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This paper presents a new method for valuing early stage ventures, a method which views new ventures as multi-stage call options. It examines the traditional methods for valuing such ventures—the ubiquitous Discounted Cash Flow (DCF) Method using a risk adjusted discount rate, and the Venture Capital method which uses high discount rates to offset optimistic forecasts—and describes their conceptual disadvantages vis a vis the Option Method. In order to make the Option Method a practical alternative to traditional approaches, the paper presents an algorithm for valuing multi-stage options, and it develops the needed input data using venture capital archives and public offerings. The Option Method is applied to a typical early-stage investment, producing values close to those predicted by venture capital "rules of thumb." In contrast, the DCF method badly underestimates the value of the venture. At this time the Option Method is a practical way to value early-stage ventures, both internal ventures and start-up companies. It offers many advantages over the venture capitalists's "rules of thumb."

I. INTRODUCTION

Valuation is the central problem in deciding whether to invest in any new venture: will it generate enough value to justify the investment needed to launch it? Valuation summarizes every aspect of a venture—its technology, its market, its operating plan and its management. The valuation problem is conceptually the same whether the investor is a venture capitalist, an informal "business angel," a corporation entering an alliance with a start-up or a corporate owner of an internal venture. The investor must estimate the future cash flows from the venture and estimate the future investments required. The investor then assigns a "present value" for each cash inflow or outflow (i.e. investment) and adds the present values

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of the individual cash flows, arriving at a net present value. For a corporate owner a positive net present value signals that the venture is worth doing. For an investor, such as a venture capitalist, the size of the positive net present value determines the fraction of the venture's equity that the investor will require.

Financial management texts formalize the "net present value" method by emphasizing that the proper estimate of each cash flow is its statistical expectation, and the discount rate for calculating present values depends on the risk of the cash flows. In practice, two aspects of early-stage ventures make them difficult subjects for the textbook method:

- High risk levels—causing difficulties in forecasting expected cash flows and in estimating an appropriate discount rate.
- Multiple investment stages—giving the investor the option of abandoning the venture prior to making all anticipated investments.

Investors in new ventures have made *ad hoc* modifications to the textbook approach to deal with the challenges of high risk and multiple stages. For example, a company may raise the discount rate by 10 percentage points, or a venture capitalist may use a "rule of thumb" such as 10 to 1 multiple of the initial investment within 5 years.

The modifications developed by companies and by venture capitalists may work well as experience with early decisions leads to improvements in the *ad hoc* adjustments and rules of thumb. However, such modifications can fare badly when circumstances change, because they require an accumulation of experience. Changes in interest rates, in risk premia, in the valuation of initial public offerings, or in competitive conditions are all circumstances that occur routinely and affect the values of early stage ventures. An investor, using modifications of the textbook methods to value early-stage ventures, will have no systematic basis for adjusting to such changes. The modified textbook methods create added difficulties for the informal investor, who typically makes far fewer investments than a full-time venture capitalist and therefore lacks the experience to develop suitable adjustments.

This paper presents a method and supporting data, based on classic principles of finance, that deal with the challenges posed by early-stage ventures (high risk and sequential investment). The method uses option valuation techniques to deal with the uncertainty and sequential aspects of new ventures. The supporting data, derived from a sample of 236 ventures—106 private and 130 that had public offerings, provide the appropriate risk parameters. The option method is used to value a typical new venture and its results are compared with valuations of the same venture derived from the "textbook" method and from venture capitalists' rules of thumb. As one might hope, the valuation given by the option method closely approximates the venture capitalist's valuation (The "textbook" method greatly understates the venture's value.). That is, the option method can match what venture capitalists have learned through many thousand investments. Thus the option method allows less experienced, informal investors to set correct values on new ventures, as well as giving all investors a straightforward method for making the proper adjustments to, e.g., changes in interest rates, or in stock market levels.

Section II reviews the traditional methods for valuing early-stage investments, showing how each method is a variation of the textbook present value method. Section III shows that an early-stage venture should be viewed as a form of stock option—specifically a compound call option. Section IV provides empirical estimates of the parameters needed to apply the option method. Section V compares the values for a new venture derived from the option method with those given by traditional methods. Section VI summarizes the advantages of the option method over traditional approaches.

II. TRADITIONAL VALUATION METHODS FOR EARLY-STAGE INVESTMENTS

Early-stage ventures may occur inside existing companies or they may involve the formation of a new company. In either case, someone needs to decide whether the economic potential of the venture justifies its investment. Conceptually, a new venture is similar to any other project—one or more investments are required early in the venture's life, and if all goes well it eventually returns an amount substantially greater than the amount invested. Hence, the discounted cash flow (DCF) methods that are widely used in capital budgeting seem to be a logical way to value early-stage ventures. In practice, various DCF approaches have been developed for different applications. The following discussion summarizes the standard model presented in all financial management texts, as well as two common modifications of that model. The first modification is widely used for capital budgeting and internal corporate ventures, and the second for securities valuation. Over time venture capitalists have combined the two modifications to arrive at an approach for valuing early-stage ventures.

Discounted Cash Flow

The discounted cash flow (DCF) formula, that is familiar from any finance text (e.g. Brealey & Myers, 1996, ch. 3; Higgins, 1995, ch. 7; Ross, Westerfield & Jordan, 1995,ch. 5), appears to fit any investment problem:

$$NPV = \sum_{t=0}^{\infty} \frac{E(CF_t)}{(1+R)^t} \tag{1}$$

Where $E(x)$ implies calculation of the statistical expectation of x

CF_t = after tax cash flow at time t

R = cost of capital adjusted for risk (e.g. using capital asset pricing model)

The cash flows may be either positive or negative—investments are simply cash flows with negative values. The secret to good decisions appears to be good forecasting and finding the correct value for R, the risk-adjusted discount rate.

Industrial companies often modify equation (1) in two ways for capital budgeting or for valuing new ventures: they raise the discount rate and use the cash flow forecast provided by the project manager (rather than calculating a statistical expectation), as shown in equation (2).

$$NPV = \sum_{t=0}^{\infty} \frac{CF_{t,IV}}{(1+R_{IV})^t} \tag{2}$$

Where the subscript "*IV*" refers to the point estimate used by the internal venture or project manager.

Equation (2) may be used for all capital budgeting decisions of a company, and the issue is simply one of how much to adjust the discount rate to compensate for a cash flow forecast that is viewed as optimistic ("optimism" meaning that the forecasts of cash inflows exceed their expected values, and the forecasts of outflows are less than their expected values—i.e. the expected value is more negative). Companies often treat their specific method of using equation (2) as confidential information, and have developed their own forecasting techniques and discount rate adjustments.

Valuation of Common Stock

Securities investors, in principle, use the variation on equation (1) shown below as equation (3)—(See, e.g. Brealey & Myers, 1996, p. 61; Ross, Westerfield & Jordan, 1995, p. 183.):

$$NPV = \sum_{t=0}^{T} \frac{E(D_t)}{(1+R)^t} + \frac{E(P_T)}{(1+R)^T} - P_0 \tag{3}$$

Where D_t = dividend at time t

P_T = market value of the a company's equity at a time horizon used in the analysis

P_0 = current market value of the equity.

Equation (3) incorporates an estimate of the price (P_T) at the analyst's time horizon (T). In principle P_T is simply the present value of the expected values of dividends beyond T, discounted back to T at the cost of capital (R). In practice, analysts often estimate P_T by applying an anticipated price-earnings ratio to a forecast of earnings at time T. In some cases analysts apply a price-sales ratio to a forecast of sales at time T. These methods for estimating P_T are summarized by equation (4).

$$E(P_T) = E[(P/NP)_T * (NP_T)] = E[(P/S)_T * (S_T)] \tag{4}$$

Where $(P/NP)_T$ = Price-earnings ratio at time T.
(NP_T) = Net profit (NP) at time T.
$(P/S)_T$ = Price-sales ratio at time T.
$E(S_T)$ = Sales at time T.

All four variables are characterized by probability distributions.

Equations (3) and (4) may be applied on a per share basis or to the total market capitalization of the company.

The Venture Capital Method

Venture capitalists combine the internal venture model, equation (2) with the common stock model, equations (3) and (4):[1]

1. They drop the terms representing dividends between times *0* and T, because start-up companies almost never pay dividends. They focus on estimating a future value for the company at a time T (usually at least 5 years) when it could "go public" or be acquired.
2. They use the company's forecasts of sales and earnings at time T. Such forecasts typically assume that the company accomplishes most of its goals (e.g., it develops its product on time and within budget, the product is easily accepted in the market, the company captures a large market share) and exceed the statistical expectations of S_T and NP_T.
3. They use a price-earnings or price-sales ratio that is close to the expected value for that ratio. Thus the estimate of P_T exceeds $E(P_T)$, since the earnings and sales forecasts exceed their expected values, and the multipliers do not offset the overestimate.
4. To compensate for using a forecast of P_T that exceeds its expected value, they increase the discount rate above the cost of capital.[2]
5. They realize that future investments will be needed prior to T, and estimate the dilution that will result from those future investments. They

use the company's forecast of future investments, which is typically less than the statistical expectation of those investments. In estimating future dilution they discount to the time of a future investment. As noted immediately above, such discounting is done at a rate above the cost of capital; however, the amount by which it exceeds the cost of capital is steadily reduced as future investment dates move closer to the estimated date (T) of a public offering. Thus the discount rate applied to P_T at the time of start-up (t = 0) may be 60 percent whereas, the discount rate used to estimate the dilution from a follow-on investment at $t = 3$ may be only 40 percent.

6. Instead of talking about discount rates, they use investment multiples. Thus they will state an objective of earning 10 times their money in 5 years for an investment in a start-up company. This is roughly equivalent to a 60 percent discount rate (i.e., $1.6^5 = 10.49$). The multipliers may easily be mathematically converted to discount rates as shown in Table 1.

The venture capitalist's approach can be translated to the present value formula given by equation (5).

$$NPV = \frac{P_{T,VC}}{\prod_{t=1}^{T}(1+R_{t,VC})} - \sum_{t=1}^{T}\frac{I_{t,VC}}{\prod_{\tau=1}^{t}(1+R_{\tau,VC})} - I_{0,VC} \tag{5}$$

Where $P_{T,VC}$ = venture capitalist's estimate of company value at T (see discussion points 2 & 3 above).

$I_{t,VC}$ = venture capitalist's estimate of additional investment required at time t (see discussion point 5 above).

Table 1
Valuation Multipliers Used by Venture Capitalists and Implied Discount Rates

Time Since Start-up (t)	*Multiplier from t to T*	*Implied Discount Rate*	*Present Value Factor (0 to t)*	*1 Year Discount Rate (t to t – 1)*
0	10.5	60%	—	—
1	5.5	53	0.524	90.5%
2	3.2	47	0.305	71.9
3	2.0	41	0.191	60.0
3.5	1.62	38	0.155	—
4	1.35	35	0.129	48.1
5 (T)	1.0	—	0.095	35.0%

$R_{t,VC}$ = venture capitalist's one year discount rate to discount from t to t-1 (see Table 1 and discussion point 4).

Note: Although equation (5) and Table 1 assume for simplicity that investments and the public offering occur on anniversaries lof the initial investment, they may easily be modified to allow for non-integer values of T and of the t's in each $I_{t,VC}$.

In equation (5) NPV is referred to as the "pre-funding value" and $NPV + I_{0,VC}$ is the "post-funding value." The venture capitalist, who is investing $I_{0,VC}$, will want a share of the company at least equal to $I_{0,VC}/[NPV + I_{0,VC}]$. For example, if the pre-funding value is \$3 million with 300,000 shares issued, and the company needs an investment of \$2 million, the venture capitalist will want at least a 40 percent share of the company which would be achieved by purchasing 200,000 newly issued shares.

Equation (2), the formula for valuing internal ventures, and equation (5), the formula describing a venture capitalist's valuation, are very similar—they are both standard net present value formulas with some modifications. Both share the same major flaws:

1. The forecasts of P_T, NP_T, and I_t are not expected values.
2. The investor may elect not to continue supporting the project if it is not doing well. That is, the investor has the option whether to keep supporting the project—an option analogous to a traded call option although more complex. The analysis of options requires methods other than the conventional present value analysis of equations (2) and (5).

The correction of these flaws is the subject of the balance of this paper. The first flaw can be alleviated by providing decision makers with data to assist in the estimation of expected values. The second flaw requires creation of an appropriate option (or "contingent claims") model.

III. VIEWING AN EARLY-STAGE VENTURE AS A COMPOUND CALL OPTION

An early-stage venture, requiring a periodic investment during its early years, may be viewed as a multi-stage call option (more appropriately, a "compound call option" defined by Black & Scholes, 1973, in their seminal paper on option pricing as "an option on an option ... on an option.") to acquire the asset P_T at time T. A simple call gives an investor the right, but not the obligation, to acquire an asset with a single known payment. An early-stage venture requires multiple payments, whose values are uncertain—a situation far more cumbersome to analyze than a simple call but in principle subject to the same valuation method.

Before examining a company at its earliest stage, it is helpful to consider a time *(T)* immediately before the last financing required for it to become self sustaining (assumed here to be a public offering). Such a company may be viewed as a simple option if the amount of the offering is known. For convenience the "investor" is assumed to own the entire company,[3] and to be contemplating a further investment of I_T, the amount of the public offering. Investing I_T will give ownership of a business worth P_T, the market value of the company after the offering. Failure to invest I_T is assumed to result in total failure of the company. In effect, the investor has a "call" option on the company with an exercise price of I_T. By investing I_T the investor gains the entire market value after the investment. Representing the investor's ownership prior to the offering by $C_{T,T}$ the value of that ownership is shown in equation (6).

$$C_{T,T} = max[P_T - I_{T,T}, 0] \tag{6}$$

Note: When a variable has two subscripts, the first subscript identifies it (e.g. C_T is the option expiring at T), and the second refers to the time at which it is estimated (in the case of I variables) or evaluated (in the case of C variables). Thus, C_{T,t_3} is the value of C_T at t_3, and $I_{T,t}$ is the estimate at time $t < T$ of what I_T will be when the investment is made at time T.

Such an option may be valued at earlier times ($t < T$) by a variety of means such as the Black-Scholes formula, the binomial lattice, or simulation if the following conditions are satisfied:

1. P_t is known and the return on P follows an Ito process (We will assume the return follows a geometric brownian motion, which is an Ito process, with a constant standard deviation, σ_P.).
2. A risk-free investment exists with an interest rate, R_f.
3. The usual assumptions about capital markets are met: costless trading, dynamically complete markets, well informed investors, costless short-selling with use of proceeds.

When conditions 1-3 are met, one evaluates the option by the well-known approach of assuming risk neutrality. The option's value is simply the expected payoff (in a risk neutral world) at maturity, discounted at the risk-free rate. This study uses the binomial method (see, e.g. Brealey & Myers, 1996, p. 575 for a simple explanation, or Hull, 1993, p. 335 ff. for a more detailed discussion) in preference to the Black-Scholes method or simulation, because the latter methods are not computationally tractable for multi-stage compound options, and our ultimate goal is to evaluate a four stage compound option.[4]

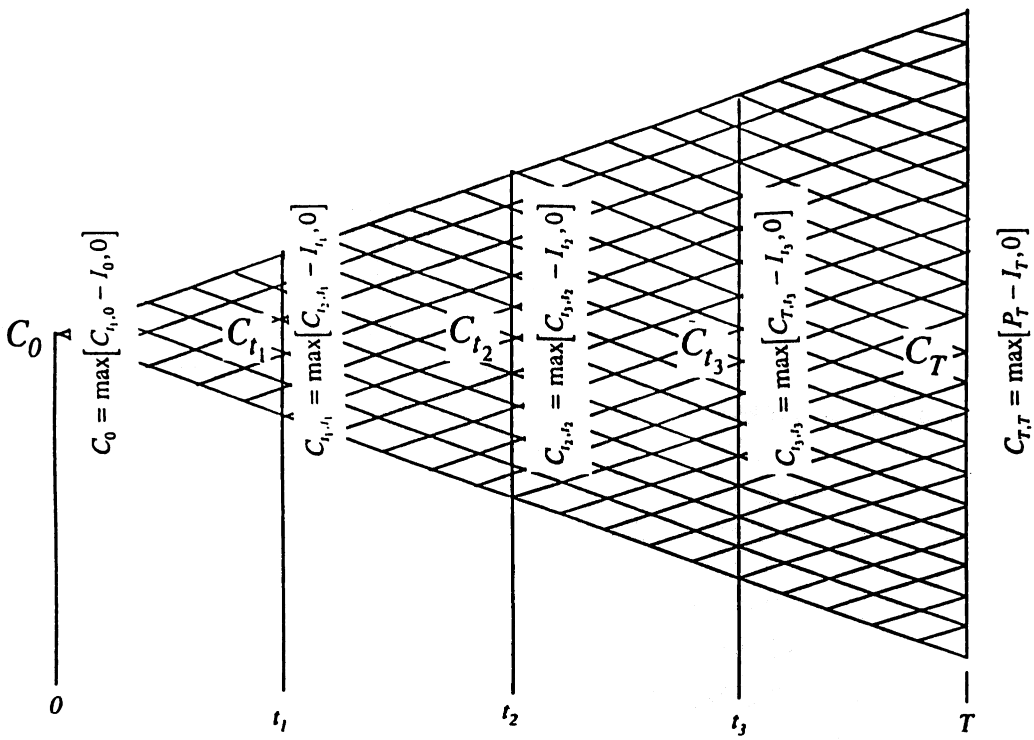

Figure 1
Binomial Lattice Representation of a 4-Stage Compound Call with Known Iterim Investments

Figure 1 illustrates a multi-stage investment process for an early-stage company that has 5 rounds of financing, including a start-up round at $t = 0$ and a public offering at $t = T$. The "first-stage" offering is at $t = t_1$; the "second-stage" offering is at $t = t_2$, and a "mezzanine" or "pre-public" round is at $t = t_3$. For notational convenience we refer to, e.g. t_3 rather than to $t = t_3$.

The last stage between t_3 and T can be viewed as a simple option, if I_T is known with certainty. One begins with P_t at t_3 and allows it to follow a binomial process (that approximates a brownian motion with drift of $[R_f - 0.5\sigma_P^2]$, and variance σ_P^2) to T. The appropriate binomial process has parameters shown in equations (7a)-(7d).

$$P_{t+\Delta t,\, up} = P_t e^{\sigma_P \Delta t} \quad \text{Price change on the upper branch.} \tag{7a}$$

$$P_{t+\Delta t,\, down} = P_t e^{-\sigma_P \Delta t} \quad \text{Price change on the lower branch.} \tag{7b}$$

$$Prob_{up} = \frac{e^{R_f \Delta t} - e^{-\sigma_P \Delta t}}{e^{\sigma_P \Delta t} - e^{-\sigma_P \Delta t}} \quad \text{“Risk neutral” probability of upper branch.} \tag{7c}$$

$Prob_{down} = 1 - Prob_{up}$ "Risk neutral" probability of lower branch (7d)

Each branch at T has a unique value for P_T that depends on the count of upward and downward price changes between t_3 and T for that branch. For each value of P_T, one applies equation (6) to find the final values of $C_{T,T}$. Once the final values are known, one finds the expected value of $C_{T,t}$ for the nodes of the tree just before T, by applying the "risk neutral" probabilities that generated the binomial tree and by discounting at R_f. By working backward through the binomial tree to t_3, one can determine the value of C_{T,t_3} for any value of P_{t_3}.

The above method for valuing a simple option needs two elaborations to handle an early-stage venture:

- The method must be extended to earlier financing stages.
- The assumption that investments are known with certainty must be relaxed.

The first extension is easily described with the aid of Figure 1. At t_3 the values of C_{T,t_3} are known for any value of P_{t_3} from calculations described immediately above. From these values of C_{T,t_3} one can immediately obtain values for C_{t_3,t_3} using equation (8).

$$C_{t_3,t_3} = max[C_{T,t_3} - I_{t_3,t_3}, 0] \tag{8}$$

The process of working backward through the binomial tree proceeds as described above, reaching t_2, then t_1 and finally $t = 0$. The probabilities for each branch are given in (7c) and (7d). At $t = 0$ there is only one value for P, the current value of the assets that will be in place at T if all interim investments are made, and only one value for $C_{t_1,0}$, the current value of the company after raising its first round of funding. The pre-funding value of the company, C_0 is given in equation (9).

$$C_0 = max[C_{t_1,0} - I_0, 0] \tag{9}$$

The method described above, and illustrated in Figure 1, views the company at each financing step as a one-stage option on an option. It is developed in detail in Keeley & Turki (1994), and is a simpler way to value compound options than the earlier approach developed by Geske (1977).

The second extension, to investments that are not known with certainty, forces abandonment of the two dimensional approach of Figure 1. If the amount, I_T, is uncertain at times prior to T, the statistical expectation of the forecast for I_T as estimated at time t will be written $I_{T,t}$. If we are currently at $t = 0$, the path of over time can be expressed as follows:

$$I_{T,t} = I_{T,0}e^{-\frac{\sigma_{I_T}^2}{2} + \sigma_{I_T}\sqrt{t}\tilde{B}} \tag{10}$$

Where $\tilde{B}$ is from a standard normal distribution. Equation (10) implies that $I_{T,t}$ is lognormally distributed. Note that the expectation of I_T for any future time (i.e. $I_{T,t}$) is itself a random variable. Its current expectation, $E_0(I_{T,t})$, can be calculated by taking the expectation of equation (10). The result is $E_0(I_{T,t}) = I_{T,0}$—that is, the expectation of a future forecast of I_T is its current expectation. The expectation does not systematically drift over time, although it experiences continuous random changes.

From a computational point of view, allowing I_T to be a random variable requires adding another dimension to the binomial tree. The number of branches at T will be the square of the number shown in Figure 1 with each pair of (P_T, I_T) having a separate branch. Calculating the transition probabilities of equations (7c) and (7d) becomes somewhat more difficult (Kamrad & Ritchken, 1991, present a method for calculating the transition probabilities of a k dimension tree.). When the amount invested at each stage is subject to uncertainty, Figure 1 can be viewed as a two dimensional projection of a higher dimension tree, conditional on a specific set of I values. The value of $C_{T,T}$ is still calculated for each branch using equation (6), and the process of working backward through the tree is as described earlier. There are simply more computations to perform. At t_3 (and between t_3 and t_2) the tree is three dimensional; each combination of $(P_t, I_{T,t}, I_{t_3,t})$ has a separate branch. The values for C_{t_3,t_3} at each branch is given by equation (8). The size of the tree depends on the number of financing stages and the number of Δt steps. The FORTRAN algorithm used in this paper to evaluate the multi-dimension version of Figure 1, a copy of which may be obtained from the first author, uses 50 steps and 4 dimensions requiring an array size of $50^4 = 6{,}250{,}000$. Note: There are really 5 variables, P_t and four I_t's, but they can be reduced to 4 ratios with I_T as the denominator in all cases. The effect is to reduce the array size from 312.5 million to 6.25 million without any loss of accuracy.

IV. ESTIMATING THE RISKS AND FUTURE VALUES OF EARLY-STAGE VENTURES

The option model requires the following information:

- Timing and current expected values of future investments: $I_{t_1, 0}$, $I_{t_2, 0}$, $I_{t_3, 0}$ and $I_{T, 0}$.
- Standard deviations of the rates of change in each investment (assumed to follow a geometric brownian motion): σ_{I_1}, σ_{I_2}, σ_{I_3}, and σ_{I_T}
- The correlation matrix of P, I_{t_1}, I_{t_2}, I_{t_3} and I_T.
- Current value of P_0, the venture's post-IPO value, assuming that all interim investments are made. Alternatively, the value $E(P_T)$ and appropriate risk-adjusted discount rate will allow one to calculate P_0. As discussed later, this study uses estimates of systematic risk (β) in the post-IPO period to estimate an appropriate discount rate for $E(P_T)$.
- σ_P, the standard deviation of the rate of growth of P_t.
- The risk-free rate, R_f.

With the exception of the risk-free rate these are not observable, nor are they parameters that investors commonly estimate. As indicated in equation (5), venture capitalists use estimates of P_T, I_{t_1}, I_{t_2}, I_{t_3}, and I_T in their current methods, although their estimates are not expected values, and they do not try to estimate standard deviations or correlations. In practice a venture capital fund could use historical data to assist in estimating the above parameters. A typical private informal investor, or business "angel," makes only a few early-stage investments and has correspondingly less past investment data from which to estimate the needed parameters. The data presented below, obtained from archives of three venture capitalists, can easily be scaled downward to fit the investment amounts of private investors.

An important part of the research reported in this paper is the examination of historic data from private and public companies in order to estimate the variables used in the option model. As the first researchers to apply option models to early-stage ventures, the authors assembled a database of private and public financings large enough to provide reasonable estimates. The process for estimating each variable is described in some detail in this section in order that practitioners and other researchers can modify these procedures as they deem appropriate to their circumstances.

Estimating the Parameters Associated with Future Investments: $I_{t_1, 0}$, $I_{t_2, 0}$, $I_{t_3, 0}$ and $I_{T, 0}$.

The estimates in this study use a database of venture capital transactions involving 106 early-stage companies. The transactions were collected from the files of three leading venture capital funds, all of whom emphasize early-stage investing and have been in business for over 20 years. Our estimates are less refined than a venture capitalist could create; however, they serve as a starting point. We (1993a) previously estimated the standard deviations of the investments—that is, the standard deviation of the rate of change in the expected value of each future investment—as well as the correlations among the investments, and the correlations of the investments with P_T. We calculated cross-sectional averages and standard deviations for, e.g. $I_{t_3, t_3}/I_0$, as well as the correlations between financings of different stages. We would have preferred to compare actual investments with the corresponding estimates from a company's initial business plan (e.g. $I_{t_3, t_3}/I_{t_{3,0,VC}}$) to obtain the unplanned variation in, e.g. I_{t_3}. The standard deviation that we estimated includes unplanned variation *and* the intended variation in the financing patterns from company to company. Unfortunately, we could not locate enough start-up business plans in the venture capitalists' files to obtain estimates of the variation in, e.g. $I_{t_3, t_3}/I_{t_{3,0,VC}}$.

Table 2 shows the expected values of future investments (scaled to a start-up round of $4.5 million), the standard deviations of their rates of variation over time, and their correlations (including their estimated correlation with P_t). Note that the

Table 2
Investment Parameters

t Time	(I_t) *Investment Round*	$(I_{t,VC})$ *Forecast Size*	$(I_{t,0})$ *Expected Size*	(σ_{I_t}) *Std. dev. (in %/yr.)*	*Correlations* I_{t_2}	I_{t_3}	I_T	P_t
0	I_0	4.5M	4.5M	—	—	—	—	—
1.5	I_{t_1}	7.5M	10.0M	106%	0.51	0.00	0.00	0.23
3.0	I_{t_2}	5.0M	7.0M	70%	1.00	0.60	0.82	0.26
4.5	I_{t_3}	5.0M	12.0M	52%		1.00	0.59	0.54
6.0	I_T	30.0M	30.0M	59%			1.00	0.00

Notes: 1. Sources: Expected sizes are from actual funding histories of 106 ventures. The average ratio of each follow-on round to the initial round (e.g. I_{t_1}/I_0) was used to derive an expected size on the assumption that the first round was $4.5M.

Standard deviation (refers to the percentage change per year in the forecast of, e.g. I_{t_1}/I_0) is from the variation in the ratios of funding rounds, based on 106 funding histories.

Time-average timing of rounds in 106 funding histories.

Forecast size-based on 10 of the 106 funding histories for which the original business plan provide values of, e.g. $I_{t_2, VC}$. The timing of financing rounds was generally more compressed than is shown in this table. The final round, I_T was forecast to occur in 5 years typically.

2. Correlations were derived from regressions of pairs of variables; e.g. (I_{t_3}/I_0) on (I_{t_1}/I_0). The correlations involving P_t used the observed pre-funding value at the time of a financing. As discussed in the text, the observed value of the company's equity prior to the IPO is really the value of a call; however, that value is highly correlated with P_t and serves as a proxy for it in estimating the correlations.

values of I_t can easily be adjusted up or down to fit early-stage ventures of different sizes. Changes in the scale of the venture are assumed not to affect the standard deviations or correlations.

Estimating the Current Value of the Business and the Standard Deviation of its Growth

A typical business plan provides a forecast of sales and net profit for the five or six years following the start-up date. That forecast is translated by the investor into a value for P_T, the value immediately following an IPO. Although the value is reasonable, if the company actually has an IPO on schedule, most companies are significantly delayed in their development, and many never reach an IPO. From our database of venture capital transactions, Keeley & Turki (1993b) have previously estimated that the average multiple earned by a start-up investor is 7.89. For the 28 percent of start-up companies that went from start-up to IPO without a delay or setback, the average multiplier was 24.16—referred to as the "success multiple." The expected multiple of 7.89 is 32.6 percent of the success multiple. In subsequent calculations, we will consider three cases whose values of $P_{T,VC}$ (i.e. post-IPO values in a "success case") are \$260M, \$195M and \$130M. The implied expected values of P_T, as forecast at $t = 0$, will be designated $P_{T,0}$; they are \$85M, \$63.7M and \$42.5M respectively. These values of $P_{T,0}$ will be discounted to the present to obtain estimates of P_0, the value at start-up of the firm's post-IPO assets assuming all interim financings are obtained.

The second task is to estimate the variation in P_t (σ_P). There are two approaches:

1. Using observations of values during the follow-on financings at t_1, t_2, t_3 and T for a sample of companies. Strictly speaking the values observed are those of the options, e.g. C_{t_2, t_1}, and therefore one is estimating the standard deviation of the option, not of the asset P_t. The variation in P_t will be less than that of the option. Thus, this approach gives an upper bound for σ_P.
2. Observation of P_t after an initial public offering (i.e. for $t > T$). In order to use that estimate of σ_P for $t < T$, the period of interest, one must assume that either σ_P is the same for $t < T$ and $t > T$, or σ_P can be adjusted from the post-IPO estimate.

Keeley & Turki (1993b) estimated an upper bound for σ_P using the first method, obtaining a value of about 83 percent per year. The second method for estimating σ_P, based on the post-IPO period, will be presented below. The second method provides an additional required parameter, systematic risk or beta (β). The beta

Table 3
Sample Companies Classified by Technology Group and by Funding Source

	Young Firms		
	VC-Backed	*Not VC-Backed*	*Total*
Listed in Compustat Database			
High-tech industries	58	36	94
Not high-tech industries	18	18	36
Not Listed in Compustat	20	40	60
Total	96	94	190

Note: The SIC codes are not available for the companies not in the Compustat database. However, an informal classification by the authors places the following in high tech industries: 16 of 20 VC-backed, 13 of 40 Not-VC backed.

coefficient can be used to estimate an appropriate discount rate for deriving P_0 from $P_{T,0}$.

To estimate σ_P and β we studied 190 companies that held IPO's in the 1980–1986 time period. The data collected for each company included daily stock returns from IPO through 1989, the amount of the IPO, and nineteen accounting measures from the IPO date to 1989 including sales, the ratio of book to market equity, and the ratio of liabilities to assets. The sample represented high-tech and non-technical companies as well as companies with and without venture capital backing, as summarized in Table 3. The NASDAQ daily returns tape from the Center for Research in Securities Prices (CRSP) provided the daily returns, and the Compustat database supplied the accounting information. As Table 3 shows, 60 companies did not have Compustat data and could not be used for the analysis relating risk measures to accounting data. The risk parameters of interest were estimated for each company for each year by applying the Scholes-Williams (1977) method to regression equation (11):

$$R_{i\tau} = \alpha_i + \beta_i R_{m\tau} + \varepsilon_{i\tau} \tag{11}$$

Where: $R_{i\tau}$ = the return on stock i between day τ and day $\tau - 1$.
$R_{m\tau}$ = the return on the stock market index (CRSP NYSE-ASE value weighted) between day τ and day $\tau - 1$.
α_i and β_i = the intercept and slope parameters
$\varepsilon_{i,\tau}$ = the residual return of stock i between day τ and day $\tau - 1$. Assumed to be normally distributed with mean of 0 and standard deviation of σ_{RES_i}.

Note: $\sigma^2_{Pi} = \beta_i^2 \sigma_m^2 + \sigma^2_{RES_i}$

The parameters, β_i and σ_{RES_i} were combined with the annual accounting measures to form a set of panel data. The risk parameters were then regressed on the accounting measures—as well as on dummy variables representing each calendar year, and each year since the IPO—for the purpose of "explaining" the values of the risk measures. Ordinary least squares (OLS) regression is not adequate for this data set because the residual values have two components: a component specific to each firm in the dataset, and a component associated with the time of observation. We used a two-stage procedure recommended by Nerlove (1971) for random effects models:

Step 1: Run an OLS on the dataset. Decompose the variance of the residual values (the residual value for firm i in year t is μ_{it}) into a firm effect and a time effect. $\mu_{it} = \varepsilon_i + \eta_{it}$ with standard deviations σ_ε and $\sigma_\eta \cdot t = 1, \ldots 10$ in this study

Step 2: Transform each variable (z_{it}) into (z'_{it}) as follows:

$$z'_{it} = z_{it} - \left(1 + \frac{\sigma_\eta}{\sqrt{\sigma_\eta^2 + 10\sigma_\varepsilon^2}}\right)z_i \quad \text{where} \quad z_i = \frac{1}{10}\sum_{t=1}^{10} z_{it}$$

Step 3: Run a generalized least squares (GLS) regression on the transformed data.

The best outcome for the purposes of this paper would be that the risk measures, σ_{RES_i} and β_i, are stationary parameters, invariant with respect the firm's size, profitability, leverage and other accounting measures at t ($t > T$) as well as invariant with respect to time. That is, the risk measures would be characteristics of the firm's industry only. In the best case, we would have substantial confidence that σ_{RES_i} and β_i of the post-IPO period would reflect the values in years prior to an IPO, based on their invariance in the years following an IPO. If they vary depending on, e.g., sales or time since an IPO, then we may wish to adjust the post-IPO values of σ_{RES_i} and β_i. The adjustments will require judgment, although the post-IPO data will help to indicate useful ranges for the risk parameters.

Prior research suggested a number a variables that might influence risk. Early research, conducted on large, mature companies, found that risk parameters vary with accounting measures of a firm, as well as varying with industry and with time (Beaver, Kettler & Scholes, 1970; Rosenberg & Guy, 1976; Rosenberg & Marathe, 1975). Since that early work was published, most research on the influence of accounting measures on risk has been done for private purposes and has not been published. This study examines data on 19 accounting measures (including some such as the price-earnings ratio that relate accounting data to market values), although not all prove useful for "explaining" risk. Included in the 19 variables is the ratio of book to market equity, which has been noted as an influence on risk by Fama and French (1992) among others. Blume (1971) studied the variation of systematic risk over time in established companies and found that variations were trendless; however, Alexander and Chervany (1980) noted that "trendless" betas do not imply stationary betas. This study will examine whether the risk measures vary by calendar year. Studies of IPO's suggests that systematic risk *(β_i)* declines in the period following an IPO (e.g. Clarkson & Thompson, 1990; Ritter, 1991); an examination of residual risk was not included in those studies. This study includes the time since a company's IPO as a possible influence on its risk. Megginson and Weiss (1991) found that the presence of an venture capital investor allows a company to command a better price at its IPO. This study will examine the presence of a venture capital investor as a possible influence on risk. Finally, Jain and Kini (1994) found that the size of an IPO influences subsequent performance—so we will examine whether IPO size is related to risk measures.

Regression results are shown in Table 4. The results can be summarized as follows:

1. Three accounting variables help to explain β_i: and σ_{RES_i}:
   - Natural log of the book to market ratio.
   - Natural log of sales ($ in millions)
   - Liabilities to assets ratio (for σ_{RES_i} only).
2. The presence of a venture capital investor is associated with a high β_i:, but is not related to σ_{RES_i}.
3. The larger the public offering (i.e. larger I_T) the higher the value of both risk measures.
4. The amount of "seasoning" (time since the IPO) has no systematic influence in this sample. Eighteen dummy variables representing the number of years since an IPO and the calendar year were used in each of the equations described by Table 4. None of the "Years Since IPO" dummies were significant at a 10 percent level. No trend in the coefficients appeared to exist. Both risk measures varied from year to year; loosely speaking, β_i tended to fall in the late 80's (vs. the average values in the early 80's) and σ_{RES_i} had no trend.

One result from Table 4 is unexpected: the tendency of β_i to rise with sales. In studies of large, mature companies (referenced in Fama, 1991) β_i is inversely related to sales. Amit and Livnat (1990) have suggested that relatively small companies, such as those comprising our sample, tend to become more integrated with the economy as they grow. Thus β_i increases and the idiosyncratic element of risk, σ_{RES_i}, falls.

Table 4
The Effects of Accounting Variables, Venture Capital Backing, and IPO Size, Industry, Seasoning, and Calendar Year on a Company's Risk

Variable	Beta	*Residual Std. Dev.*
1. Intercept	0.47	58.50
	(0.17)	(6.94)
2. Ln (Book/Market Equity)	–0.24	6.90
	(0.034)	(1.26)
3. Ln(Sales, $ in millions)	0.072	–6.32
	(0.022)	(0.82)
4. Ln (Liabilities/Assets)	–0.13	24.03
	(0.14)*	(3.90)
5. IPO Size ($ in millions)	0.003	0.079
	(0.001)	(0.029)
6. Venture Capital Backing	0.23	0.77
	(0.057)	(1.73)*
7. SIC 35 (Computers)	0.31	10.70
	(0.06)	(1.74)
8. SIC 36 (Electronics)	0.28	5.00
	(0.09)	(2.05)
9. SIC 73 (Software)	0.07	4.38
	(0.07)*	(2.13)
10. Calendar Year (see notes)		
11. Years since IPO (see notes)		
12. Adj. R^2	0.29	0.29
13. Degrees of freedom	637	637

Notes: 1. Std. errors in ( ). Variables are significant at $p < 0.05$ unless marked with *.
2. Intercept includes average effect of calendar year. The values of the calendar year dummy variables for β_i average 0 and have a standard deviation of 0.27. They appear to trend downward over the decade of the '80's. For, σ_{RES_i} they average 0 and have a standard deviation of 3.84. They have no apparent time trend.
3. "Years since IPO" were represented by 9 dummy variables, as companies had data for up to 10 years following the IPO. None was significant in either regression.

The results from Table 4 indicate some problems if one wishes to use them in an option-based model of an early-stage venture: the risk measures change as a company grows, and as its market value changes. Thus it is likely that σ_P is different at, e.g. t_1 and t_3, and that it is different for different values of P_t in the binomial lattice of Figure 1—holding t constant and moving vertically. The size of that lattice is held to a manageable size only by assuming that σ_P is invariant with respect to P_t, so despite our doubts we assume that σ_P is a constant. Sensitivity analysis can examine the effect of using different values of σ_P, but the effect of allowing it to vary for different values of P_t (with t given) can not be ascertained. The model could accommodate changes in σ_P over time, but the regression suggests that time or company maturity *per se* is not a determinant of the risk parameters.

Table 4 also raises the issue of how to use the sales, liability/asset, and book to market value measures in an option model. The risk measures are treated as functions of contemporaneous accounting data in the regression, but we really need to assess risk measures based on forecasts of subsequent accounting data. The contemporaneous accounting data act as indicators of the future variability of a company's cash flow—referring back to equation (1) they are indicators of the variability of $E(CF_t)$ for all future t. In this paper we make the simplest assumption, that σ_P and β at $t = 0$ are the same as they are at $t = T$. This allows us to use forecasts of accounting values at $t = T$.

Table 5 estimates the values of β and σ_P for the company that will be valued in a following example—a company that is forecast to have the average values of our IPO sample for Ln(book/Market Equity), Ln(Sales), Liabilities/Assets, and to have an expected IPO amount of \$30 M, to have venture capital backing and to be in the computer industry. The resulting value for β is 1.55 and for σ_P is 59 percent per year. Table 5 also estimates the risk-adjusted discount rate needed to translate $P_{T,\,0}$, the current statistical expectation of the post-IPO value, into P_0, the present value of $P_{T,\,0}$. The discount rate is 18.97 percent, and the risk-free rate is 8.9 percent.

Table 5
Estimating Beta, Residual Risk and the Risk-Adjusted Discount Rate for a Typical Company

		Beta		*Residual Std. Dev.*	
Variable	*Value*	*Coeff.*	*Value*Coeff.*	*Coeff.*	*Value*Coeff.*
1. Intercept	1.0	0.47	0.47	58.50	58.5
2. Ln (Book/Market Equity)	–0.84	–0.24	0.20	6.90	–5.8
3. Ln(Sales, \$ in millions)	4.12	0.072	0.30	–6.32	–26.0
4. Ln(Liabilities/Assets)	0.42	–0.13	–0.05	24.03	10.1
5. IPO Size (\$ in millions)	30.0	0.003	0.09	0.079	2.4
6. Venture Capital Backing	1.0	0.23	0.23		
7. SIC 35 (Computers)	1.0	0.31	0.31	10.70	10.7
Estimated value			1.55		49.9

Notes: Values of Ln (Book/Market Equity), Ln(Sales), and Liabilities/Assets are average values for sample of 130 companies that had IPO's between 1980 and 1986. The company in this example is assumed to be planning a \$30 M IPO, to have venture capital backing, and to be in the computer indsutry.

Total variance $\sigma^2_{Pi} = \beta^2_i\sigma^2_m + \sigma^2_{RES_i} = 1.55^2*(0.2)^2 + 1.499^2 = 0.345$

Estimated $\sigma_{Pi} = \sqrt{\sigma^2_{Pi}} = 0.59$ or 59 percent per year.

Risk-adjusted discount rate *(R)*:

Risk-free rate (R_f) on 3 year notes for mid-1980's averaged 8.9 percent. We use the mid-1980's because that is the time period for much of our data.

Estimated equity market risk premium over 3 year notes = 6.5 percent

$R = R_f + \beta(E(R_m) - R_f) = 8.9 + 1.55*6.5 = 18.97$ percent

V. COMPARING THE VALUATION METHODS

Three methods—the Discounted Cash Flow Method (DCF) summarized by equation (1), the Venture Capital Method summarized by equation (5), and the Option Method—will be used to value a representative new venture. The venture requires start-up financing of $4.5 million with three additional private financings before an IPO. Investment forecasts from Table 2 and the risk-adjusted discount rate of Table 5 are used in the valuation calculations. Two estimates of volatility (σ_P) will be used in the option valuation: the 59 percent/year value derived in Table 5, and the 83 percent/year value estimated by the authors (Keeley & Turki, 1993b) from a study of private start-up companies. The example considers three forecasts of a post-IPO value. These would be derived from the start-up company's business plan, with the IPO value depending on the perceived growth potential of the company. The results, presented in Table 6, show the pre-funding values for the start-up company (For example, a pre-funding value of $11.8 million implies that an investment of $4.5 million will require the company to sell $\frac{4.5}{4.5 + 11.8} = 27.6\%$ of the company). The results are very similar for the option model and for the venture capitalist's "rules of thumb."

Given that the "rules of thumb" have evolved out of decades of experience by hundreds of venture capital firms and have produced satisfactory long-term rates of return (reported by Morgan Stanley, 1994, as 16 percent per year over the 1945–1993 period), the comparison serves to validate the Option Method—which has never before been used to value early-stage companies.

The conceptual weakness of the traditional DCF method is exposed in Table 6. It badly understates the value of the new venture, giving negative net present values in all three cases. It uses the same assumptions as the Option Method, so the difference in values is purely a result of the methods. The weakness of the DCF is, of course, that it assumes the follow-on investments will be always made, regardless of the venture's interim performance. In contrast, the Option Method recognizes that follow-on investments will only be made if the company is doing well. The fact that the follow-on investments are "optional" adds between $13M and $18M to the values calculated in the DCF method.

VI. CONCLUDING COMMENTS

The concept behind the venture capitalist's valuation method combines capital budgeting with securities valuation. The specific parameters of the method, the "rule of thumb" multipliers in Table 1, have evolved from decades of experience with thousands of investments. The option method replicates the accumulated val-

Table 6
Comparison of Valuation Methods for 3 Forecasts of P_T: Pre-funding Values of a Start-up Company

Forecast of P_T		*Valuation Method*		*Option*	
$P_{T,\,VC}$ *Success*	$P_{T,\,0}$ *Expected*	*DCF*	*Venture Capital*	σ_P = *59%*	σ_P = *83%*
\$260M	\$85 M	–\$2.4M	\$11.8M	\$10.8M	\$12.3M
195M	63 M	–9.9M	5.0M	5.0M	6.6M
130M	42.5M	–17.4M	–1.2M	0.1M	1.3M

Notes: 1. The DCF method uses equation (1) with the expected forecast of P_T and the expected investment amounts from Table 2. The risk-adjusted discount rate of 18.97 percent is calculated in Table 5.
2. The venture capital method uses equation (5) with the present value factors from Table 1 and the forecasts in this table and Table 2 with a "VC" subscript. The investments are assumed to occur at t = 0, 1, 2, 3.5 and 5.
3. The option method uses parameters in Tables 2 and 5 (discussed in detail in section 4 of the text). Forecasts and risk-adjusted discount rate are the same as in the DCF model.

uation experience of the venture capital community, as expressed in their "rules of thumb," very well. It also highlights the grave weakness of conventional DCF valuations when dealing with staged investments. Beyond its ability to replicate venture capitalist valuations, the option method has several advantages:

1. The venture capitalist's "rules of thumb," being derived from many years of experience, apply best to a typical investment, one that is the average of all the earlier investments from which the rules were developed. The option method can easily accommodate changes in funding patterns, in time delays between funding rounds, in interest rate levels, in IPO valuations, or in market volatility.
2. As venture capitalist activities spread to different industries and countries, the "rules of thumb" may not fit the new situations. The option method provides a technique that does not require decades of experience in order to give accurate valuations. The required estimates needed to use the option model can be obtained from a sample of 50 to 100 companies.
3. The option method allows analysts with relatively limited exposure to new ventures to make accurate valuations. It should be of great benefit to informal, "angel" investors or to internal venture managers, who may evaluate only a handful of proposals annually.
4. Entrepreneurs, who typically start only one or two companies in a lifetime, can use the option method to offset their inexperience at valuing new companies. With the option method they can estimate

values for their companies with confidence, and will be at less of a disadvantage when negotiating with investors.

5. The option method is conceptually sound. Other option models are the basis of large markets for publicly traded options in equities, currencies and commodities. If venture capitalists and other private investors adopt the option method they can simplify the task of valuing prospective investments, and can devote more time to other activities.

As a final note we should add that the values given by the option method are upper limits. That is, the investor should not pay more than the value implied by the method. To pay more would mean the investor is accepting a risk/return tradeoff less favorable than is generally available in the capital markets. As always investors should strive to negotiate favorable prices. The option method helps them assess whether they are succeeding in their efforts.

NOTES

1. Scherlis & Sahlman, 1989, describe the principal method used by venture capitalists. The method described here is consistent with the discussion in Scherlis & Sahlman, although somewhat simpler. It is used by the venture capital firms that provided the data used in section 4. The characteristics of those venture capitalists are summarized in section 4.
2. Points 2–4 are not easily documented with published research. Most data on venture capitalists is in private databases. However, two published studies support statements 2–4 in this section. Scherlis & Sahlman (1989) note that venture capitalists use high discounts rates—from 40 to over 60 percent. Bygrave, et. al. (1989), citing their own data and other studies, believe that the average return realized on venture capital investments is approximately 20 percent. Morgan Stanley (1994) estimates it at 16 percent for the period from 1945-1993. A realized return below the discount rate implies that the realized terminal value was below its forecast, or the interim investments were above their forecasts.
3. This assumption allows us to avoid a concern with the price per share. The assumption is not as restrictive as it may appear; it is equivalent to assuming that transactions take place at market value. Assuming that the "investor" is diversified with large resources, and that capital markets are complete and in equilibrium (completeness and equilibrium are necessary assumptions for use of traditional investment models such as net present value as well), the investor will be indifferent between making the investment I_T personally or letting others make the investment by buying shares at market value. Similarly, other investors in the market will be indifferent between buying shares in the company or letting the existing investors buy every offering. Since it is a matter of indifference who buys the offering, when transactions occur at market value, this analysis uses the simple case of a single investor.
4. Geske (1977) extended the Black–Scholes formula to compound options. Unfortunately the formula is extremely time consuming to evaluate for all but the simplest compound option. Barraquand (1995) presents an elegant simulation method that works with many elements of uncertainty in a single-stage option. The simulation method does not appear to extend to multi-stage options.

REFERENCES

Amit, R. & Livnat, J. (1990). Diversification, capital structure, and systematic risk: An empirical investigation. *Journal of Accounting, Auditing and Finance,* 19–43.

Barraquand, J. (1995). Numerical valuation of high dimensional multivariate European securities. *Management Science, 41*(12), 1882–1891.

Beaver, W., Kettler, P., & Scholes, M. (1970). The association between market-determined and accounting-determined risk measures. *The Accounting Review, 45* (October), 654–682.

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

Blume, M. (1971). On the assessment of risk. *Journal of Finance, 26* (March 1970), 1–10.

Brealey, R.A., & Myers, S.C. (1996). *Principles of corporate finance,* 5th. ed. McGraw-Hill, New York.

Bygrave, W., Fast, N., Khoylian, R., Vincent, L., & Yue, W. (1989). Early rates of return of 131 venture capital funds started 1978-1984. *Journal of Business Venturing, 4*(2), 93–105.

Clarkson, P., & Thompson, R. (1990). Empirical estimates of beta when investors face estimation risk. *Journal of Finance, 45* (June), 431–453.

Fama, E.F., & French, K.R. (1992). The cross-section of expected stock returns. *Journal of Finance, 47,* 427–465.

Geske, R. (1977). The valuation of corporate liabilities as compound options. *Journal of Financial and Quantitative Analysis, 12*(4), 541–552.

Higgins, R.C. (1995). *Analysis for financial management 4th. Ed.,* Irwin, Chicago.

Hull, J.C. (1993). *Options, futures, and other derivative securities 2nd. Ed.*, Prentice Hall, Englewood Cliffs, NJ.

Jain, B.A. & Kini, O. (1994). The post-issue operating performance of IPO firms. *Journal of Finance, 49*(5), 1699–1726.

Kamrad, B., & Ritchken, P. (1991). Multinomial approximating models for options with *k* state variables. *Management Science, 37*(12), 1640–1652.

Keeley, R.H, & Turki, L. (1993a). A new approach to the valuation of new ventures. *Frontiers of Entrepreneurship Research 1993.* Babson College, Babson Park, MA:661–675.

Keeley, R.H, & Turki, L. (1993b). Risk-return profiles of new ventures: An empirical study. *The Journal of Small Business Finance, 2*(2), 87–109.

Keeley, R.H, & Turki, L. (1994). *Compound options pricing: A simplified approach.* Presented at French Finance Association meeting, June 21–26, 1994, Tunis, Tunisia.

Megginson, W., & Weiss, K. (1991). Venture capitalist certification in initial public offerings. *Journal of Finance, 46* (July), 879–903.

Morgan Stanley (1994). Risk and return. *The Economist* (February 19), 12.

Nerlove, M. (1971). Further evidence on the estimation of dynamic relationships from a time series of cross sections. *Econometrica, 39,* 359–382.

Ritter, L. (1991). The long-run performance of initial public offerings. *Journal of Finance, 46* (March), 3–27.

Rosenberg, B., & Guy, J. (1976). The prediction of investment risk: Systematic and residual risk. *Financial Analysts Journal, 32* (July–August), 62–70.

Rosenberg, B., & Marathe, V. (1975). *The prediction of investmentt risk: systematic and residual risk.* Reprint 21, Berkeley Working Paper Series, (November).

Ross, S.A., Westerfield, R.W., & Jordan, B.D. (1995). *Fundamentals of corporate finance 3rd. Ed.,* Irwin, Chicago.

Scherlis, D.R., & Sahlman, W.A. (1989). *A method for valuing high-risk long-term investments: The venture capital method.* Harvard Business School Note # 9-288-006, Harvard Business School, Boston.

Scholes, M., & Williams, J. (1977). Estimating betas from nonsynchronous data. *Journal of Financial Economics, 5*, 309–327.