to implement in a binomial framework. We use a proprietary data base of employee stock option grants to measure the magnitude of the annual non-marketability premium associated with ESOs and estimate the value of an at-the-money ESO on the grant date relative to a parallel plain vanilla option. We show that the model is aligned with empirical findings of ESOs.

An ESO has special characteristics that differentiate it from standard traded options: First, it has a vesting period – a period in which the employee cannot exercise the option. If job termination takes place during the vesting period, the options are forfeited. Job termination after the vesting period usually means the employee cannot continue to hold the options (typically, exercise is required within 90 days after the job termination date). In addition ESOs are non-transferable and the employee is not allowed to hedge his ESOs by taking short positions in the firm's stock (León and Vaello-Sebastią, 2009).[2] The non-transferability and non-hedgeability features may lead to early exercise of the options and also contribute to the fact that ESOs have no market price (Cvitanić et al., 2008; Carpenter et al., 2010).

A large body of existing literature deals with the pricing and economic implications of ESOs. This extensive literature can be divided into three segments; our model relates to all three of these segments. The first segment of the literature discusses the value of an ESO, and contains two approaches (Bajaj et al., 2006). The *arbitrage-pricing approach* (which can also be referred to as the *reduced-form approach*) uses either lattice-based or continuous-time valuation frameworks to value the ESO with its special features. The models in this approach are usually variations of the Black and Scholes model (BS, 1973) or the Cox et al. (1979) binomial model, and as such, implicitly assume that the options are marketable. Another property of these models is that the early exercise decision is exogenous. Examples include the Hull and White (2004) model, Cvitanić et al. (2008) and León and Vaello-Sebastią (2009). The *utility approach* of the valuation literature uses utility-based models to value the ESO (examples include Detemple and Sundaresan, 1999; Hall and Murphy, 2002; Ingersoll, 2006; Leung and Sircar, 2009). However, while the arbitrage strand of the literature results in explicit pricing formulas of ESOs, the utility

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[2] See Section 16(c) of the U.S. Securities Exchange Act. In addition, Paragraph B80 in FAS 123(R) mentions that "Federal securities law precludes certain executives from selling shares of the issuer's stock that they do not own, and the Board understands that many public entities have established share trading policies that effectively extend that prohibition to other employees". See also Meulbroek (2001) and Bettis et al. (2005).

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approach is not as explicit—pricing in this approach requires assumptions such as the risk aversion and the employee's income and wealth, which make it difficult to implement directly or to infer from publicly observable data (Chance, 2004; Bajaj et al., 2006). Utility models often predict early exercise given the choices the employee faces. Both the arbitrage approach and the utility approach to valuation tend to the conclusion that the BS and binomial models overvalue ESOs (Finnerty, 2005; Carpenter, 1998; Carpenter et al., 2012).[3]

Our model is somewhere between the two approaches above, and includes the advantages of both: In contrast to the reduced-form models, which require somewhat arbitrary assumptions about early exercise, our model (like the utility models) endogenizes this decision into the pricing function. As opposed to the utility approach models (and concordantly with the reduced-form models), our model is based on state prices with a reduced-form specification and is simple to implement. Compared to the utility maximizing models, the model can be viewed as a model that incorporates the utility model parameters into a single factor, thus providing a simplified and more flexible approach to describing exercise behavior and to computing the ESO value. Therefore, our model has both the simplicity of the reduce-form models along with the predictive power of the utility based models.

The second segment of the ESO literature documents actual behavior of the ESOs holders. Typically this strand of the literature documents the early-exercise behavior of ESO holders. Huddart and Lang (1996, 2003) and Carpenter et al. (2012) are typical exponents of this part of the literature. The employee-behavior part of the ESO literature shows clearly that employees tend to early-exercise their options. This behavior contradicts the prediction of standard option-pricing models, in which early exercise of calls is nearly always sub-optimal. Early exercise of ESOs has been attributed to various reasons, typically the difficulty of employees hedging or trading their ESOs, even when the vesting period has passed, because of the long-term nature of the ESO (see Hall and Murphy, 2002; Cvitanić et al., 2008; Carpenter et al., 2010). Our paper is also part of the employee behavior strand of the ESO literature in two ways. First, the analytical model explains early exercise of ESOs by pricing the non-diversifiable aspects of the ESO. Second, our large and unique data base of ESOs enables us to both document early-exercise and calibrate our model's non-marketability measure.

The third segment of the ESO literature relates to the accounting treatment of employee stock options. IFRS2 and ASC 718 (previously FAS 123(R)) require the attribution of the cost of ESOs grants in financial statements. Abstracting from philosophical issues of cost versus value, the actual implementation of the accounting regulations typically ascribes the ESO cost using a standard valuation model, be it BS or one of the other lattice models discussed above. Roughly speaking this literature (of which Chance, 2004; Rubinstein, 1995; Hall and Murphy, 2002 are the most important articles) discusses whether the accounting cost of an ESO should be its value in a perfect-markets setting or the value incorporating the various option restrictions. Our contribution to this discussion is to provide an explicit pricing model that accounts for non-diversification and is both easily implementable and has some connection to the non-diversification of the ESO holder.

The ESO valuation model in this paper uses state prices, which represent the state-dependent present value of \$1 in the future. We adjust the standard state prices by an additional pricing factor that represents the lack of marketability and use the resulted state prices in the valuation. These adjusted *private state prices* are the appropriate state prices for risk-averse employees who are restricted in their diversification, and are therefore exposed to some of the firm's idiosyncratic risk. The adjustment (to the idiosyncratic risk) is measured by an additional discount factor, which we name the non-marketability discount factor, measured in annual terms.

We calibrate the model using a proprietary data set obtained from Tamir Fishman & Co.[4] This comprehensive stock option database includes complete histories of employee stock option grants, vesting structures, option exercises, and cancellation events for all employees. The sample period of ESO grants is between April 1995 and March 2009, and the exercise events period is between December 1998 and October 2009. Our unit of analysis is an exercise event of an ESO by the employee. We use 26,843 ESOs exercise events of 8537 employees employed by 67 firms to estimate the non-marketability measure associated with the private pricing model. We calibrate the estimated non-marketability measure and calculate the ratio of the ESO relative to the value of an at-the-money plain vanilla option (calculated using the BS model), and find that the average (and median) value of the ESO is about 45% relative to an at-the-money plain vanilla BS option.

Finally, we show that the use of the private pricing model is aligned with empirical findings in studies on ESO databases. We present the model predictions regarding the ratio between the stock price to exercise price on the option's exercise date, and demonstrate that these predictions are aligned with the findings of studies that use ESO databases, such as Huddart and Lang (1996), Carpenter (1998) and Bettis et al. (2005). In addition, we calculate the ratio of the private option value relative to the BS value on the exercise date and find again that the model predictions are within the range of empirical estimations (such as Huddart and Lang, 2003; Bettis et al., 2005). Additional predictions of the model are that the employee tends to exercise earlier as more restrictions are added to the stock options, if he is more undiversified, and when the stock's volatility is higher.

The paper contributes to existing literature in several aspects. First, it presents an ESO valuation model which quantifies the non-diversification effects, provides an endogenous explanation of ESO early exercise (relative to the arbitrage models) and is easy to implement (relative to the utility models). In this respect pricing ESO using the private pricing model combines the flexibility of the binomial model along with a theoretical framework which models the behavioral approach that characterizes utility maximizing models. Second, the unique database allows measuring the non-marketability premium associated with ESO and present further evidence on employee's behavior. Because Israeli tax law imposes a tax rate on option exercise profits that is not related to other sources of income, there is little bias in our sample related to the links between ESO exercise and taxation consequences to the employee. Third, our results provide important implications regarding accounting treatment of ESOs cost.

The structure of this paper is as follows: Section 2 extends the BHS (2005) model to ESO pricing. Section 3 discusses the employee option database. Section 4 presents the empirical results of the non-marketability discount of ESOs. Section 5 concludes.

2. Imperfect markets, non-diversification, and the valuation of ESOs

2.1. The model

We use a model developed by Benninga et al. (BHS 2005) to represent the impact of non-diversification on pricing. BHS model

[3] An exception to generally found undervaluation is Hodder and Jackwerth (2011), who incorporate executive control of corporate decisions into ESO valuation.

[4] Tamir Fishman & Co. is an Israeli-based investment house which offers management services of share-based compensation programs. Most firms in the sample are Israeli firms traded on Nasdaq, but the sample also includes a number of Israeli subsidiaries of U.S. firms operating in Israel.

pricing in a binomial framework and assumes that the non-diversified consumer has too much consumption in the good states and too little consumption in the bad states of the world. The resulting state prices of a non-diversified consumer will be *lower* than the market state prices in good states and *higher* than the market prices in bad states.[5]

Let $\{q_u, q_d\}$ represent the *public* price of \$1 in an up/down state world, and let $\{p_u, p_d\}$ represent the *private* price of \$1 in an up/down state world, respectively. We assume that firms use the public state prices for valuation, whereas employees use the private state prices. We assume that:

$$q_u \cdot U + q_d \cdot D = 1$$
$$q_u + q_d = p_u + p_d = 1/R$$
$$p_u < q_u, p_d > q_d$$
$$p_u = q_u - \hat{\delta}$$
$$p_d = q_d + \hat{\delta}$$

where R is the gross one period interest rate, U is the gross one period move-up factor and D is the gross one period move-down factor. The non-diversification measure $\hat{\delta}$ is the spread between the public and the private state prices. U, D, R and $\hat{\delta}$ are related to the size of the interval Δt, but for simplicity we have repressed this relationship in much of our notation. For completeness, if U and D are derived from a lognormal process with annual mean μ and standard deviation σ, then

$$U = \exp\left[\mu\Delta t + \sigma\sqrt{\Delta t}\right],$$
$$D = \exp\left[\mu\Delta t - \sigma\sqrt{\Delta t}\right],$$
$$R = \exp[r\Delta t],$$
$$\hat{\delta} = \delta\sqrt{\Delta t},$$

where δ is the annual non-marketability discount factor. In Section 4 we estimate δ based on actual employee stock option data.

The use of the same state prices by both the firm and employees assumes that the employees can trade freely in all the assets in the market (i.e., can create long and short positions). Differentiating between public and private state prices allows us to drop this assumption. Essentially, we assume that—as a result of trading and hedging restrictions on option grants—risk-averse employees are restricted in their diversification and are therefore exposed to some of the firm's specific risk. The limitations on the stock option granted to the employee and on the employee hedging activity are designated to tie the employee to firm performance.[6] Hence, the standard (i.e. public) state prices are inappropriate to measure the value of the ESO from the employee's perspective.[7]

The technical meaning of the above assumptions is that both private and public state prices assume equal access to the borrowing/lending market and hence face the same borrowing rate. However, the private price for the up state p_u is lower than the public price for the same state q_u and the private price for the down state p_d is higher than the public price for the same state q_d. Were the state prices computed using the probability-adjusted marginal rates of substitution, then the condition $p_u < q_u$, $p_d > q_d$ can be interpreted as meaning that the employee would like to transfer consumption from the good state to the bad state: Relative to his optimal consumption pattern, an employee has too much consumption in the good state and too little consumption in the bad state. $\hat{\delta}$ is the spread between the public and private state prices that captures the non-diversification measure of the employee. In other words $\hat{\delta}$ represents the higher tolerance to the firm's risk of the well-diversified investor than that of the incompletely diversified employee (BHS 2005).[8] Since $p_u < q_u$ and since an employee stock option pays off in the up states, it is obvious that the private valuation of an ESO is less than the public valuation.

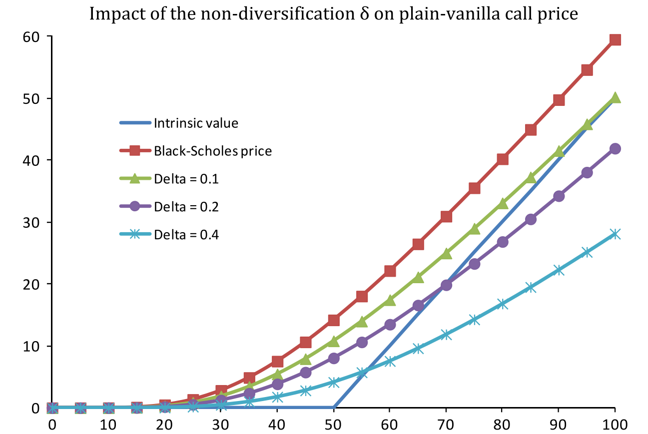

Fig. 1. The value of a European plain vanilla call option using the private pricing model with different values of the non-diversification measure δ. We use the following parameters: exercise price = 50; time to expiration = 4 years; annual interest rate = 5%; annual dividend yield = 0%; a lognormal process with annual mean of 15% and standard deviation of 25% and 50 subdivisions per annum.

2.2. ESO valuation effects of public versus private state pricing

Fig. 1 shows the valuation of an European plain-vanilla call option using the Black–Scholes model (BS) and the private state price model for different values of δ. The graphs assume that both the private and public prices face the same interest rate, so that $q_U + q_D = p_U + p_D$.

From Fig. 1 it is clear that non-marketability (i.e., $\delta > 0$) leads to endogenous early exercise—for some stock price $S > X$, the value line for the non-marketable model is below the option intrinsic value. This outcome is different from classical option pricing theory, and it is due to the non-diversification of the option holder. In Section 4, we use this feature of the model to calibrate the value of δ.

Fig. 2 illustrates the value of an American option using the private pricing model, with different stock option characteristics. The figure shows the effect of dividends, vesting period and employment termination of the employee. Employment termination leads to forfeit of the option when it is not vested and to forced exercise if it is vested (usually, employment termination leads to forced exercise of the ESOs over a period of 90 days from the employment termination date). Following Ammann and Seiz (2004) and Hull and White (2004), we call the employment termination risk *exit rate*, and use this terminology to reflect both forfeit and forced exercise. During the option life we consider a positive probability to the possibility that the employee may leave the firm. The prob-

[5] State prices are the marginal rates of substitution adjusted for the employee's state probabilities and pure rate of time preference.

[6] In addition, employees typically have a higher exposure to the firm's risk, since in addition to equity-based compensation rewards, their future wealth and consumption is also affected from the salary they receive from the same firm.

[7] Chance and Yang (2005) mention that it is not clear that risk-neutral valuation is appropriate for accommodating risks, such as forfeiture and early exercise. These risks are not irrelevant, probably not diversifiable, and almost surely do not have a zero market price of risk.

[8] Bick (1987) shows that geometric Brownian motion for a stock price is compatible with a utility function if and only if the utility function exhibits constant relative risk aversion and the consumption process is multiplicative. It follows that only in the cases described by Bick is the Black–Scholes pricing for European options underpinned by utility foundations. Note that any binomial model and any utility function necessarily give rise to a set of state prices and a (binomial) pricing function for options. However, only in the case that the Bick assumptions hold (they evidently do not in the private pricing model) do we get to Black–Scholes.

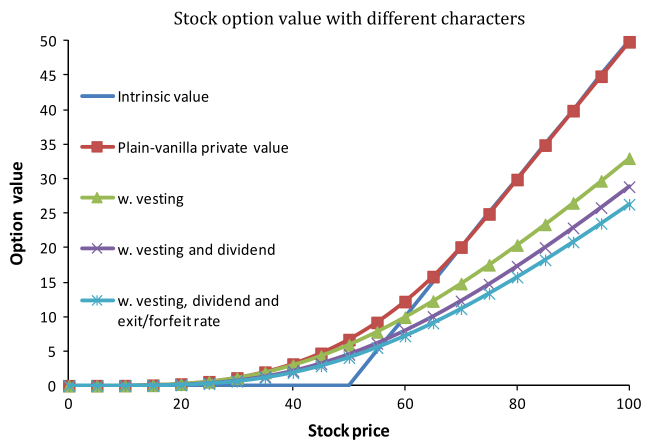

Fig. 2. The value of an American call option using the private pricing model with different characteristics. We present the following options: plain vanilla option (without dividends); option with vesting period; option with vesting period and positive dividend yield; and option with vesting period, forfeit/exit rate and positive dividend yield. We use the following parameters: exercise price = 50; time to expiration = 10 years; annual interest rate = 5%; a lognormal process with annual mean of 15% and standard deviation of 25%; non-diversification measure $\delta = 0.2$ and 50 subdivisions per annum. In addition, we use an annual dividend yield = 2%; vesting period = 3 years and an annual forfeit (exit) rate of 3% (the forfeit rate is during the vesting period; the exit rate is after the vesting period).

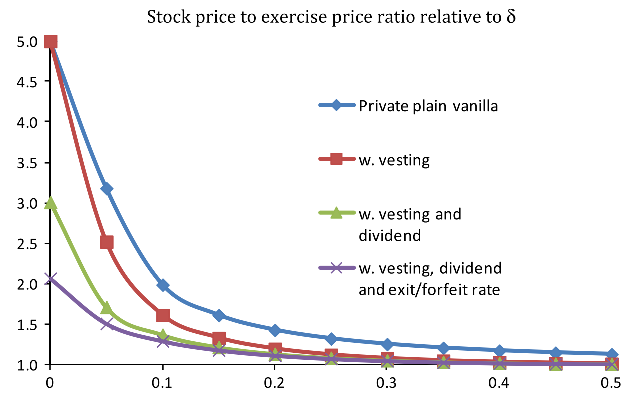

Fig. 3. The implied stock price to exercise price ratio for different values of δ. We use the following parameters: exercise price = 50; time to expiration = 10 years; annual interest rate = 5% and a lognormal process with annual mean of 15% and standard deviation of 25% and 50 subdivisions per annum. For the relevant graphs, we use a vesting period = 3 years; annual exit rate = 3%; annual dividend yield = 2%.

ability the employee leaves the company is modeled by an annual exit rate e and can be determined for each period of time Δt as $e\Delta t$. During the vesting period, the option value is a weighted average of the private value (with a probability of $1 - e\Delta t$) and zero in a case of possible forfeit (with a probability of $e\Delta t$). After the vesting period, the option value is a weighted average of the private value and $\text{Max}(S_t - X, 0)$ with the same probabilities as above.[9] Fig. 2 shows that as more limitations are added to the stock options, the employee attributes a lower value to the stock option and exercises it earlier. From the simulation it seems that the vesting period has more impact than the dividend rate or the employees exit rate.[10]

An additional simulation which relates to the option literature is the implied stock price to exercise price (S/X) ratio on the (early) exercise date. For a given value of the non-diversification measure δ, the option holder will early exercise the option, and the S/X ratio will be determine. Fig. 3 presents the S/X ratio as a function of the non-diversification measure δ, for ESOs with different characteristics, and demonstrates that as we add more limitations to the ESO, the employee will tend to exercise it earlier once the option is in the money. The implied S/X ratio using the private pricing model, presented in Fig. 3, is within the range of the empirical findings (which are presented in Section 4 in the paper).

3. Data

We calibrate the model using a proprietary data set obtained from Tamir Fishman & Co., an Israeli-based investment house which offers management services for share-based compensation programs. The data set includes both Israeli firms and Israeli subsidiaries of major American firms operating in Israel. Tamir Fishman supplied this data on the condition that the companies and employee identity remain anonymous. In this paper we identify the companies using a two-digit SIC code.

The database is comprised of complete histories of stock option grants, vesting structures, option exercises and cancellation events for all employees in both private and public firms. We identify 94 firms that are either currently public, were public in the past or were acquired by a public firm and now serve as its subsidiary. After cleaning up the data, the final sample includes 26,843 exercise events of 8537 employees in 67 firms. The ESO grants sample period is between April 1995 and March 2009, and the exercise events period is between December 1998 and October 2009.

The unit of analysis is based on the exercise events of the employees in the sample (usually, each grant has several exercise events, and there are employees who are granted more than one ESO grant). Each exercise event contains information on the specific grant (grant date, grant number, etc.), the amount of option exercised, the stock price on the exercise date and the currency in which the stock is traded. We clean the data by performing the following actions:

- We focus on employees of the sample firms, and exclude subcontractors which were also granted with stock options (as part of their compensation) from the sample.
- We exclude exercise events in which the exercise price is lower than 0.1 (options with low exercise are parallel to restricted stocks) or in case less than 50 shares were exercised, to avoid microstructure effects.[11]
- Since we are interested in only in voluntary exercise of ESOs, we exclude from the sample exercise events which represent forced exercise. Forced exercise usually results from job termination or merger and acquisition.[12] Hence, we exclude all exercise events that were made 100 days before or after the employee job termination. This period reflects the common practice to allow employees up to 3 months to exercise their stock options after they cease working in the company. We exclude 100 days preceding the job termination to account for the case that the employee exercises his stock option as part of his plan to cease working in the company.

[9] For simplicity only, we use the same exit (forfeit) rate before and after vesting. Changing this assumption will adjust the stock option value accordingly.

[10] We can also use the private pricing model to value restricted stocks. In that case, since the stock is restricted only during the vesting period, we use the private state prices during this period and public state prices subsequently. Consistent with the literature (Longstaff, 1995; Finnerty, 2007), we find that longer vesting period leads to higher discounts for non-marketability.

[11] We exclude SIC code 79 since in contains only one firm with only three exercise events.

[12] We did not exclude exercise events in case a company did not force the employee to exercise her option.

Table 1
Sample description.

Industry	Number of firms	Number of exercise events	Number of employees in the sample
Food and kindred products	1	51	17
Paper and allied products	1	236	136
Chemicals and allied products	4	140	51
Industrial machinery and computers	12	5029	1610
Electronic and other electrical, except computer equipment	17	11,864	3789
Measuring, analyzing, and controlling instruments	6	2438	709
Communications	5	2102	730
Wholesale trade-durable goods	1	515	318
Depository institutions	1	669	251
Business services	17	1521	689
Engineering, accounting and management services	2	2278	237
Total	67	26,843	8537

This table provides summary statistics regarding the relevant industries of the sample firms from the Tamir Fishman database. The summary statistics are organized by the two-digit firm-level SIC categories as reported in CRSP.

Table 2
Time to maturity (in years) of the sample option.

Industry	Mean	Standard deviation	Standard error	Lower quartile	Median	Upper quartile
Entire sample	8.24	1.91	0.01	7.00	9.01	10.01
Food and kindred products	6.30	0.94	0.13	5.89	6.01	7.00
Paper and allied products	5.22	0.81	0.05	5.00	5.00	5.00
Chemicals and allied products	10.01	0.09	0.01	10.01	10.01	10.01
Industrial machinery and computers	7.40	1.56	0.02	6.00	7.01	8.12
Electronic and other electrical, except computer equipment	9.11	1.46	0.01	7.16	10.01	10.01
Measuring, analyzing, and controlling instruments	5.82	1.61	0.03	5.00	5.00	6.95
Communications	9.91	0.47	0.01	10.01	10.01	10.01
Wholesale trade-durable goods	9.53	1.47	0.06	10.01	10.01	10.01
Depository institutions	5.76	0.74	0.03	6.00	6.00	6.00
Business services	8.81	2.06	0.05	7.47	10.01	10.01
Engineering, accounting and management services	6.95	0.68	0.01	7.00	7.01	7.01

This table reports the time to maturity of the option grants on the grant date. The time to maturity is measured as the number of years between the grant date and the expiration date of the option. The summary statistics are computed over all the exercise events in the sample period. The summary statistics is organized by the two-digit firm-level SIC categories as reported in CRSP.

- We exclude exercise events that were 100 days before the option expiration date, since it does not represent suitable early exercise patterns. In addition, according to the underlying theory, if the option is exercised near its maturity, the non-marketability measure is zero.
- ESOs with lifetime of less than 4 years were excluded from the sample. Most of these grants represent restructuring of equity-based compensation during the year 2001 or lack sufficient data.

We also collect data regarding stock prices, dividends and interest risk-free rates in the estimation procedure. Stock prices and dividend payments are obtained from CRSP, Tel-Aviv Stock Exchange (TASE) website, Yahoo! Finance and websites of the companies themselves; the term structure of annual interest rates is obtained from CRSP, the Bank of Israel website and European central banks websites.

Stock prices are used to calculate historical volatility, calculated using the daily continuous compounded return of 60 trading days, subject to a minimum of 13 trading days in a month restriction.[13] Dividends are used to incorporate the expected dividend yield in the pricing model. Only 12 out of 67 firms (17.91%) paid dividends during the sample period. We calculate the annual dividend yield for each firm, and calculate the expected dividend yield of year t as the arithmetic mean of the dividend yield of years $t-1$ to $t-3$. The term structure of interest rates using government bonds is used to match a risk-free rate to the pricing model. For each exercise event, we matched an interest rate with the closest duration to the remaining time to maturity of the option, controlling for the currency of the underlying stock.

3.1. Sample description

Table 1 describes the industries according to the two-digit firm-level SIC codes from CRSP. There is a considerable heterogeneity in the firm industries in the sample. In addition, a major part of the firms comprising the dataset are new-economy firms.[14] These new economy firms represent 41.17% of the sample firms, 21.92% of the employees in the sample and 18.31% of the exercise events in the sample. 86.57% of the sample firms are traded in the US, 28.36% in TASE and 4.48% in European stock exchanges. 22.39% are dual firms (their stocks are traded in more than one exchange).

Table 2 provides summary statistics on the ESO's lifetime (i.e. the contractual option life) and presents a relatively homogeneous picture: The contractual option life sample mean (median) is 8.24 (9.01), indicating on the nature of ESOs as a compensation tool.

[13] The results of Section 4 remain the same if we use an estimation of historical volatility using continuous compounded return of 126 trading days and 30 days.

[14] New economy firms defined as companies with primary SIC codes of 3570 (computer and office equipment), 3571 (electronic computers), 3572 (computer storage devices), 3576 (computer communication equipment), 3577 (computer peripheral equipment), 3661 (telephone and telegraph apparatus), 3674 (semiconductor and related devices), 4812 (wireless telecommunication), 4813 (telecommunication), 5045 (computers and software wholesalers), 5961 (electronic mail-order houses), 7370 (computer programming, data processing), 7371 (computer programming service), 7372 (prepackaged software) and 7373 (computer integrated systems design).

Table 3
The stock to exercise price (S/X) ratio on the exercise date.

Industry	Mean	Standard deviation	Standard error	Lower quartile	Median	Upper quartile
Panel A: Empirical evidence on the stock price to exercise price (S/X) ratio in our sample						
Entire sample	2.96	8.52	0.05	1.35	1.72	2.79
Food and kindred products	2.63	0.89	0.13	1.62	2.86	3.42
Paper and allied products	2.52	0.97	0.06	1.87	2.40	2.58
Chemicals and allied products	1.93	0.61	0.05	1.43	1.89	2.33
Industrial machinery and computers	3.32	8.57	0.12	1.31	1.70	2.37
Electronic and other electrical, except computer equipment	2.64	2.93	0.03	1.28	1.56	3.18
Measuring, analyzing, and controlling instruments	1.92	1.30	0.03	1.37	1.54	1.88
Communications	2.28	1.00	0.02	1.70	2.12	2.63
Wholesale trade-durable goods	3.69	1.61	0.07	2.59	3.16	4.86
Depository institutions	1.56	0.18	0.01	1.44	1.63	1.70
Business services	8.68	30.45	0.78	1.45	2.17	4.68
Engineering, accounting and management services	2.14	0.81	0.02	1.60	1.90	2.39

Panel B: Empirical evidence on the stock price to exercise price (S/X) ratio in previous literature

Huddart and Lang (1996)	Average	Median	1st Quartile	Quartile	Sample		Sample period
	2.20	1.60	1.28	2.50	All employees		Late 1980s–Early 1990s
Carpenter (1998)	Average	Median	Quartile	Quartile	SD	Sample	Sample period
	2.75	2.47	1.15	8.32	1.42	Executives	1979–1994
Bettis et al. (2005)	Average	Median	1st percentile	99th percentile	Sample		Sample period
	3.55	2.57	1.04	17.34	Corporate insiders		1996–2002

Panel A provides the summary statistics over the sample period of the stock price to exercise price ratio on the exercise date. Panel B reports the empirical findings of the stock price to exercise price (S/X) ratio on the exercise date in previous literature. The summary statistics are organized by the two-digit firm-level SIC categories as reported by CRSP.

Most of the option grants across industries range between 8 and 10 years. Exceptions include the industries of paper and allied products and measuring, analyzing, and controlling instruments, which have a mean and median of less than 6 years.

Panel A of Table 3 reports the summary statistics of the stock price to the exercise price ratio (S/X) of the sample data. The mean (median) S/X ratio in the sample is 2.96 (1.72), reflecting the fact that the sample contains very high S/X ratios of ESO exercises during run-ups in the stock market which cause to deviations of the mean relative to the median (note that the entire sample mean is higher from the upper quartile). Specifically, these ratios stem from market run-ups during the end of the 1990s and the beginning of 2000. This difference indicates that only few employees enjoyed the high profit from ESO exercise. This phenomenon is especially noticeable in the business services industry. In addition to the difference within the sectors, there is also difference in the S/X ratios across sectors. The business services and the wholesale trade-durable goods industries have high mean S/X ratios (but only the wholesale trade-durable goods industry has a high median). Low S/X medians are found in the electronic and other electrical and in the measuring, analyzing, and controlling instruments industries (1.56 and 1.54, respectively). Panel B of Table 3 provides a focused summary of the empirical findings of the S/X ratio in the literature. Our findings are consistent with the findings of Carpenter et al. (2012) and Bettis et al. (2005).[15]

4. Empirical results

We use the proprietary database to estimate the ESO value using the private pricing model on the option's grant date. The estimation procedure includes two stages: in the first stage we estimate the non-diversification measure δ on the ESO exercise date. In the second stage we calibrate the non-diversification estimation and calculate the ESO value using the private pricing model. We present the pricing results as percentage to a plain vanilla stock option, calculated using BS model on the grant date.

The non-diversification estimation is based on the revealed preference approach. When an employee exercises her ESOs, she reveals her preferences which indicate that in the specific point in time, the option value is lower than the intrinsic value. As a result, we use the intrinsic value as a proxy for the subjective ESO value of the employee.[16]

The procedure of the non-diversification estimation focuses on the ESO's exercise date. In a standard pricing procedure, the parameters of the option pricing are used to determine the option value. For example, using the remaining time to maturity of the option along with the risk free rate, underlying price, underlying volatility, dividend rate and the exercise price, the option value can be calculated (using the BS or the binomial model). Here, we set the intrinsic value to serve as the ESO price, and calculate the parameter δ, which is unknown. Formally speaking, we find an annualized δ such that

$$\mathrm{ESO}_{\mathrm{private}}(S, X, \delta, r, \sigma, T - t, div, e) = IV$$

where $\mathrm{ESO}_{\mathrm{private}}$ represents the private ESO value using the private pricing model, S denotes the underlying stock price on the exercise date, X denotes the option's exercise price, r denotes the risk-free rate on the exercise date, σ denotes the standard deviation of the underlying share, $T - t$ denotes the remaining time to maturity of the option, div denotes the expected dividend yield and e denotes the employee's exit rate.

Table 4 reports the estimation results of the annual non-diversification measure δ. We calculate the non-diversification measure for every exercise event, and present the aggregate results according to industries. We apply the following parameters in the estimation procedure: the market parameters include the price, the dividend rate and the annual historical volatility of the stock on the exercise date. The interest rate is the government bond rate with the closest duration to the remaining time to maturity of the option. The option parameters include the exercise price, the remaining time to maturity, and following Bettis et al. (2005) an

[15] Possible explanations to the variation in the S/X ratio in the literature are the differences in the sample period and in the sample population. The empirical evidence presented on Table 4 do not include the findings reported by Carpenter et al. (2012), which provide extensive documentation regarding the S/X ratio across industries, and report similar results.

[16] We ignore taxes: under Israeli tax law, option exercise is largely independent of taxes; there is a lower tax rate for ESOs if the option is exercised 2 years after the grant date, and this tax obligation cannot offset parallel tax losses.

Table 4
Estimation of the non-marketability measure δ and the empirical measures in the literature.

Industry	Mean	Standard deviation	Standard error	Lower quartile	Median	Upper quartile	t-Statistics	Pr > |t|
Entire sample	0.180	0.248	0.002	0.045	0.102	0.210	119.13	<.0001
Food and kindred products	0.027	0.044	0.006	0.000	0.000	0.047	4.38	<.0001
Paper and allied products	0.004	0.015	0.001	0.000	0.000	0.000	3.70	0.0003
Chemicals and allied products	0.199	0.297	0.025	0.045	0.097	0.208	7.96	<.0001
Industrial machinery and computers	0.193	0.250	0.004	0.050	0.114	0.237	54.57	<.0001
Electronic and other electrical, except computer equipment	0.218	0.295	0.003	0.041	0.133	0.255	80.31	<.0001
Measuring, analyzing, and controlling instruments	0.168	0.192	0.004	0.068	0.100	0.180	43.21	<.0001
Communications	0.107	0.120	0.003	0.044	0.082	0.140	40.86	<.0001
Wholesale trade-durable goods	0.092	0.095	0.004	0.040	0.075	0.096	22.10	<.0001
Depository institutions	0.127	0.186	0.007	0.048	0.068	0.128	17.68	<.0001
Business services	0.148	0.197	0.005	0.026	0.088	0.192	29.28	<.0001
Engineering, accounting and management services	0.117	0.113	0.002	0.055	0.085	0.148	49.58	<.0001

This table reports the non-marketability estimation on the exercise date using the specific characters of each ESO. Time to maturity is measured as the number of years between the exercise date and the original expiration date of the option grant. Annual risk-free rate is adjusted according to the share's currency. Volatility is estimated by historical volatility of the share. The summary statistics are computed over all the exercise events in the sample period and grouped using two-digit firm-level SIC categories as reported in CRSP.

Table 5
Remaining time to maturity of the sample options (in years) on the exercise date.

Industry	Mean	Standard deviation	Standard error	Lower quartile	Median	Upper quartile
Entire sample	4.84	2.42	0.01	2.90	4.90	6.94
Food and kindred products	1.89	0.76	0.11	1.11	2.05	2.58
Paper and allied products	1.49	0.74	0.05	0.85	1.50	1.95
Chemicals and allied products	7.18	1.58	0.13	6.60	7.29	8.07
Industrial machinery and computers	4.09	2.36	0.03	2.24	3.65	6.05
Electronic and other electrical, except computer equipment	5.40	2.14	0.02	4.01	5.50	7.12
Measuring, analyzing, and controlling instruments	2.42	1.93	0.04	0.95	1.90	2.87
Communications	7.16	1.20	0.03	6.46	7.36	7.92
Wholesale trade-durable goods	7.99	1.83	0.08	8.04	8.70	8.86
Depository institutions	3.12	1.31	0.05	1.97	2.96	4.20
Business services	5.64	2.23	0.06	4.12	6.01	7.38
Engineering, accounting and management services	3.53	1.42	0.03	2.62	3.61	4.47

This table provides the summary statistics over the sample period for the remaining term (in years) of the stock option on the exercise date. The remaining term is measured as the difference between the expiration date and the exercise date. The summary statistics are organized by the two-digit firm-level SIC categories as reported by CRSP.

annual exit (forfeit) rate e of 3%. Since the calculation of δ performs after vesting, we refer to the option value as a weighted average of the private value with the probability of $1 - e\Delta t$ and Max $(S_t - X,0)$ with the probability of $e\Delta t$, which reflects the common practice of forced exercise of vested options upon job termination. We use 40 subdivisions per annum in the calculation.

The mean (median) non-diversification measure δ in the entire sample is around 0.1804 (0.1018). A relatively high mean non-diversification measure is found in the chemicals and allied products, industrial machinery and computers and electronics. These industries, which represent a major part of the new-economy firms, contain more non-diversified employees. A relatively low mean non-diversification measure is found in the food and kindred products and the paper and allied products industries.

Table 5 reports the remaining time to maturity (in years) of the ESOs on the early exercise date. Combined with the data of Table 2, its findings indicate on the remaining option life relative to the lifetime of the ESO. The mean (median) of the entire sample indicates that the ESOs in the sample are exercised after 41.3% (45.6%) of its lifetime. There is a considerable heterogeneity across industries: in the food and kindred products and the paper and allied products industries employees tend to exercise their ESO relatively late (after 70% and 71.3% of the option lifetime, respectively), while in the wholesale trade-durable goods, communications and chemicals and allied products industries, ESOs are exercised relative quick (after 16.1%, 27.7% and 28.3% of the option lifetime, respectively). Most of the ESOs are exercised when the remaining time to maturity is approximately two-thirds to half of the option life term. These findings are consistent with the findings of Huddart and Lang (1996) and Carpenter et al. (2012).

In addition, the findings in Table 5 correspond with the findings in Panel A of Table 3, and match the underlying theory predictions. An agent with a lower non-diversification measure will tend to keep the option rather than exercising it (recall that if the non-diversification measure is zero and the underlying stocks do not pay dividends, according to the theory the option will be exercised on the maturity date). One can observe that when the non-diversification measure is low (high), the remaining time to maturity on the early exercise date is smaller (larger). For example, in the food and kindred products and the paper and allied products industries a low non-diversification measure is followed by a relatively later exercise of the ESO.

Table 6 presents the private pricing model estimations of at-the-money ESOs divided by the value of plain vanilla stock options calculated using BS model on the grant date. After obtaining the non-diversification measure for every event in the sample, we calibrate it into the pricing model and calculate the ESO's private value. Formally speaking, we carry out the following estimation

$$\frac{\text{ESO}_{\text{private}}(S, X, \delta, r, \sigma, T, div, e)}{\text{ESO}_{\text{BS}}}$$

where $\text{ESO}_{\text{private}}$ is the private option value, T is the option's contractual life and ESO_{BS} is the option value using the BS model, both on the grant date.

Table 6
ESO private value relative to Black–Scholes value (in percentage) on the grant date.

Industry	Mean (%)	Standard deviation (%)	Standard error (%)	Lower quartile (%)	Median (%)	Upper quartile (%)	*t*-Statistics	Pr > |*t*|
Entire sample	44.83	23.27	0.14	26.48	44.64	62.74	315.69	<.0001
Food and kindred products	72.22	18.16	2.54	58.33	78.71	89.92	28.39	<.0001
Paper and allied products	91.64	6.19	0.40	91.87	93.78	93.78	227.47	<.0001
Chemicals and allied products	38.42	19.41	1.64	22.80	41.29	54.53	23.42	<.0001
Industrial machinery and computers	44.76	24.00	0.34	25.22	42.13	63.59	132.27	<.0001
Electronic and other electrical, except computer equipment	41.88	23.34	0.21	23.06	37.71	63.57	195.49	<.0001
Measuring, analyzing, and controlling instruments	45.21	22.04	0.45	32.81	50.01	58.79	101.3	<.0001
Communications	48.25	20.82	0.45	33.53	47.19	60.99	106.24	<.0001
Wholesale trade-durable goods	48.04	17.32	0.76	40.13	48.45	62.38	62.93	<.0001
Depository institutions	42.26	15.62	0.60	35.63	46.25	51.60	69.99	<.0001
Business services	49.96	25.30	0.65	30.73	48.35	71.16	77.01	<.0001
Engineering, accounting and management services	48.32	20.36	0.43	33.60	50.61	61.86	113.25	<.0001

This table reports the value of the ESO using the private pricing model relative to a plain vanilla Black–Scholes value of the ESO on the grant date. The non-marketability measure is estimated on the exercise date and calibrated into the model. Time to maturity is measured as the number of years between the grant date and the original expiration date of the option grant. Annual risk-free rate is adjusted according to the share's currency. The volatility is estimated by historical volatility of the stock. The summary statistics are computed over all the exercise events in the sample period, and grouped using two-digit firm-level SIC categories as reported in CRSP.

The private value calculation in Table 6 uses market parameters which include the price, the dividend rate and the annual historical volatility of the stock on the grant date. The interest rate is the government bond rate with the closest duration to the lifetime of the option. In addition, we use the option parameters which include the exercise price, the option lifetime, vesting period and an assumed annual exit (forfeit) rate *e* of 3%.[17] During the vesting period, the option value is calculated as a weighted average of the private value (with a probability of $1 - e\Delta t$) and zero in a case of possible forfeit (with a probability of $e\Delta t$). After the vesting period, the option value is a weighted average of the private value and $\mathrm{Max}(S_t - X,0)$ with the same probabilities as presented above. We also use 40 subdivisions per annum in the calculation. The value of at-the-money plain vanilla stock option is calculated using the Black–Scholes formula with parallel parameters.

According to Table 6, the mean private ESO value is about 45% relative to a plain vanilla BS value. In the industries food and kindred products and the paper and allied products the value is higher, around 72.2% and 91.6%, respectively. The lower values appear in the industries chemicals and allied products, electronics and depository institutions. These findings are consistent with the predictions of Meulbroek (2001) and with the findings of Ikäheimo et al. (2006). According to Meulbroek (2001), in more volatile industries, (such as new economy firms), an undiversified manager would assign lower value to his stock options relative to undiversified manager from less volatile industries, which is consistent with our results. For example, in entrepreneurially-based firms with higher stock volatility, Meulbroek estimates that an undiversified manager would value options at 53% of their cost to the granting firm. Further, Ikäheimo et al. (2006) use the prices of tradable executive stock options, traded at the Helsinki stock exchange after the options are vested (which means these are transferable stock options). Ikäheimo et al. (2006) show major underpricing of the ESO which can reach over 50% discount relative to BS value. Since Ikäheimo et al. (2006) examine tradable ESOs, the non-marketability associated with these options should be less comparing to the standard case of non-tradable stock options, which in turn implies that the discount of untradable stock options should be higher than the one found by Ikäheimo et al. (2006). Overall, these results point out a relative high discount of equity based compensation.

[17] Since each ESO grant has a graded vesting schedule, the vesting period of options that were granted together is different. Hence, the vesting period of each exercise event is calculated as follows: in case the date in which the option grant is fully vested is known, we take middle of the vesting period to be the vesting period of this record. In case this date is not reported, we define the vesting period to be 20% of the option life (which is parallel to a middle of a vesting period for an ESO with 4 years of vesting and a lifetime of 10 years).

4.1. Calculating the foregone BS value on the exercise date

A possible implementation of the private pricing model is to use its predictions to calculate the remaining (or foregone) BS value on the option's exercise date. For options on non-dividend paying stocks, the BS value always exceeds the intrinsic value. Hence, early exercise of such an ESO implies that the employee waives the embedded time value, which is the gap between the private value and the BS value. This value, which we name the remaining (foregone) value and calculate it in BS terms, should be a positive function of the non-diversification measure δ, since higher δ causes to earlier exercise.

Fig. 4 presents the foregone BS value, calculated as $1 - \frac{ESO_{private}}{BS\ value}$ for a given value of the non-diversification measure δ on the ESO

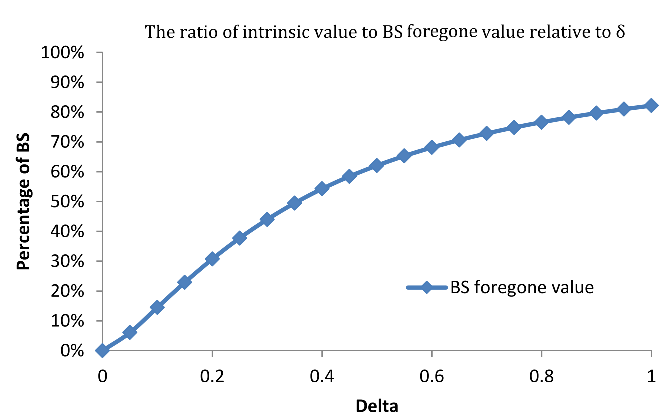

Fig. 4. The BS foregone value (in %) upon early exercise of ESO under the assumption that the employee exercises the stock option when his private value equals the intrinsic value. We use the following parameters: exercise price = 50; time to expiration = 4 years; annual interest rate = 5%; annual dividend yield = 2%; vesting period = 1 year; and a lognormal process with annual mean of 15% and standard deviation of 25% and 50 subdivisions per annum.

Table 7
The foregone time value of the ESO on the exercise date.

Industry	Mean (%)	Standard deviation (%)	Standard error (%)	Lower quartile (%)	Median (%)	Upper quartile (%)	t-Statistics	Pr > |t|
Panel A: The ESO's foregone time value in our sample								
Entire sample	21.85	19.03	0.12	7.28	15.01	32.55	188.14	<.0001
Food and kindred products	7.44	5.86	0.82	2.33	5.25	11.56	9.06	<.0001
Paper and allied products	6.21	3.80	0.25	2.85	5.78	9.15	25.13	<.0001
Chemicals and allied products	26.01	19.05	1.61	12.70	18.08	33.45	16.15	<.0001
Industrial machinery and computers	19.61	17.36	0.24	5.26	14.80	29.01	80.12	<.0001
Electronic and other electrical, except computer equipment	26.62	21.93	0.20	7.63	18.20	41.80	132.24	<.0001
Measuring, analyzing, and controlling instruments	15.21	13.33	0.27	6.29	11.18	19.53	56.33	<.0001
Communications	23.44	13.33	0.29	13.80	20.25	30.60	80.63	<.0001
Wholesale trade-durable goods	13.87	9.17	0.40	7.84	13.03	15.53	34.33	<.0001
Depository institutions	18.98	12.72	0.49	8.39	19.12	23.83	38.57	<.0001
Business services	19.70	18.76	0.48	3.65	14.44	30.89	40.95	<.0001
Engineering, accounting and management services	13.33	10.73	0.22	7.14	11.60	16.05	59.31	<.0001

Panel B: ESO's foregone time value in the literature

Huddart and Lang (2003)						
Average	Median	Quartile	Quartile	SD	Sample	Sample period
74.23%	79.15%	55.44%	96.50%	23.08%	All employees	1985–1994
Bettis et al. (2005)						
Average	Median	1st percentile	99th percentile	SD	Sample	Sample period
90.00%	84.00%	12.00%	100.00%	NA	Corporate insiders	1996–2002

Panel A reports the average value the intrinsic value relative to a plain vanilla Black–Scholes value of the ESO on the exercise date across industries using two-digit firm-level SIC categories as reported in CRSP. Time to maturity is measured as the number of years between the exercise date and the original expiration date of the option. Annual risk-free rate is adjusted according to the share's currency on the exercise date, adjusted to the remaining time to maturity. The volatility is estimated by historical volatility of the stock. The summary statistics are computed over all the exercise events in the sample period. Panel B provides results of the option's intrinsic value relative to the BS value in the literature. Huddart and Lang (2003) estimated the ratio for an average month. Bettis et al. (2005) report the ratio on the exercise date.

Table 8
ESO private value relative to Black–Scholes value (in percentage) on the grant date for non-international conglomerates.

Industry	Mean (%)	Standard deviation (%)	Standard error (%)	Lower quartile (%)	Median (%)	Upper quartile (%)	t-Statistics	Pr > |t|
Entire sample	50.67	22.10	0.16	34.91	52.50	67.33	323.79	<.0001
Food and kindred products	72.21	18.16	2.54	58.33	78.70	89.91	28.40	<.0001
Paper and allied products	91.63	6.19	0.40	91.86	93.78	93.78	227.48	<.0001
Chemicals and allied products	38.42	19.41	1.64	22.80	41.30	54.54	23.42	<.0001
Industrial machinery and computers	52.02	23.09	0.42	34.56	53.99	71.74	123.55	<.0001
Electronic and other electrical, except computer equipment	53.35	21.00	0.25	37.65	58.61	70.27	212.28	<.0001
Measuring, analyzing, and controlling instruments	45.21	22.04	0.45	32.80	50.01	58.79	101.30	<.0001
Communications	48.25	20.82	0.45	33.53	47.19	60.99	106.24	<.0001
Wholesale trade-durable goods	48.04	17.32	0.76	40.13	48.45	62.39	62.93	<.0001
Depository institutions	42.26	15.62	0.60	35.64	46.26	51.60	69.99	<.0001
Business services	49.96	25.30	0.65	30.73	48.35	71.17	77.01	<.0001
Engineering, accounting and management services	48.32	20.36	0.43	33.59	50.62	61.86	113.25	<.0001

This table reports the average value the intrinsic value relative to a plain vanilla Black–Scholes value of the ESO on the exercise date across industries using two-digit firm-level SIC categories as reported in CRSP. The sample includes 19,941 employees from 61 firms. International conglomerates are excluded from the sample. Time to maturity is measured as the number of years between the exercise date and the original expiration date of the option. Annual risk-free rate is adjusted according to the share's currency on the exercise date, adjusted to the remaining time to maturity. The volatility is estimated by historical volatility of the stock. The summary statistics are computed over all the exercise records in the sample period.

exercise date. According to Fig. 4, the ratio between the private value and the BS value is also within the range of the empirical findings. In addition, Fig. 4 shows that the value the employee waives is an increasing monotonic function of his non-diversification measure. Under the specific option characteristics, a waiver of approximately 20% of BS value is parallel to a non-diversification measure δ of 0.14.

Table 7 reports the empirical findings of this ratio within our dataset (Panel A) and in the previous literature (Panel B). The data indicates a large variation in this ratio. We follow Bettis et al. (2005) and measure this ratio on the exercise date (Huddart and Lang, 2003, measure it for an average month).[18] Overall, the results are aligned with empirical findings, indicating that the model is suitable for ESOs valuation.

[18] Huddart and Lang (2003) used the Barone-Adesi and Whaley (1987) model to estimate the ESO value at time t. Additional empirical evidence is reported by Mazumdar et al. (2010), which documented the case of Zions Bancorp, which issued securities that replicate the ESO cash flow.

Table 9
ESO private value relative to Black–Scholes value (in percentage) on the grant date from January 2005 and October 2009.

Industry	Mean (%)	Standard deviation (%)	Standard error (%)	Lower quartile (%)	Median (%)	Upper quartile (%)	*t*-Statistics (%)	Pr > |*t*|
Entire sample	43.29	23.17	0.16	25.09	42.07	61.04	276.75	<.0001
Food and kindred products	72.78	18.56	2.68	58.55	79.90	89.91	27.17	<.0001
Paper and allied products	92.59	1.46	0.13	91.86	93.35	93.78	693.02	<.0001
Chemicals and allied products	38.69	19.51	1.67	22.84	42.54	54.72	23.21	<.0001
Industrial machinery and computers	45.23	24.00	0.36	25.67	42.70	63.95	127.38	<.0001
Electronic and other electrical, except computer equipment	39.41	22.88	0.23	21.32	33.90	60.34	174.06	<.0001
Measuring, analyzing, and controlling instruments	45.67	22.11	0.47	33.05	50.36	59.23	98.12	<.0001
Communications	50.99	21.36	0.52	34.31	50.17	66.42	97.44	<.0001
Wholesale trade-durable goods	48.04	17.32	0.76	40.13	48.45	62.39	62.93	<.0001
Depository institutions	42.26	15.62	0.60	35.64	46.26	51.60	69.99	<.0001
Business services	45.70	24.52	0.72	27.38	42.88	62.72	63.86	<.0001
Engineering, accounting and management services	46.78	18.32	0.55	35.95	51.32	60.15	84.36	<.0001

This table reports the average value the intrinsic value relative to a plain vanilla Black–Scholes value of the ESO on the exercise date across industries using two-digit firm-level SIC categories as reported in CRSP. The sample includes 21,950 employees from 67 firms. The sample includes exercise records from January 2005 until October 2009. Time to maturity is measured as the number of years between the exercise date and the original expiration date of the option. Annual risk-free rate is adjusted according to the share's currency on the exercise date, adjusted to the remaining time to maturity. The volatility is estimated by historical volatility of the stock. The summary statistics are computed over all the exercise records in the sample period.

4.2. Robustness checks

We perform several robustness checks on the private ESO value relative to the BS model, calculated on the grant date. The first check excludes employees of Israeli braches of international companies. The sample in this case includes 19,941 exercise records of 6239 employees in 61 firms. The results (Table 8) are similar to those of the full sample.

An additional robustness check is to examine sub-periods of the dataset. We examine the model predictions on ESO exercises which were made from January 2004 until October 2009. The results (Table 9) are largely indistinguishable from the results of the full sample.

Since we do not have estimation on the exit rate of employees in the sample, we also examine the effect of different annual exit rate on the ESO estimation. We used annual exit rates of 2%, 4%, 6% and 8%, and received average ESO values (relative to BS) of 45.56%, 44.11%, 42.70% and 41.33%, respectively. As expected, and with accordance to Fig. 2, increasing exit rate decreases the ESO value. It also demonstrates that the effect of exit rate is less than the effect non-marketability on the ESO value.

5. Conclusion and summary

Our model formalizes non-marketability in a way that it can be applied to employee stock options. That non-marketability is a significant factor in pricing is well-known, but this paper is the first to present a technical mechanism for pricing non-marketability: Brenner et al. (2001) studied non-marketable currency options and concludes that it trades at a discount of approximately 21% relative to otherwise similar liquid options. Eldor et al. (2006) investigate non-marketable and marketable identical Treasury derivatives and find that non-marketability is significant and covaries positively with interest rate volatility. Ikäheimo et al. (2006) use the prices of tradable executive stock options which are traded at the Helsinki stock exchange after the options are vested. Their findings indicate a major under-pricing of the ESO, which can reach over 50% discount relative to BS value. Meulbroek (2001) computes a lower bound to the value managers attribute to their ESOs, assuming the managers are undiversified and exposed to the company's stock. According to her estimation, a manager would typically value ESOs at a 30–50% discount relative of its market value, with higher discounts associated with more volatile industries. Overall, these results point out a relative high discount of equity based compensation, an issue of particular relevance in at publicly traded companies (Damodaran, 2005).

The private pricing model has two computational advantages over existing approaches in pricing ESOs. First, compared to lattice and continuous-time models which employ an arbitrary rule to explain early exercise, the private pricing model provides an endogenous explanation of ESO early exercise. Compared to the utility maximizing models which provide endogenous early exercise decision, the private pricing model can be viewed as a model that incorporates the utility model parameters into a single factor and thus provides a simplified and more flexible approach to describe exercise behavior and to compute the ESO value. The second advantage of the private pricing model in pricing ESOs is that we are able to quantify the non-diversification effects. In addition, we demonstrate that the model is aligned with empirical findings of ESO databases.

In addition to the private pricing model, the paper uses a proprietary data base to estimate the non-diversification measure δ. We use the data to estimate an annual non-diversification measure for each exercise event and present the aggregate outcome across industries. We also calibrate the non-diversification measure into ESO pricing and find that the average discount, on the grant date, of an at-the-money ESO relative to at-the-money plain vanilla BS value is 45%, on average, in the sample data.

ESO compensation has economic implications for a wide variety of situations. It assists companies in attracting and motivating employees, provides retention incentives using a combination of vesting provisions and long option terms, and in addition may serve as substitute to cash compensation (Ittner et al., 2003).[19] It also has financial reporting implications, since accounting standard mandates companies to record an expense once an ESO is granted. Our model contributes to the accounting and provides a method of valuing the ESO to account for non-diversification and thus to measure the ESO contribution to the employee compensation.

[19] Hall and Murphy (2002) and Hodder and Jackwerth (2011) discuss the economic implications of ESO valuation.

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