The Value of Knowledge and Intangible Capital:

a Methodological Investigation

by

William Henry Newman

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Abstract

This research examines the value of knowledge and other intangible capital in corporations.

One objective of this work is to develop a methodology to value intangible capital. Four separate valuations models are developed and applied to firms in the computer and computer electronics industry in the years 1981-1989. The first valuation approach identifies intangible capital using a model based on Tobin's q, the ratio of the firm's market value to the replacement cost of its physical assets. The second approach constructs an employee-specific measure of the value of the firm from the sum of tangible assets and expenditures that represent investments in intangible assets. The final two models present a novel approach that calculates the financial market's mispricing of firm value by comparing actual to expected performance. Market mispricing is then related to unexpected returns on various classes of asset investments, both tangible and intangible.

The second objective of this research is the determination of the value and appropriability of knowledge and other intangible assets in a particular industry. Results are presented here for the computer and computer electronics industry. The major finding is that in smaller firms, the value of intangible knowledge assets, represented by R&D expenditures, is not immediately appropriable by the firm. Rather, earnings and advertising are the significant determinants of firm value. This indicates the importance of a market orientation for smaller firms and suggests that advertising is the mechanism, or at least the explanatory variable, which describes the importance of securing an appropriable market advantage. For larger firms, the opposite is true: the value of knowledge assets is greater, indicating that owners are quite confident of appropriating the benefits of ideas that are produced by the company. One explanation consistent with these results and with economic theories of the firm is that due to its reduced appropriability, the risk associated with R&D is greater in the small firm, and, when discounted for risk, the market value of the R&D investment is less.

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CHAPTER 1 INTRODUCTION

This thesis studies the determination of the value and appropriability of intangible assets in corporations. The objective of this work is to develop a methodology to value intangible capital. A second objective is to differentiate the value of intangible capital according to the characteristics of the firms which employ it and which attempt to capture it. This is a preliminary investigation, and as such can be further refined to quantify more precisely the results reported here. Future studies can then apply this methodology to answer questions of broader interest, such as its application to other industries to identify inter-industry differences, or to countries to identify national differences.

While intangible assets take many forms - reputation, goodwill, trademarks, etc. - this study specifically focuses on the value to the firm of knowledge-based and employee-specific assets. Examples include the research and investigative skills of scientists in the R&D department of a company, or the marketing expertise of senior product managers. Questions as to the value of such assets have relevance to service-oriented firms such as consulting and law firms. However, they are of particular significance to technology companies, whose principal assets are their employees and the knowledge they develop. The ability of the firm to succeed depends on its capability to derive value from the efforts of its employees. In the short term, these skills provide immediate benefit to the company, yet they will be a source of permanent, long-term value only if the company is able to assimilate those skills into its body of organizational knowledge, and reduce its dependence on individual employees. To illustrate, in larger firms, the organization may be able to assimilate the research discoveries of its employees or the sales and marketing expertise of talented individuals. Therefore, current expenditures in R&D, marketing, etc. may be confidently expected to produce future benefits, and so will provide marketable value to the firm. In smaller firms, the company may be heavily dependent on key individuals, and be unable to retain key competitive factors should those individuals depart. Firm value would be expected to be more dependent on immediate and appropriable benefits: current and near future earnings, or appropriable intangible assets such as patents and licenses. This thesis will develop valuation approaches that allow such differences to be discerned.

In particular, this thesis will focus on the determination of the value and appropriability of research and brand-name intangible assets to firms in the computer and computer electronics industry. This industry was chosen because it is characterized by a diverse group of companies spanning the range from exclusive dependence on knowledge assets (such as software companies) to companies more reliant on tangible assets. The worth of such assets on the open market depends on the extent to which these assets may be transferred. Questions to be addressed include the appropriability, to the firm and its owners, of these different types of assets.

The models to be developed will attempt to determine the value of tangible and intangible assets to companies characterized by different factors, including firm size and number of employees, among others. For example, this research will examine whether companies which depend on tangible assets have markedly different characteristics than companies which have a much greater dependence on intangible assets. Similarly, companies that have a high market capitalization per employee relative to the industry average will be examined to determine factors which lead to this exceptional value.

The results to be presented provide insight on the role and value of intangible capital in organizations. Each of the four valuation models is consistent in placing a lower valuation on investments in knowledge assets (identified by R&D expenditures) in smaller companies than in larger companies or for the industry sample taken as a whole. For these smaller companies, value is principally determined by brand-name (e.g. advertising) investments and operating earnings, indicating that the ideas produced by the R&D do not intrinsically produce marketable value. Rather, it is the validation of these ideas in the market that confirms their value. While this does not imply that the importance (vs the market price) of knowledge assets in smaller corporations is less than in larger corporations, its lower market value may be due to two factors. First, the success of R&D in smaller companies is likely to be more uncertain than in larger companies. Smaller companies face greater constraints due to financial limitations, lack of organizational infrastructure, and insufficient resources to adequately handle all phases of production from inception to production and marketing. Secondly, the owners of smaller companies may be less able to appropriate the results of R&D investments, which may rest with certain key individuals, until that knowledge is "locked in" to a stream of earnings via a strong product and a brand-name reputation. In either case, the risk of investments in R&D in smaller organizations is greater, and when discounted for risk, the market value of such investments is less.

Organization

This thesis is organized as follows. Chapter 2 briefly presents different economic views on property rights, and reviews some of the recent literature on the valuation of knowledge and intangible capital. Chapter 3 outlines the research plan of this study, identifying the industry, data sources, and valuation methodology and models. Chapter 4 presents descriptive information on this industry, including size, financial, and other measures. The valuation analyses are presented in Chapter 5. After each valuation model is developed on conceptual grounds, its implementation for regression analysis is described; results are presented, discussed, and interpreted; and potential sources of error are discussed. Conclusions are made in Chapter 6, and recommendations for further work identified in Chapter 7. Appendix 1 provides more technical detail concerning the data sample, and Appendix 2 briefly describes alternate valuation models which yielded results less conclusive than those presented in Chapter 5.

CHAPTER 2 BACKGROUND

The valuation of intangible assets is increasingly important for technology-based companies, whose main assets may lie in intangibles such as patents, expertise, know-how, its ability to innovate, or its organizational structure and culture (Brynjolfsson, 1994). Even in such traditional industries as manufacturing, the adoption of Flexible Manufacturing Systems is shifting management emphasis from manufacturing to the creation and management of intellectual assets (Jaikumar, 1986).

Carrying this argument to an extreme, Drucker (1992) argues that knowledge is *the* primary resource, not only for the organization but for the economy overall. The function of the organization is to acquire specialized knowledge and apply it to the optimal use of the traditional economic resources - land, labor, and capital. This necessarily creates a tension between the individuals who possess specialized knowledge, but lack the organizational structure to apply it, and organizations, which seek to appropriate the knowledge and any ensuing economic benefits. The means of production - the specialized knowledge - and the tools of production - the organization - are now separated. The division of benefits is determined by a negotiation between the employees and the owners, as one seeks to retain, the other to appropriate the knowledge assets.

Therefore, in determining the worth of intellectual assets, it is first necessary to ascertain ownership. In this chapter, a brief review of property rights is presented to place these issues in an economic perspective. Next, results of recent research into the value of intangible assets are reviewed. This literature survey will serve to illustrate relevant methodologies as well as to compare results from different investigations.

Economic Theories of the Firm

From a financial perspective, the valuation of an entity depends only on the earnings it produces and the risk which it incurs. This is true independent of the nature of the item to be valued, whether it is an organization, such as an entire firm or division, or simply a project. From an economic perspective, these issues are certainly important; however, other questions also arise when considering the economic value of organizations. These are concerned with the nature, justification for, and limits of the firm. What constitutes the firm? What provides the firm with value in excess of that which could be achieved by a simple combination of the productive assets? If the conclusions of Drucker are accepted, that the organization exists to transform knowledge into goods and services, and knowledge-based assets are the primary economic resources, such questions are fundamental.

Hart (1989) reviews the evolution of economic theories of the firm. These serve as a useful starting point when considering the valuation of intangible assets and the appropriability of the benefits they produce.

In the simplest, *neoclassical theory*, the firm is viewed as a set of available production plans. Managers optimally choose among these alternatives to maximize profit (or its discounted present value), given a competitive strategy and the competitive environment. The environment consists of the existing market and industry structure, and other exogenous factors, i.e. government. This is a mathematical theory in that it does not consider how the optimization goal is achieved. Issues such as agency problems, conflicts of interest, or firm boundaries (i.e the limits of firm ownership or influence) are ignored. The theory is simplistic in that the ability to operate a production function depends on skills and people, as well as tangible property. It nonetheless provides insight, for example in understanding oligopolistic industry structure, changes in government policies, etc.

Some of these issues and conflicts are addressed by *principal-agent theory*. This is a managerial theory which recognizes that the firm is run by hired agents of the owners. The owners do not run the firm directly, and thus lack the detailed information about the firm that the managers possess. To compensate for this lack of information the owners seek to align the managers' incentives so that they will act in the owners' interests and maximize profit. This theory starts to explain conflicts of interest and why non-optimal production plans are chosen. However, it does not adequately explain the extent of the firm, for incentives can be between independent contractors as well as between managers and owners. It also does not describe the ability of the firm to capture and develop scarce or unique resources.

Transaction cost theory attempts to more finely delineate the formal extent of the firm by hypothesizing that the firm reduces the repetitive contracting costs involved in arranging for the factors of production by setting up long-term contracts and lines of authority to control production, rather than individually arranging every transaction for goods and services in the open market. Disadvantages of these fixed contractual agreements are a lack of flexibility, and a greater risk of error. Firm boundaries are thus at the point where the marginal costs of these drawbacks equal the marginal savings from having these transactions incorporated.

Transaction theory is further extended in *contract theory*, which posits that the firm is simply a nexus of different contracts. The organization of the firm represents somewhat arbitrary boundary in a continuum of contracted arrangements covering every aspect of market transactions. However, this theory is ineffective in explaining why one particular organizational form should be chosen over another. For example, it can not explain firm size, nor why breakups or mergers occur.

More recently, *property rights theory* asserts that the ownership of an asset provides a control premium in excess of the asset value. When contracts governing the use of assets are incomplete, the asset owners possess residual rights to use those assets outside of contractually agreed upon uses. These are intangible assets that confer value to the owner.

According to property rights theory, both the owners and the employees of a firm have the incentive to make investments in the firm, even if for the employee those investments are firm-specific and not readily appropriable by the employee. For the firm's owners, ownership increases the incentive to invest since the threat of expropriation is reduced. For employees, investments which improve the value of assets to the firm's owners can increase the employee's bargaining power; conversely, failure to do so can cause the employer to deprive the employee of the use of the firm's assets. The value of the firm's employment is presumably greater when the company provides significant resources to its employees. For example, the resources and (professional) benefits of working for a large, successful company would be more valuable to an employee than the benefits of employment at a smaller company, where the employee himself provides all the value (i.e. the employee contributes more than the firm does in the value-producing relationship).

One implication of this theory is that the value of intangible assets is tied to the ownership of tangible assets. Otherwise, this intangible capital is mobile and free to leave the firm. Thus, for firms whose value is disproportionately dependent on intangible assets, i.e. for firms whose market value greatly exceeds tangible asset value, one would expect that additional intangible investments may be difficult to appropriate since they may not necessarily be linked to the tangible assets. (However, this may be difficult to prove, since the high market valuation could be an indication that the market believes exactly the opposite.) In fact, the results to be presented in Chapter 5 support this observation. For firms whose market value greatly exceeds their tangible asset value, investments in R&D are worth less than the value of R&D to the aggregated data set and less than the value of R&D to larger firms. This supports the complementary relation between intangible and tangible assets. In addition, R&D investments generate higher unexpected returns for highly intangible asset-dependent firms, suggesting that the market's initial expectation of the value of such investments in intangible capital are lower for these firms (otherwise, return would equal the expected return).

Review of Research Results on the Valuation of Intangible Assets

The literature on the valuation of intangible, and in particular, intellectual property assets is extensive. The summary to be presented here makes no attempt to trace this body of research, but instead focuses on methodologies and results relevant to this investigation. In general, methods to value property, tangible as well as intangible, from market data utilize one of two approaches: asset-based approaches and earnings-based approaches. Asset-based methods generally use Tobin's q - the ratio of market value to replacement cost - to determine the value of intangible assets, while earnings-based approaches use a profitability measure such as return on assets (ROA) to identify sources of exceptional value.

1. Asset-based valuation approaches

Tobin's q, the ratio of market value to tangible (replacement) asset cost, arises naturally when considering intangible assets. Since market value is the sum of the economic value of the firm's tangible and intangible assets, the deviation of Tobin's q from 1.0 is a measure of the firm's value that is associated with intangible assets. When Tobin's q is greater than one, the value of the firm exceeds its open market replacement value by the exceptional, unique investment opportunities it offers its owners (such as market power) or by the value of the unique resources possessed by the owners (skills, entry barriers, etc.). Similarly, the value will be less than the replacement value of the assets when investment opportunities are poor, such as entry into a regulated utility or monopoly-controlled market. A basic assumption is that an efficient capital market will appropriately capitalize the firm. Since market values embody long-run expectations, this assumption should be valid and the measure of q should be relatively free of short-term and disequilibrium effects. In justifying the use of Tobin's q, Lindenberg and Ross (1981) observe that financial data provide a market valuation, while accounting data describe the resources used by the firm. This difference is thus a measure of firm performance: the relation of the firm's output to its input.

General studies

Numerous investigations have focused on the analysis of Tobin's q to identify and value intangible factors affecting a business. Some of these different factors and interrelationships are market factors (monopoly power), industry factors (concentration), firm factors (diversification, organization, and unionization), and intellectual property rights (patents, R&D, advertising, etc.).

One of first careful methodological investigations to relate industry-wide organizational factors to excess market valuation was that of Lindenberg and Ross (1981). This study illustrates the rather complex methodology that is necessary to faithfully calculate Tobin's q. In general, the idiosyncracies of accounting conventions made economic interpretations of asset costs and investments difficult. First, market value was determined as follows: the value of common stock was taken at the year-end price; the value of preferred issues was calculated by valuing preferred dividends at the S&P preferred stock index; and each issue of a firm's debt was valued by its maturity, bond rating, and coupon. Replacement costs for certain assets (PP&E, inventory, and cost of good sold) are required by the SEC and reported in the 10-K. This allowed replacement costs for these items to be found. Inventory corrections were required depending on the inventory method (LIFO vs FIFO, for example), and past purchases were corrected by the relevant price indices over the period of study to account for inflation. For other assets (cash, marketable securities, or land), actual replacement values were unavailable and book values were used.

The hypothesis of Lindenberg and Ross was that increasing industry concentration would be associated with monopolistic behavior and excess profits, and hence would be correlated with excess market value. Instead, the results showed that the correlation of industry concentration with high Tobin's q was not significant, but that monopoly profits were related to the Lerner ratio (the excess of price over marginal costs, approximated by operating margin). Thus market factors, as opposed to industry factors, determined excess value.

Salinger (1984) looked at monopoly power and union interactions, using regression models based both on Tobin's q and a profitability measure (ROA). This study also found industry concentration not to be a statistically significant descriptor of excess value or excess profitability, while sales growth, a market factor, was an important explanatory variable. In addition, Salinger found the union effect to be large and statistically significant, with unions appropriating up to 70% of monopoly rents, leading to the conclusion that the primary beneficiaries of monopoly power are unionized workers.

Similar to Lindenberg and Ross, Smirlock et al. (1984), also used a regression model based on Tobin's q to identify the proportion of the capitalized value of the firm attributable to monopoly and firm specific factors. They also found that market share and market share growth were significant sources of intangible value to the firm, and that other factors such as entry barriers and concentration were not significant explanatory factors. One explanation suggested by the authors is that rents may be dissipated in forming entry barriers. Another plausible explanation, given the significance of market factors as a source of excess value, is that firm- and industry-specific factors such as concentration and entry barriers have no intrinsic value, but are important only when used to create market advantage. Another may simply be a measurement problem: market share is itself a significant entry barrier, so that the observation of the value of entry barriers may be difficult.

Montgomery and Wernerfelt (1988) analyzed a 1976 industry cross-section of firms to study the effect of diversification on firm value. They found that the relation between market value and diversification is negative, and once again, that market share is a significant and positive explanatory factor. Other significant explanatory variables are advertising and R&D. Although industry concentration is statistically significant, its coefficient is near zero.

Valuation of knowledge-based intangible assets

Several studies have specifically applied these valuation models to determine the value to the firm of investments in firm-specific intangible assets such as know-how, expertise, brand-name value, and reputation. In these models, variables which approximate the yearly expenditures on these assets are obtained from available accounting data - for example, investment in a knowledge asset is approximated by

R&D expenditures or patents received, and investments in brand name are approximated by advertising expenditures.

In calculating the value to the firm of these intangible assets, two approaches are generally taken. In each, market value is calculated as the sum of the firm's tangible assets, plus some multiple of a variable representing the intangible asset. This multiplier represents the appropriability or long-term value to the firm of the intangible asset. In the first approach, the increase in market value due to an investment in the intangible asset is taken to be proportional to the relevant current year's expenditures - R&D or advertising for example. This is referred to as the "flows" approach. This approach does not account for depreciation of the intangible asset except indirectly (via a lower net appreciation rate for current expenditures as an unknown fraction of the current year's spending goes to replenish the depleted asset). In an alternate approach, the "stocks" approach, a generalized knowledge or brand-name asset is constructed by summing past years' expenditures. This asset is then assumed to depreciate at a known rate. For example, Salinger (1984) depreciate R&D at a 10% yearly rate and advertising at 30%. Either approach has been shown to give consistent and similar results. For example, Montgomery and Wernerfelt (1988) found the valuation of R&D and advertising using the flows approach to be the same as those of Salinger (1984) who used the stocks approach; while Hall (1993) applied both approaches to the same data set and found the market value of R&D to be the same for both approaches.

Application of a valuation method based on Tobin's q to determine the worth of such knowledge and reputation intangible assets include Griliches (1981), Salinger (1984), Montgomery and Wernerfelt (1988), Hall (1993), and Megna and Klock (1993). Table 2.1 briefly compares the major results found in those studies. The valuation model is generally represented as follows:

investigator	data	asset valuation method	coefficient value: R&D	advertising	other	notes
Griliches (1981)	157 firms 1968-74	stock	2	n.a.	patents: $200K per patent	
Salinger (1984)	manufacturing firms, 1976	stock	3.0-3.4	1.4-1.5	concentration not significant sales growth significant	depreciation: R&D = 10% adv'ng = 30%
Montgomery and Wernerfelt (1988)	sample of public firms 1976	flow	9.4	2.4	concentration near zero market share significant diversification negative	
Hall (1993)	all public firms, 1973-1991	stock & flow	2.4-3.1	0.5-1.0	cash flow significant sales growth significant	depreciation: R&D = 15%
Megna and Klock (1993)	11 firms, 1972-1990	stock	0.5-0.8	n.a.	rival R&D also significant	semiconductor industry; time-varying depreciation rates

Table 2.1 Comparison of the value of intangible assets found in various industry and economy-wide analyses

$$MV = TA + \sum_i \beta_i A_i \qquad (1)$$

where MV is market value, TA is tangible assets, and each intangible asset A_i contributes to firm value according to the coefficient β_i.

As seen from the Table, the general conclusion from these studies is that R&D contributes more to firm value than advertising. However, these studies are economy-wide (except for that of Megna and Klock, which focuses on the semiconductor industry, but which only considers 11 firms). Otherwise, none of these studies focused on a particular industry, nor was there any attempt to value intangible assets as a function of firm characteristics. Such industry-specific differences are likely to be significant, for it is obvious that R&D and advertising play different roles in different industries. For example, the value of R&D in semiconductor industry as calculated by Megna and Klock is certainly quite different than that calculated by Hall or Montgomery and Wernerfelt for the economy as a whole. Similarly, the economic arguments presented earlier suggest that even in the same industry, an investment in an intangible asset will have a different value depending on the characteristics of the firm making the investment.

Variations in the worth of the intangible assets over time are also likely to be significant. In the economy-wide study of Hall (1993), the market value of investments in R&D was calculated on a yearly basis. Over the period 1981 - 1986, the value of R&D plummeted by approximately a factor of three, while the relative value of advertising increased. Hall argues that these observations are difficult to explain by a reduction in the market valuation for R&D, whether due to a lower rate of return to R&D or market short-sightedness. An alternative hypothesis is that this apparent market-wide decline represents the market's focus on finding excess returns from merger and acquisition activities during this period. Much of this activity was concentrated in heavily advertising-dependent industries, and Hall suggests that speculation led to an increase in market value in these industries relative to more research-intensive industries. Clearly, in order to explore these questions more fully a time- and industry-dependent model would be required.

2. Earnings-based valuation approaches

Pratt (1989) argues that if intangible assets have true economic value, this value will be reflected in earnings. Thus, in valuing a firm, greater reliance should be placed on earnings versus asset valuation approaches. In the literature, various earnings-based valuation approaches have been described, each of which use some profitability measure to describe return. However, these approaches are often criticized as being overly susceptible to tax law distortions, accounting conventions, short-term effects, and in addition, these approaches neglect risk.

Methodological difficulties also arise due to questions as to the treatment of intangibles in earnings and asset measures. Pratt recommends eliminating intangible items from balance sheets and amortization charges from income statements. For example, Grabowski and Mueller (1978) correct net income for R&D expenditures, observing that if R&D is not capitalized, this amounts to effectively a 100% depreciation rate. Methodological difficulties may also make results harder to discern. Salinger (1984) carried out simultaneous earnings (ROA) and asset (Tobin's q) valuation approaches on the same data sample and found that while the significant explanatory variables and the conclusions were the same for both models, the earnings-based method had lower R^2 and significance levels.

An improvement to the earnings approach has been suggested by Healy and colleagues (1992), who propose "cash flow rate of return" as a more appropriate profitability measure. This measure corrects for accounting and tax distortions by using pre-tax cash flow instead of accounting net income as the income measure, and corrects for risk by using market vs book assets. Healy applies this measure to assess firm performance following mergers, but the use of cash flow rate of return as opposed to accounting ROA to determine the value of intangible property has not been reported in the economic literature.

Typical results are presented by Salinger (1984) and Grabowski and Mueller (1978), who describe regression models for ROA using a large sample of public firms. Each model relates return on assets (ROA) to a number of explanatory variables including R&D and advertising stocks, industry concentration, sales growth, market share, and firm size. The explanatory variables that were found to be significant in describing ROA were the same as those variables which were significant in asset valuation models based on Tobin's q: industry concentration was not significant, but market share and share growth were found to be significant variables.

The results of Grabowski and Mueller were particularly significant concerning the influence of R&D expenditures on firm profitability. Two distinct types of firms were distinguished based on the amount of R&D spending as a fraction of total assets. Firms labeled as progressive invested a large fraction of total assets in R&D stocks, in contrast to non-progressive firms. Progressive firms received a larger return on R&D spending than non-progressive firms, but overall firm profitability had a negative correlation with concentration. The hypothesis proposed is that concentration in research-intensive industries leads to excessive rivalry and marginally productive R&D. On the other hand, non-progressive firms received lower returns on R&D, even below those than on other capital investments. For these firms, concentration was positively correlated with profitability. This suggests that market power is key to profitability in these industries.

These results suggest that in knowledge-intensive industries (characterized by large amounts of R&D spending), R&D is a source of exceptional profitability, and so leads to value. However, as firms grow and the industry becomes more concentrated, firms engage in fiercely competitive, destructive R&D, believing that it is possible to so dominate the industry and capture the entire market. This is in contrast to the non-progressive firms, generally in tangible asset-dependent industries, where firms are aware of the intrinsic value of the assets (real estate, minerals, etc.), and R&D may not be of much value in giving any firm an advantage. Rather, each firm's earnings are tied to their fraction of ownership of the entire tangible asset base, and so concentration leads to monopolistic coexistence.

Conclusions

The transaction cost and property rights theories of the firm provide important insights for this research. Transaction cost theory provides a mechanism to explain how the value of the contract, and hence the imputed value to the firm of the relation-specific investment, can vary with firm characteristics such as size and stability. For example, a large, stable firm can be expected to enter into relatively low risk, certain contracts. Therefore, an investment decision by the firm which requires employees to make specialized investments (time, learning, skills, etc.) can be expected to yield maximal returns, as the employees commit the results of their specialized knowledge to the company in return for the security of the contract. By contrast, smaller or more speculative firms cannot make as credible contracts. In this case, the decision to invest in employee-specific resources will not yield such large returns, as the employees retain for themselves certain of the benefits of their specific investment. From a property rights point of view, the conclusions are similar although the reasoning is different. The advantages of working for larger firms can provide greater incentives to employees as compared to smaller firms, and so the incentive to transfer rights to the firm can be greater. Thus, one would expect to observe lower appropriable returns to R&D in smaller, speculative firms as compared with larger firms. This does not imply that R&D would be less important to smaller firms than larger - indeed, the contrary is probably true - but that the risk of the R&D investment is that much greater in the smaller firm.

The general studies of industrial organization and firm value, whether based on asset or earnings models, indicate that industry-specific factors (industry concentration, entry barriers) are not significant sources of excess firm value. Rather, *firm-specific factors* (advertising and R&D) and *market factors* (share, share growth, and sales growth) are the critical determinants of value. Asset-based approaches to value intangible assets suggest that the value of R&D may be industry-dependent; however, the valuation of intangible assets as a function of firm characteristics and within particular industries does not appear to have been investigated in the literature.

CHAPTER 3 RESEARCH PLAN: INDUSTRY, METHODOLOGY, AND DATA SOURCES

The objective of this study is to relate the value of a firm's intangible assets, and hence their appropriability by the firm, to firm characteristics such as firm size, Tobin's q, or firm market value. The methods that will be used employ publicly available financial data, and, for purposes of illustration, will be applied to the study of intangible capital in a particular industry. In this chapter we provide the rationale for the industry chosen, briefly outline the methodologies that will be investigated, and describe the data and data sources used.

Industry Selection and Rationale

The goal of the valuation method is to identify and assign value to different types of intangible capital, and relate value to firm characteristics. One particular industry will be chosen to eliminate the confounding influences of differential response to economy-wide factors across industries, differences in valuations and types of capital among industries, and differences in market characteristics. The industry should possess a wide range of firms, from those heavily tangible asset-based to those dependant on intangible assets (i.e. knowledge, brand name, etc.). Across asset classes, firms should not compete, but rather should be complementary. Complementary firms in the same *market* will participate equally with market risk; similarly, complementary firms in the same *industry* will participate equally in industry growth and technology risk. The results that will be obtained will therefore be relative to the particular industry chosen. These results should be free of external influences which may tend to enhance or devalue the absolute worth of company investments for a particular industry, and so obscure differences in value between tangible and intangible capital. In particular, an industry-specific valuation will allow differences in intangible asset valuations related to firm size to be more easily identified. Such intangible assets are the value of a firm's R&D or marketing abilities, the skills of its personnel, the number of patents, etc., and their worth to the company clearly depends on the ability of the company to appropriate the asset.

The industry chosen is the computer and computer electronics industry. This industry was chosen for several reasons. Companies in this industry span a broad range, from those heavily dependent on intangible assets (knowledge, reputation, market power, i.e. software) to those dependent on tangible assets (i.e. components, printed circuit boards). Each particular class of firms (tangible vs intangible asset-based) do not compete, but rather are complementary. There are a large number of companies, may of them public, and so financial, accounting, and market data are readily available. In particular, figures that approximate spending on intangible assets are measurable and available from financial reporting records (e.g. R&D, advertising).

Other industries could equally well have been chosen to investigate the valuation of intangible capital. In fact, an examination of industry differences should provide insight into characteristics which govern the valuation of intangible capital. For example, companies in the medical industry include a wide range of tangible asset-dependent and intangible asset-dependent firms such as medical device manufacturers, bioengineering firms, medical information services, and research institutes. Similarly, drug and pharmaceutical firms span the range of companies from those selling standard, commodity-like items such as over-the-counter medications to research-intensive pharmaceutical firms and highly speculative biotechnology companies.

Valuation Methodologies

Several different valuation methodologies were developed and applied to the industry data. In each, the fundamental concept is that the market value of a firm is equal to the value of its tangible assets plus the value of intangible assets. These include market-specific factors (monopoly power) and firm-specific factors (scarce or unique resources which it possesses).

1. Valuation based on Tobin's q

Tobin's q, the ratio of market value to the replacement value of the firm's assets, has been proposed to measure the capitalized value of the firm attributable various tangible and intangible factors. Using the methodology of Wernerfelt and Montgomery (1988), a regression model for Tobin's q will be evaluated:

$$q = \frac{MV}{RV} = 1 + \frac{ITA}{RV} \tag{1}$$

where MV is firm market value, RV is the replacement value of the firm's assets, and ITA represent intangible assets, which, in the models investigated, are approximated by annual values of expenditures, earnings, and growth. Multiple regression analysis is used to quantify the value of these intangible assets purchased by research expenditures, by advertising, and from investor expectations.

2. Employee-specific valuation

The market value of the firm, normalized by firm size as measured by the number of employees, should specifically value the contribution made by each employee to the value of the firm, and thus should clearly illustrate the firm's ability to appropriate value. Thus, this second valuation approach investigates a relationship of the form:

$$\frac{MV}{employee} = \frac{tangible\ asset\ value}{employee} + \frac{intangible\ asset\ value}{employee} \tag{2}$$

This employee-specific market valuation analysis is applied to the data sample to determine the contributions of revenue, revenue growth, R&D, and advertising, on a per-employee basis, to the value of the firm.

3. Market valuation of the firm and unanticipated returns

The market value of the firm represents a consensus estimate of firm prospects that includes industry, market, and firm expectations, expectations as to appropriability of value, and estimated risk. With historical data, a retrospective study can verify whether or not these estimates were accurate by comparing actual to expected performance. A comparison of the risk-adjusted, discounted value of the firm at two points in time represents the degree to which the firm exceeded or disappointed expectations. This model attempts to relate these "unanticipated returns" to investments by the firm in intangible assets, and to other measures of worth which include earnings and growth. This model is of the form:

$$\frac{NPV_t}{MV_t} = 1 + \textit{unanticipated returns on investments} = 1 + f(\textit{firm expenditures}) \quad (3)$$

In this model, MV_t is the current market value. It represents the discounted, risk-adjusted estimate of firm value based on current estimates of expected future cash flows. NPV_t is the net present value of the firm. It represents the discounted, risk-adjusted estimate of firm value based on cash flows actually received. Using T periods of actual financial data, NPV_t is calculated from the cash flows received over the time period (t...t+T), plus the market's estimate for firm value at the end of that time period, MV_{t+T}, each discounted for risk at the rate r:

$$NPV_t = PV(cash\ flow_{t...t+T}\ @\ r\%) + \frac{MV_{t+T}}{1 + r^T} \quad (4)$$

Thus, today's market value, MV, represents today's expectations; NPV represents the discounted value of cash flows received up to tomorrow plus tomorrow's expectations, and the difference between the two represents changes in expectations due to changes in the ability of the investors to appropriate the firm's value, in earnings prospects, in risk, etc.

The NPV of the firm is calculated each year from the actual performance of the firm as reported in financial statements. A one-year discounting period is used (T=1 in eq. 4). This valuation model is effectively an analysis of market mispricing of the firm, and multiple regression analysis is used to relate the extent of mispricing with expenditures on intangible assets (R&D and advertising).

4. Market valuation of firm equity and unanticipated returns

This model simplifies the previous market valuation model by observing that since much of the risk inherent in the development of intangible assets is borne by the equity investors (vs the holders of debt), an analysis of market mispricing compared to discounted cash flow for firm equity alone should provide a more sensitive measure of the value of investments in intangible assets.

Each of the above valuation models are applied to subsets of the data sample, stratified according to firm size (total assets and number of employees), high-q and low-q firms, highly capitalized firms (high market value per employee), and tangible asset-dependent firms (identified by total assets per employee).

Additional valuation models

Other valuation models were developed and applied to the data set without notable success. Results from these models are summarized briefly in Appendix 2.

Data Sources

The companies used in this analysis were chosen according to the 4-digit SIC codes relevant to the computer and computer electronics industry. A total of 195 firms were used in this study. The different SIC codes, descriptions, and representative firms in each code are presented in Appendix 1. Data consisted of publicly available accounting and market financial data which was retrieved from the COMPUSTAT data service. These data items are also listed in Appendix 1. Data from the years 1981-1989 was used for this analysis. These years were chosen because, aside from the 1981 recession and indications of the 1990-1991 downturn, it was a period of overall economic stability and growth. These years were also a period of explosive growth and investment in the computer and computer electronics industry. Thus, this period should be ideally suited for the observation of investments in tangible and intangible capital in this industry, and should be relatively free of perturbing economy-wide shocks.

CHAPTER 4 INDUSTRY DESCRIPTIVE STATISTICS

This chapter presents descriptive data and graphs for the computer and computer electronics industry as derived from the COMPUSTAT data sample. In the discussion which follows, attention is focused on R&D as an approximation to the firm's investment in intangible, knowledge-based assets.

Sample size

There were a total of 195 firms in the COMPUSTAT sample. Firm size, as measured by total assets, ranged from $1.5M to $2.5B. Size as measured by number of employees ranged from 15 to over 34,000 employees. Approximately 33% of firms had less than 300 employees and/or less than $50M in total assets, while the upper third of the sample included firms with over 1000 employees and $100M in assets.

However, in a given year only a subset of firms reported sufficiently complete data for inclusion into the regression analyses. When those firms that did not report adequate asset, R&D, advertising, or income measures were eliminated from the data sample, a total of approximately 700 observations of the original 1755 remained. (Apparently, once a firm enters the COMPUSTAT database, a listing is created for that firm for every year of the database, whether or not information is available or whether the company even existed. For example, there are listings for Compaq for the entire 1981-1989 period, yet all variables are reported as "not available" until its first year of public operations in 1983.)

Relation of R&D to firm value and intangible capital

Figure 1 presents a histogram of the ratio of firm market value (MV) to net total assets (TA) for the year 1986. This ratio represents the extent to which firm value depends on intangible assets, and is used in later analyses as an approximation to Tobin's q. Most firms cluster about 1.0, but there are a large number of firms (approximately one-quarter of the sample) whose value is heavily dependent on

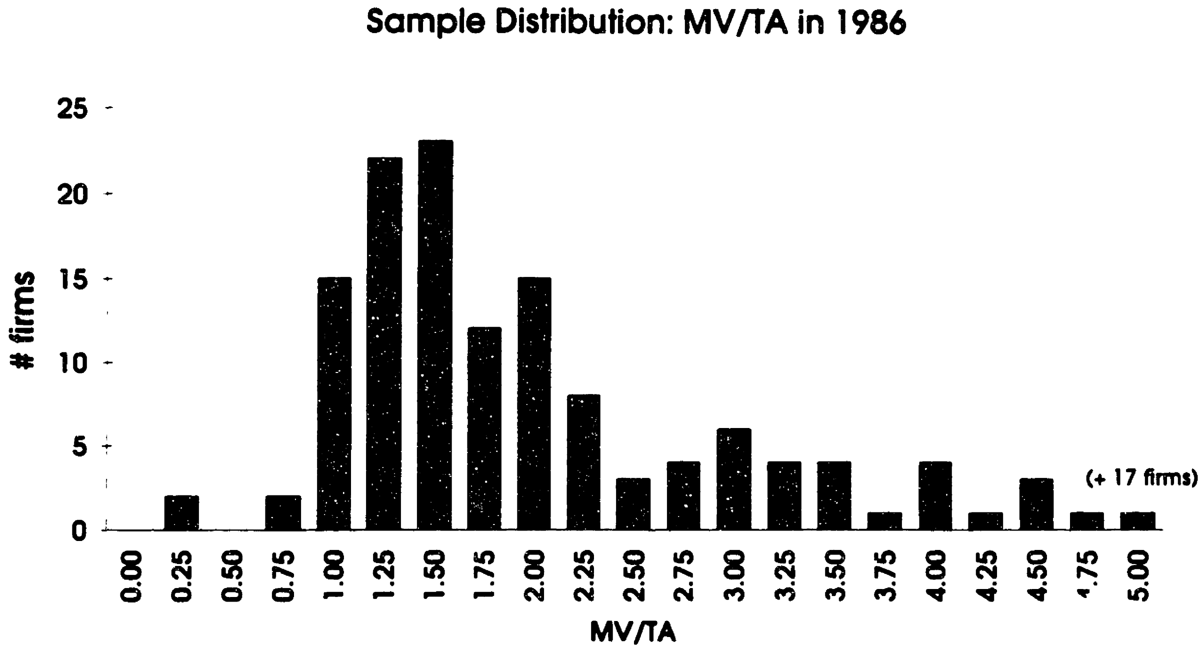

Figure 1 Sample distribution of the ratio of firm market value to net total assets (MV/TA) in 1986 in the computer and computer electronics industry.

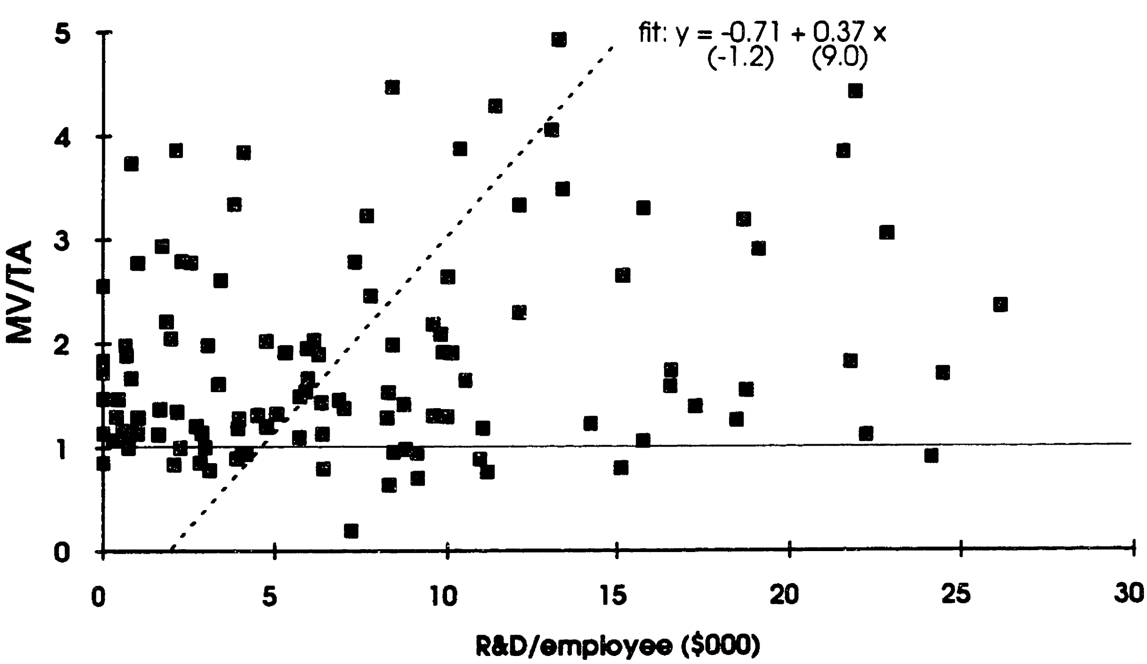

Figure 2 Relationship of MV/TA to per-employee R&D expenditures in the computer and computer electronics industry in 1986. The regression line, with t-statistics, is also shown.

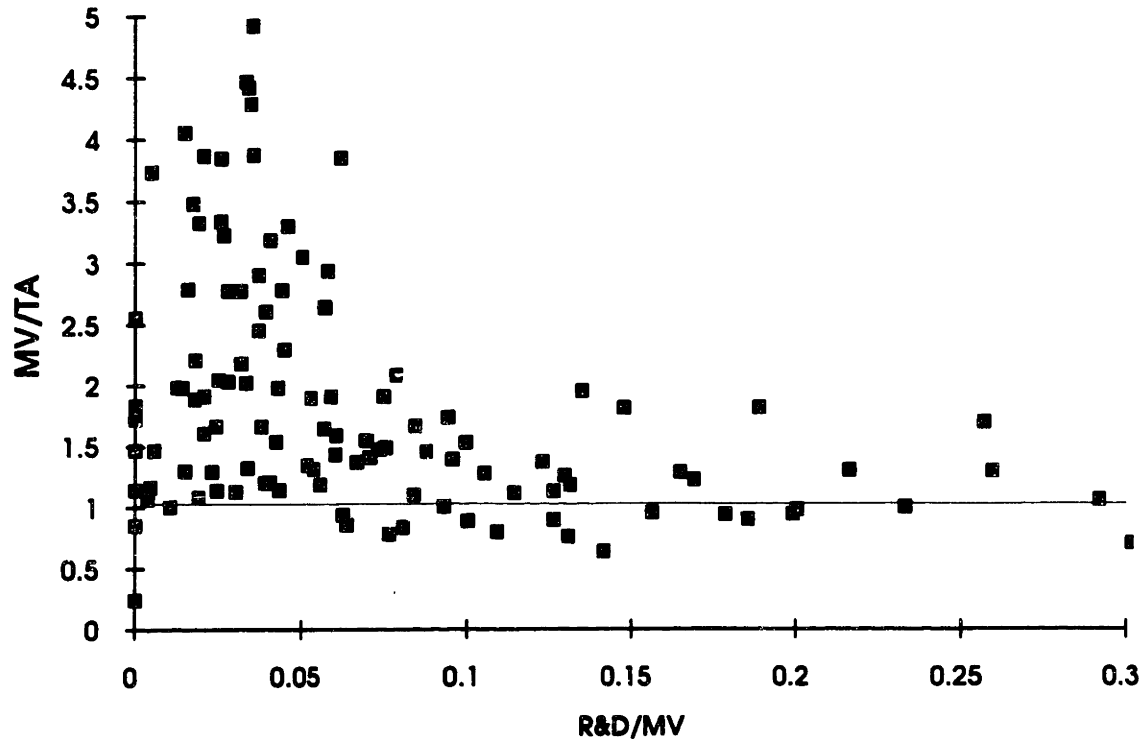

Figure 3 MV/TA as a function of the fraction of firm value spent on R&D in 1986 in the computer and computer electronics industry.

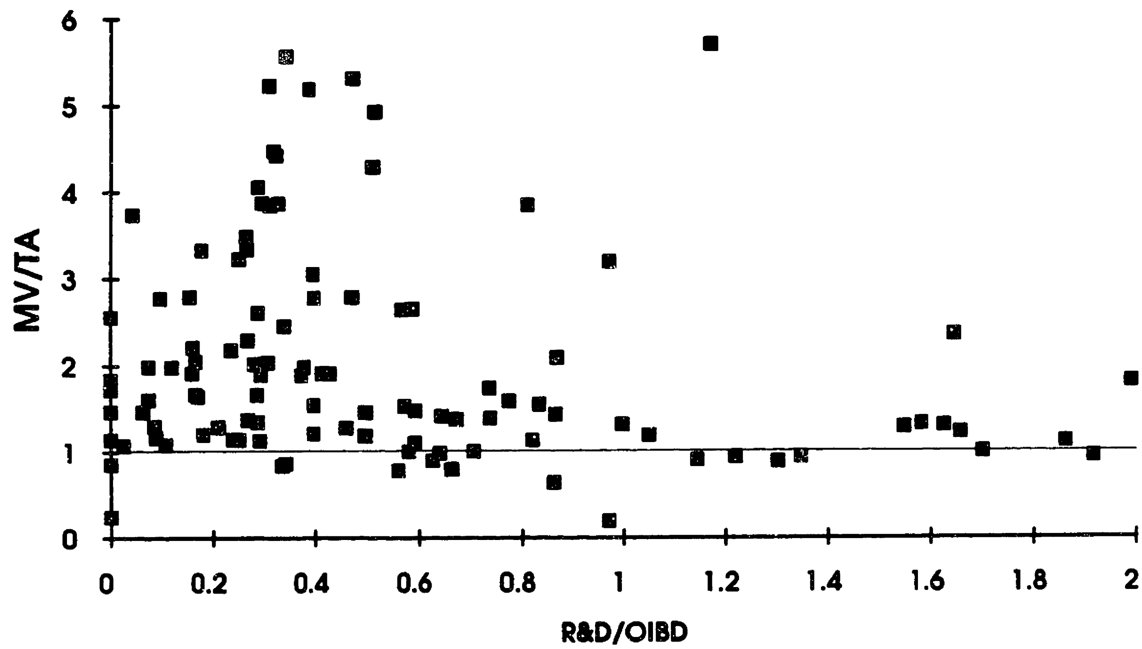

Figure 4 MV/TA as a function of operating cash flow spent on R&D in 1986 in the computer and computer electronics industry. R&D investments lead to increases in market valuation over and above tangible asset value only up to a certain point.

intangible assets, and whose value of MV/TA exceeds 2.0. As shown by Figure 2, there is some indication that high per employee R&D expenditures lead to a greater proportion of firm value being attributed to intangible assets; however, Figures 3 and 4 show that beyond a certain amount, further increases in R&D expenditures add no value. Figure 3 plots MV/TA as a function of the fraction of firm value spent as R&D each year, while Figure 4 plots MV/TA as a function of the fraction of operating cash flow (OIBD) allocated to R&D. R&D investments lead to increases in market valuation over and above tangible asset value only up to a certain point. MV/TA increases with the fraction of operating income allocated to R&D until R&D is 40-50% of operating income before depreciation (OIBD). Beyond this level of R&D spending, market valuation is strictly dependent on tangible assets.

One explanation for this behavior is that the market has little belief in the value of this R&D, perhaps interpreting such high levels of R&D spending as an indication that the firm has lost its competitive position and is desperately searching for new sources of advantage. Another possibility is that R&D expenditures in this industry do not add to a capital stock, but are depreciated rapidly. For example, this may be the case in the software industry, where product development is very rapid and significant development funding is required simply to maintain parity. Both these factors act to reduce the long-term benefits of R&D investments. A third possibility, less plausible in this industry, is that R&D in heavily tangible asset-dependent firms, rather than a source of value, is a sign of irresponsibility on the part of management. These arguments are developed more fully in part 1 of Chapter 5, where the sources of intangible capital are examined more closely.

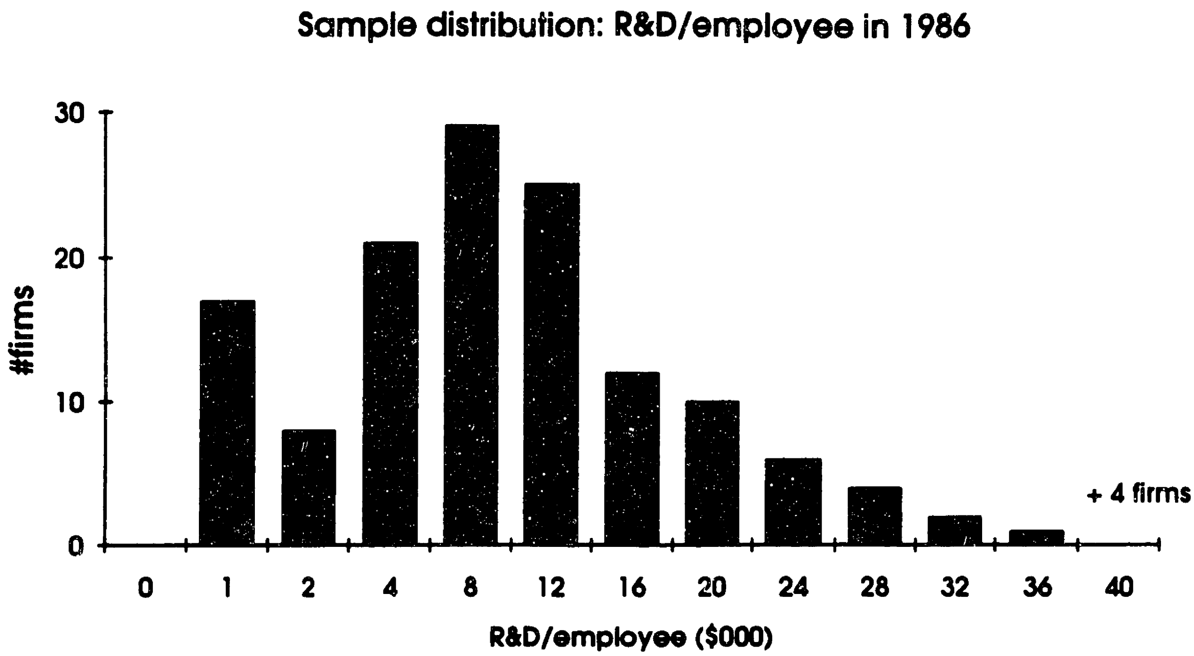

Figure 5 Distribution of per-employee R&D expenditures in 1986 in the computer and computer electronics industry.

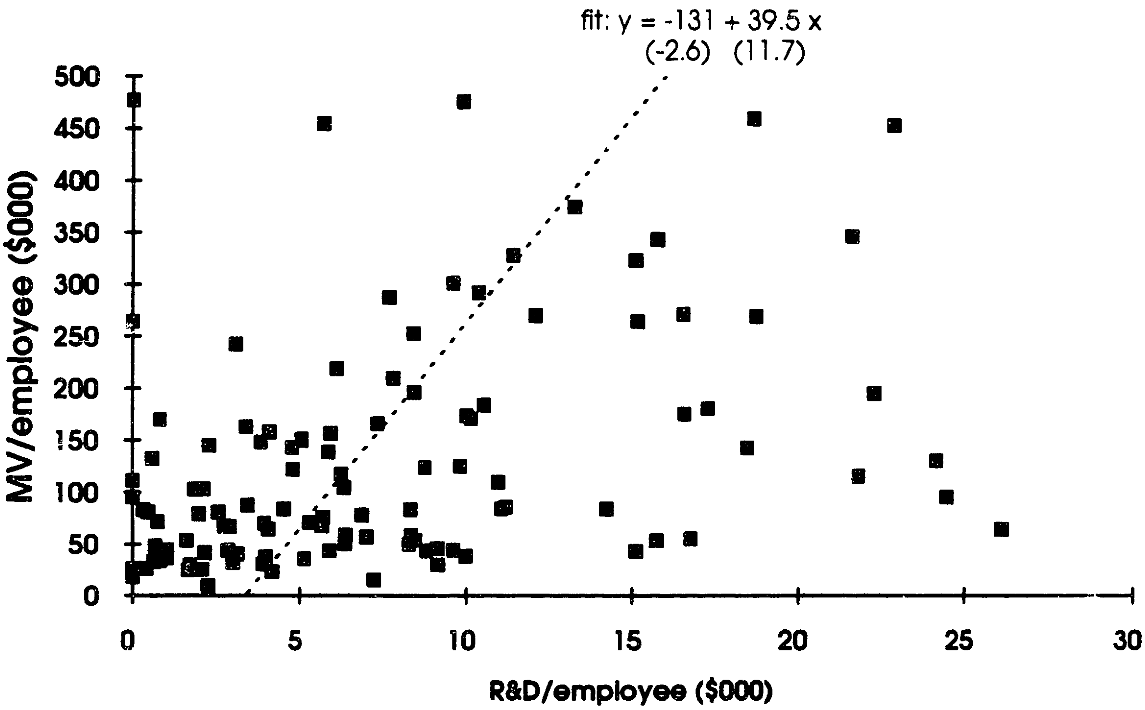

Figure 6 Market value per employee as a function of per-employee expenditures in 1986 in the computer and computer electronics industry. The regression line, with t-statistics, is also shown. Higher R&D spending per employee seems associated with a higher market capitalization per employee.

Figure 5 presents a histogram for R&D expenditures per employee, again for the year 1986. This graph shows a smoothly falling distribution, with approximately 50% of the firms spending less than $12,000 per employee on R&D. The expenditures of R&D per employee do not seem to be strongly associated with firm size, whether measured by total book assets, number of employees, or market value. However, as shown by Figure 6, higher R&D spending per employee does seem to be associated with a higher market capitalization per employee. These observations are examined more closely in part 2 of Chapter 5, where we explicitly study the role of per employee expenditures and earnings in determining market valuation.

Figures 7 and 8 present interesting observations for this industry. Figure 7 suggests that R&D per employee is positively associated with gross margin, implying that high per employee R&D expenditures lead to market power. However, this observation is biased by the software firms in the sample, for which development costs are large while variable costs are negligible. Figure 8 shows that high levels of R&D spending are inversely related to the firm's debt ratio. This is consistent with modern theories of finance, which argue that firms seek to reduce financial leverage, and hence the risks and costs of financial distress, when they are otherwise heavily leveraged. Thus, firms that employ high operating leverage (i.e. high fixed costs) avoid large amounts of debt; similarly, in this industry, firms that are highly leveraged on innovative and speculative technologies, leading to large amounts of technology and market risk, also avoid high debt levels.

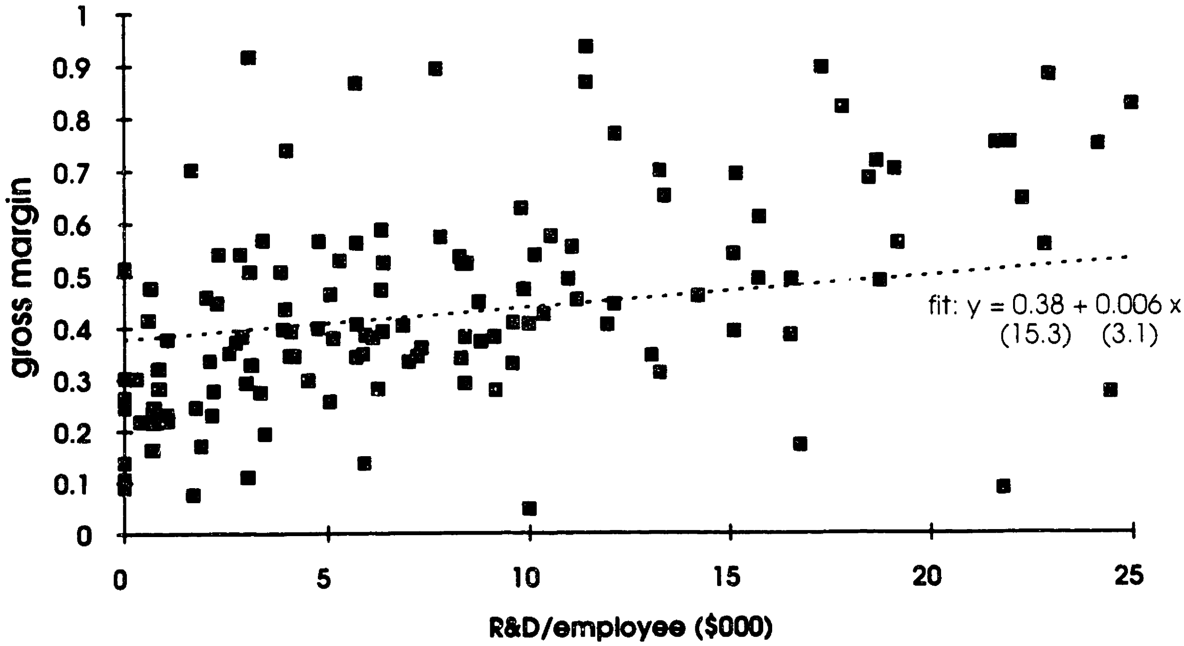

Figure 7 Gross margin as a function of per-employee expenditures in 1986 in the computer and computer electronics industry. The regression line, with t-statistics, is also shown.

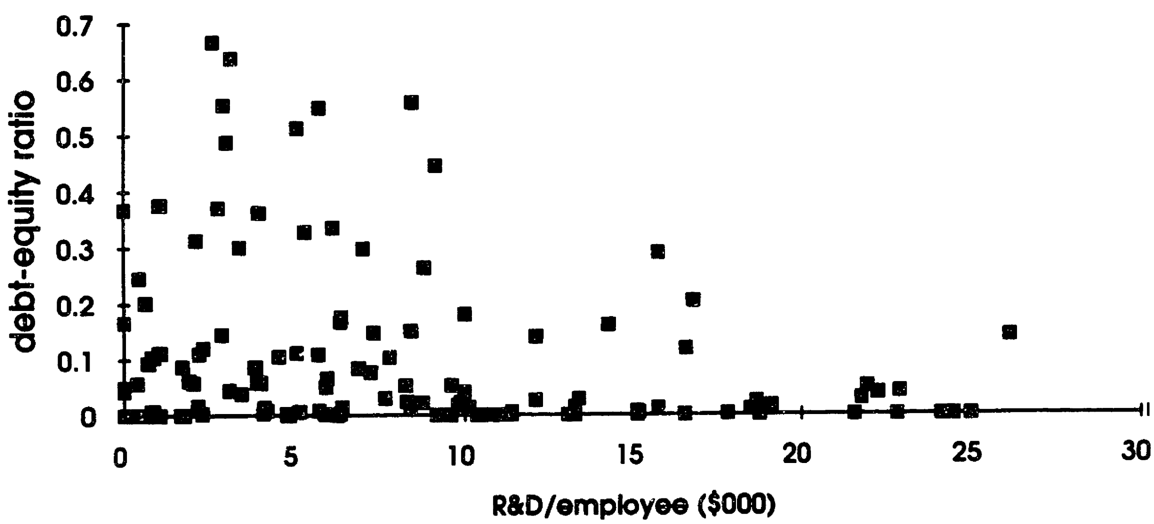

Figure 8 Debt-to-equity ratio as a function of per-employee expenditures in 1986 in the computer and computer electronics industry. Firms that are highly leveraged on innovative and speculative technologies (via R&D) seem to avoid high debt levels.

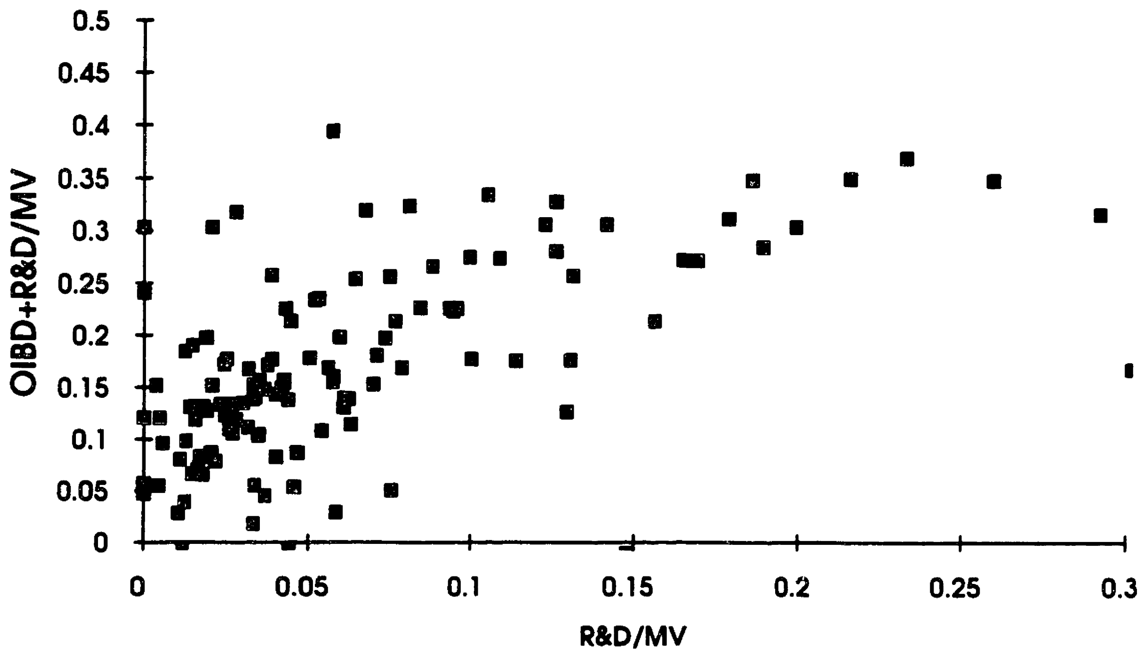

Figure 9 Cash flow rate of return as a function of the fraction of firm value spent on R&D over 1981-1989 in the computer and computer electronics industry. Return increases with R&D up to approximately 10-15% of firm value, after which a saturation effect appears evident.

Cash flow rate of return

Healy et al. (1992) suggest that an effective measure of firm performance is its pretax operating cash flow return on the market value of its assets. Figure 9 presents a gross measure of cash flow rate of return (prior to R&D) as a function of R&D investment, also expressed as a fraction of the firm's market value. Again, a saturation effect seems to be evident: cash flow rate of return increases with R&D until R&D reaches 10-15% of the firm's market value (equivalently, 40-50% of OIBD), after which, increasing amounts of R&D have no effect.

Market returns

Market return to equity in this industry was calculated on a yearly basis over the period 1981-1988. Large amounts of R&D, whether measured on a per employee basis, as a fraction of firm market value, or as a fraction of firm earnings, tend to reduce the variation in, and the amount of, equity return (for example, Figure 10 presents market return as a function of R&D per employee). Thus, large amounts of R&D are not associated with significant returns to the firm's owners - these investments do not always provide them with appropriable value. However, this does not indicate that intangible assets provide no value to the firm. On the contrary, Figure 11 suggests if intangible assets can be appropriated by the firm, they will provide superior market returns, as would be expected by their greater risk. There is a positive association between market return and the MV/TA ratio (although such association may only be spurious since both market return and MV/TA are correlated with market value). While this subject is not pursued further here, valid questions are whether a relation between returns and intangible assets actually exists, and whether *risk-adjusted returns* increase with MV/TA, i.e. Do intangible assets provide excess returns in comparison to tangible assets?

Unanticipated returns (market mispricing)

In parts 3 and 4 of Chapter 5 we develop a valuation model for this industry that seeks to answer the question as to whether certain firm actions can lead to unexpected returns for the firm's owners. The model attempts to determine whether the firm is fairly valued at a point in time, on a risk-adjusted basis, by comparison to actual, measured, future performance. Market mispricing, the degree to which firm performance exceeds or disappoints investors, is defined as the net present value of actual performance to the market value at a given point in time, or mispricing $\equiv$ NPV / MV.

Large amounts of R&D, whether measured on a per employee basis, as a fraction of firm market value, or as a fraction of firm earnings, show no clearly discernible relation to market mispricing (for example, Figure 12 presents mispricing

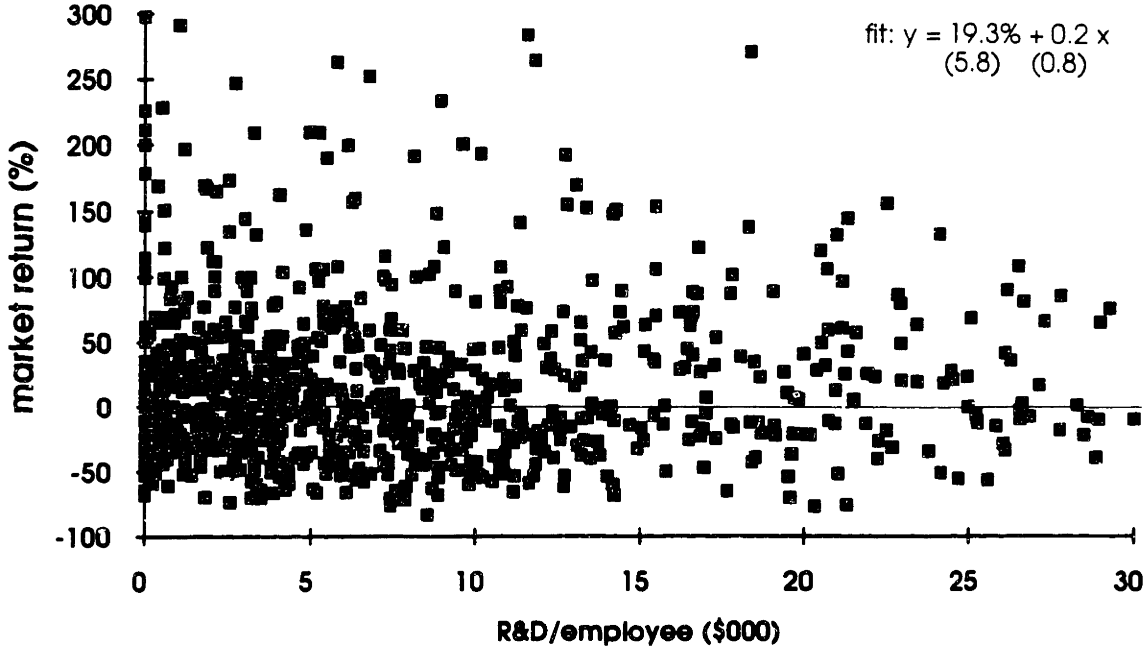

Figure 10 Market return on firm value as a function of per-employee R&D expenditures over 1981-1989 in the computer and computer electronics industry. There is not a significant relationship, as shown by the regression fit with t-statistics.

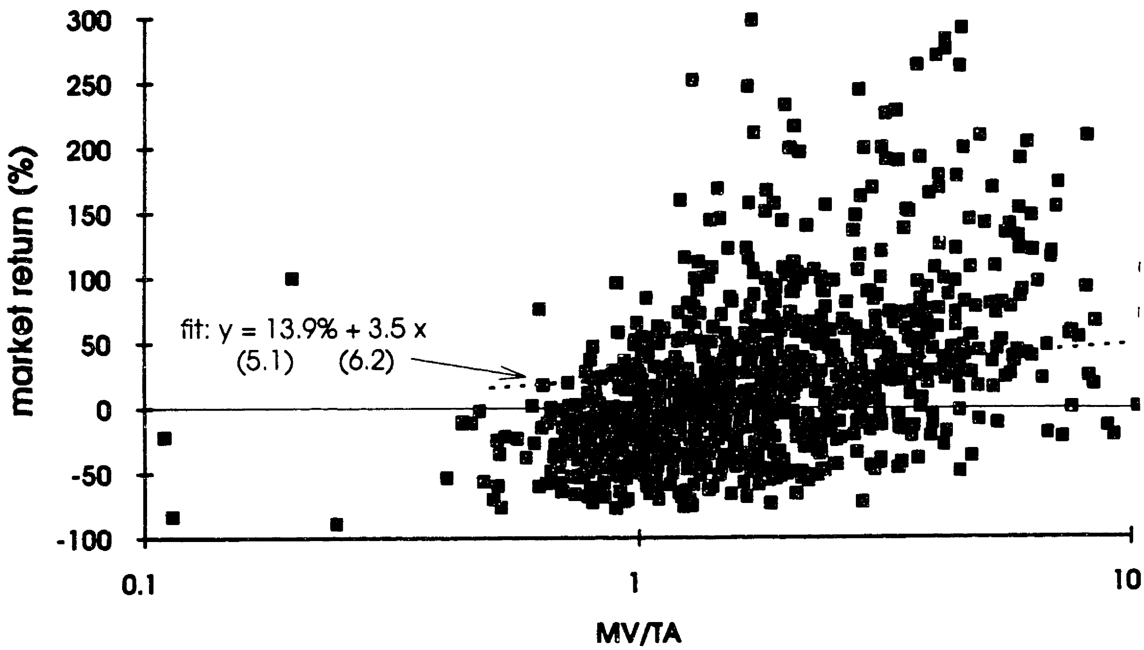

Figure 11 Market return on firm value as a function of MV/TA over 1981-1989 in the computer and computer electronics industry. There is a significant, although perhaps spurious relationship, as shown by the regression fit with t-statistics.

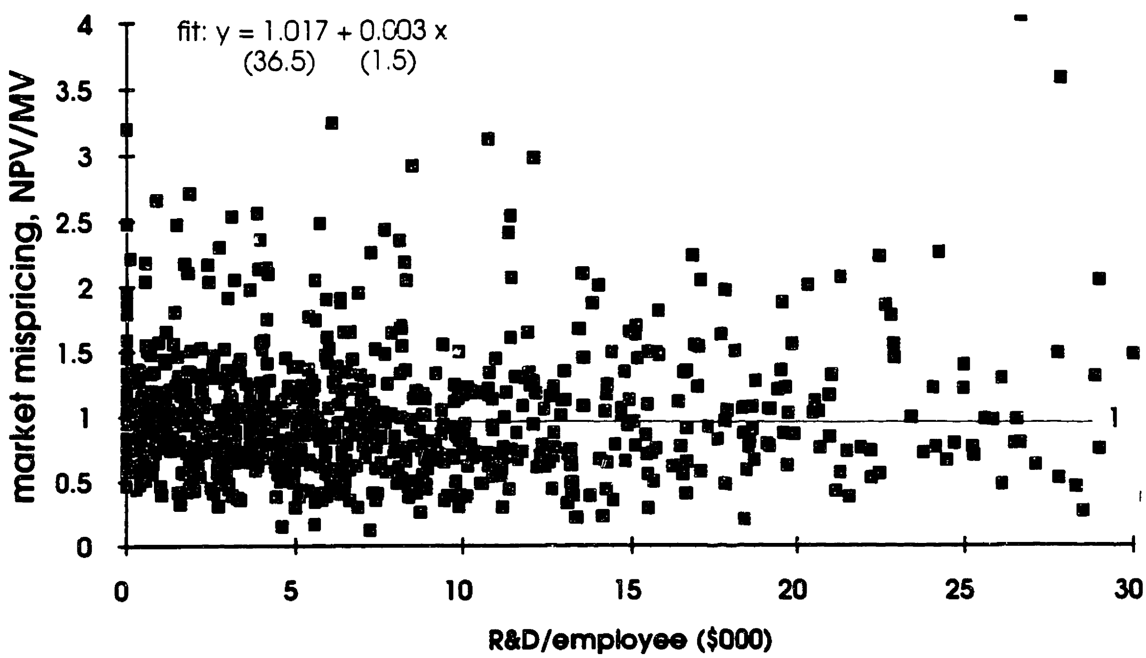

Figure 12 Market mispricing of firm value as a function of per-employee R&D expenditures over 1981-1989 in the computer and computer electronics industry. There is not a significant relationship, as shown by the regression fit with t-statistics.

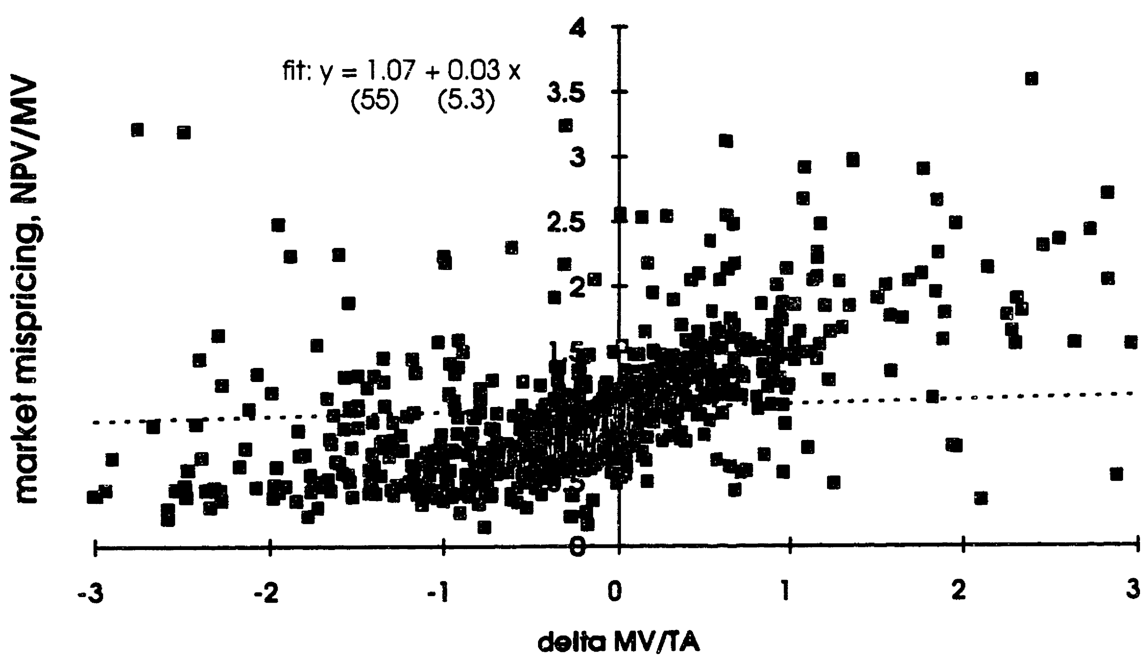

Figure 13 Market mispricing of firm value as a function of the annual change in MV/TA over 1981-1989 in the computer and computer electronics industry. There is a significant positive relationship, as shown by the regression fit with t-statistics.

as a function of R&D per employee). Similarly, mispricing shows no clear relationship with MV/TA. However, Fig. 2 indicates that R&D can increase the intangible value of the firm, while Figs. 4 and 9 show that over a certain range, firm market value and earnings, respectively, are positively related to R&D expenditures. These suggest that changes in the intangible value of the firm will be associated with firm mispricing. This mispricing arises since expectations for the future of the firm change as its composition of tangible and intangible assets change. As discussed above, mispricing is either due to increased returns on intangible capital, or simply represents a correction for risk. Figure 13 shows that mispricing does in fact increase with MV/TA, consistent with the observation for market returns.

CHAPTER 5 VALUATION ANALYSES

1. Valuation Based on Tobin's q

A market valuation of the firm's assets possesses numerous advantages over accounting measures of value. Market values measure current economic worth, while accounting measures are historical values distorted by convention, regulation, and law. In particular, the market value of a firm is equal to the value of its tangible assets plus the value of intangible assets. Intangible assets include market-specific factors (e.g. monopoly power) and firm-specific factors (scarce resources which it possesses). Tobin's q, the ratio of market value to the replacement value of the firm's assets, has been proposed as a measure of the capitalized value of the firm attributable to monopoly and firm specific factors. The use of q as a measure of the intangible value of the firm is justified by Lindenberg and Ross (1981), who emphasize the distinction between financial data, which give a market valuation of the firm's earning prospects, and accounting data, which tabulate the resources used by the firm. Tobin's q thus represents firm performance: the relation between outputs and inputs. Furthermore, the use of Tobin's q has several advantages over accounting measures of firm performance (Salinger, 1984; Smirlock et al., 1984): q is a firm-specific measure of return; it incorporates long run expectations; is risk-adjusted (accounting returns are not corrected for risk and so could present misleading estimates of the earning ability of the specific assets); and it embodies more information than accounting data.

Model Development

Viewed as a collection of assets, the value of the firm is the sum of tangible and intangible assets. Intangible assets are broadly defined as knowledge and brand-name assets. Knowledge assets consist of the accumulated knowledge of the firm which allow it to compete and create market advantage based on product differentiation, technical features, or innovation. Brand-name assets consist of firm goodwill, reputation, recognition, etc. that the firm has acquired. The firm may also possess other specific advantages that are not included in physical, knowledge, and brand-name asset measures. For example, the firm may have exceptional profitability due to factors such as market power or manufacturing efficiency; it may have extraordinary long-run profit and growth prospects; or its sales and marketing efforts may be a source of competitive advantage. Firm market value (MV) is the sum of these asset values,

$$MV = V_{TA} + V_R + V_A + V_P + V_S \tag{1}$$

where V_{TA}, V_R, and V_A represent respectively the capitalized value of tangible assets, knowledge (i.e. research and development) assets, and brand-name assets.

In order to account for intangible factors not captured by the knowledge and brand name assets, two other intangible assets are included. V_P represents a generalized profitability asset that provides the firm value through market power, manufacturing efficiency, etc. Similarly, V_S represents a generalized intangible asset representing exceptional long-term prospects via factors such as superior growth prospects or sales and marketing expertise. The profitability asset V_P will be proxied by f(OCF), where the function f(OCF) represents the value of extraordinary firm-specific profitability and long-run prospects and OCF is some appropriately defined measure of cash flow to the firm. Similarly, V_S will be approximated by $g(\dot{S})$, where the function $g(\dot{S})$ is an intangible asset representing the value of the firm's sales and marketing efforts as well as prospects for long-term growth and $\dot{S}$ is some measure of sales performance, such as sales growth. While each of the intangible assets should contribute independently to firm value, the manner in which the latter two are defined in terms of available accounting variables (i.e. relating market power to cash flow, and marketing efficiency to sales growth) may introduce problems with double counting and multi-collinearity. For example, tangible assets (V_{TA}) generate cash flows which lead to market value. However, the regression coefficients and significance levels did not change appreciably when these variables were eliminated (Tables 5.1 to 5.12), implying that this is not a significant problem. In addition, other investigators have used similar formulations (Grabowski and Mueller, 1978; Salinger, 1984; Hall, 1993) without apparent methodological difficulties. This formulation for firm value is attractive, for it offers two alternative, perhaps orthogonal mechanisms to explain how the firm creates value: either via investments in knowledge and brand name asset stocks, which will produce a future stream of profits; or via immediate and near-term earnings and earnings growth.

Making the substitutions outlined above and dividing through in eq. 1 by TA, Tobin's q is expressed as

$$q = \frac{MV}{V_{TA}} = 1 + \frac{V_R}{V_{TA}} + \frac{V_A}{V_{TA}} + \frac{f(OCF)}{V_{TA}} + \frac{g(\dot{S})}{V_{TA}} \tag{2}$$

Alternatively, the functional formulation for firm value may include scale effects, such that firm value is given by

$$MV = \alpha(V_{TA} + V_R + V_A + f(OCF) + g(\dot{S}))^{\beta} \tag{3}$$

where α is a multiplicative factor and β is the scale factor. Taking logarithms of both sides and using the approximation $\log(1+x) \approx x$ for small x, firm value is

$$\log(MV) = \log(\alpha) + \beta \log(V_{TA}) + \beta \frac{V_R}{V_{TA}} + \beta \frac{V_A}{V_{TA}} + \beta \frac{f(OCF)}{V_{TA}} + \beta \frac{g(\dot{S})}{V_{TA}} \tag{4}$$

These two formulations will be the basis for a regression model of firm value that will be applied to the computer industry. These functional forms may be compared with other such descriptions of firm value described in the literature. Wernerfelt and Montgomery (1988), in their analysis of a random sample of 167 firms for the year 1976, proposed a regression model for Tobin's q as follows:

$$q = \beta_0 + \beta_1 \frac{R}{V_{TA}} + \beta_2 \frac{A}{V_{TA}} + \beta_3 C + \beta_4 S + \beta_5 D + \beta_6 F + \beta_7 G \qquad (5)$$

where the β_i are regression coefficients and the following values characterize each firm:

R = R&D expenditures
A = advertising expenditures
C = concentration in the firm's market
S = market share
D = diversification
F = foreign sales
G = market growth
V_{TA} = replacement value of physical assets

This formulation may be simplified by making certain assumptions that are arguably valid for the computer industry. First, the effects of diversification will be assumed to be small, as the computer industry is relatively young and focused. Certainly, for the smaller firms that are of interest in this work, diversification should be negligible. In addition, foreign sales (F) will not be specifically separated. One can also hypothesize that smaller firms will have negligible market power, and the principal intangible assets are firm-specific. Therefore, market concentration (C) will be ignored. Wernerfelt and Montgomery found its coefficient to be near zero, while Lindenberg and Ross (1981) found it not to be statistically significant as an explanatory variable. Instead, Smirlock et al. (1984) argued that the significant variable in explaining market premia is market share, and at a secondary level, market share growth. Alternatively, Salinger (1984) suggests that sales growth is an important explanatory variable. Thus, under these assumptions, eq. 5 reduces to

$$q = \beta_0 + \beta_1 \frac{R}{V_{TA}} + \beta_2 \frac{A}{V_{TA}} + \beta_3 G \qquad (6)$$

and, if some additional measure is included to account for market power and profitability, the functional form is identical to eq. 2.

Hall (1993) proposes a value function for the firm in a form similar to eq. 3

$$MV = Q\left(V_{TA} + a_1 V_{K_1} + a_2 V_{K_2} + \dots\right)^{\sigma} \tag{7}$$

where, as in eq. 3, Q and σ are multiplicative and scale factors, respectively, and the $a_i V_{K_i}$ represent the capitalized values of intangible stocks. These stocks are identified by Hall as knowledge (i.e. R&D) stocks, brand-name value (proxied by advertising), and, by arguments such as those above, a cash flow and sales growth measure. Thus, this form is substantially equivalent to eq. 4.

Model Implementation

The linear and logarithmic forms of the firm valuation model, eqs. 2 and 4, are used as a basis for a regression model to be applied to the industry data set. The regression model for Tobin's q is

$$q = \frac{MV}{V_{TA}} = \beta_0 + \beta_1 \frac{R}{V_{TA}} + \beta_2 \frac{A}{V_{TA}} + \beta_3 \frac{OCF}{V_{TA}} + \beta_4 \dot{S} \tag{8}$$

where the β_i are regression coefficients. The regression model for firm value as a sum of asset stocks is

$$\log(MV) = \log(\alpha) + \beta \log(V_{TA}) + \beta_1 \frac{R}{V_{TA}} + \beta_2 \frac{A}{V_{TA}} + \beta_3 \frac{OCF}{V_{TA}} + \beta_4 \dot{S} \tag{9}$$

where the β_i again represent the regression coefficients for this model. Here, β is the exponential (scale) factor of eq. 3, and the β_i actually represent the product of the asset coefficient with the scale factor. However, in the following results the scale factor is always quite close to 1.0, and this distinction is ignored.

The firm's market value (MV) is taken as the sum of the market value of common stock plus the book value of outstanding long-term debt. The value of preferred stock is ignored. Of the firms for which complete accounting data were available, less than 6% had issued preferred stock, and less than 3% had outstanding issues in excess of 10% of firm value (debt plus market equity). Therefore, this omission is unlikely to be significant.

Replacement cost (V_{TA}) is taken as the listed book value of total assets. These are defined as total assets less current liabilities and so include working capital, inventory, property, plant and equipment, as well as investments in goodwill and unconsolidated subsidiaries. In general, the use of book over replacement values inflates the measure of q due to low book values from depreciation. Thus, any distinctions between high-q firms (possessing large amounts of intangible assets) and low q firms will be blurred since many more firms will be listed as high-q than is actually the case. This will lead to conservative estimates of the value of intangible or knowledge capital.

However, for the industries and firms used in this study, the discrepancy between book and replacement value is ambiguous for several reasons. First, many of the firms are young. Thus, differences between historical and market costs of tangible assets are minimized both because substantial depreciation has not accumulated and because historical costs are at least "recent" historical costs. This is likely true even for long-established firms, due to the rapidly changing and innovative nature of the industry which requires firms to continually replace assets to remain technologically competitive. Following this reasoning, book value may only slightly underestimate replacement cost. Secondly, historical cost behavior in the semiconductor, electronic, and computer industries has been to provide equivalent performance at steadily reduced prices, or equivalently, state-of-the-art performance at constant prices. Therefore, book values should be reflective of replacement costs, and for older assets, may even overstate replacement cost.

Knowledge assets (V_R or R) are assumed to be directly related to the current level of R&D expenditures. This is consistent with related studies such as those by Wernerfelt and Montgomery (1990) and Hall (1993). While some studies have constructed this asset from weighted averages of past and present R&D spending, patent stocks, industry R&D, etc. using assumed depreciation rates (Grabowski and Mueller, 1978; Salinger, 1984), this level of sophistication will not be adopted here. In fact, Hall (1993) examined the valuation of R&D using both the current R&D expense and an R&D asset formed by a weighted past average, and found similar results.

Similar to the R&D measure, brand-name assets (V_A or A) are approximated as being directly related to the current level of advertising expense. Again, other more complex measures can be hypothesized. For example, brand-name assets might be best approximated using measures of sales, marketing, and service expenses. However, this financial information is not readily available and, in this initial study, such a level of sophistication may not be warranted.

The variable representing cash flow is calculated in two ways. Healy and colleagues (1992) argue that operating income before depreciation (OIBD) represents a valid measure of the firm's operating performance as evidenced by its ability to generate cash. OIBD is a measure of cash flow to the firm before taxes, capital investment decisions, and working capital requirements, and thus represents the cash generated in the past year from actual firm operations. It is independent of any firm-specific tax advantages or of management decisions that, although they affect the current year's cash flow, are not relevant in evaluating the firm's operational performance with the resources that were available in the current year. Thus, this measure is not affected by short-term decisions that affect working capital (through credit, inventory, short-term financing decisions, etc.), nor is it affected by longer-term decisions such as capital investments or tax-loss carry-forwards and investment tax credit incentives.

A second measure of cash flow to the firm is the standard measure of cash available to the firm's owners after all operating, investment, and current debt obligations relevant to the firm's operations have been satisfied. Free cash flow to the firm is defined by (Copeland, 1991)

$$FCF = NI + depreciation + I - \Delta WC - \Delta PPE + \Delta DT \qquad (10)$$

where FCF is free cash flow available to the firm's owners, NI is net accounting income, depreciation also includes amortization, and WC, PPE, and DT represent, respectively, working capital, property plant and equipment, and deferred taxes. This measure of free cash flow implicitly includes depreciation and interest tax shields, and thus would represent the cash flow in an "adjusted present value" valuation of the firm as defined by Brealey and Myers (1991). Note that each of these cash flow measures is net of R&D and advertising (consistent with the approach of Hall, 1993).

Sales growth is calculated for any given year as a central difference (i.e. sales growth in $year_i$ is one-half the sum of sales growth over $year_{i-1}$ to $year_i$ and sales growth over $year_i$ to $year_{i+1}$). This is adopted in order to partially account for company-to-company differences in reporting dates, seasonal variations, and to implicitly include expectations for the coming year that would be known with reasonable certainty by advance bookings.

Results and Discussion

Four separate regression models were applied to the computer and computer electronics industry data. Two models examine the value of intangible assets implicitly, through Tobin's q, and differ only in the measure of cash flow, OIBD vs FCF. Two models use the logarithmic representation for firm value to explicitly value research, brand name, and profitability factors. These also differ only in the measure of cash flow. These models are as follows:

Tobin's q, operating cash flow:

$$q = \frac{MV}{V_{TA}} = \beta_0 + \beta_1 \frac{R}{V_{TA}} + \beta_2 \frac{A}{V_{TA}} + \beta_3 \frac{OIBD}{V_{TA}} + \beta_4 \dot{S} \quad (11)$$

Tobin's q, free cash flow:

$$q = \frac{MV}{V_{TA}} = \beta_0 + \beta_1 \frac{R}{V_{TA}} + \beta_2 \frac{A}{V_{TA}} + \beta_3 \frac{FCF}{V_{TA}} + \beta_4 \dot{S} \quad (12)$$

Firm value, operating cash flow:

$$\log(MV) = \log(\alpha) + \beta \log(V_{TA}) + \beta_1 \frac{R}{V_{TA}} + \beta_2 \frac{A}{V_{TA}} + \beta_3 \frac{OIBD}{V_{TA}} + \beta_4 \dot{S} \quad (13)$$

Firm value, free cash flow:

$$\log(MV) = \log(\alpha) + \beta \log(V_{TA}) + \beta_1 \frac{R}{V_{TA}} + \beta_2 \frac{A}{V_{TA}} + \beta_3 \frac{FCF}{V_{TA}} + \beta_4 \dot{S} \quad (14)$$

Table 5.1 presents results for the linear regression model using OIBD as the cash flow measure. Table 5.2 presents the results for free cash flow with the linear model. Table 5.3 presents results for the logarithmic regression model using OIBD as the cash flow measure, and Table 5.4 presents the results for free cash flow with the logarithmic model. Results are stratified according to five criteria:

firm size (total assets): results from the entire data set are compared with results for large firms (book value of assets > \$100M) and with small firms (book value of assets < \$50M).

firm size (number of employees): results from the entire data set are compared with results for large firms (> 1000 employees) and with small firms (< 300 employees).

asset intensive firms (Tobin's q): results from the entire data set are compared with results for tangible asset-intensive firms (MV/TA < 1.25) and with firms whose market value is more dependent on intangible assets (MV/TA > 2.25).

highly capitalized firms (market value per employee): results from the entire data set are compared with results for firms that are highly capitalized on a per employee basis (MV/employee > \$200,000).

tangible-asset dependent firms (assets per employee): results from the entire data set are compared with results for firms heavily dependent on tangible assets (total assets per employee > \$100K) and with firms possessing few tangible assets (total assets per employee < \$60K).

Table 5.1 Linear regression for Tobin's q (MV/TA) with OIBD

data subset	R^2	n	intercept	R&D/TA	A/TA	sales growth	OIBD/TA
total data set	0.106	556	1.734	3.206	6.936		
			(15.243)	(5.966)	(3.956)		
	0.248	556	1.456	2.728	6.995	1.013	
			(13.500)	(5.511)	(4.349)	(10.258)	
	0.258	556	1.254	3.248	7.143	1.023	0.740
			(9.941)	(6.239)	(4.472)	(10.423)	(3.027)
total assets < $50M	0.243	259	1.596	2.123	11.746	0.933	0.298
			(7.673)	(2.916)	(3.323)	(7.144)	(0.866)
total assets > $100M	0.581	198	-0.077	4.609	0.676	0.928	6.408
			(-0.458)	(3.415)	(0.520)	(3.611)	(11.849)
< 300 employees	0.265	153	1.546	2.066	16.659	1.207	0.345
			(4.734)	(1.512)	(2.930)	(6.162)	(0.648)
> 1000 employees	0.559	223	-0.095	4.600	1.362	1.088	6.185
			(-0.590)	(3.724)	(1.059)	(4.079)	(11.571)
MV/TA < 1.25	0.121	160	0.899	-0.130	-0.575	0.384	0.152
			(28.018)	(-0.551)	(-1.128)	(4.217)	(1.263)
MV/TA > 2.25	0.168	202	3.340	2.121	6.651	0.549	-0.672
			(11.189)	(2.565)	(2.448)	(3.946)	(-1.539)

(t-statistics in parentheses)

Table 5.1 (continued) Linear regression for Tobin's q (MV/TA) with OIBD

data subset	R^2	n	intercept	R&D/TA	A/TA	sales growth	OIBD/TA
MV/employee > $200K	0.321	165	2.315	9.606	5.850	0.577	-1.169
			(5.626)	(4.358)	(1.814)	(3.006)	(-1.657)
assets/employee < $60K	0.233	176	1.346	3.980	6.231	0.587	0.138
			(6.389)	(5.068)	(1.920)	(3.285)	(0.391)
assets/employee > $100K	0.545	209	0.266	5.660	-0.927	1.190	5.240
			(1.247)	(4.565)	(-0.513)	(10.834)	(9.396)

(t-statistics in parentheses)

Table 5.2 Linear regression for Tobin's q (MV/TA) with FCF

data subset	R^2	n	intercept	R&D/TA	A/TA	sales growth	FCF/TA
total data set	0.106	556	1.734	3.206	6.936		
			(15.243)	(5.966)	(3.956)		
	0.248	556	1.456	2.728	6.995	1.013	
			(13.500)	(5.511)	(4.349)	(10.258)	
	0.246	556	1.454	2.742	7.021	1.011	-0.014
			(13.016)	(5.167)	(4.267)	(9.764)	(-0.076)
total assets < $50M	0.240	259	1.680	1.955	10.971	0.925	0.007
			(8.617)	(2.631)	(3.049)	(6.873)	(0.030)
total assets > $100M	0.293	198	0.803	6.103	4.967	2.084	1.162
			(4.154)	(3.466)	(3.061)	(5.345)	(2.142)
< 300 employees	0.264	153	1.626	1.867	15.881	1.161	-0.323
			(5.641)	(1.464)	(2.776)	(5.543)	(-0.554)
> 1000 employees	0.306	223	0.830	5.268	4.478	2.497	1.230
			(4.770)	(3.391)	(2.839)	(6.624)	(2.353)
MV/TA < 1.25	0.113	160	0.912	-0.153	-0.644	0.424	0.043
			(29.840)	(-0.648)	(-1.238)	(4.227)	(0.383)
MV/TA > 2.25	0.160	202	3.133	2.234	6.607	0.617	0.185
			(12.041)	(2.553)	(2.299)	(4.362)	(0.689)
MV/employee > $200K	0.310	165	1.875	11.270	4.896	0.609	0.174
			(5.970)	(5.711)	(1.518)	(2.992)	(0.289)

(t-statistics in parentheses)

Table 5.3 Logarithmic regression for Tobin's q (MV/TA) with OIBD

data subset	R^2	n	intercept	log(TA)	R&D/TA	A/TA	sales growth	OIBD/TA
total data set	0.833	556	0.259	0.965	0.326	0.922		
			(6.818)	(50.524)	(3.999)	(3.599)		
	0.855	556	0.210	0.972	0.273	0.916	0.133	
			(5.869)	(54.503)	(3.573)	(3.831)	(9.139)	
	0.867	556	0.188	0.946	0.416	1.020	0.135	0.252
			(5.461)	(54.171)	(5.489)	(4.448)	(9.704)	(7.122)
total assets < $50M	0.565	259	0.415	0.798	0.267	0.723	0.108	0.139
			(6.319)	(15.461)	(3.105)	(1.748)	(7.104)	(3.421)
total assets > $100M	0.888	198	-0.193	1.011	0.280	-0.028	0.247	1.332
			(-2.401)	(30.431)	(1.128)	(-0.115)	(4.977)	(12.962)
< 300 employees	0.592	153	0.445	0.768	0.082	1.322	0.132	0.145
			(5.517)	(12.240)	(0.532)	(2.174)	(6.262)	(2.539)
> 1000 employees	0.908	223	-0.182	1.002	0.419	0.159	0.253	1.288
			(-2.933)	(37.618)	(1.872)	(0.674)	(5.169)	(12.988)
MV/TA < 1.25	0.937	160	0.070	0.916	-0.161	-0.114	0.225	0.182
			(1.744)	(46.698)	(-1.027)	(-0.337)	(3.738)	(2.257)
MV/TA > 2.25	0.947	202	0.615	0.926	0.084	0.760	0.042	0.043
			(17.151)	(52.602)	(1.335)	(3.716)	(4.170)	(1.317)

(t-statistics in parentheses)

Table 5.3 (continued) Logarithmic regression for Tobin's q (MV/TA) with OIBD

data subset	R^2	n	intercept	log(TA)	R&D/TA	A/TA	sales growth	OIBD/TA
MV/employee > $200K	0.912	165	0.503	0.879	1.009	0.662	0.041	0.219
			(9.900)	(34.148)	(5.513)	(2.426)	(2.555)	(3.400)
assets/employee < $60K	0.855	176	0.228	0.939	0.399	0.743	0.082	0.111
			(4.128)	(29.740)	(3.934)	(1.877)	(3.837)	(2.570)
assets/employee > $100K	0.898	209	0.035	0.954	0.762	-0.229	0.143	1.013
			(0.628)	(36.259)	(3.847)	(-0.775)	(8.139)	(11.218)

(t-statistics in parentheses)

Table 5.4 Logarithmic regression for Tobin's q (MV/TA) with FCF

data subset	R^2	n	intercept	log(TA)	R&D/TA	A/TA	sales growth	FCF/TA
total data set	0.833	556	0.259	0.965	0.326	0.922		
			(6.818)	(50.524)	(3.999)	(3.599)		
	0.855	556	0.210	0.972	0.273	0.916	0.133	
			(5.869)	(54.503)	(3.573)	(3.831)	(9.139)	
	0.856	556	0.199	0.973	0.329	1.010	0.124	-0.052
			(5.522)	(54.678)	(4.042)	(4.153)	(8.175)	(-1.956)
total assets < $50M	0.546	259	0.406	0.832	0.228	0.532	0.100	-0.026
			(6.020)	(16.067)	(2.534)	(1.233)	(6.265)	(-0.884)
total assets > $100M	0.794	198	-0.265	1.121	0.525	0.736	0.510	0.194
			(-2.444)	(25.740)	(1.550)	(2.328)	(6.695)	(1.866)
< 300 employees	0.586	153	0.465	0.780	0.004	1.011	0.112	-0.129
			(5.793)	(12.329)	(0.031)	(1.640)	(4.971)	(-2.060)
> 1000 employees	0.840	223	-0.144	1.074	0.542	0.681	0.538	0.197
			(-1.754)	(31.221)	(1.829)	(2.209)	(7.481)	(1.971)
MV/TA < 1.25	0.936	160	0.074	0.923	-0.180	-0.203	0.277	0.062
			(1.800)	(46.948)	(-1.134)	(-0.583)	(4.134)	(0.833)
MV/TA > 2.25	0.947	202	0.625	0.932	0.054	0.662	0.041	0.011
			(17.076)	(54.850)	(0.794)	(3.116)	(4.001)	(0.570)
MV/employee > $200K	0.906	165	0.520	0.916	0.743	0.722	0.040	-0.003
			(9.544)	(37.015)	(4.328)	(2.557)	(2.311)	(-0.055)

(t-statistics in parentheses)

These stratification criteria were chosen to investigate the value, and hence the appropriability, of intangible assets as a function of firm characteristics. Cutoff points were chosen so that each sample group constituted approximately one third of the data set. For example, small firms (book value of assets < $50M) comprised approximately the lower third of the data set when sorted by size, while those firms classed as larger formed approximately the upper third when the data were sorted by size.

Complete data set

As seen from Tables 5.1-4, the value and the significance of the regression coefficients remains fairly constant as the model is enlarged to include more explanatory variables. Multicollinearity is thus probably not a significant concern. For either the linear or the logarithmic regressions, slightly greater explanatory power is provided when operating cash flow vs free cash flow is used as an explanatory variable. This is uniformly true for every subset of the data that has been analyzed. In addition, for these regressions on the entire data set, the influence of FCF is not significant, while OIBD is a very significant explanatory variable. While FCF is significant for certain subsets of the data (to be presented below), in each case the significance level of OIBD is greater. Therefore, subsequent discussion will concentrate on the results given by the operating cash flow model. However, differences between operating and free cash flow models, when significant, will be noted.

Residual plots (not presented) suggest that the linear model may not be homoskedastic, as residuals increase linearly with MV/TA. However, a residual plot using the logarithmic model shows that measurement error is homoskedastic for this model. This may be due to measurement error as the effect of outliers is reduced in the logarithmic model. Another explanation is that there are in fact scale effects which are not included in the linear model. Yet another possibility is that low MV/TA firms *are* significantly different from high MV/TA firms, both in the value derived from the particular intangible assets studied here (R&D, advertising), as well as others not included. This possibility is discussed further below.

Each of the four regression models results show that all of the variables chosen (with the exception of FCF) are very important in describing the data. In particular, sales growth is a critical explanatory variable. This is logical, for market valuations of a firm are based on market forecasts and depend critically on expectations for sales growth. The fact that the regression intercept (ideally 1.0 in the linear model and 0.0 in the logarithmic model) continues to decrease towards these values as more variables are added suggest that there may be other explanatory factors not taken into account here. For example, gross margin as a measure of monopoly profits has been found to have explanatory power (Lindenberg and Ross, 1981). When this variable is included in the regression analysis, the adjusted R^2 increases slightly and the regression intercept decreases. In this industry, however, the significance and meaning of gross margin is ambiguous. For some firms (e.g. certain types of hardware manufacturers) it may in fact describe market power. For other firms (e.g. software firms, where variable costs are negligible but large development costs are incurred), gross margin may be a misleading measure. Fortunately, the value and significance of the other regression coefficients do not significantly change, and so inferences as to the significance of these intangible assets would not be affected. Other explanatory variables may also be useful: market share and market share growth (Smirlock et al., 1984), number of patents (Griliches, 1981), and so on. However, given that book values were used to approximate replacement value, a regression intercept value slightly greater than 1.0 (in the linear case) is not unreasonable. Furthermore, the R^2 value of 0.25 in the linear model compares quite favorably with the value of 0.29 reported by Wernerfelt and Montgomery (1988), while the value of R^2 of 0.87 in the logarithmic model compares well with the value of 0.94 as found by Hall (1993), even though the number of observations in this study is less than 3% that of the latter (556 observations vs 24,333). Thus, for the purposes of this study, further investigation will use the four explanatory values as shown by the models presented above.

As shown in the Tables, the market valuation of advertising is 2-3 times greater than R&D in this industrial sector. This contrasts with the results of Hall (1993) and Montgomery and Wernerfelt (1988) who, in broad-based studies of the entire manufacturing sector, found the opposite: R&D investment is valued at 2-4 times advertising expenditures. This difference illustrates the particular dynamics which may be relevant to a particular industry, in this case the computer and computer electronics industry, as compared to the entire manufacturing sector. For example, the value for the coefficient of R&D found here is 3.2, which compares with a value of approximately 9 found by Montgomery and Wernerfelt. This implies a shorter life, or faster depreciation rate for R&D in the computer industry as compared to the economy on average. In the entire economy, R&D has an average life of approximately 9 years (or 11% depreciation per year), whereas its life is estimated at only 3 years in the computer and computer electronics industry, implying a 30% depreciation rate. By contrast, $1 spent on advertising generates approximately $7 in brand name value in the computer industry, vs $3 for the economy on the average, as found by Montgomery and Wernerfelt. These differences are consistent with the observations of Grabowski and Mueller (1978), who found the effect and value of R&D to be industry specific. For example, the effect of R&D was found to be greatest in high profit industries, implying R&D is needed to secure market power, yet, in contradiction, there was a negative correlation of the value of R&D with market concentration, leading to the hypothesis that concentration in research-intensive industries leads to excessive rivalry and marginally productive R&D. Thus, in this latter case, R&D, rather than a source of advantage, may be required simply to maintain parity and hence would affect firm value only in its absence. For example, R&D was found to be extremely important in the high-profit pharmaceutical industry, yet its value, found by constructing an asset based on a depreciating sum of past R&D expenditures, was found to depreciate twice as fast in this industry as in other manufacturing industries. One could imagine arguments being constructed along similar lines to justify these regression results for the computer electronics industry, given the proliferation of cross-licensing agreements, patent trading, relatively low barriers to entry, and extensive availability of information.

Firm size (total assets)

The entire data set was stratified based on total firm assets, with small firms being defined as those with less than $50M in total assets and large firms as those with over $100M in total assets. For each regression, the R^2 of the fit was greater for the larger firms as compared to the smaller firms, indicating the spread of the data and the variability in firm characteristics for the smaller firms.

The linear regression results for Tobin's q show that relative to the entire industry data set, R&D expenditures create a smaller intangible asset in smaller firms and a larger asset in the larger firms. The contribution to market value of expenditures in R&D in larger firms is more than twice that in smaller firms. This would be consistent with the ability of larger firms to assimilate research results into the organization, so permitting the firm's owners to appropriate the results of that research. Another way to interpret these findings is that R&D constitutes a larger capital stock in larger companies, implying that the company is better able to appropriate the results into its knowledge base. By contrast, advertising is very important for the smaller firms, even more so than for the entire industry data sample, yet is insignificant for the larger firms. This suggests that in this industry, a brand name recognition is necessary for survival, yet a reputation, once achieved, is durable.

Sales growth is significant for both sizes of firms, but current cash flows are insignificant for the smaller firms and very significant for the larger firms. Combined with the advertising results, this would indicate that investors in large firms are reaping the rewards of a process of firm growth, reputation building, and name recognition, while investors in small firms are forgoing current payments (e.g current cash flows) in order to develop a market presence. Advertising likely represents only one of several intangible assets that these small firms are developing that, as a whole, will permit the smaller firm to establish and maintain itself in the future. Patent and other intellectual property protection may be another: patents not only protect the company against rivals, but effectively transfer the knowledge of key individuals to the company. Significantly, Scherer (1986), in a statistical analysis based on 1955 economy-wide data, has found that patents provide increasing returns to sales for smaller companies, yet may actually result in diminishing returns for larger and diversified corporations.

Results using the free cash flow variable in the linear regression model confirm these observations, but indicate that advertising, although perhaps less important for the larger firms, is nonetheless significant. Results for the logarithmic model are similar in trend, but differ in significance as compared to the linear model. Although the value of R&D is greater for the larger firms, its explanatory power is significant only for the smaller firms. A major determinant of value for all firms is still sales growth, and, as in the previous model, smaller firms rely on advertising to create value while larger firms obtain value in the form of current cash flows. Now, however, advertising is insignificant for both sizes of firms and cash flow is significant for small as well as large firms.

Firm size (number of employees)

The entire data set was stratified based on total firm assets, with now small firms being defined as those with less than 300 employees and large firms as those with over 1000 employees. As was the case for regressions stratified by size on the basis of firm assets, the R^2 of the fit was again greater for the larger firms, indicating the spread and variability in firm characteristics for smaller firms.

The regression results for Tobin's q are nearly identical to those for firm size as measured by asset value, yet here the observations are more clearly defined and more significant, and so more strongly support the interpretations discussed above. When firm size is defined by number of employees, the value of R&D in larger firms is nearly two times that of R&D in smaller firms, and its value as an intangible asset in smaller firms is not significantly different from zero ($p > 0.1$). Here, it is not difficult to formulate arguments relating to appropriability of intellectual property in firms with large numbers of employees vs smaller firms whose key intellectual assets may reside with unique individuals.

While advertising represents a very important asset for the smaller firms, its value is smaller and insignificant for larger firms. Cash flow value is complementary - of little significance for smaller firms but highly significant for the larger firms. In the smaller firms, intangible asset value is due primarily to advertising ($16 for every dollar spent), while in the larger firms, intangible firm value depends both on R&D ($4.60 return per dollar) and on operating cash flow ($6 return).

Results are quite consistent for each of the different regression models, with the exception that the value of R&D as determined by the logarithmic regression for firm value, while still much greater than for smaller firms, is now significant only at the 6% level, while operating cash flow is an explanatory variable of some significance for the smaller firms where it was not for the linear regression model.

Of particular interest in both sets of these size-stratified regressions is the regression intercept value. For the linear regressions, the intercept value for the larger firms is close to zero, implying that the firm's assets, in and of themselves, contribute little to firm value. Rather, it is the ability to transform ideas (R&D) into cash flows that is valued by investors. By contrast, the regression coefficient for the tangible assets of smaller firms is greater than one, which would not indicate that these assets are valued at greater than replacement cost, but rather that the full explanation of value for these smaller firms depends on other (intangible) assets that have not been incorporated into the valuation model. The logarithmic regressions support this view: the multiplier α is approximately 0.7 for the larger firms and nearly 3 for the smaller firms. Thus, the regression model of intangible and tangible assets reasonably explains firm value for the larger firms, while the fact that smaller firms are valued at a multiple of their asset sum may indicate several alternative possibilities. Perhaps other, unaccounted-for factors determine firm value for these smaller firms; another likely possibility is that investors place great expectations on the future promise of these firms. Each of these explanations is consistent with the differing values placed on advertising, R&D, and immediate cash flow for smaller vs larger firms. The owners of small firms recognize that the firm needs to first establish a durable market presence and credibility, based on assets controlled by the firm, before value is appropriable either from the market (in the form of cash flow) or from the firm's own research. The payoff is in the future, and depends, at least in part, from intangible assets developed now. These intangible assets may be market assets, such as brand name, reputation, customer loyalty, and trademarks, for which advertising is a reasonable descriptive variable. As noted above, these intangible assets may also include those that the firm can appropriate from individuals - intellectual property in the form of patents and copyrights, or sales and marketing expertise that, over time, can become institutionalized. Other sources of value could include licensing agreements, and, perhaps especially in the computer hardware and software industry, network effects including installed base, compatibility issues, adherence to standards, etc. All of these factors are potential explanatory variables that, aside from advertising, have not been explicitly included in the regression models presented here.

Correlation of Sales with R&D

Stratification by firm size (total assets)

total assets ($M)	1.505 - 19.86	correlation	-0.139
	20.02 - 44.74		0.042
	44.93 - 126.9		0.143
	130.5 - 2595		0.880

Stratification by firm size (# employees)

# employees(000)	0.015 - 0.201	correlation	0.253
	0.214 - 0.583		0.146
	0.619 - 1.792		0.737
	1.928 - 34.41		0.886

Exhibit A Correlation of $R\&D_{firm}/R\&D_{industry}$ with $Sales_{firm}/Sales_{industry}$ in 1986 (each group represents a quartile)

These observations are further confirmed by the results of calculations shown in Exhibit A. Firm sales as a fraction of total industry sales were correlated with firm R&D as a fraction of the total industry R&D for the year 1986. The data sample was divided into four groups according to size, where both measures of firm size (total assets and number of employees were used). In each case, the correlation is poor for the smaller firms, but strong for the largest firms. Thus, R&D does not appear to lead to sales, and hence income and value, for smaller firms, confirming the low market valuation placed on R&D for the smaller firms.

Asset intensive firms (Tobin's q)

Residual plots for the linear valuation model showed that residuals increased linearly with MV/TA. Two potential sources are scale effects and measurement error. However, a third possibility is that low MV/TA firms are significantly different from high MV/TA firms, both in the value attributed to intangible assets as well as the nature of those assets. To examine this possibility, the data set was stratified according to MV/TA, and separate regressions for the linear and logarithmic models were calculated for tangible asset-dependent firms (MV/TA $<$ 1.25) and for intangible asset-dependent firms (MV/TA $>$ 2.25).

Low MV/TA firms serve primarily as a control, and as expected, the intercept regression coefficient for tangible asset-dependent firms is close to 1.0 in the linear case. In the logarithmic model, the intercept regression coefficient (the logarithm of the multiplying factor) is not significantly different from zero and the coefficient of TA is close to 1.0. These results imply that there are no scale effects for asset-dependent (small MV/TA) firms, and that firm value is reasonably described by the explanatory variables used here. By contrast, for large MV/TA firms the linear regression coefficient is large ($>$ 3.3) as is the logarithmic multiplying factor ($\alpha >$ 4). While this may suggest that scale effects are important for these firms, a much more likely explanation is that all relevant explanatory variables have not been included.

When these regression results are compared to each other and to the regression results for the entire data set, interesting observations emerge. First, low MV/TA firms are nearly exclusively dependent on the value of tangible assets. The coefficients for the intangible asset factors are not significantly different from zero, and the coefficient values attributed to sales growth and operating cash flow are either insignificant, or, when significant, lower in value or significance than that of the data set as a whole. While such valuation might be expected for firms in characteristically asset-dependent industries, such as real estate or raw materials, firms with these characteristics in the computer and computer electronics industry are surprising. Some of these low MV/TA firms include Iomega, General Automation, Quantum, and Pitney-Bowes, for example. Given the nature of this industry, with its dependence on innovation and ideas, these results may instead indicate that investors have lost confidence in the ability of these companies to remain technologically competitive. This is supported by the low value given research and advertising expenditures, and the rather desultory value and/or significance given to sales growth and operating income.

By contrast, high MV/TA firms display a markedly different character. As expected by definition, these firms derive nearly all their value from intangible assets. Like the low MV/TA firms, sales growth and operating income are less important in determining firm value than for the data set as a whole, but unlike these low MV/TA firms, advertising and R&D are significant factors. Although the value and explanatory power of these variables is less than for the data set as a whole, in relative terms advertising contributes nearly three times as much to firm value than R&D for these firms, vs a factor of two for advertising vs R&D in the data set as a whole. In fact, in the logarithmic model, R&D loses explanatory significance for high MV/TA firms, and advertising is the strongest determinant of firm value. As discussed above, the fact that the regression results change depending on whether a linear or logarithmic model is used may be interpreted as implying scale effects, but further investigation should first determine that all relevant factors are being included in the model. In light of the nature of this industry, intangible factors to be investigated should be technology-related: patents, license agreements, employment (specifically R&D) turnover, etc.

Many of these high MV/TA firms are software producers (Adobe, Computer Associates, Lotus, Microsoft). The regression results, combined with observations of the rapid rate of product development in the software industry, would imply that R&D is a current expenditure which depreciates almost immediately, and provides no long-term value. This suggests the interpretation that brand name is the most important determinant of firm value while R&D may only be required to maintain competitiveness within the industry. However, this group of firms is not composed exclusively of hardware producers. There are a number of hardware firms (Apple, Sun, Silicon Graphics, Seagate, Western Digital) and retailers (Tandy, Dell).

Highly capitalized firms (market value per employee)

Previous stratifications of the data set compared firms on the basis of size and asset intensity in order to identify the characteristics that differentiate the different groupings of companies. Here, the characteristics of firms that are highly valued by the market (on a per employee basis) are compared with the data set as a whole. A high per employee market capitalization indicates both the high value of employee effort *and* that such efforts are appropriable by the firm.

For the COMPUSTAT data set, the composite market value per employee is $141,000 and the median is $107,000. Tables 5.1-4 present the regression coefficients for firms capitalized at over $200,000 per employee, approximately the upper third of the data set. Although this sample of firms includes many software companies (Lotus, Microsoft, Interleaf, Computer Associates, Novell), there are nearly as many data entries under the 4-digit SIC code for prepackaged software that are not included in this sample. This sample of highly capitalized firms also contains many hardware producers, including Apple, Compaq, Maxtor, Quantum, Silicon Graphics and Sun.

These results show that advertising, sales growth, and operating cash flow are all less important explanatory variables for these firms than for the data set as a whole, but that R&D is much more highly valued, by factors of 2 - 5. Such results in this industry indicate that the market is valuing the ability of the firm to appropriate knowledge capital. The discounted value applied to the sales and advertising variables for these highly capitalized firms relative to the entire sample can be interpreted as indicating that these companies are able to value and appropriate knowledge capital immediately, rather than having to wait to obtain value later in the product cycle via manufacturing and product sales. This would also imply that highly capitalized (per employee) firms are also high MV/TA firms (since these knowledge assets are intangible, and represent the promise of future payoffs rather than immediate benefits). Market value per employee and MV/TA are in fact highly correlated, with a correlation coefficient of 0.671.

Once again, the presence of intercept values greater than 1.0 in the linear model and multiplicative factors greater than 1.0 in the logarithmic model indicates that other explanatory variables may be significant. For these firms, such variables should be measures of knowledge and innovation, and might include R&D employment, average tenure of the R&D staff, number of Ph.D.'s, issued patents, etc.

Tangible-asset dependent firms (assets per employee)

Previous stratifications to identify the characteristics of intangible asset-dependent firms divided the data set based on measures of the dependent variable (MV/employee, MV/TA). Here, we examine tangible- and intangible-asset dependent firms based on the amount of total (tangible) assets per employee. Approximately one third of the data set consisted of firms with more than $100,000 of tangible assets per employee. The opposite third consisted of firms with less than $60,000 in tangible assets per employee. For the purposes of this study, those in the first group are regarded as tangible asset-dependent firms, while those with fewer tangible assets per employee are assumed to be more dependent on intangible assets. However, this distinction does not produce a clear differentiation in terms of the lines of business of firms in each group, and more careful investigation and definition would be warranted in future work. For example, one would expect that software firms would have relatively fewer tangible assets per employee, while hardware manufacturers would have more. However, most of the major hardware (Apple, Compaq) *and* software manufacturers (Lotus, Microsoft) were in the high total assets per employee category, whether assets were defined as total assets (current assets plus property, plant, and equipment) or even simply PP&E. Thus, if differentiation is desired based upon lines of business, future studies should simply stratify based upon 3- and 4-digit SIC codes.

Regression results for these this grouping of firms are quite similar to those for a stratification based on firm size, either by total assets or by number of employees. Similar to those larger firms, the most significant explanatory variables for firms with high amounts of tangible assets per employee are R&D and operating cash flow. The coefficient value for operating cash flow is nearly 9 times that of the data set as a whole, while the value of R&D is also more important for these firms than for the data set as a whole. Advertising, on the other hand, is not significant as an explanatory variable. By contrast, there is a suggestion that firms with lower amounts of tangible assets per employee derive greater value from advertising (advertising is nearly significant as an explanatory variable at the 6% level), while R&D is also significant. Sales growth, while significant, is less important than for the data set as a whole and operating cash flow is insignificant. One interpretation of these results may be that R&D, when carried out in firms with large amounts of tangible assets, is appropriable and is associated with market power and profitability. In firms with fewer tangible assets, however, profitability only comes later, after a brand name reputation has been established and the firm has a market presence.

2. Employee Specific Valuation

The valuation model based on Tobin's q attempted, within the confines set by use of limited financial data, to identify intangible sources of firm value and their relative importance for firms of different types. One of the results of that regression model was an indication that firms that are highly capitalized on a per employee basis are so because the company not only has creative and innovative employees, but that it believes it can appropriate the intellectual capital of those employees. The market value thus reflects the confidence that this knowledge capital will produce future benefits, and the security that these benefits will accrue to the company.

In this section, these issues are pursued in greater depth. First, a model is developed that attempts to explicitly value the contribution of each employee to firm value. Using the financial data for the computer and computer electronics industry, this model seeks to identify some of the factors that lead to a high market valuation per employee, and to investigate how these factors may differ among firms of different sizes and characteristics. A high market valuation per employee means that employees are making important contributions to the company, and that these contributions are appropriable by the firm. Therefore, it is reasonable to ask what factors contribute to a high market valuation, and how these factors vary for small vs large firms, or for tangible vs intangible asset-dependent firms.

At the outset, it is recognized that this model will be necessarily deficient in accounting for all the explanatory factors that determine firm value, even on the aggregate level. The data sample consists of only financial and accounting data, and no attempt has been made to identify other firm and industry specific factors. Several such factors have been discussed previously, primarily of a technological nature. However, in evaluating the ability of the firm to realize employee value, other factors that may now be important include employee mobility, both in terms of physical displacement and transferability of skills; conditions in the employment market; employment prospects in related industries; the structure of company ownership (i.e. whether employees are also owners); etc. To illustrate the implications of omitting such factors, Salinger (1984) applied a similar regression model to a selection of industries and firms to assess the influence of one employee-specific factor - unionization - on firm value. Unionization was found to be a significant factor in reducing value to the firm's owners via a shift to the employees. Fully 77% of monopoly rents were appropriated by the unions. Thus, for the industries analyzed in that study, the primary beneficiaries of monopoly power were unionized workers.

Model Development

Similar to the valuation model based on Tobin's q, the firm is viewed as a collection of tangible and intangible assets. Firm market value (MV) is the sum of these asset values,

$$MV = V_{TA} + V_R + V_A + f(OCF) + g(\dot{S}) \qquad (15)$$

where, as in the previous model, V_{TA}, V_R, and V_B represent respectively the capitalized value of tangible assets, knowledge (i.e. research and development) assets, and brand-name assets. The function f(OCF) represents the value of extraordinary firm-specific profitability and long-run prospects, where OCF is some appropriately defined measure of cash flow to the firm, and g($\dot{S}$) represents the value of the firm's sales and marketing efforts as well as prospects for long-term growth, where $\dot{S}$ is some measure of sales performance, such as sales growth. On a per employee basis, firm value is expressed as

$$\frac{MV}{employee} = \frac{V_{TA}}{employee} + \frac{V_R}{employee} + \frac{V_A}{employee} + \frac{f(OCF)}{employee} + \frac{g(\dot{S})}{employee} \qquad (16)$$

Alternatively, on a per employee basis the functional formulation for firm value may include scale (or network) effects,

$$\frac{MV}{employee} = \alpha \left[\frac{V_{TA}}{employee} + \frac{V_R}{employee} + \frac{V_A}{employee} + \frac{f(OCF)}{employee} + \frac{g(\dot{S})}{employee} \right]^{\beta} \tag{17}$$

where α is a multiplicative factor and β is the scale factor. Taking logarithms of both sides, and using the approximation $\log(1+x) \approx x$ for small x, firm value is

$$\log(\frac{MV}{employee}) = \log(\alpha) + \beta \log(\frac{V_{TA}}{employee}) + \beta \frac{V_R}{V_{TA}} + \beta \frac{V_A}{V_{TA}} + \beta \frac{f(OCF)}{V_{TA}} + \beta \frac{g(\dot{S})}{V_{TA}} \tag{18}$$

Model Implementation

The linear and logarithmic forms of the firm valuation model, eqs. 16 and 18, are used as a basis for a regression model that will be applied to the industry data set. As in the previous analysis, market value (MV) is taken as the sum of the market value of common stock plus the book value of outstanding long-term debt, and preferred stock is ignored. Replacement cost (V_{TA}) is taken as the listed book value of total assets less current liabilities; knowledge assets (V_R) are approximated as linearly related to the current level of R&D expenditures; brand-name assets (V_A) are approximated by the current level of advertising expense; and sales growth is calculated for any given year as a central difference. The variable representing cash flow is again calculated in two ways: as operating income before depreciation (OIBD) and as the standard measure of free cash flow to the firm (FCF).

Results and Discussion

Four separate regression models were applied to the computer and computer electronics industry data. The models differ in the linear or logarithmic form of the valuation equation, and in the measure of cash flow, OIBD vs FCF. These models are as follows:

Linear model, operating cash flow:

$$\frac{MV}{empl} = \beta_0 + \beta_1 \frac{V_{TA}}{empl} + \beta_2 \frac{R}{empl} + \beta_3 \frac{A}{empl} + \beta_4 \frac{OIBD}{empl} + \beta_5 \dot{S} \qquad (19)$$

Linear model, free cash flow:

$$\frac{MV}{empl} = \beta_0 + \beta_1 \frac{V_{TA}}{empl} + \beta_2 \frac{R}{empl} + \beta_3 \frac{A}{empl} + \beta_4 \frac{FCF}{empl} + \beta_5 \dot{S} \qquad (20)$$

Logarithmic model, operating cash flow:

$$\log(\frac{MV}{empl}) = \log(\alpha) + \beta \log(\frac{V_{TA}}{empl}) + \beta_1 \frac{R}{V_{TA}} + \beta_2 \frac{A}{V_{TA}} + \beta_3 \frac{OIBD}{V_{TA}} + \beta_4 \dot{S} \quad (21)$$

Logarithmic model, free cash flow:

$$\log(\frac{MV}{empl}) = \log(\alpha) + \beta \log(\frac{V_{TA}}{empl}) + \beta_1 \frac{R}{V_{TA}} + \beta_2 \frac{A}{V_{TA}} + \beta_3 \frac{FCF}{V_{TA}} + \beta_4 \dot{S} \quad (22)$$

Once again, in the logarithmic models ß represents the exponential (scale) factor and the $ß_i$ are actually the product of the asset coefficient with the scale factor. Again, except in one case to be discussed below, the scale factor is always quite close to 1.0, and this distinction is ignored.

Table 5.5 presents results for the linear regression model using OIBD as the cash flow measure. Table 5.6 presents the results for free cash flow with the linear model. Table 5.7 presents results for the logarithmic regression model using OIBD as the cash flow measure, and Table 5.8 presents the results for free cash flow with the logarithmic model. Results are stratified according to the five criteria used previously:

firm size (total assets):

large firms: book assets > $100M

small firms: book assets < $50M

firm size (number of employees):

large firms: greater than 1000 employees

small firms: less than 300 employees

asset intensive firms (Tobin's q):

tangible asset-intensive firms: MV/TA < 1.25

intangible asset-intensive firms: MV/TA > 2.25

highly capitalized firms (market value per employee):

firms highly capitalized per employee: MV/employee > $200,000

tangible-asset dependent firms (assets per employee):

firms dependent on tangible assets, assets per employee > $100,000

firms less dependent on tangible assets: assets per employee < $60,000

Table 5.5 Linear regression for market value (MV) per employee with OIBD

data subset	R^2	n	intercept	TA/empl	R&D/empl	A/empl	sales growth	OIBD/empl
total data set	0.432	556	-13.020	1.584	6.654	6.760		
			(-1.10)	(12.13)	(7.81)	(4.23)		
	0.511	556	-23.714	1.547	5.082	7.175	79.314	
			(-2.15)	(12.77)	(6.29)	(4.84)	(9.50)	
	0.592	556	-30.141	0.914	6.645	3.169	81.340	3.558
			(-2.98)	(7.25)	(8.83)	(2.25)	(10.66)	(10.51)
total assets < $50M	0.534	259	-46.391	1.364	4.856	22.277	74.756	2.537
			(-2.63)	(4.99)	(3.95)	(4.37)	(7.94)	(4.18)
total assets > $100M	0.712	198	-28.798	0.347	4.643	0.508	93.922	6.197
			(-2.01)	(2.26)	(3.49)	(0.37)	(3.35)	(10.26)
< 300 employees	0.583	153	-23.038	0.635	5.707	28.227	106.668	3.355
			(-0.88)	(2.98)	(3.79)	(4.86)	(7.57)	(5.54)
> 1000 employees	0.751	223	-17.243	-0.123	5.441	0.902	65.768	7.457
			(-1.24)	(-0.38)	(3.03)	(0.75)	(2.80)	(10.86)
MV/TA < 1.25	0.938	160	-4.570	1.004	-1.013	-0.168	36.442	0.284
			(-1.98)	(40.88)	(-4.39)	(-0.32)	(4.60)	(2.01)
MV/TA > 2.25	0.583	202	-22.340	2.478	6.950	4.041	47.501	1.263
			(-0.91)	(7.07)	(4.59)	(1.65)	(4.26)	(1.90)

(t-statistics in parentheses)

Table 5.5 (continued) Linear regression for market value (MV) per employee with OIBD

data subset	R^2	n	intercept	TA/empl	R&D/empl	A/empl	sales growth	OIBD/empl
MV/employee > $200K	0.336	165	108.495	0.591	6.834	2.890	86.778	2.534
			(2.58)	(2.45)	(3.92)	(1.19)	(5.32)	(4.09)
assets/employee < $60K	0.278	176	5.830	1.577	3.250	6.207	15.152	-1.808
			(0.35)	(2.96)	(3.75)	(2.01)	(2.75)	(-3.09)
assets/employee > $100K	0.538	209	-67.354	0.778	6.738	1.019	113.868	5.197
			(-1.89)	(3.68)	(4.84)	(0.51)	(8.28)	(9.46)

(t-statistics in parentheses)

Table 5.6 Linear regression for market value (MV) per employee with FCF

data subset	R^2	n	intercept	TA/empl	R&D/empl	A/empl	sales growth	FCF/empl
total data set	0.540	556	-9.227	1.190	5.840	8.823	61.984	-1.442
			(-0.84)	(9.03)	(7.36)	(6.03)	(7.21)	(-6.00)
total assets < $50M	0.543	259	-26.496	1.480	3.207	24.678	57.434	-1.900
			(-1.46)	(5.99)	(2.97)	(4.94)	(5.87)	(-4.80)
total assets > $100M	0.555	198	-23.839	0.925	8.315	5.919	156.519	-0.295
			(-1.25)	(4.34)	(4.65)	(3.65)	(4.08)	(-0.59)
< 300 employees	0.558	153	7.570	0.713	3.513	34.106	84.308	-1.775
			(0.28)	(3.23)	(2.39)	(5.53)	(5.57)	(-4.56)
> 1000 employees	0.618	223	-50.760	1.246	11.030	4.341	141.842	0.714
			(-2.89)	(3.27)	(5.04)	(3.01)	(4.28)	(1.16)
MV/TA < 1.25	0.938	160	-2.967	0.999	-0.940	0.148	35.606	-0.169
			(-1.27)	(39.17)	(-4.04)	(0.25)	(4.45)	(-2.06)
MV/TA > 2.25	0.583	202	-13.849	2.651	6.344	6.357	36.707	-0.843
			(-0.56)	(8.76)	(4.33)	(2.68)	(3.24)	(-1.94)
MV/employee > $200K	0.296	165	158.252	0.631	6.538	6.601	61.986	-1.069
			(3.74)	(2.41)	(3.63)	(2.68)	(3.52)	(-2.62)

(t-statistics in parentheses)

Table 5.7 Logarithmic regression for market value (MV) per employee with OIBD

data subset	R^2	n	intercept	log(TA/empl)	R&D/TA	A/TA	sales growth	OIBD/TA
total data set	0.551	556	0.046	1.082	0.406	0.818		
			(0.58)	(25.69)	(5.11)	(3.23)		
	0.608	556	0.111	1.027	0.321	0.847	0.132	
			(1.49)	(25.77)	(4.29)	(3.57)	(8.98)	
	0.635	556	0.072	1.014	0.476	0.897	0.136	0.229
			(1.00)	(26.35)	(6.27)	(3.92)	(9.56)	(6.54)
total assets < $50M	0.578	259	0.249	0.960	0.310	0.891	0.107	0.109
			(2.34)	(16.66)	(3.48)	(2.10)	(6.79)	(2.65)
total assets > $100M	0.813	198	-0.317	1.085	0.209	-0.060	0.222	1.368
			(-3.13)	(19.84)	(0.83)	(-0.25)	(4.56)	(13.67)
< 300 employees	0.544	153	0.485	0.846	0.162	1.271	0.133	0.117
			(3.04)	(10.92)	(1.02)	(2.01)	(6.06)	(1.97)
> 1000 employees	0.804	223	-0.221	1.027	0.391	0.139	0.250	1.289
			(-2.30)	(17.62)	(1.69)	(0.58)	(5.12)	(13.34)
MV/TA < 1.25	0.757	160	0.092	0.906	-0.108	-0.016	0.240	0.103
			(1.17)	(21.36)	(-0.67)	(-0.04)	(3.81)	(1.23)
MV/TA > 2.25	0.751	202	0.552	0.970	0.145	0.532	0.045	0.006
			(6.55)	(22.50)	(2.16)	(2.59)	(4.20)	(0.17)

(t-statistics in parentheses)

Table 5.7 (continued) Logarithmic regression for market value (MV) per employee with OIBD

data subset	R^2	n	intercept	log(TA/empl)	R&D/TA	A/TA	sales growth	OIBD/TA
MV/employee > $200K	0.282	165	1.613	0.403	0.498	0.386	0.058	0.091
			(10.92)	(5.99)	(2.95)	(1.65)	(4.15)	(1.79)
assets/employee < $60K	0.304	176	0.411	0.816	0.426	0.582	0.088	0.098
			(2.24)	(6.80)	(4.29)	(1.49)	(4.07)	(2.31)
assets/employee > $100K	0.599	209	-0.447	1.187	0.870	-0.273	0.144	0.998
			(-2.02)	(11.79)	(4.24)	(-0.94)	(8.23)	(11.19)

(t-statistics in parentheses)

Table 5.8 Logarithmic regression for market value (MV) per employee with FCF

data subset	R^2	n	intercept	log(TA/empl)	R&D/TA	A/TA	sales growth	FCF/TA
total data set	0.610	556	0.131	1.011	0.369	0.950	0.124	-0.052
			(1.75)	(24.93)	(4.69)	(3.92)	(8.15)	(-1.92)
total assets < $50M	0.568	259	0.297	0.945	0.277	0.751	0.100	-0.032
			(2.74)	(15.79)	(3.06)	(1.73)	(6.11)	(-1.05)
total assets > $100M	0.638	198	0.069	0.971	0.644	0.906	0.473	0.203
			(0.51)	(12.89)	(1.84)	(2.85)	(6.15)	(1.91)
< 300 employees	0.555	153	0.643	0.777	0.098	0.846	0.112	-0.178
			(4.19)	(10.09)	(0.69)	(1.34)	(4.88)	(-2.75)
> 1000 employees	0.650	223	-0.031	1.031	0.541	0.802	0.525	0.210
			(-0.24)	(13.23)	(1.75)	(2.58)	(7.15)	(2.09)
MV/TA < 1.25	0.755	160	0.112	0.898	-0.118	-0.082	0.281	0.059
			(1.46)	(21.30)	(-0.73)	(-0.23)	(4.06)	(0.77)
MV/TA > 2.25	0.751	202	0.550	0.973	0.137	0.507	0.045	0.005
			(6.52)	(21.82)	(2.00)	(2.32)	(4.21)	(0.25)
MV/employee > $200K	0.281	165	1.664	0.392	0.365	0.494	0.049	-0.074
			(11.34)	(5.80)	(2.40)	(2.13)	(3.37)	(-1.70)

(t-statistics in parentheses)

Complete data set

As seen from Tables 5.5-8, both linear and logarithmic models have similar explanatory power on this data set. However, the interpretation of the results differs depending on the model. The linear model suggests that high R&D expenditures per employee are nearly twice as important as advertising in creating firm value, while the logarithmic model indicates the opposite. For either model, sales growth and operating income are explanatory parameters.

In the linear model, the negative value of the intercept could simply be an artifact of model mismatch or measurement error; another possible explanation is that it represents contracted liabilities incurred by employees such as pension and health care benefits. In the logarithmic model, the scale coefficient is insignificant and the multiplicative factor is close to 1.0, suggesting that for the aggregate data set, the explanatory variables adequately describe firm value. This result is interesting, for it indicates that other factors, such as monopoly power, are adequately included in the income variable. In fact, when gross margin is included as an additional explanatory variable, its influence in the linear model is insignificant and the regression coefficients in both linear and logarithmic models are essentially unchanged.

For either the linear or the logarithmic regressions, slightly greater explanatory power is provided when operating cash flow vs free cash flow is used as an explanatory variable, although the improvement is not nearly as great as for the regression results for Tobin's q. This is true for the entire data sample as well as subsets of the data to be discussed. Since in most cases the influence of FCF is not significant, while OIBD is a very significant explanatory variable, subsequent discussion will concentrate on the results given by the operating cash flow model. However differences, when significant, will be noted.

Firm size (total assets)

The means by which firms can realize value from employees are depend on the size of the firms and are generally similar to the observations made for the regression model based on Tobin's q. For larger firms, increases in sales and cash flow lead directly to increases in market value (or, equivalently, realizable value for the firm's owners), whereas for smaller firms, these factors, although significant, are less important and advertising is the important variable governing market value per employee. Use of free cash flow as an explanatory variable provides some evidence that R&D is more important for larger firms than for smaller firms, but this is not maintained when operating cash flow is used to describe firm profitability. Rather, these results are demonstrating that a firm achieves value not by any intrinsic measure of the worth of its ideas (i.e. via R&D), but by an objective valuation in the market for its products. Thus, small firms must first obtain credibility, recognition, and reputation in their product marketplace - a "track record" - before investors will judge that the firm has long-term value, or that future expenditures in product development will create value.

Logarithmic regression results for the smaller firms show that the value of the multiplicative factor is significantly greater than 1.0, indicating either that all explanatory factors have not been included, or that investors regard current expenditures as leading to future rather than present value. However, the variability in the data is quite large for these smaller firms, and factors may be firm-specific. As in the regression for Tobin's q, the R^2 of the fit was greater for the larger firms as compared to the smaller firms, indicating the greater variability in firm characteristics for smaller firms.

Firm size (number of employees)

Regression results for market value per employee for small vs large firms, where now firm size is measured by number of employees, parallel nearly exactly those for firm size as measured by total assets. Small firms are once again more variable than larger firms, but market value per employee depends significantly on advertising expenditures, vs sales measures for the larger firms. Thus, while a dollar in operating income increases firm value by nearly three times as much for large firms as for small firms, advertising expenditures increase firm value for smaller firms by more than 20 times their effect in larger firms.

Results are fairly consistent, at least in trend, for each of the different regression models, explanatory variables, and size measures. However, greater similarity in results was found using the expression for Tobin's q to describe firm value rather than this employee-specific valuation approach. This may be due to the fact that in addition to omission of explanatory variables describing industry technical characteristics, a deficiency common to both valuation approaches, the employee-specific model must now also consider factors particular to the market for technical and professional talent.

Asset intensive firms (Tobin's q)

One fundamental question in the valuation of intangible capital, phrased in a manner appropriate to the present analysis, is: For a firm whose market valuation consists primarily of intangible assets, how should spending for each employee be allocated so as to maximize value? To investigate this question, admittedly in a preliminary way, separate regression analyses were calculated for tangible asset-dependent firms (MV/TA < 1.25) and for intangible asset-dependent firms (MV/TA > 2.25).

Tangible asset-dependent firms act as a control sample in this analysis. As expected, the single most important explanatory variable describing market value is the value of tangible assets, with a coefficient equal to 1.00 in each of the regressions. While sales growth has some explanatory power, both the significance and value of all variables other than tangible assets are considerably reduced when compared to those values calculated for the data set as a whole. Indeed, spending on intangible assets (R&D, advertising) in these firms actually decreases firm value. In other industries, such a results might be interpreted to imply that the company's assets have fixed, intrinsic value, and hence, research monies are simply wasted as they have no effect. In these industries, the results must be regarded as a lack of confidence in the ability of these companies remain technologically competitive or to profitably develop new products.

By contrast, high MV/TA firms derive significant value from high levels of R&D spending per employee. In each model, the coefficient of R&D is highly significant, and for the linear models, the coefficient for R&D spending per employee is greater than for the regression on the entire data set. Advertising, sales growth and cash flow are all either insignificant or are less important than for the data set as a whole. For these high MV/TA firms, the implication is that knowledge capital is being valued. As indicated by the linear models, a firm will create 3 times as much value by R&D spending per employee than by a similar expenditure on a tangible asset. The fact that cash flows are discounted relative to the valuation placed on cash flow for the entire data set implies that the benefits from this R&D are not likely to be received until some time in the future. This is also suggested by an asset coefficient greater than 2 in the linear regressions and a multiplier greater than 3 in the logarithmic model, indicating that firm value is a multiple of current asset values. This provides support for this hypothesis, but also suggests that other explanatory factors may be relevant for these firms.

These results are intuitively satisfying for this industry. The computer and computer electronics industry has been characterized by rapid innovation and growth. One would expect that those firms which possess large amounts of intangible capital (high MV/TA) to have them in the form of technical know-how and other intellectual property. For such firms, employees will create maximal value when adding to that store of knowledge; the fact that the company already possesses large amounts of knowledge capital implies that it can incrementally assimilate additional R&D results. Clearly, a validation of this valuation approach would be a similar analysis in an industry where the sources of intangible capital are different: health care products, where distribution networks may be significant; or a consumer goods industry such as cosmetics or packaged foods, where advertising and brand name are the key factors.

Highly capitalized firms (market value per employee)

A fourth regression analysis specifically examines firms which, on a per employee basis, are highly capitalized (MV/employee > $200,000). As noted, a high per employee market capitalization indicates both the high value of employee effort *and* that such efforts are appropriable by the firm.

These results show that sales growth, advertising, and cash flow are at least as important for these firms as for the entire data set, but the value of R&D is nearly twice as important[1]. Compared to the entire industry data set, R&D is the single most important source of high market capitalization. Thus, this result suggests the not surprising observation that those firms which realize maximal value from each employee not only have effective research organizations which allow the organization to assimilate the knowledge gained, but also are skilled at marketing the resulting products. It is interesting to note that this capitalization derives primarily from intangible assets: the linear regression model indicates that spending on tangible assets increases market value by less than the value of the asset purchased.

When compared with the regression results for the entire data set, these results imply that beyond a certain per employee capitalization, diminishing returns set in. This is suggested by the intercept value in the linear model changing from a negative number ($\approx$ -30) to a large positive number ($\approx$ 100-150), indicating that the slope of the MV/employee curve is flattening; and also by the exponential factor of approximately 0.4 in the logarithmic model. However, the fit for this regression is considerably poorer than any of the other subsets, and so any conclusions may simply be artifactual. For example, the large intercept value on the linear model strongly suggests the possibility of excluded variables, as does the multiplicative factor of approximately 40 in the logarithmic model.

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[1]Due to the structure of the logarithmic regression model, the actual asset coefficients are the regression coefficients divided by the exponent β, which is the coefficient of log(TA/employee). For all other subsets of the data, the coefficient was sufficiently close to 1.0 that this correction has been ignored.

Tangible asset dependent firms (assets per employee)

As in the regression model based on Tobin's q, we examine tangible- and intangible-asset dependent firms based on the amount of total (tangible) assets per employee using the same stratification criteria as before.

Results for these this grouping of firms are again quite similar to those for a stratification based on firm size, either by total assets or by number of employees. In this employee-specific valuation model, the value and significance of the variables are more strongly defined than for the regression model based on Tobin's q. The most significant explanatory variables for firms with high amounts of tangible assets per employee are R&D, sales growth, and operating cash flow. Each of these factors are more important for these firms than for the data set as a whole, while advertising is insignificant as an explanatory variable. By contrast, the coefficient value for R&D in firms with lower amounts of tangible assets per employee is only one-half that for the more asset-dependent firms, and the value of advertising is nearly 6 times greater. However, these results are somewhat paradoxical: while sales growth contributes to value for these firms (although less than for the data set as a whole), the operating cash flow variable is significant and contributes *negatively* to firm value. One potential explanation could be that investors look to these firms to establish market presence and market power (hence the high value placed on advertising), and do not expect profits yet. This is a tenuous interpretation, for as noted earlier, there is a relatively heterogenous collection of firms in this grouping.

3. Market Valuation of the Firm and Unanticipated Returns

The previous analyses have examined the determinants of market value and have attempted to relate the firm's activities, on the aggregate level, to firm value. In this section we develop a valuation model that specifically examines *changes* in firm value and its relation to firm actions. In particular, the purpose of this model is to highlight *unanticipated* changes in firm value, due either to unanticipated firm performance or unanticipated returns on the firm's investments.

At any given point in time, a discounted cash flow analysis is used to compare actual firm performance in a subsequent time period year with the current expectation for firm prospects as given by the current market price. The ratio of the present value of actual future firm performance to the current market price represents the extent to which the firm exceeded or disappointed expectations during the time period studied.

In the computer and computer electronics industry that is being used to investigate these valuation methodologies, this degree of market mispricing can also be interpreted as describing the extent to which a firm was able to appropriate the productive effort of its employees. For example, if a firm consistently exceeds market expectations for its performance, the discounted value of its actual performance will always exceed its current market price. Since expectations of future performance (given by the market price) and the discount rate used to discount future cash flows are based on the same risk factors that apply to firms in similar businesses, the implication is that these firms are less risky than other similar firms. Sources of risk include market risk, technology risk, foreign competition, government legislation, etc. However, for these knowledge-dependent firms, one source of risk for all these firms is the inability to appropriate the efforts of key employees. For many industries, such risk would be firm-specific and unique, and hence not reflected in market value (for investors can always diversify to reduce or eliminate this risk). However, in this industry such risk must be regarded as one component of the total risk industry-wide. One investment that the company makes that is directly related to this "knowledge appropriability" risk is spending on R&D. R&D spending represents an expenditure to develop knowledge by its professional staff that the company as an entity will assimilate to a greater or lesser extent. If a company is better able to appropriate this knowledge, we would expect to see a greater degree of market mispricing, for the value that the firm would obtain from its R&D investment would exceed the value that the market would customarily attribute to such expenditures. Similar arguments can be made for advertising and market expenditures, pricing power, and the like.

Model Development

The value of a company is the net present value of the cash flows it produces from product sales, less all payments required to run the business: inventory, accounts payable and receivable, cash on hand, capital investment, etc. These cash flows are discounted at an "appropriate" rate that accounts for the risk incurred by this particular investment project. Thus, if MV_0 is the market value of the firm now (year 0) and NPV() is a net present value operator,

$$MV_0 = \sum_{i=1}^{\infty} NPV(FCF_i) = \sum_{i=1}^{n} NPV(FCF_i) + TV_n \tag{23}$$

where FCF_i is the free cash flow received in year i and TV_n is the terminal value - the net present value of the value of the firm from year n on. The net present value of a cash flow in year j is calculated at the compounded risk rate, where r_j is the discount rate for cash invested during year j:

$$NPV(FCF_j) = \frac{FCF_j}{(1 + r_0)(1 + r_1) \ldots (1 + r_{j-1})} \tag{24}$$

This model for valuation is typically used to evaluate potential investment projects ranging from the decision to enter a line of business to the decision to acquire another firm. The project is evaluated on its merits, and the cash that is produced is assumed available for whatever uses the investors desire.

In this study, we propose to use this model to compare the NPV of the firm, based on the cash flows it actually generated over a certain period of time, with the firm's market value at the start of that period. Therefore, this model will relate expectations with performance, and attempt to relate the degree of divergence to actions taken by the company. This will include investments in R&D and advertising, sales growth, and operating income. However, as presented, the model above is unsuitable for this analysis for several reasons.

Valuation Model: Error Sources

One source of error is due to the cash flows themselves and the assumptions as to the use to which they will be put. The valuation model assumes that each year these cash flows will be distributed to the investors. In fact, these companies are not highly leveraged and the dividend yield is modest. Most of the free cash flow - that in excess of capital needed to run the company and investment required to grow the company - is either held by the company or used for other investments and acquisitions. If these free cash flows are reinvested in the same business or a business of equal risk, then this valuation approach is applicable. However, if these cash flows are invested in investments and acquisitions with different risk attributes, the net risk of the business changes. These risk factors will be incorporated into the NPV of the company once they occur, since each year, the discount rate reflects the current risk. They will not be reflected in the company's present market value, because, although it incorporates the expected value of past investments, such investments in the coming year are not only unanticipated, they are specifically excluded from the model.

Another effect of reinvestment has to do with the terminal value (TV) of the company. If the terminal value is simply a projection of the current free cash flows at an expected growth rate, the model applies. However, as this is a retrospective study, looking at past firm performance, we can look to the market to provide a better estimate of terminal value. At year j, the best projection of firm performance in the future is already available: it is the market price. However, this market price includes the value of the free cash flows that were reinvested. Thus, if these free cash flows are used with a market estimate of terminal value, they will be double counted.

A third source of error is forecasting error: it is simply not reasonable to expect that current market value can accurately forecast performance, risk, discount rates, and other market factors in the later years of the time horizon. Although the later years' results are discounted, somewhat reducing the influence of earnings in these later years, this source of uncertainty cannot be eliminated in a multi-year model.

A fourth source of error relates to inflation expectations. If inflation is treated consistently, using the same expectations for inflation in the cash flows as are embodied in the discount rates, inflation is not relevant. However, any discrepancies in inflation expectations used in developing a market projection increase the measurement noise in the data sample. This noise is greater when inflation is higher and the longer the time horizon for the multi-year model.

Finally, there is simply the problem of data consistency. Market value is measured at a point in time, while NPV takes into account multiple years of performance. In effect, a noisy point value is being compared with an averaged value. If observations from the data set are not obscured by this effect, they will certainly be suspect as subject to point fluctuations. Use of a multi-period time horizon also reduces the data set, as all observations from the horizon of the NPV analysis are aggregated into a single observation.

Model Modifications

Each of these sources of error can be addressed and either eliminated or reduced by the following modifications to the valuation model. First, we reduce the planning horizon to one year. This resolves most of the forecasting errors that derived from longer time periods. Any forecasting errors are now due to uncertainty in only the coming year. Not only is this the only source of forecast error, it should also be the smallest. Note that this also allows us to evaluate the market's reaction to firm performance every year, and so eliminates problems with reduction of the data set. Second, market value is taken as the best estimate of terminal value. In order to deal with double counting, the free cash flows only include cash actually paid to the firm's investors, both debt and equity holders.

The modified model is as follows. At the end of year i, the best estimate of the net present value of the firm is MV_i. This represents the NPV all cash flows to be received by the company's owners in the future. Now, at the end of the next year, year (i+1), we actually observe the firm's performance (FCF_{i+1}) and revise our estimate of the company's value, obtaining MV_{i+1}. Had we known of the firm's actual performance at the beginning of the year, then, assuming risk was constant over the year, we would have estimated the value of the company, NPV_i, as

$$NPV_i = \frac{FCF_{i+1} + MV_{i+1}}{1 + r_i} \tag{25}$$

Then, the degree of mispricing, the extent to which expectations were not met or were exceeded, is given by

$$mispricing \equiv \frac{NPV_i}{MV_i} \tag{26}$$

This can be interpreted as representing the degree of mispricing due to the ability of the firm to appropriate earnings on its investments over the year. Note that the free cash flows can only include the cash flows received or disbursed, for the next year's market value provides a risk-adjusted estimate of all the cash flow put to other uses by the company. Therefore, if I_{i+1} and D_{i+1} represent, respectively, the interest and dividends paid to debt- and equity holders, then mispricing is

$$mispricing = \frac{NPV_i}{MV_i} = \frac{I_{i+1} + D_{i+1} + MV_{i+1}}{MV_i \ (1 + r_i)} \tag{27}$$

In the present formulation, additional debt or equity invested during the year is included in the value of the firm at the end of the year, MV_{i+1}. To be rigorous, market value should be adjusted for all these non-operating transactions, which include acquisitions and spin-offs, debt issues and retirements, stock issues, buybacks, splits, exercise of options and warrants, debt/equity conversions, etc. However, the mean value of firm mispricing in this industry sample was not significantly different from 1.0. This indicates that these effects are not likely to skew the results found. although it is possible that they introduce sufficient measurement noise to obscure valid relationships. Nonetheless, in this preliminary analysis these transactions are ignored due to their complexity and the lack of complete data.

This valuation model can be expressed in a form suitable for regression analysis on the industry data sample. With perfect expectations, the degree of market mispricing is zero, and NPV/MV is equal to one. Presumably, mispricing results from unanticipated gains (or losses) in investments made by the firm. In the context of this study, these investments are in knowledge assets, brand name, and in market power and profitability. If V_R represents the unanticipated value of a knowledge investment, V_A the value of a brand name investment, and f(OCF) and g($\dot{S}$) account for market power and profitability, then NPV is given as

$$NPV = MV + V_R + V_A + f(OCF) + g(\dot{S}) \tag{28}$$

or, expressed in a form suitable for regression,

$$mispricing = \frac{NPV}{MV} = 1 + \frac{V_R}{MV} + \frac{V_A}{MV} + \frac{f(OCF)}{MV} + \frac{g(\dot{S})}{MV} \tag{29}$$

Alternatively, mispricing may include scale effects,

$$NPV = \alpha\left(MV + V_R + V_A + f(OCF) + g(\dot{S}) \right)^{\beta} \tag{30}$$

where α is a multiplicative factor and ß is the scale factor. Taking logarithms of both sides, NPV is expressed as

$$\log(NPV) = \log(\alpha) + \beta \log(MV) + \beta \frac{V_R}{MV} + \beta \frac{V_A}{MV} + \beta \frac{f(OCF)}{MV} + \beta \frac{g(\dot{S})}{MV} \tag{31}$$

Model Implementation

The valuation model described by eq. 27 is used as the basis for a regression model that will be applied to the COMPUSTAT data sample as follows.

Market value is taken as the market value of common stock and the book value of long-term debt. Interest and common dividends are as reported. As before, preferred stock is ignored, both its value and dividends. Similar assumptions are used for knowledge, brand name, and market power variables, namely knowledge assets (V_R) are approximated as linearly related to the current level of R&D expenditures; brand-name assets (V_A) are approximated by the current level of advertising expense; the variable representing cash flow is operating income before depreciation (OIBD); and sales growth is calculated for any given year as a central difference.

The discount rate is calculated separately each year using the Capital Asset Pricing Model (CAPM). In this model, the discount rate is determined by adding a risk premium to the current risk-free rate of return to account for market risk. Idiosyncratic risk is specifically ignored, since it is assumed that investors can diversify to eliminate firm-specific risk. Market risk is measured by ß, the covariance of the asset's return with the market return. Thus, for a given firm, its required rate of return (r_F) is

$$r_F = r_f + \beta_F(r_m - r_f) \tag{32}$$

where r_f is the risk free rate of return appropriate to a project of this duration, β_F represents the firm's risk relative to the market, and $(r_m - r_f)$ represents the market's excess return over the risk free rate. After Brealey and Myers (1991), the market excess return is taken as 8.4%. The risk-free rate of return is taken as the 3-year (nominal) Treasury rate, as obtained from the *U.S. Statistical Abstract* (1992) for each of the years of the sample:

year	3-year Treasury rate (%)
1981	11.51
1982	12.93
1983	10.45
1984	11.92
1985	9.64
1986	7.06
1987	7.68
1988	8.26
1989	8.55

According to the CAPM, the discount rate depends on firm risk given by β_F. In general, β_F of the firm is not available and must be calculated from the equity β_E by "unlevering," assuming the debt is risk-free,

$$\beta_F = \frac{\beta_E}{(1 + \frac{D}{E})} \tag{33}$$

where D/E is the firm's debt-equity ratio. Other models which do not assume riskless debt could also be used. However, these require knowledge of the firm's borrowing rate.

Finally, the market risk of the firm's equity (β_E) must be determined. Equity betas are calculated and published by investment services (Merrill Lynch, *Security Risk Evaluation*, annually) and can also be calculated from actual firm performance, using on-line data such as that on the CRSP database. However, for this study, determining equity β from a published beta compilation would require looking up 195 entries for 9 years, a tedious task. For the larger firms, β_E is directly available from the CRSP database, but for smaller firms, its value must be calculated individually. For this preliminary, methodological investigation, such effort is not warranted and a much simpler approach has been taken. The equity β_E used in this preliminary analysis is a gross approximation: equity β for different industries in 1993 were found from the *Value Line Industry Review* (1993) and used to determine an average β_E for the entire data sample for all the years of the study. The different industry betas are:

Industry group betas

computers and peripherals	1.22
computer software	1.29
semiconductors	1.30
average β_E	1.27

Thus, the implicit assumption in this simplified analysis is 1) that market risk does not change over the period of the study, and 2) that all firms in the industry bear the same market risk. The effect of the first assumption is likely minimal, since industry risk changes only gradually and since this analysis only compares firms in the same industry.

However, the second assumption - that all firms in the industry bear the same market risk - can skew the results found. Since all firms are assumed to bear the same market risk, riskier firms will be preferentially favorably treated, since their risky cash flows will be discounted at an artificially low rate. This will amplify the extent of market mispricing observed for these firms, and falsely indicate that they receive large, unexpected returns from their investments when the actual risk-adjusted return may simply be at, or even below, the market return. If these risky investments are correlated with the variables used to describe market mispricing (i.e. a firm may invest in large amounts of extremely speculative R&D), then the results of the regression model would falsely value the risky investment. The variable representing the risky investment would have strong explanatory power, and other variables would be reduced in importance. The risky investment would thus be interpreted as a source of unexpected value when on a risk-adjusted basis it may simply provide an expected return, and other investments would correspondingly be viewed as providing less value.

For example, such arguments may be relevant for smaller firms. Empirical evidence shows that market returns and price variability are greater for small firm equities (Brealey and Myers, 1991). This may be due to greater market risk. Alternatively, a lack of information or simply measurement error due to volatility may make it difficult to discern the true value of the firm. This can lead investors, who are risk-averse, to imperfectly diversify and thus inflate estimates of market risk due to these firms' greater idiosyncratic risk.

Results and Discussion

Two regression models were applied to the computer and computer electronics industry data. The models are based on eqs. 29 and 31, and use OIBD as the relevant measure of cash flow. These models are as follows:

Linear Model:

$$mispricing = \frac{NPV}{MV} = \beta_0 + \beta_1 \frac{R}{MV} + \beta_2 \frac{A}{MV} + \beta_3 \frac{OIBD}{MV} + \beta_4 \dot{S} \qquad (34)$$

Logarithmic Model:

$$\log(NPV) = \log(\alpha) + \beta \log(MV) + \beta_1 \frac{R}{MV} + \beta_2 \frac{A}{MV} + \beta_3 \frac{OIBD}{MV} + \beta_4 \dot{S} \qquad (35)$$

An initial correlation study showed that spending in both the current year ($year_i$) and the next year ($year_{i+1}$) correlated with firm mispricing. Thus, both sets of spending are included as possible explanatory variables, i.e.

$$mispricing_t = \frac{NPV_t}{MV_t} = \ldots + \beta_{1,t}\frac{R_t}{MV_t} + \beta_{1,t+1}\frac{R_{t+1}}{MV_t} + \ldots \qquad (36)$$

This formulation immediately suggests that collinearity problems. However, several regressions are described in Appendix 2 that do not include the current year's R&D as an explanatory variable. The values and significance of the remaining coefficients were not substantially different from those of the same variables in the more complete model.

Table 5.9 presents results for the linear regression model, and Table 5.10 presents the results for the logarithmic model. As before, results are stratified according to the five criteria used previously:

<u>firm size (total assets)</u>:
- large firms: book assets > \$100M
- small firms: book assets < \$50M

<u>firm size (number of employees)</u>:
- large firms: greater than 1000 employees
- small firms: less than 300 employees

<u>asset intensive firms (Tobin's q)</u>:
- tangible asset-intensive firms: MV/TA < 1.25
- intangible asset-intensive firms: MV/TA > 2.25

<u>highly capitalized firms (market value per employee)</u>:
- firms highly capitalized per employee: MV/employee > \$200,000

<u>tangible-asset dependent firms (assets per employee)</u>:
- firms dependent on tangible assets: assets per employee > \$100,000
- firms less dependent on tangible assets: assets per employee < \$60,000

Table 5.9 Linear regression for mispricing of firm market value

			Intercept	R&D/MVf		A/MVf		OIBD/MVf		sales growth
data subset	R^2	n		year i	year i+1	year i	year i+1	year i	year i+1	
entire data set	0.185	542	0.791	-1.266	2.051	0.343	-0.978	-0.336	1.329	0.086
			(21.54)	(-2.81)	(4.13)	(0.22)	(-0.62)	(-2.43)	(9.21)	(3.21)
total assets < $50M	0.114	245	0.900	-1.040	1.924	-1.741	-0.360	-0.456	0.935	0.060
			(15.82)	(-1.75)	(2.97)	(-0.62)	(-0.12)	(-2.49)	(4.70)	(1.88)
total assets > $100M	0.439	196	0.447	0.449	0.129	2.079	-2.174	0.655	2.408	0.392
			(6.83)	(0.34)	(0.09)	(0.82)	(-0.89)	(1.79)	(7.93)	(3.44)
< 300 employees	0.119	149	0.945	-2.470	3.749	-1.048	-1.884	-1.555	1.597	0.048
			(11.50)	(-2.76)	(3.64)	(-0.26)	(-0.46)	(-3.01)	(4.40)	(1.08)
> 1000 employees	0.363	227	0.480	0.693	-0.267	1.804	-1.919	0.545	2.375	0.381
			(7.83)	(0.70)	(-0.23)	(0.68)	(-0.76)	(1.95)	(8.06)	(3.61)
MV/TA < 1.25	0.203	155	0.749	-0.039	1.123	0.323	-1.363	0.303	0.665	0.549
			(10.58)	(-0.04)	(1.07)	(0.15)	(-0.61)	(1.17)	(3.59)	(2.50)
MV/TA > 2.25	0.205	192	0.842	-5.905	6.741	-3.549	3.041	-2.719	2.300	0.020
			(11.00)	(-2.60)	(3.47)	(-0.70)	(0.79)	(-3.92)	(4.59)	(0.60)

(t-statistics in parentheses)

Table 5.9 (continued) Linear regression for mispricing of firm market value

data subset	R^2	n	Intercept	R&D/MVf year i	R&D/MVf year i+1	A/MVf year i	A/MVf year i+1	OIBD/MVf year i	OIBD/MVf year i+1	sales growth
MV/employee > $200K	0.465	160	0.656	-7.423	7.216	-4.352	4.415	-3.431	4.917	0.052
			(8.03)	(-3.19)	(3.68)	(-1.14)	(-1.14)	(-4.84)	(9.24)	(1.55)
assets/employee < $60K	0.147	174	0.872	0.026	0.343	0.677	-2.651	-0.383	1.186	0.043
			(15.63)	(0.02)	(0.32)	(0.23)	(-0.96)	(-2.66)	(5.05)	(1.17)
assets/employee > $100K	0.424	209	0.597	-2.684	2.936	1.976	-1.782	0.122	2.868	0.085
			(9.63)	(-2.17)	(2.15)	(0.98)	(-0.88)	(0.29)	(9.09)	(2.47)

(t-statistics in parentheses)

Table 5.10 Logarithmic regression for mispricing of firm market value

data subset	R^2	n	Intercept	log(MVf)	R&D/MVf year i	R&D/MVf year i+1	A/MVf year i	A/MVf year i+1	OIBD/MVf year i	OIBD/MVf year i+1	sales growth
entire data set	0.934	542	-0.064	0.966	-0.343	0.460	-0.103	0.062	-0.099	0.610	0.037
			(-2.31)	(81.12)	(-1.96)	(2.38)	(-0.17)	(0.10)	(-1.85)	(10.81)	(3.60)
total assets < $50M	0.769	245	0.129	0.836	-0.343	0.620	-1.268	0.180	-0.087	0.505	0.041
			(2.16)	(21.87)	(-1.52)	(2.53)	(-1.19)	(0.17)	(-1.27)	(6.69)	(3.34)
total assets > $100M	0.938	196	-0.177	0.986	0.236	-0.430	0.474	-0.426	0.022	1.038	0.154
			(-2.95)	(51.15)	(0.47)	(-0.78)	(0.49)	(-0.46)	(0.16)	(8.92)	(3.54)
< 300 employees	0.798	149	0.155	0.836	-0.894	0.938	-0.392	-0.191	-0.521	0.746	0.038
			(2.05)	(17.91)	(-2.67)	(2.51)	(-0.26)	(-0.13)	(-2.74)	(5.54)	(2.34)
> 1000 employees	0.944	227	-0.180	0.990	0.423	-0.637	0.386	-0.351	0.048	1.006	0.154
			(-3.58)	(58.84)	(1.08)	(-1.41)	(0.37)	(-0.35)	(0.44)	(8.70)	(3.70)
MV/TA < 1.25	0.935	155	0.039	0.919	-0.031	0.212	-0.303	-0.072	-0.001	0.314	0.221
			(0.89)	(43.83)	(-0.09)	(0.59)	(-0.42)	(-0.09)	(-0.01)	(4.91)	(2.96)
MV/TA > 2.25	0.923	192	-0.138	0.992	-1.901	2.133	-1.716	1.267	-0.807	1.122	0.020
			(-2.39)	(40.37)	(-2.12)	(2.78)	(-0.85)	(0.83)	(-2.88)	(5.61)	(1.47)

(t-statistics in parentheses)

Table 5.10 (continued) Logarithmic regression for mispricing of firm market value

data subset	R^2	n	Intercept	log(MVf)	R&D/MVf year i	R&D/MVf year i+1	A/MVf year i	A/MVf year i+1	OIBD/MVf year i	OIBD/MVf year i+1	sales growth
MV/employee > $200K	0.932	160	-0.141	0.969	-1.999	1.803	-1.701	2.176	-1.041	1.955	0.031
			(-2.34)	(39.52)	(-2.01)	(2.15)	(-1.04)	(-1.04)	(-3.37)	(8.61)	(2.16)
assets/employee < $60K	0.921	174	-0.003	0.937	0.221	-0.147	0.017	-0.781	-0.080	0.641	0.024
			(-0.07)	(40.07)	(0.43)	(-0.33)	(0.01)	(-0.66)	(-1.30)	(6.27)	(1.55)
assets/employee > $100K	0.942	209	-0.141	0.982	-0.837	0.655	0.516	-0.043	-0.186	1.153	0.036
			(-3.01)	(53.02)	(-1.72)	(1.24)	(0.66)	(-0.05)	(-1.13)	(9.41)	(2.74)

(t-statistics in parentheses)

Complete data set

As seen from Tables 5.9 and 5.10, the linear model has relatively poor explanatory power when compared to the logarithmic model. The fact that both the multiplicative and scale factors (α and β in the logarithmic model) are close to 1.0 suggest that the logarithmic model fits the data relatively well, and the poor fit produced by the linear model indicates that the data has wide variation. This is not completely unexpected, for the entire data set uses the same risk beta, which is admittedly a gross simplification. Therefore, this model may not be as clear as the previous two models in defining relationships between parameters, but trends should nonetheless be evident. In the discussion to follow, interpretations will be based primarily on the logarithmic model, due to its greater explanatory power.

Before discussing results, some interpretation may be required. In general, if a given explanatory variable (e.g. R&D) has a consistent effect on firm value, the signs of the coefficients for the current and next year's value will change. A *positive* coefficient for the next year's parameter indicates a positive contribution to firm value, as does a *negative* coefficient for the current year's parameter. For example, imagine that R&D always increases firm value. Then, since the next year's spending ($R\&D_{i+1}$) cannot affect the current year's market value (MV_i), only NPV_i will increase and mispricing will increase, resulting in a positive coefficient for $R\&D_{i+1}$. By the same reasoning, the current year's $R\&D_i$ must act to increase the current year's market price (MV_i) and, perhaps to a lesser extent, the next year's market price (MV_{i+1} and NPV_i). Thus, the net effect will be to reduce mispricing. We would then expect the coefficient for $R\&D_i$ to be negative, although its value and significance may be less than the coefficient for $R\&D_{i+1}$ due to its actions on both MV_i and NPV_i.

For the data set as a whole, R&D, sales growth and operating cash flow are significant explanatory variables and each contributes positively to firm value. The current year's cash flow and R&D contribute positively to firm value, but the value of the coefficient and its significance is less, in accordance with the reasoning presented above. Advertising appears to be insignificant in explaining changes in value. However, note that this model is designed to illustrate unanticipated - or unappropriated - changes in firm value. Thus, the effects of investments in advertising (a proxy for brand-name reputation, marketplace credibility, etc.) are apparently well anticipated by investors, whereas the return on R&D investments cannot always be predicted.

Firm size (total assets)

The results shown in Table 5.10 are interesting, for they indicate that smaller firms (<$50M in total assets) have positive, significant returns on R&D, while larger firms (>$100M in assets) have slightly negative, although statistically insignificant, unexpected returns on R&D. This may be interpreted to indicate diminishing returns, or only marginally productive R&D in larger firms compared to smaller firms. Such an interpretation is consistent with the results of Scherer (1989), who finds decreasing returns to patents as firm size increases. It may also indicate the market's unwillingness to fully value R&D in smaller companies, either due to its greater risk or due to uncertainty as to whether the company will be able to achieve the full benefits of the R&D (i.e. whether it can appropriate this knowledge). For neither group of firms is advertising significant, although there is some suggestion, in accordance with the previous results, that advertising benefits smaller companies, while larger companies may achieve less-then-hoped returns on advertising spending. Operating cash flow and sales growth contribute positively to both sets of firms, although this variable is more significant for larger vs smaller firms, in accordance with the previous results.

Firm size (number of employees)

Regression results for firm groupings based on firm size as measured by number of employees closely parallel those for firm size as measured by total assets. The observations for R&D in small vs large firms - diminishing returns in small vs large firms, positive unanticipated returns to R&D in smaller firms - are more strongly supported by this segmentation of the data, while evidence to the ability of firms to gain unexpected returns from advertising has less statistical significance. Operating cash flow and sales growth are equally important and significant for this grouping of firms.

In particular, the current year's R&D is statistically significant and contributes to reducing market mispricing. Thus, its effect is primarily to increase market value in the year in which the expenditure was made, implying a short time horizon for R&D in small firms. This may indicate that the R&D itself will rapidly result in revenues to the company (certainly a reasonable inference in the software industry); however it may also simply be an early indication of the likely results of the research and the ability of the company to profit from it.

Asset intensive firms (Tobin's q)

As expected, firms whose market value depends primarily on tangible assets show no significant evidence of any unanticipated returns to intangible investment such as R&D and advertising. Coefficient values are small and statistically insignificant. By contrast, high MV/TA firms have large coefficients for R&D and advertising, indicating positive unexpected returns from these investments. High MV/TA firms are able to achieve high returns from R&D. Coefficient values are quite large, by factors of 5 - 20 as compared to the entire data sample. However, while the returns to R&D are significant and positive, the evidence is not statistically significant for positive unexpected returns to investments in other intangible capital stocks, as indicated by the values for advertising.

For both sets of firms, operating cash flow contributes positively to firm value. However, the coefficient values for low MV/TA firms are smaller and less significant than for the data sample as a whole, and the current year's earnings are unrelated to firm value. By contrast, the coefficient values for high MV/TA firms are several times larger than the low MV/TA firms or the entire data sample, and both current and next year earnings are statistically significant. These findings can be interpreted by considering the predictability of earnings in these firms. In low

MV/TA firms, value depends primarily on tangible assets. Hence, the uncertainty of these firms' earnings is low, and they can be accurately forecasted reasonably well in advance. Therefore, any change in earnings and cash low is anticipated well in advance and incorporated into the market price, and the current earnings have little effect on firm value. By contrast, high MV/TA firms are dependent on intangible assets, and earnings are not well predicted in advance. Consequently, market value is volatile and very sensitive to the level of earnings, and returns on unanticipated earnings are high. For low MV/TA firms, sales growth has explanatory power, perhaps indicating the market's view that past performance is a good indicator of the future, while sales growth is not significant for high MV/TA firms, indicating the opposite for these firms.

As noted previously, in this research-intensive industry these results for low MV/TA firms support an alternate explanation. The insignificance of R&D to firm mispricing can be regarded as a lack of confidence in the ability of these companies to remain technologically competitive, while the low coefficient values for current cash flows indicate a general pessimism for the long-term prospects of these firms. However, the importance of sales growth to market value must then be interpreted as predicting a change in fortune.

Highly capitalized firms (market value per employee)

We again examine firms which are highly capitalized per employee (MV/employee > $200,000). Results are very similar to those for firms that are highly dependant on intangible assets (high MV/TA). There are very large, positive and significant returns to R&D, and a suggestion, although statistically insignificant, of positive returns to advertising. Unanticipated changes in market power or profitability, here approximated by operating cash flow, also contribute significantly to firm value. These results indicate the market's willingness to immediately value investments in intangible assets, presumably due to confidence that the firm will be able to appropriate the benefit form these investments. As noted, the high value placed on both R&D and operating cash flow indicates the market's confidence in the firm's ability to both develop products and market them effectively.

Tangible asset dependent firms (assets per employee)

Finally, we again examine tangible asset-dependent firms based on the amount of total (tangible) assets per employee, using the same stratification criteria as before (<$60K and >$100K total assets per employee).

For firms with few tangible assets per employee, neither R&D or advertising have significant explanatory power, and operating cash flow is the principal determinant of firm mispricing or unexpected returns. This contrasts with firms having large amounts of tangible assets per employee, where R&D generates significant positive unexpected returns. Operating income is now a more important and more highly significant explanatory factor, and sales growth is also significant.

These findings suggest that for firms with few tangible assets, the market can base value only on expectations of earnings, hence only changes in earnings correlate positively with changes in expectations of firm value. R&D is not appropriable, and provides value only to the extent that it leads to a demonstrable, realizable return, e.g. via earnings. For firms with greater amounts of tangible assets, however, the R&D knowledge is presumably linked to the asset base, and so is more readily appropriated by the firm. Therefore, not only do R&D expenditures lead to greater returns to the firm's owners, but the greater confidence in the appropriability of the earnings generated by the R&D (due to its link with the asset base) results in greater value being placed on those earnings and on sales growth. The enhanced prospects for the firm that are created by the R&D efforts of its employees are assimilated into the firm, whereas for firms with a smaller (per employee) asset base, such knowledge necessarily remains with individuals, and is appropriated by the firm only to the extent to which the firm can negotiate with the individual employees. Thus, the confidence in the realization of those eventual earnings is reduced, and the returns are less.

4. Market Valuation of Firm Equity and Unanticipated Returns

The previous valuation model related market mispricing to firm performance in an attempt to relate unanticipated changes in firm value to firm actions. Results were somewhat ambiguous, perhaps due to some of the assumptions regarding the discount rate and model implementation, as noted. However, the structure of the model itself may have obscured significant relationships. For firms not in financial distress, debt is nearly risk-free. Effectively, all of the market risk is borne by the equity holders, and all excess returns are received by them. This study is primarily concerned with the returns to risky investments. These returns will be received by the equity holders, the owners of the firm. Therefore, a different and perhaps more sensitive measure of market mispricing should examine mispricing in the firm equity value. In reasoning identical to the previous model, we argue that the ratio of the present value of actual equity performance to the current market price represents the extent to which the firm exceeded or disappointed expectations during the time period studied, and that this degree of market mispricing can be interpreted as describing the extent to which a firm was able to appropriate the productive effort of its employees.

Model Development

In contrast to the previous model, market mispricing now represents the discounted present value of payments received by the firm's equity holders. In a development parallel for mispricing of total firm value, we find, on a year-to-year basis,

$$equity\ mispricing = \frac{NPV_{e,i}}{MV_{e,i}} = \frac{D_{i+1} + MV_{e,i+1}}{MV_{e,i}\ (1 + r_t)} \qquad (37)$$

where D_{i+1} represents dividends paid to equity holders and the subscript e refers to equity.

Again, this valuation model can be expressed in a form suitable for regression analysis on the industry data sample, leading to

$$equity\ mispricing = \frac{NPV_e}{MV_e} = 1 + \frac{V_R}{MV_e} + \frac{V_A}{MV_e} + \frac{f(OCF)}{MV_e} + \frac{g(\dot{S})}{MV_e} \qquad (38)$$

Alternatively, in logarithmic form,

$$\log(NPV_e) = \log(\alpha) + \beta \log(MV_e) + \beta \frac{V_R}{MV_e} + \beta \frac{V_A}{MV_e} + \beta \frac{f(OCF)}{MV_e} + \beta \frac{g(\dot{S})}{MV_e} \quad (39)$$

Model Implementation

The valuation model described by eq. 37 is used as the basis for a regression model in exactly the same manner as for firm mispricing, and with the same assumptions. The only differences are now that market value is taken solely as the market value of common stock, only common dividends are included, and the discount rate is calculated separately each year using the CAPM for equity. There is no unlevering as was required to find the asset beta. As before, the equity β_E used is the average β_E for the industries of the data sampie for all the years of the study. Thus, the same assumptions hold: that risk does not change over the period of the study, and that all firms in the industry bear the same market risk. As in the firm mispricing model, a rigorous development should also take into account all non-operating financial transactions of the firm. However, equity mispricing for the entire industry sample was not significantly different from 1.0, which suggests that the main effect of this approximation is to increase measurement uncertainty. Thus, for simplicity, these additional transactions are also ignored in this equity mispricing model.

Results and Discussion

The two regression models used appear as below. Each use OIBD as the relevant measure of cash flow.

Linear Model:

$$equity\ mispricing = \frac{NPV_e}{MV_e} = \beta_0 + \beta_1 \frac{R}{MV_e} + \beta_2 \frac{A}{MV_e} + \beta_3 \frac{OIBD}{MV_e} + \beta_4 \dot{S} \quad (40)$$

Logarithmic Model:

$$\log(NPV_e) = \log(\alpha) + \beta \log(MV_e) + \beta_1 \frac{R}{MV_e} + \beta_2 \frac{A}{MV_e} + \beta_3 \frac{OIBD}{MV_e} + \beta_4 \dot{S} \quad (41)$$

Again, investments in both the current year ($year_i$) and the next year ($year_{i+1}$) are included as possible explanatory variables. Table 5.11 presents results for the linear regression model, and Table 5.12 presents the results for the logarithmic model. Results are stratified according to the first four criteria used previously: firm size (total assets and employees), MV/TA, and highly capitalized firms.

As seen by comparing Tables 5.9 and 5.11, and Tables 5.10 and 5.12, results for firm vs equity mispricing are nearly identical, although less pronounced and less significant for the equity-only model as compared to the entire firm model. This is true for all subsets of the data and all variables, with two exceptions. First, for small firms, measured either by total assets or number of employees, advertising now contributes positively to firm value. Thus, these small firms are able to effectively create value by developing recognition and reputation. The second exception is for firms highly capitalized on a per employee basis, where advertising now also contributes significantly and positively to firm value. Each of these findings is consistent with and supports the results of the first two valuation models. Conversely, the consistency of results provides support for the validity of these market mispricing models.

Table 5.11 Linear regression for mispricing of firm's equity market value

data subset	R^2	n	Intercept	R&D/MVe		A/MVe		OIBD/MVe		sales growth
				year i	year i+1	year i	year i+1	year i	year i+1	
entire data set	0.101	542	0.805	-0.749	1.207	-1.159	0.495	-0.126	0.808	0.088
			(21.29)	(-1.75)	(2.55)	(-0.83)	(0.35)	(-1.09)	(6.39)	(3.10)
total assets < $50M	0.045	245	0.874	-0.149	0.951	-3.278	1.424	0.007	0.586	0.068
			(13.76)	(-0.24)	(1.45)	(-1.25)	(0.52)	(0.04)	(3.02)	(1.93)
total assets > $100M	0.314	196	0.614	-1.343	1.258	1.880	-1.919	-0.185	1.513	0.368
			(10.50)	(-1.44)	(1.16)	(0.94)	(-1.00)	(-0.91)	(7.55)	(3.53)
< 300 employees	0.119	149	0.919	-2.236	4.036	-4.052	0.459	-1.440	1.293	0.050
			(10.57)	(-2.59)	(3.94)	(-1.20)	(0.13)	(-3.03)	(3.84)	(1.05)
> 1000 employees	0.202	227	0.657	-0.532	0.584	1.586	-1.768	-0.120	1.277	0.356
			(10.82)	(-0.65)	(0.61)	(0.65)	(-0.76)	(-0.64)	(6.09)	(3.27)
MV/TA < 1.25	0.132	155	0.841	-0.355	0.700	0.257	-1.045	-0.212	0.533	0.461
			(11.90)	(-0.49)	(0.90)	(0.16)	(-0.61)	(-1.23)	(3.65)	(2.14)
MV/TA > 2.25	0.147	192	0.871	-4.727	5.931	-2.141	2.391	-2.498	1.463	0.021
			(10.98)	(-2.19)	(3.13)	(-0.42)	(0.60)	(-3.83)	(3.09)	(0.58)
MV/employee > $200K	0.410	160	0.603	-6.382	6.976	-8.793	8.822	-2.347	3.914	0.055
			(7.04)	(-2.67)	(3.45)	(-2.66)	(-2.66)	(-3.68)	(8.05)	(1.51)

(t-statistics in parentheses)

Table 5.12 Logarithmic regression for mispricing of firm's equity market value

data subset	R^2	n	Intercept	log(MVe)	R&D/MVe year i	R&D/MVe year i+1	A/MVe year i	A/MVe year i+1	OIBD/MVe year i	OIBD/MVe year i+1	sales growth
entire data set	0.920	542	-0.084	0.966	-0.158	0.233	-0.727	0.595	-0.017	0.453	0.041
			(-2.83)	(73.13)	(-0.90)	(1.19)	(-1.26)	(1.02)	(-0.36)	(8.63)	(3.54)
total assets < $50M	0.745	245	0.067	0.857	0.019	0.243	-2.052	1.207	0.062	0.373	0.045
			(1.06)	(21.34)	(0.08)	(0.97)	(-2.03)	(1.16)	(0.94)	(5.04)	(3.27)
total assets > $100M	0.930	196	-0.257	1.019	-0.163	-0.070	0.750	-0.733	-0.095	0.753	0.175
			(-3.91)	(46.89)	(-0.39)	(-0.14)	(0.83)	(-0.84)	(-1.03)	(8.29)	(3.70)
< 300 employees	0.778	149	0.136	0.831	-0.769	1.044	-1.612	0.546	-0.473	0.657	0.039
			(1.74)	(17.20)	(-2.42)	(2.85)	(-1.31)	(0.43)	(-2.75)	(5.39)	(2.26)
> 1000 employees	0.930	227	-0.200	1.004	0.036	-0.214	0.604	-0.681	-0.073	0.660	0.160
			(-3.53)	(51.33)	(0.10)	(-0.50)	(0.56)	(-0.65)	(-0.86)	(7.01)	(3.25)
MV/TA < 1.25	0.894	155	0.070	0.876	-0.032	0.142	-0.124	-0.250	-0.058	0.325	0.178
			(1.46)	(31.82)	(-0.11)	(0.45)	(-0.18)	(-0.36)	(-0.81)	(5.38)	(2.04)
MV/TA > 2.25	0.915	192	-0.170	1.004	-1.694	2.065	-1.170	0.981	-0.740	0.884	0.021
			(-2.80)	(38.99)	(-1.96)	(2.73)	(-0.57)	(0.62)	(-2.79)	(4.63)	(1.52)
MV/employee > $200K	0.924	160	-0.160	0.962	-1.581	1.846	-2.887	3.519	-0.709	1.634	0.031
			(-2.53)	(36.80)	(-1.54)	(2.13)	(-2.04)	(-2.04)	(-2.55)	(7.83)	(1.98)

(t-statistics in parentheses)

5. Potential sources of error

Sources of error that may change the results reported here include data insufficiency, missing explanatory variables, and methodological inadequacies.

Missing data

Missing data reduced the data sample by more than 60%. This high figure is somewhat misleading, for many companies listed in the COMPUSTAT database in this industry were founded in the 1981-1989 period and obviously no information is available prior to public filing. Nonetheless, as described in Appendix 1, approximately 30-40% of companies had missing or combined data items (identified by special COMPUSTAT data codes) for critical items such as sales, R&D, and advertising that restricted their inclusion into the analysis. Even in cases where data is included, the values bring into question the reliability of the entire data sample. For example, over the study period, Tandy reported $0 R&D; Silicon Graphics reported $0 advertising.

Missing explanatory variables

Missing explanatory variables have also been discussed in the text. Potential variables that may be significant for inclusion into the analysis depend on the model being studied and the questions being asked. These missing variables may describe technical factors (number of patents or licensing agreements), market factors (market share or share growth), employee specific factors (average tenure, level of training), or financial (firm-specific market risk). In general, the failure to include these factors would be expected to lead to reductions in explanatory power of the model, but would not be expected to seriously alter the interpretations, except for one case: the failure to properly account for firm risk.

As described in the text, use of an industry average market risk ß in the market mispricing regression models most likely has led to a skewing of results and blurring of distinctions of the factors which lead to creation of value and exceptional returns for firm owners. Use of the industry average ß preferentially advantages risky firms by undercorrecting for their market risk, and so artificially inflates the unexpected returns achieved by these firms. If these firms' risk is due to investments which are correlated with the explanatory variables in our models (in this industry, for example, R&D can be a source of value as well as a risky investment), this effect would be to elevate the significance and explanatory power of these investments while diminishing the significance of other variables which, on a risk-adjusted basis, might truly be a source of exceptional value.

In addition to the approximations for the discount rate and individual market risk, the market mispricing model also used simplifying assumptions in accounting for non-operating financial transactions between the firm and its owners, creditors, and other firms. Lacking complete data as to the magnitude and prevalence of these transactions, it is certain that at a minimum the measurement error in the data sample has been increased, leading to a reduction in the explanatory power of each of the market mispricing models.

Methodological errors

Sources of methodological error can be improper explanatory models or statistical errors due to the improper application of regression methods. The major sources of statistical error are interaction, multicollinearity, heteroskedasticity and serial correlation.

The choice of explanatory model has been based on economic and financial arguments, rather than an empirical basis. There is thus justification for the regression models chosen. However, a key point of each regression model is the assumption that the process being modeled is stationary. While this may be true on a year-to-year basis, it is harder to support over the 9-year period of this study. In fact, Hall (1993) found that the value for R&D may have declined by as much as 50% over the period 1981-89. This would imply that the regression coefficients found in the models developed here represent a weighted average for the period, and that the relative importance of R&D and other intangible assets may be somewhat skewed. Various techniques can be used to model a non-stationary process; Hall addressed this issue by using year dummies (which also addresses the problem of serial correlation, discussed below).

Interaction and multicollinearity as sources of statistical error do not appear to be significant. In test regressions, interaction terms had no significance, while varying the number of explanatory variables did not change the level or significance of the regression coefficients, indicating that multicollinearity was not important. Examination of residual plots suggested that measurement error increased with the value of certain regression variables (MV/TA for example, but not firm size, whether measured by book or market value). As discussed in the text, this may be due to measurement error, scale effects, or more fundamental differences between firm subclassifications (e.g low vs high MV/TA firms). However, when a logarithmic transformation was made, measurement error was approximately evenly distributed when plotted as functions of the independent and dependent variables. Therefore, while the linear models may violate the homoskedastic assumption, this is corrected in the logarithmic model.

A significant, remaining source of error in these results may be due to serial correlation. The regression data set included up to 9 years of observations for the 195 firms in the industry. It is very likely that within-firm variables are correlated on a year-to-year basis. In order to examine serial correlation, lagged residual plots were made for the linear and logarithmic regressions for Tobin's q. Lag-1 residuals were positively and significantly correlated with a correlation coefficient of 0.28 and 0.45 for the linear and logarithmic models, respectively. Using the Durbin-Watson test for serial correlation, both regressions thus exhibit significant serial correlation. These could be corrected using the method of generalized differences with an autoregressive term; however, in this study, a simpler approach was examined. Several test regressions using the method of first-differences to correct for serial correlation were calculated. This method overcorrected for serial correlation, as lagged residuals were now negatively correlated. However, serial correlation was not significant under the Durbin-Watson test.

Correction for serial correlation altered the regression results somewhat for certain of the variables. Both the magnitude and level of significance of the certain of the regression coefficients changed, although the major trends remained. However, it is unclear whether the correction for serial correlation actually corrected the regression results, or whether the correction process introduced problems of its own due to the unreliability of the data set. The explanatory power of the regression on the corrected data sample sharply decreased. The missing data in this data set made correction difficult, as there were many interrupted runs of data. The correction method of first differences necessarily reduces each 9-year set of observations by 1, a 12% reduction. In addition, due to missing values, further observations had to be eliminated and the net result of the correction process was the elimination of approximately 25% of the already reduced data sample. Therefore, the reliability of the data sample must first be addressed before significant effort is expended to implement detailed correction procedures.

Based on this discussion, the potential uncorrected sources of error in the analysis and results reported here are the use of a stationary model to fit a non-stationary process and serial correlation. In this initial, methodological investigation, detailed correction procedures are not warranted. Further work must address completing the data sample and verifying its reliability. Data items that must be added include, in addition to missing accounting and other data, firm-specific risk measures. As discussed above, correction procedures which simultaneously address non-stationarity and serial correlation, such as the use of year dummies, can then be applied.

CHAPTER 6 CONCLUSIONS

This study represents a methodological investigation into the value of intangible capital in firms. Various valuation models were developed and applied to the computer and computer electronics industry. Conclusions from this study thus fall in two categories: judgements as to the suitability of the techniques applied, and conclusions relating to the results found.

The major finding from the industry study is that the value of intangible knowledge assets is set not by some intrinsic measure, but by how well the firm is able to translate those assets into products and market power. For smaller firms, whether measured by assets or employees, a knowledge advantage, in and of itself, is not appropriable. The analyses presented here strongly indicate that a market validation is required and advertising is the mechanism, or at least the explanatory variable, which describes the importance of securing an appropriable market advantage. Value is based not on the promise of ideas (e.g. R&D) alone, but on the ability of the firm to turn those ideas into earnings.

For larger firms, the opposite is true: the market value of knowledge assets, here approximated by R&D spending, is greater. Owners and investors are quite confident of deriving benefits from ideas that are produced by the company. Thus, both short-term and long-term value is created: in the short term, by earnings, and in the long term by R&D.

These differences are not due to any differences in the intrinsic value of these knowledge assets - indeed, any difference in value is in the direction of greater value to smaller companies, whose entire future depends on the ideas of its key individuals. However, its worth to investors is less, as they can not be sure of appropriating the benefits of that knowledge which may rest with individuals. In larger companies, by contrast, knowledge is assimilated into the organization, and thus is appropriated by the firm and is a source of value to the investor.

These results are confirmed by studying the sources of value for firms that have the highest capitalization per employee. A high per employee market capitalization indicates that employee contributions are valuable *and* that such contributions are appropriable by the firm. For these firms, R&D is the single most important source of high market capitalization, while advertising and earnings are also significant sources of value. Thus, firms which realize maximal value from each employee not only have effective research organizations which create knowledge and then allow the organization to assimilate the knowledge gained, but also are skilled at marketing the resulting products. While the companies in this category could not be neatly categorized as falling into one particular industry or market (e.g. software manufacturers), most were recognizable as fitting the above characterization. Firms in this group are commercially successful innovators and market leaders, including for example Apple, Compaq, Silicon Graphics, Adobe, Sun Microsystems, Lotus and Microsoft, among others.

These results are consistent with either the transaction cost or the property rights theories of the firm discussed in Chapter 2. According to transaction cost theory, employees will make relation-specific investments for the benefit of the firm, and cede their option to retain the rights to that investment, only when the firm can make a credible contract with the employee. Alternatively, according to the property rights interpretation, employees will cede rights to intellectual property only when doing so will either increase their bargaining power with the employer, or would cause them to risk losing access to complementary firm assets which enable them to pursue their profession. Thus, one explanation for greater returns to R&D in larger firms is that the advantages of working for larger firms provides greater incentives to employees as compared to smaller firms; another is simply that employees will accept lower returns in compensation for the career security provided by larger firms. In either case, the incentive to transfer rights to the firm is greater. As we have noted earlier, this does not imply that R&D is less important for smaller firms, but, due to its reduced appropriability, its worth to investors is less. The risk of the R&D

investment is that much greater in the smaller firm, and, when discounted for risk, the market value of the R&D investment is less.

Results and interpretations were very similar for each of the four different valuation models used. A valuation approach based on Tobin's q provided the strongest differentiation among the different firm classifications in this industry, while the employee-specific valuation model permitted investments in employees (in R&D, advertising, and sales) to be valued. The market mispricing model for firm or equity value represents an innovative, potentially sensitive measure of extraordinary returns to firm investments. However, future work must first address the reliability and completeness of the data sample. This would include additional relevant explanatory variables and missing entries for all the valuation models, and the incorporation of firm-specific market risk factors for the market mispricing models.

CHAPTER 7 RECOMMENDATIONS FOR FURTHER WORK

The results of this investigation suggest numerous avenues for further work. Some of these have been discussed in the text. Others are noted here.

Alternate explanatory variables may be significant determinants of firm value. These include market factors (market share, market share growth), R&D-related factors (rate of change of R&D spending, lagged measures of R&D spending, or an accumulated R&D stock), sales and marketing factors (sales per employee, or rate of change of sales per employee), efficiency factors (asset turnover or rate of change of asset turnover), etc. Similarly, mispricing may also be dependent on employee-specific factors such as MV/employee, R&D/employee, sales/employee, etc.

Insight may also be provided by applying such regressions across industries, i.e. biotechnology, manufacturing, medical equipment, or across national economies.

An arbitrage pricing model for firm risk, originally developed for equity valuation (APT), may provide insight into the value and risk of investments in intangible assets and their variations among firms and industries. For example, the APT can be applied to determine the risk factors associated with expenditures on intangible assets, and those risk factors can be compared as a function of firm characteristics. One question that could be addressed within this framework is whether the variance in market returns, and hence the risk, is explainable by the measures used here (i.e. R&D/TA, R&D/MV, R&D/employee, per cash flow, etc.).

Nonetheless, the results that have been presented here, although preliminary, offer insights into success factors for technology-based firms. Such observations, if validated by more extensive analysis, can potentially serve to confirm economic theories of the firm. In the short-term, these results should be more carefully verified and extended by more rigorous statistical analysis, concentrating on one of the models presented here. Areas of improvement should include:

Data sample: missing data reduced the data sample by more than 60%. A more complete and carefully maintained data set should provide more general results. For example, the economy-wide data set used by Hall (1993), although based on the COMPUSTAT database, is maintained by NBER.

Missing variables: multiple potential explanatory variables have been discussed in the text. One variable that is central to the value and appropriability of intellectual property, and which should be included in further analysis, is patent information on a yearly and per company basis.

Methodological improvements: Numerous methodological improvements can be implemented to address the deficiencies identified in the text. These include techniques to model a non-stationary process, such as year dummies; corrections to account for serial correlation; industry dummies for an economy-wide analysis, perhaps based on 3- or 4-digit SIC codes; elimination of outliers (Hall (1993) eliminates outliers at the 4σ level); categorical variables to account for such factors as size, R&D spending, etc.; comparison of stock vs flow measures of R&D and advertising; interaction terms among variables; etc.

Approximations: Approximations such as those of the of the market mispricing model should be corrected by using firm-specific market risk measures and more careful accounting for non-operating transactions of the firm. A more careful treatment of the components of Tobin's q - market value of debt and equity, and replacement cost of assets including PP&E and inventory - such as described by Lindenberg and Ross (1981) may also clarify results.

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APPENDIX 1 DATA SAMPLE COMPOSITION

The data sample used in this study was obtained from the COMPUSTAT database for the years 1981-89. Here the relevant SIC codes, companies, and COMPUSTAT data items are listed.

Companies

Both the COMPUSTAT Primary-Secondary-Tertiary (PST) and the over-the-counter (OTC) data files were searched. The Primary file contains the larger companies of greatest interest listed on the NYSE (S&P 400, S&P 40 Financial Index, etc.); the Secondary file contains 800 more companies of lesser interest; and the Tertiary file completes the coverage for the New York and American Exchanges. The OTC file has 850 OTC companies. These files thus include all the firms on the New York and American stock exchanges, as well as a large number of smaller firms that are traded on smaller exchanges (including NASDAQ). All companies in the COMPUSTAT database that list themselves under the 4-digit SIC codes in the following table were included in the analysis.

SIC code	# firms	Description	Representative companies
3571	23	electronic computers	AST Research, Atari, Compaq, Cray, Dell, Silicon Graphics
3572	15	computer storage devices	Conner Peripherals, Iomega, Maxtor, Quantum, Seagate
3575	4	computer terminals	Moniterm, North Atlantic Industries
3577	24	computer peripheral equipment	KeyTronic, QMS, Sun Microsystems, Symbol Technologies, Weitek
3579	7	office machines	Information International, Pitney Bowes, Smith Corona
3672	8	printed circuit boards	Advance Circuits, Data Design Laboratories
3679	19	electronic components	Augat, Computer Products, Medicore, Vicor
3695	2	magnetic & optical media	TDK
5045	9	peripheral equipment, software	Egghead, Inmac, Microage
7371	9	computer programming services	Analysts International, Computer Task Group, Technalysis
7372	41	prepackaged software	Adobe, Autodesk, Computer Associates, Interleaf, Lotus, Microsoft, Novell
7373	22	computer integrated systems design	Bolt Beranek & Newman, Computer Data Systems, Mentor Graphics
7374	9	computer processing and data preparation services	Automatic Data Processing, Computer Language Research
7375	0	information retrieval services	
7376	0	computer management services	
7377	3	computer rentals and leasing	Comdisco
7378	0	computer maintenance & repair	
7379	0	other computer services	
Total	**195**		

Compustat Variables

The following COMPUSTAT variables were retrieved:

I. Balance Sheet

A. Assets

3	inventory
4	current assets
33	intangible assets
7	PP&E
8	net PP&E
69	other assets
6	total assets

B. Liabilities and Owner's Equity

5	current liabilities
35	deferred taxes and investment tax credits
74	deferred taxes
9	long term debt, book value
181	total liabilities
60	total, common stock
130	par, preferred stock
216	total shareholder equity

C. Supplemental Information

179	working capital
240	LIFO reserve
235	liquidation value, common stock
11	tangible value, common stock
10	liquidation value, preferred stock

E. Supplementary Information

182	beginning value, PPE
30	capital expenditures
187	ending value, PPE
103	depreciation expense

II. Income Statement

12	sales revenues
41	cost of goods sold
189	SG&A expenditures
13	operating income before depreciation
14	dep'n and amortization
178	operating income
15	interest
272	earnings before taxes, domestic
170	earnings before taxes
16	tax
18	net income before extraordinary items
172	net income

C. Supplemental

46	R&D expenditures
45	advertising expenditures
42	labor expense

III. Statement of Cash Flows

318	code, funds statement
110	cash flow from operations, use of funds (A,B,C)
308	cash flow from operations, cash flow (D)
180	change in working capital (A)
128	capital expenditures, statement of cash flows (A,B,C,D)
127	cash dividends (C/S and preferred)

V. Miscellaneous

A. Market

24	closing share price
21	common dividends

B. Common Stock

25	number of common shares

C. Other

59	inventory valuation method
29	number of employees

All cash amounts are in millions of dollars, except share price which is in dollars. Number of shares is in millions, and number of employees is in thousands.

Many of the data entries contained special codes, indicating special treatment for the data item. The most frequent (and troublesome) codes are the following:

0.0001	data item unavailable
0.0004	data item combined with other items (individually unavailable)
0.0008	data item insignificant

Data items reported as codes 0.0001 and 0.0004 were treated as unavailable; data items reported as code 0.0008 were treated as 0.0.

APPENDIX 2 ALTERNATIVE VALUATION MODELS

Several different regression models and explanatory variables were investigated during the course of this study. For completeness, a summary of the models used and results found are provided here.

Market Valuation and Unanticipated Returns

In addition to the models described in the text, three other valuation models describing firm mispricing were explored. None provided explanatory power or significance equal to the models described, but, as noted, due to the approximations involved in calculating cash flows and setting the discount rate, this particular valuation model is imperfect and results may be skewed.

The first of these relates market mispricing solely to the current year's expenditures and performance (i.e. data from year (i+1) alone, vs years (i) and (i+1) in the model that was presented). The methodological justification is to reduce the effects, if any, of collinearity. An economic justification is that estimates of firm value change solely due to actions in the current year, while effects of the prior year's investment decisions are already incorporated into the market price. Thus, this model is, in linear form,

$$mispricing = \frac{NPV_i}{MV_i} = \beta_0 + \beta_1 \frac{R_{i+1}}{MV_i} + \beta_2 \frac{A_{i+1}}{MV_i} + \beta_3 \frac{OIBD_{i+1}}{MV_i} + \beta_4 \dot{S} \qquad (1)$$

This model was applied in both linear and logarithmic form. As expected, explanatory power as compared to the fuller model in the text was reduced, yet the values and significance of the variable coefficients were not substantially different from those of the same variables in the more complete model.

In the second such model, market mispricing is assumed to be related solely to *changes* in the fraction of firm value invested in different assets over a given year. For example, if the change in R&D from one period to the next is given by

$$\Delta R = R_{t+1} - R_t \tag{2}$$

then the regression model is

$$mispricing = \frac{NPV}{MV} = \beta_0 + \beta_1 \frac{\Delta R}{MV} + \beta_2 \frac{\Delta A}{MV} + \beta_3 \frac{\Delta OIBD}{MV} + \beta_4 \dot{S} \tag{3}$$

Note that compared to the model presented in the text, this model simply takes the coefficients for prior and current years' expenditures and sets them equal and opposite in sign. In addition to focusing on changes in firm variables, it was hypothesized that such a model would reduce collinearity (or equivalently, serial correlation) in the explanatory variables. However, this model yielded only minor differences compared to the results reported in the text. The worth of R&D in larger firms was slightly increased, but there was no substantial change in the differences between data subsets or in their interpretation.

The third model in similar to the second model, except now market mispricing is related to changes in the fraction of firm book assets that are invested in different types of assets from a given year to the next. Thus, these explanatory variables are similar to those used to explain Tobin's q:

$$mispricing = \frac{NPV}{MV} = \beta_0 + \beta_1 \, \Delta \frac{R}{TA} + \beta_2 \, \Delta \frac{A}{TA} + \beta_3 \, \Delta \frac{OIBD}{TA} + \beta_4 \, \dot{S} \tag{4}$$

While various explanations might be proposed for such a model, it was chosen empirically. Results with this model suggested that both R&D and advertising reduce market mispricing, and thus either do not provide unexpected returns to firm owners or are rapidly incorporated into firm expectations. However, the model showed reduced explanatory power, and there was little distinction in the results between different subsets of the data (such as between large and small firms).

Earnings Valuation Models

Pratt (1989), in describing business valuation approaches, argues that if intangible assets have true economic value, that value will be reflected in earnings. Therefore, more reliance should be placed on earnings rather than asset valuation approaches. Earnings approaches have been taken by others, including Grabowski and Mueller (1978) and Smirlock et al (1984). One typical such regression model that has been suggested (Wernerfelt, 1993) is of the form

$$market\ price = f(earnings,\ appropriability\ of\ assets) \tag{5}$$

which is applied to the data set as

$$MV = \beta_0 + \beta_1 \pi + \beta_2 \pi K + \ldots \tag{6}$$

where π is a measure of earnings (net income, free cash flow, OIBD, etc.), K represents the (generalized) knowledge asset (i.e. R&D) and β_0, β_1, β_3 are regression coefficients.

However, this model presents greater complexities than other models described, since the reconciliation of intangible items between the income and balance sheets can be ambiguous. Pratt suggests that all intangible items as well as amortization charges be eliminated from the income statement. Another approach has been to correct net income for R&D and advertising by capitalizing R&D based on a weighted sum of prior year expenditures and assuming a depreciation rate.

Several models of this form were applied to the industry sample data set using, among others, explanatory variables such as firm size, R&D expenditures, and various expressions for interactions among the variables. However, none provided strong explanatory power, nor showed any ability to differentiate between different subsets of the sample or among the different sources of intangible capital.