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Knowledge-Based Organization Evaluation

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Abstract

Knowledge has become the main value driver for organizations nowadays. In particular, knowledge-based organizations (KBOs) allocate resources for intangible assets (e.g., R&D) in the rapidly changing and highly competitive environment in order to gain competitive advantages. Therefore, how to evaluate knowledge-based organizations has become one of the most important issues in knowledge management. This paper aims to provide a framework for the evaluation of KBOs under uncertainty, using the state-of-the-art methodology in Real Options. We specify the unique features of KBOs and explain their value drivers. This paper makes three contributions: (1) it bridges the gaps existent in the knowledge management literature on evaluating knowledge capital, (2) it provides a systematic application of Real Options models in the context of knowledge-based organization evaluation, (3) it uses a real world case to demonstrate the implications of the main findings for management.

Keywords: Knowledge-Based Organizations; Evaluation; Real Options

1. Introduction

Knowledge is increasingly important to organizations when they strive to gain competitive advantages (Evans et al. 1997; Rayport et al. 1995). The issues of knowledge management and knowledge measurement become even more critical to knowledge-based organizations in the era of knowledge economics. Many competitive advantages result from intangible assets rather than traditional tangible assets. A significant part of the value of commodities or services provided depends on the underlying knowledge. Intangible knowledge has become the main value driver for organizations nowadays.

Knowledge-based organizations have grown at a high rate. Take Yahoo for example. Yahoo's stock price soared ten times within a year and its market value is also about ten times the book value. In the industrial era, land, capital and labor are the main drivers of competitive edges. However, knowledge plays a more critical role in the knowledge economics era, and knowledge has also become the most valuable asset in knowledge-based organizations.

More and more organizations allocate resources for intangible assets (e.g., R&D) in the rapidly changing and highly competitive environment to gain competition advantages. Therefore, how to evaluate knowledge-based organization has become one of the most

important issues in knowledge management. This paper makes three contributions: (1) it bridges the gaps existent in the knowledge management literature on evaluating knowledge capital, (2) it provides a systematic application of Real Options models in the context of knowledge-based organization evaluation, (3) it uses a real world case to demonstrate the implications of the main findings for management.

The remainder of this paper is organized as follows. In section 2, we provide an overview of the existent literature, including the traditional evaluation methods and the Real-Options method. In section 3, we explore the features of knowledge-based organizations and provide a model to evaluate such organizations. In the fourth section, we illustrate our method using empirical data of Lotus, a well-known software company, and present the results of our analysis. In the fifth section, we discuss the implications for management.

2. Previous Work in Company Evaluation

Although knowledge management has been one of the most challenging research topics in the past decade, relatively few methods have been proposed for the task of evaluating knowledge-based organizations. Valuing KBOs is a formidable problem due to their massive investments in intangible assets (e.g., R&D) whose values are difficult to measure. Traditionally, the following valuation methods are most commonly used:

1. Net Present Value (NPV): Using an appropriate discount rate to discount the cash flows generated by a proposed project (Higson et al. 2000).
2. Comparative Valuation Using Financial Multiples (e.g., Tobin's Q Ratio, the most commonly used multiple): Tobin's Q Ratio equals market value/asset value. A positive Q Ratio can be attributed to the intangible part of the intellectual capital that is not captured by traditional accounting systems (Luthy 1998).
3. Asset-Based Valuation: Companies with large tangible assets, such as a power plant or a steel plant, have some "assets in place" that can be used as a basis for evaluation.

Unfortunately, all the traditional evaluation methods above fail to incorporate the value of future opportunities and uncertainties (Myers 1974; Trigeorgis 1988). Intangible knowledge capital, in contrast to tangible assets, has different values under different levels of uncertainty. In other words, the traditional methods ignore the important fact that the organization's value drivers change over time. Thus those methods are inadequate when valuing knowledge-based organizations, most of whose assets consist of intangibles. High-tech companies, in particular, derive their value mostly from such intangible assets. It would be very difficult to attach a value to some or all of these assets, such as the R&D capacity.

The Real Options theory, which aims to deal with uncertainty in a better way, has gained significant progress in the finance field since the late 1980s. Earlier researchers had long endeavored to find a rigorous way to price options, but it was not until the early

1970s when the Nobel Prize winning works by Black et al. (1973) and Merton (1973) achieved the task. Based on stochastic calculus and the concept of dynamic portfolio hedging, the authors made an important breakthrough by deriving a stochastic differential equation that must be satisfied by the boundary conditions of the call option value. The solution of the equation is the celebrated Black-Scholes formula. Their seminar work opened a new avenue for derivatives pricing and resulted in the booming development of options research.

An option is defined as the right, but not the obligation, to trade (i.e., exercising an option) on a real or financial asset at a predetermined cost, called the exercise price, within a predetermined period of time. The option payoffs are asymmetrically distributed due to the limited liability of the option. In essence, they shift the possible distribution toward a more favorable pattern. This enables the option holder to take potential upside advantages while taking only limited downside risks. Myers (1974) first recognizes that the option-pricing theory can be applied to real assets and non-financial investments. Later, applying the Real Options method to strategic capital budgeting and valuing opportunities marks a second revolution in the option pricing theory. Following Myers, Kester (1984) and Dixit (1995) suggested the use of option-based techniques to value the managerial flexibility implicit in investment opportunities. They stressed the importance of irreversibility encountered in most investment decisions, together with the ongoing uncertainty of the environment in which those decisions are made. Kulatilaka et al. (1988) also discussed the strategic value of managerial flexibility and its option-like properties. Trigeorgis (1993) used this theory to deal with features and problems associated with the evaluation task for investment projects.

A real option is especially valuable in an environment with high degree of uncertainty because it takes time for new information to arrive in and resolve the uncertainty (Copeland et al. 2001). Since the value drivers of knowledge-based organizations are contingent on unknown future states, the Real Options thinking is suitable for valuing such drivers. The Real Options framework therefore offers a new and more realistic way to value strategic opportunities and uncertainty.

There are some studies that attempted to use the Real Options methodology for knowledge-based organization evaluation. Buckley et al. (2002) used the Black and Scholes (1973) formula to value the initial public offering (IPO) of companies. By feeding the model inputs into the valuation equation they find that the value of the firm is far from being rationally priced at the time of IPO. Kellogg et al. (2000) use a binomial-tree method to illustrate the possible value path of a biotechnology company. Schwartz and Moon (2000) use the Real Options method to evaluate an e-business for the case of Amazon and they point out that the high growth rate of the revenues explains the dramatic increase in stock price.

Some issues related to these works need to be noted. First, using financial option-pricing formulas has some practical problems when we model complex real assets. The Black and Scholes (1973) formula is for financial options that mature at a fixed day. Models for real assets such as organizations are much more complex and the Black-

Scholes formula may not be suitable. Second, the tree models have difficulties in dealing with more than one risk factor, thus limiting the applicability of these models. We therefore propose an evaluation model that is based on Schwartz et al. (2000). In contrast to their model, important novel characteristics of KBOs are specified and incorporated into our model. Knowledge-based organization valuation is complicated and must consider more specialized conditions in practice.

Firstly, Schwartz and Moon consider two sources of uncertainty (i.e. revenues uncertainty and growth rate uncertainty) in modelling Amazon, an internet bookstore. However, this two-sources approach is not realistic for KBOs, especially for the software industry. Amazon's core business depends mainly on the above-mentioned uncertainty of sales growth rate. In order to value a non-internet company like Lotus, it is not reasonable to consider only uncertainty about revenues and the sales growth rate. The company has great potentials and most of its value is generated by knowledge expenditures, which bring market growth opportunities. For e-business, the sales growth rate supports the company value. However, for knowledge-intensive organizations, the most significant feature is that investment in knowledge capital such as R&D contributes to most of the value. Moreover, the uncertainty in cost fluctuations must also be taken into account. Therefore, we incorporate cost uncertainty as the third risk factor into our model.

Secondly, they assume a mean-reverting process in the underlying asset price pertaining to both revenue and sales growth rate, in order to describe typical characteristics such as the seasonal effect. For an e-business, costs are related to fixed and variable costs. However, for KBOs, especially for software companies, the cost structure is much different. Most of the assets in software companies are explicitly intangible, which means that a large part of the company's value must also arise from intangible assets. In the software industry, the biggest costs are the knowledge expenditures such as R&D costs (Scavo 2005). The reproduction costs are mostly trivial. Thus, the costs exhibit the behavior of a jump and should be modeled as a jump process. This novel feature describes the significant cost decline each time when the competitor's R&D activity comes to a success. We will thus discuss our proposed model that deals with such unique characteristics of KBOs in the following section.

3. Modeling Knowledge-Based Organization

3.1 The Proposed Model

The major difference between Amazon and Lotus is the structure in their R&D costs. In order to value a non-Internet company like Lotus, we define KBOs as organizations whose R&D make up 15-20% of the firm's total costs in our scope.

Consider a KBO with instantaneous rate of revenues (or sales) at time t that is denoted as R_t . Assume that the dynamics of these revenues are given by the stochastic differential equation:

$$\frac{dR_t}{R_t} = \mu_t dt + \sigma_t dz_1 \quad (1)$$

We assume μ_t , the drift, is the expected rate of growth of revenues and follows a mean-reverting process with a long-term average drift $\bar{\mu}$, σ_t is volatility in the rate of revenue growth, and z_1 is a random variable whose probability distribution is normal. That is, the initially very high growth rates of a KBO are assumed to converge stochastically to the more reasonable and sustainable rate of growth for the industry to which the company belongs:

$$d\mu_t = \kappa(\bar{\mu} - \mu_t)dt + \eta_t dz_2 \quad (2)$$

where η_0 is the initial volatility of the expected rates of growth in revenues. The mean-reversion coefficient, κ , describes the rate at which the growth is expected to converge to its long-term average. Therefore, $\ln(2)/\kappa$ can be interpreted as the half-life of the deviations, in that any deviation is expected to be halved over this time period.

The unanticipated changes in revenues are also assumed to converge to the normal level, and the unanticipated changes in the drift are assumed to converge to zero:

$$d\sigma_t = \kappa_1(\bar{\sigma} - \sigma_t)dt \quad (3)$$

$$d\eta_t = -\kappa_2 \eta_t dt \quad (4)$$

Equation (1) through (4) can be represented in the following form (see (Schwartz & Moon, 2000) for details):

$$R_{t+\Delta t} = R_t e^{\{[\mu_t - (\sigma_t^2/2)]\Delta t + \sigma_t \sqrt{\Delta t} \varepsilon_1\}} \quad (5)$$

$$\mu_{t+\Delta t} = e^{-\kappa\Delta t} \mu_t + (1 - e^{-\kappa\Delta t}) \left(\bar{\mu} - \frac{\eta_t}{\kappa} \right) + \sqrt{\frac{1 - e^{-2\kappa\Delta t}}{2\kappa}} \eta_t \sqrt{\Delta t} \varepsilon_2 \quad (6)$$

where Δt is the time increment, ε_1 and ε_2 are standard normal variates, and $\sigma_t = \sigma_0 e^{-\kappa_1 t} + \bar{\sigma}(1 - e^{-\kappa_1 t})$.

Assume that the R&D costs follow a stochastic jump process that, in most of the time, fluctuates continuously. Nonetheless, it can also take a jump when the competitor's R&D activity comes to a success. Let λ be the mean possibility of this event, then during a time interval of dt the probability that the event will occur is given by λdt . Let q denote the jump process:

$$dq = \begin{cases} 0, & \text{with probability } 1 - \lambda dt \\ u, & \text{with probability } \lambda dt \end{cases} \quad (7)$$

Thus the value of the R&D costs follows the process:

$$dV = -Vdq \quad (8)$$

where the event is $u=1$ with probability λ . Then the value equals (Dixit & Pindyck, 1994):

$$V = \frac{\pi}{\alpha + \lambda} \quad (9)$$

where π is the total benefits and α is the discount rate.

3.2 Empirical Data

We illustrate the above valuation approach with empirical data from the Lotus Development Company, one of the best-known software companies. The data is collected from the COMPUSTAT database on a quarterly basis, ranging from 1989 to its acquisition by IBM in 1995 (as a result of its high profit potential attributable to knowledge investment in R&D). The basic data are shown in Table 1, including sales, costs and other items.

Most of the parameters, such as “sales”, “costs”, and “R&D expenditures”, can be obtained directly. However, some items such as “long-term volatility of the rate of growth in revenues” are not directly observable and need to be estimated from the quarterly data available. The determination of some parameters, however, requires the use of subjective judgment based on a solid knowledge of the specific background. The relevant parameters are shown in Table 1.

Table 1 Financial data of Lotus (1989-1994)

Year	Quarter	Selling, General, and Admin Expenses (MMS)	Sales (MMS)	R&D Expenditures (MMS)	Depreciation and Amortization Expense (MMS)	Interest Expense (MMS)	Cost of Goods Sold (MMS)
1989	1	89.091	119.97	20.565	6.432	n/a	18.353
1989	2	91.875	132.199	22.181	8.974	n/a	18.931
1989	3	96.562	153.906	26.222	9.216	n/a	18.627
1989	4	99.638	149.958	25.375	9.205	n/a	15.211
1990	1	101.724	166.518	0	12.313	n/a	20.884
1990	2	109.15	177.487	0	13.168	n/a	22.368

1990	3	116.18	159.817	0	14.885	n/a	18.387
1990	4	121.697	188.42	110.35	13.233	n/a	26.776
1991	1	125.599	174.409	0	16.6920	0.36	20.105
1991	2	131.749	186.406	0	17.9110	0.88	21.226
1991	3	141.355	218.846	0	18.3590	0.566	26.159
1991	4	158.473	249.234	130.486	17.6630	0.103	36.094
1992	1	143.641	227.063	0	20.1840	0.66	29.861
1992	2	149.153	220.319	0	21.1270	0.607	27.417
1992	3	148.049	206.742	0	20.7940	0.304	26.595
1992	4	170.381	246.025	140.508	22.2140	0.976	31.911
1993	1	155.902	227.004	0	21.6310	0.831	28.748
1993	2	159.416	235.785	0	21.6440	0.238	29.39
1993	3	165.2	240.104	0	22.1020	0.852	24.707
1993	4	179.081	278.275	171.984	21.5960	0.604	32.625
1994	1	168.552	246.992	0	21.4130	0.762	24.995
1994	2	171.709	224.009	0	21.2960	0.63	17.572
1994	3	183.906	235.246	0	21.5960	0.717	21.134
1994	4	200.418	264.476	255.713	23.0870	0.186	21.232

For the initial expected rate of growth in revenues, we took the average of the growth rates over the last six years. The standard deviation of past percentage changes in revenue, namely, 0.22, was used as the initial volatility of revenues. For the long-term rate of growth in revenues for the industry, we use a value of 5 percent per quarter, with a reference from the average of Oracle from 1997 to 2004 because they are in the same industry sector and have similar cost structures, and a value of 7 percent per quarter for the long-term volatility of revenues. We assume that the half-life of the deviations is 20 quarters, so the three speed-of-adjustment, or, mean reversion coefficients are $\ln(2)/20=0.03$ and the tax rate is 20% for the company. Estimated variable costs for the next five years are obtained by the regression equation $y = 5.4395x + 114.67$, where $R^2 = 0.9128$ and estimated R&D costs for the next five years are obtained from the regression equation $y = 75.24e^{0.1826x}$, where $R^2 = 0.9401$. Thus the value can be obtained by the following equation:

$$\text{Value} = \left[\frac{\text{Revenue} - \text{Cost}(\text{Variable})}{WACC} - \frac{\text{Cost}(\text{R \& D})}{(WACC + q)} \right] * (1 - \text{tax}) \quad (10)$$

where the revenues can be obtained by (5) and (6), variable costs obtained from (10), and R&D costs from (11). Because the revenues are assumed to follow a mean-reverting process, the growth can be expected to continue for the next few years, but afterwards the growth rate will decrease. Costs are composed of two parts. The variable cost is discounted with the weighted average cost of capital (WACC), and the R&D expenditure,

which is a large portion of the total costs in the software industries, is assumed to follow a jump process and is discounted with a combination of the WACC and the probability of a jump event, as described in (Dixit 1995).

4. Analysis Results

For all the valuations, we run 10,000 simulations. In the benchmark valuation run, which use the parameters in Table 2. The total value of Lotus was \$1,578 million, which is very close to \$1,992 millions, the average market value of Lotus in 1995 (when it was acquired by IBM). Compared to the data shown in Appendix 1, Lotus had less than \$1 billion of identifiable tangible and intangible net assets in 1995. The tangible net assets consist primarily of cash, accounts receivable, land, buildings, leasehold improvements and other personal properties. Our model is thus more powerful for explaining the real - world value of such a knowledge-intensive company. As a further step, we conduct comparative statics analysis to explore the degree to which each parameter affects the company's value.

Table 2 The parameters

Parameters	Denoted as	Description	Value
Initial revenue	R	Observable from current income statement	\$264 million/quarter
Initial expected rate of growth in revenues	μ	From past income statements and projections of future growth	0.13/quarter
Initial volatility of revenues	σ	Standard deviation of percentage change in revenues over the recent past	0.22/quarter
Speed of adjustment for the rate of growth process	κ	Estimated from assumptions about the half-life of the process to $\bar{\mu}$	0.03/quarter
Speed of adjustment for the volatility of revenue process	κ_1	Estimated from assumptions about the half-life of the process to $\bar{\sigma}$	0.03/quarter
Speed of adjustment for the volatility of the rate of growth process	κ_2	Estimated from assumptions about the half-life of the process to zero	0.03/quarter
Long-term volatility of the rate of growth in revenues	$\bar{\sigma}$	Volatility of percentage changes in revenues for a stable company in the same industry as the company being valued	0.07/quarter
Time increment for the discrete version of the model	Δt	Chosen according to data availability, which is usually quarterly	1 quarter
Initial volatility of expected rates of growth in revenues	η	Inferred from the market volatility of stock price	0.12/quarter
Long-term rate of growth in revenues	$\bar{\mu}$	Rate of growth in revenues for a stable company in the same industry as the company being valued	0.05/quarter
Tax	x	Tax that the company has to pay	20%

In Figure 1, changes in the project value volatility (σ) affect the company value in a positive way. The company is more valuable with a higher σ . An increase in σ of 0.1%

approximately increases the company value by 19%. This can be explained by the fact that high growth opportunities constitute a substantial part of the company's value.

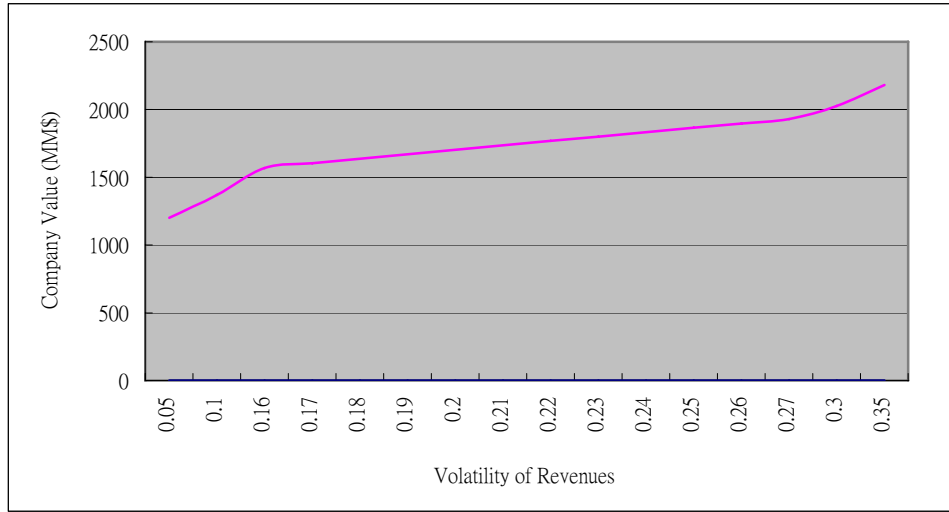


Figure 1 The effects of changes in the volatility of revenues (σ) on company value

Next, we examine the effect of changes in the initial volatility of the expected growth rate of revenue (η) on the company value. Figure 3 shows that the company value is very sensitive to η . The company value increases by an amount of 22% when η increases from 0.12 to 0.24. But the value increases abruptly (55%) as η increases from 0.12 to 0.36. Thus the volatility of the expected growth rate of revenue (η) needs to be carefully estimated when evaluating KBOs. Such an effect of η is not surprising, since according to the option pricing theory more volatility means more possibility to act in a favorable way. Thus a higher volatility of the expected growth rate of revenue implies that the company has more profit potential in the future.

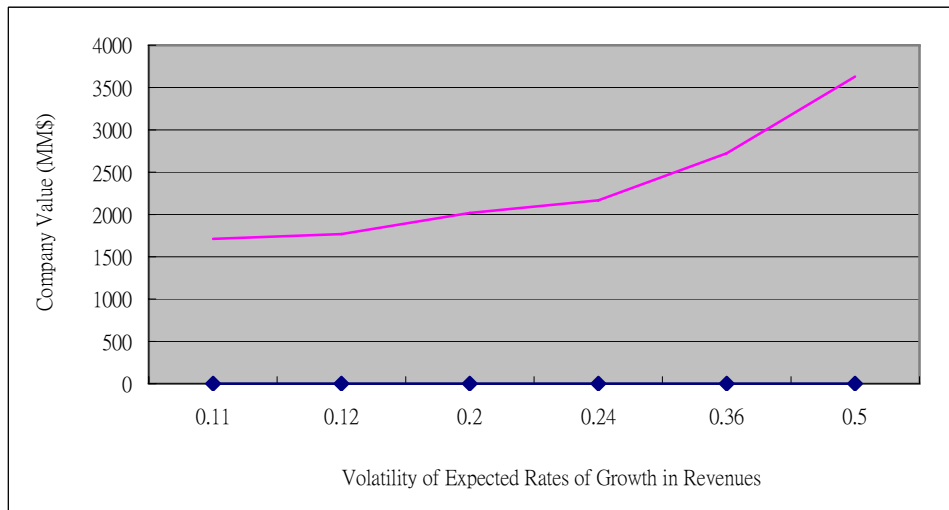


Figure 2 The effect of changing volatility of the expected growth rate of revenue (η) on company value

In Figure 3, we can see the sensitivity of the company value to changes in the initial expected growth rate of revenue (μ). Given the same margin rate of increase, more growth rate brings more possibility to be profitable. The results show that the higher μ , the more valuable the company is. Their relationship approximately follows a linear pattern.

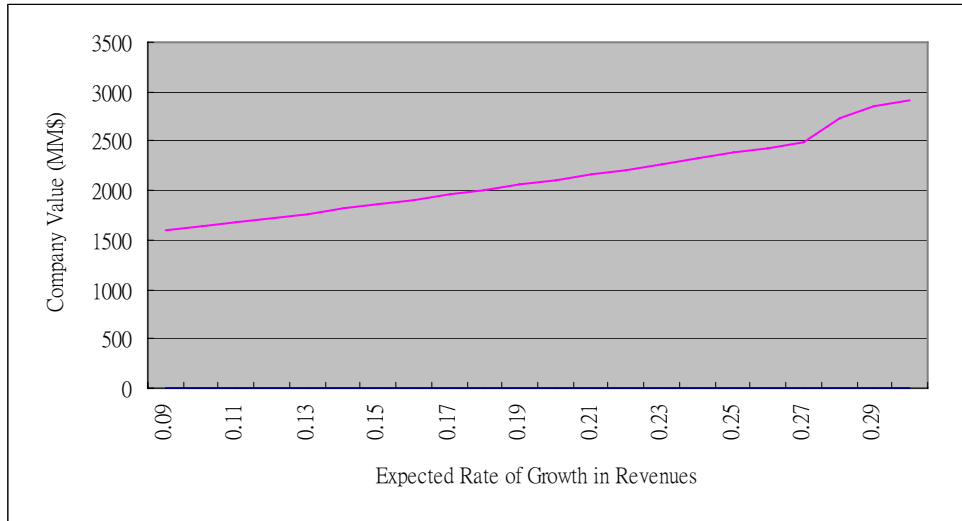


Figure 3 The effect of changing expected growth rate of revenue (μ) on the company value

5. Conclusions and Discussions

In a highly competitive knowledge-based world, investments in knowledge are crucial to organizations. In this paper, we present a model that considers novel features of KBOs. The analysis shows that changes in the project value volatility (σ), the volatility of the expected growth rate of revenue (η), and the expected growth rate of revenue (μ) play an important role in determining the company value. Among them, η is the dominant determinant of value.

This poses some important managerial implications. Although knowledge-intensive organizations make massive investments in knowledge development that can lower their earnings in the short run, rapid growth and long-term competitive advantages often follow from these huge investments. Management should therefore be more serious about investing in knowledge capital, such as R&D activities, in order to sustain a high growth rate for future competition.

Our goal in this paper is to advance an evaluation framework, rather than to find the company value through perfectly accurate model parameters. Because the step of estimating the model parameters is the most critical one in the analysis, practitioners will need the relevant expertise in estimating the parameters. Although we describe the possible range of the value for KBOs and use sensitivity analysis to explore the degree to

which the parameters affect the company value, inevitably valuing by estimated data can result in some bias. More precise data estimation can be done in future studies. An analyst must also use personal judgment and knowledge about the industry characteristics to estimate the parameters. Although for simplicity we consider only the more important value drivers by ignoring other less important ones such as tax-shield, the excluded factors can be easily added to our model. Future studies can investigate the value drivers of KBOs in even more depth and consider the effect of regulations on accounting practices.

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Appendix Net assets of Lotus (1988-1995)

year	Quarter	Cash and Short-Term Investments (MMS)	Receivables (MMS)	Inventories (MMS)	Current Assets (MMS)	Property, Plant, & Equip (MMS)	Assets (MMS)	Assets Total (MMS)
1988	1	164.931	63.598	12.278	8.071	59.124	36.067	344.069
1988	2	186.199	68.268	11.578	9.138	64.406	31.656	371.245
1988	3	195.781	81.418	13.702	8.668	72.183	27.617	399.369
1988	4	192.433	92.035	18.088	7.43	86.953	25.183	422.122
1989	1	173.3	94.367	18.029	21.705	99.667	30.158	437.226
1989	2	179.716	95.412	19.976	25.912	108.918	36.952	466.886
1989	3	221.603	106.438	26.388	28.582	115.503	39.636	538.15
1989	4	274.977	97.712	23.171	13.937	129.702	64.778	604.277
1990	1	287.178	103.085	19.4	24.381	133.786	68.805	636.635
1990	2	320.009	106.337	20.781	15.529	137.315	97.116	697.087
1990	3	298.632	118.461	22.443	17.43	139.968	97.916	694.85
1990	4	245.386	120.346	21.7	12.036	147.758	109.581	656.807
1991	1	202.878	128.867	18.278	14.084	144.979	131.867	640.953
1991	2	217.282	129.208	20.657	11.923	145.646	132.05	656.766
1991	3	229.429	166.051	25.82	13.829	148.352	132.353	715.834
1991	4	224.81	172.201	30.922	13.384	146.478	137.742	725.537
1992	1	250.486	166.575	21.658	15.417	141.593	137.062	732.791
1992	2	248.159	164.926	22.138	16.313	141.011	138.265	730.812
1992	3	266.112	162.732	21.376	17.708	139.805	119.61	727.343
1992	4	293.094	178.34	23.56	19.04	135.667	113.743	763.444
1993	1	319.567	169.58	19.448	22.159	130.004	109.073	769.831
1993	2	331.658	168.184	21.758	22.361	127.82	106.401	778.182
1993	3	376.998	167.887	21.445	30.795	124.259	106.357	827.741
1993	4	416.693	217.336	21.22	20.817	127.437	101.842	905.345
1994	1	476.889	189.838	17.102	27.715	124.298	98.079	933.921
1994	2	452.048	168.57	15.22	28.866	128.23	100.191	893.125
1994	3	388.965	193.539	18.551	26.065	132.607	114.661	874.388
1994	4	376.218	230.977	20.711	24.452	138.664	113.057	904.079
1995	1	401.145	196.307	19.027	30.597	147.421	108.595	903.092