Order Number 9238771

Information systems investment evaluation

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Louisiana Tech University, 1992

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INFORMATION SYSTEMS INVESTMENT EVALUATION

by

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A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Business Administration

COLLEGE OF ADMINISTRATION AND BUSINESS
LOUISIANA TECH UNIVERSITY

August 1992

LOUISIANA TECH UNIVERSITY

THE GRADUATE SCHOOL

June 18, 1992
Date

We hereby recommend that the dissertation prepared under our supervision by

James A. Connell, Jr.

entitled "Information Systems Investment Evaluation"

be accepted in partial fulfillment of the requirements for the Degree of

Doctor of Business Administration

Supervisor of Dissertation Research

Recommendation concurred in:

Advisory Committee

Approved:

Director of Graduate Studies

Dean of the College

Approved:

Dean of the Graduate School and University Research

GS Form 13

ABSTRACT

The objectives of the study were to determine whether an announced information system investment by a firm is associated with a change in shareholder risk and to determine whether firms which invest in information systems have similar patterns of change in operational efficiency as measured using financial ratios.

Several related articles have examined the importance of information systems to corporate performance. Assorted methods for measuring the value of an investment in an information system have been examined, with conflicting results. This manuscript resolves the controversy created by these multiple methods of evaluating information system performance so as to add to the knowledge in the fields of finance, accounting and information systems.

A broad-based test of the impact of an information system investment on shareholder wealth is undertaken to better understand how investors perceive value to be affected when a firm invests in an information system. This dissertation extends previous work by considering the effect of the information system investment on several risk measures of the firm as reflected in the stock market and on a group of financial ratios.

A sample of firms reporting information system investments in their annual report or Form 10-K during fiscal year 1988 or 1989 was collected and matched with a control sample based on SIC industry code and pre-investment beta. The rates of return earned by stockholders in the year following the information system investment were compared to determine whether a statistically significant difference exists between the test group and the control sample. A similar series of tests was conducted using a selection of financial ratios in an attempt to identify the type of change associated with the information system investment

The results suggest that an investment in an information system reduces the semivariance risk of the investing firm. This finding is not associated with a measurable change in operating efficiency.

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ACKNOWLEDGEMENTS

In any dissertation, there are always many more people who lend help than are acknowledged, but several merit specific thanks for their efforts. First, my committee gave time, help, and advice far beyond that required, and for this I am deeply grateful. Dr. Ralph Byington, my chairman, took an interest in the initial idea and deserves credit for its growth into a dissertation. Dr. Roger Shelor encouraged me to complete this final version and guided me in developing a plan of attack. Dr. Deana Nance was valuable when it came time to select the measures of operating efficiency, and she provided me the needed motivation to meet several important deadlines. Although he did not serve as a committee member, my department chairman, Dr. Tom S. Sale III, listened when I needed someone to listen and gave advice when I needed someone to give me advice. Few people understand the difference.

My parents have been unselfish in their support and encouragement. Their help made the completion of this doctoral program possible.

Art Gilbert first conceived of the idea that grew into this dissertation and provided both advice and direction in the initial background research. Sam Riner, fellow-sufferer in the dissertation process, patiently accepted my phone calls and offered a second opinion on the statistical tests and initial write-up.

Marvin Smith has gone above and beyond the call of duty to offer proof-reading, research and word-processing services.

George Banks and Tom Harrison of the Louisiana Tech University Computing Center patiently corrected my programs, wrote code when necessary and allowed me increasing amounts of computer memory and time. This dissertation would not have been completed as rapidly as it was had they not been so generous with their time and ability.

Although space limitations preclude a complete listing, I would also like to acknowledge the encouragement I have received from Karen Brown, Ken Bass, Claudia Denker, Selwyn Ellis, Pamela Hall, Kyleen Hawkins, Hadley Leavell, Cat Mandue, Melissa Melancon and Judy Siquaw.

CHAPTER I

INTRODUCTION

Capital budgeting techniques currently being used are designed to compare cash inflows to cash outflows. This is appropriate for the majority of the offensive capital budgeting decisions businesses are concerned with. Offensive capital budgeting decisions are investment projects which generate new cash inflows or directly reduce existing cash outflows. For example, an investment in a revenue-enhancing project would be examined by comparing the present value of the expected future cash-flows arising from the project to the present value of the investment. Any project with a non-negative net present value would earn investor's minimum cost of capital and should be accepted. These projects are easily measurable and existing capital budgeting techniques have been developed and refined to assist managers in making these decisions.

This manuscript tests for the possible existence of a different type of investment, a defensive investment. This is an investment which is undertaken primarily to protect a competitive or strategic position. There may not be an increase in cash flows directly attributable to the investment, but management deems it necessary to defend market share, productive advantage or a related strategic area. Defensive investments are related to the concept of overhead, but would generally be considered more optional than the expenditures normally thought of as overhead. This is a unique type of investment which has value in that even though it does not promote cash flow, it protects cash flow.

In the current Accounting and Finance literature, the evaluation of investment opportunities is accomplished by focusing on the relevant changes the investment is expected to cause in the firm. The main focus of most decision rules is on incremental cash flows. This focus is on the changes the investment will cause rather than on the reasons for the investment. The common assumption is that all investments are undertaken to increase cash flow and therefore only cash flows are relevant to the investment decision. The intention of this manuscript is not to disregard the importance of cash flows, but to recognize that other considerations exist when investments are being considered. Kaplan (1986) illustrated this point as follows:

> When the Yamazaki Machinery Company in Japan installed an $18 million flexible manufacturing system, the results were truly startling: a reduction in machines form 68 to 18, in employees form 215 to 12, in the floor space needed for production from 103,000 square feet to 30,000, and in average processing time from 35 days to 1.5. After two years, however, total savings came to only $6.9 million, $3.9 million of which had flowed from a one-time cut in inventory. Even if the system continued to produce annual labor savings of $1.5 million for 20 years, the project's return would be less than 10% per year. Since many U.S. companies use hurdle rates of 15% or higher and payback periods of five years or less, they would find it hard to justify this investment in new technology - despite its enormous savings in number of employees, floor space, inventory, and throughput times. (p. 87)

If investments can be defined as having offensive or defensive purposes, a richer set of theories open up for investment decision making. The continuing transition from positive to normative theories in Accounting as well as the other business disciplines requires better understanding of the concepts being applied. Without a common definition, the exchange of ideas and information will not occur. A distinction between offensive and defensive investments will subtly change the decision-making process and allow for a more complete understanding of investment-selection behavior.

Although he did not use the term "defensive investments," Robert Kaplan (1986) discussed computer integrated manufacturing (CIM) as a type of investment which is made for defensive as well as offensive strategic purposes.

> Companies also commonly underinvest in CIM and other new process technologies because they fail to evaluate properly all the relevant alternatives. Most of the capital expenditure requests I have seen measure new investments against a status quo alternative of making no new investments - an alternative that usually assumes a continuation of current market share, selling price, and costs. Experience shows, however, that the status quo rarely lasts. Business as usual does not continue undisturbed.
>
> In fact, the correct alternative to new CIM investment should assume a situation of declining cash flows, market share, and profit margins. Once a valuable new process technology becomes available, even if one company decides not to invest in it, the likelihood is that some of its competitors will. As Henry Ford claimed, "If you need a new machine and don't buy it, you pay for it without getting it." (p.88)

If a special class of investments exist, which are purchased primarily for defensive purposes, an investment in an information system would be an example. Information systems tend to be intangible assets providing benefits which are difficult to measure using traditional capital budgeting techniques. Researchers in the field of Information Systems in general, and Accounting Information Systems in particular, have devoted considerable effort to the correct evaluation of information systems as investments by the company.

Information systems have been increasing in importance in recent years. The rapid growth of computer technology is changing the way many jobs are carried out. Organizations recognize the ability of information systems to speed up the internal and external transmission of information. Two reasons for the increased interest are the potential impact of an information system on firm profitability and the size of the capital investment required for most systems. As information systems become common segments of business organizations, researchers are developing models to explain and identify the benefits information systems offer to organizations. A well-planned information system will allow a company to take full advantage of its strengths and accomplish its goals.

> A competitive (or business) strategy is the approach a firm follows in pursuing its goals in a given market. Coordinating MIS planning with competitive strategy enables a firm to seize opportunities in its markets, position itself effectively vis-a-vis its rivals, make efficient use of resources, and access information pertinent to making strategic decisions. The factors can give a company advantage over its competitors, thereby leading to superior financial performance. This is supported by an A.T. Kearney study which reported that companies with integrated business and MIS strategic plans outperformed those without such integration by a factor of six to one. (Das, Zahra and Warkentin, 1991, p. 953)

There have been attempts to identify and measure the resulting benefits from an investment in an information system (Hamilton and Chervany (1981a,b); Clemons and Weber (1990)). Research has attempted to measure tangible cost reductions or profit improvements (Keim and Janaro (1982); Wilkerson and Kneer (1987)) and have directed efforts to establishing a value for the intangible benefits associated with possessing a better information set to base decisions on (Money, Tromp and Wegner (1988) Hirsch (1968)).

The majority of the existing studies explore the expected benefits of information systems. The studies examining the results of information systems investments tend to be case studies and are company or industry specific. For example, Banker, Kauffman and Morey (1990), report on the operational efficiency gains resulting from the adoption of the positran system at Hardee's Inc. It would be difficult, if not impossible, to begin with a study of a single fast food company and develop conclusions applicable to the effects of information systems on organizations in general. There is a lack of broad-based research dealing with the effects of information systems in general.

The industry specific research generally deals with highly regulated financial services industries. Harris and Katz (1989) studied 40 insurance firms over a four year period and concluded that more profitable firms allocate a higher proportion on their non-interest operating expenses to information systems. Turner (1985) investigated 58 savings banks but could not support a positive relationship between organizational performance and data processing investment. Cron and Sobol (1983) reported that warehousing firms which make extensive use of computers tended to be either very strong or very weak financial performers.

The measures used focus on changes within a limited area of the company but generally overlook the overall impact of the information system. An overall measure would encompass both the benefits directly associated with the information system investment and indirect benefits which arise as the firm becomes more computer-oriented and is able to take advantage of technological advances. It is not unusual for one company's investment in an information system to change an entire industry in ways that were never considered when the investment was first proposed (Clemons, 1991).

A purpose of any investment by the firm is to maximize shareholder wealth, regardless of whether the investment is for offensive or defensive purposes. The investment in an information system should not be an exception. Because of this, a significant investment in information system technology by a publicly traded company should be reflected in the market performance of the firm.

Risk plays a major role in the valuation of the firm in contemporary financial theory. If an information system investment allows a firm to react better to changing market conditions or reduces the variability of the firm's earnings, this should be reflected as a reduction in the risk of the firm which will increase the value of investors' holdings. The primary purpose of this research is to examine the impact of an investment in an information system on the risk of a publicly traded firm as measured in the stock market.

Not all risk is priced in financial markets. The classic example is the distinction between systematic and unsystematic risk. Systematic risk (commonly measured as beta) is the risk associated with the system, it is the risk which all investors who participate in the market must accept. This is not to say that systematic risk is the same for all assets. Systematic risk is a function of both the system and the relationship between the system and the asset in question. This is why the mathematical definition of beta contains the covariance between the market and the individual asset.

Investors must accept some systematic risk if they choose to invest. All assets do not have equal levels of systematic risk. These two statements lead to the conclusion that risk-averse investors will require some extra compensation (in the form of higher rates of return) in order to entice them into investing in assets which have more systematic risk than competing assets. This is what is meant by the statement that systematic risk is priced in the market.

Unsystematic risk is risk that is asset-specific rather than common to all assets in the market. Although this risk affects the asset in question, it is not a form of risk to which an investor must be subject. If an investor holds two assets, the unsystematic risk of one will offset some of the unsystematic risk of the other. Given only two assets, it is not likely that this diversification will be on a one-to-one basis. Empirical work by Wagner and Lau (1971) suggests that when randomly selected securities are added to a portfolio the risk (measured using standard deviation) of the portfolio decreases at a decreasing rate. Additional reductions in risk are relatively minor after approximately the tenth security. Because of diversification, the investor is not subject to the effects of the unsystematic risk of each individual asset. An investor can offset the unsystematic risk of any one asset with the unsystematic risk of the group. Unsystematic risk is not priced in financial markets because investors are not forced to accept unsystematic risk.

Other measures of risk exist. Variance may be considered total risk because it measures the uncertainty of individual returns relative to the mean (expected) return. This is not to say that variance is the same as systematic or unsystematic risk. The concepts of systematic and unsystematic risk deal with the relationship of an individual asset to the market as a whole. Variance is concerned with the uncertainty in an asset unrelated to any other asset.

Semivariance is a special, well-defined portion of total variance. Semivariance risk is a measure of the uncertainty of individual returns falling below the overall expected return. This is a way of focusing on the downside risk, or potential problems which exist. If semivariance decreases, the risk of below-average returns has decreased also. An ideal risk change would be for semivariance to decrease at the same time that overall variance changes little if any. This combination would mean that the chance of returns below the mean has decreased but above-the-mean returns have changed little. This is the same as truncating one tail of a two-tailed statistical distribution, in the case, the "bad" tail containing lower returns.

Variance and semivariance are absolute measures of risk, meaning that they are measured in absolute terms. They are measured in squared units of the original distribution. This presents a minor problem because most people are not comfortable using results expressed in squared units. For example, the variance of the possible absolute returns from a financial investment would be in dollars squared rather than actual dollars. The coefficient of variance is a relative risk measure which shows the amount of risk investors are accepting per unit of return.

A defensive investment may be justified if it controls or reduces risk. If information systems are an example of a defensive investment, an evaluation of the risk changes associated with an announced information system investment will identify both the effects of the information system investment on the company and any special characteristics of the effects of a defensive investment on risk.

Statement of the Problem

A number of methods for measuring the impact of an investment in an information system have been examined, with conflicting results (Hamilton and Chervany (1981a,b); Clemons and Weber (1990)). Potential problems have been suggested for each of the alternatives. In order to be useful, the method should consider the numerous relationships vital to the success of the corporation.

Investors are in a position to observe the effects of firm action from an unbiased viewpoint. If an information system investment adds to the worth of the firm, (and thus to investor wealth) investors will invest more. If they do not approve of the decision, investors may choose to invest less as a result. It would be useful for information systems specialists and financial analysts to better understand how investors perceive value to be affected when a firm invests in an information system.

Resolving the controversy created by these conflicting opinions of the effects of an information system investment will add significantly to the knowledge in both the areas of Information Systems and Investment Analysis. This study examines investor reaction as reflected in the stock market response to a firm's announcement of an information system investment.

Purpose of the Study

The purpose of this dissertation is to investigate the perceived impact of an information system investment on the firm's owners. The main concern is the effect of the investment on the risk of a publicly traded firm as reflected in the firm's stock market performance. It is possible that a firm's investment in an information system will cause investors to view the firm as less risky. This dissertation will extend previous work by explicitly considering the effect of the information system investment on several risk measures of the firm which are available in the stock market. Multiple risk measures are used to gain a better understanding of the effects of the information system investment on risk.

The impact of an information system on the operating efficiency of the firm is also examined. If the information system changes the riskiness of the firm, this change may be accompanied by measurable differences in operational categories. Commonly used Accounting and Financial measures are used to test for an improvement in operational efficiency.

Limitations

This dissertation is limited to firms announcing information system investments during fiscal years ending in 1988 and 1989. This limitation is necessary because the existing CRSP and Compact Disclosure databases both end with December 1990 data. The statistical tests performed in this manuscript require daily stock market rates of return for a one year period following the end of the fiscal year in which the information system investment occurred.

Each firm in the test sample must have either an annual report or form 10-k report available on the Compact Disclosure database and be listed on the CRSP tapes for a one year period two years prior to and one year following the appropriate fiscal year ending date. Firms in the control sample are required to be listed on the CRSP tapes for the same time period.

Assumptions

The following assumptions are necessary for this study:

1. The primary goal of management is to maximize shareholder wealth as reflected by the price of the common stock.
2. Investors are risk averse, *ceteris paribus*.
3. The variables used have been correctly specified and measured.
4. The information collected and analyzed on the sample firms is representative of the population of all common stocks.

Hypotheses

One of the benefits of investing in an information system is the ability of the firm to react to internal or external environmental changes or to take advantage of a more complete information set. Specifically, the theory is examined that an information system investment allows a firm to reduce various risk measures which are reflected in the stock market.

The first research question is whether the group of firms investing in information systems earned rates of return which were different from the rates of return earned by the control sample. Thus, the first hypothesis to be tested will be:

Hypothesis I:

H_o: An investment in an information system has no effect on the mean of the distribution of rates of return earned from an investment in the firm's stock. ($\mu_{test} = \mu_{control}$)

The mean of the individual potential outcomes is the expected value of a distribution. In this study, it is the rate of return earned by an investor who purchased and held the stock for a one-year period. The purpose of this hypothesis is to determine whether there is a statistically significant difference between the test group and the pair matched control sample in the year following the announcement of an information system investment. This includes an implied assumption that the returns have a statistically normal distribution.

The first hypotheses includes an implicit assumption that the data are normally distributed. Fama (1965a,b) presents empirical evidence that this assumption is not always valid for financial data. The second hypothesis also tests for a difference in risk levels, but is not dependent on this assumption.

Hypothesis II:

H_o: An investment in an information system has no effect on the semivariance of the distribution of rates of return earned from an investment in the firm's stock. ($SV_{test} = SV_{control}$)

Semivariance is similar to standard deviation but it concentrates on the risk of returns below the mean. Standard deviation assumes a normal distribution and assigns equal importance to outcomes above and below the mean. The test for semivariance change follows Hypothesis I because it relaxes the assumption of a normal distribution of returns. If the distribution of returns is skewed, semivariance can be used to compare the distributions. Proponents of semivariance also argue that focusing on downside risk is appropriate because investors are assumed to be risk averse. Semivariance (SV) is defined as

$$SV = \sum_{j=1}^{K} P_j (R_j - \overline{R})^2$$

where

j	=	the set of all values of the random variable which are less than the expected value
K	=	number of outcomes in set *j*

The above risk measures are absolute measures. They are stated in the units of the original distribution. An alternative to this is a measure that converts risk into a relative measure. Hypothesis III tests for change in a relative risk measure.

Hypothesis III:

H_o: An investment in an information system has no effect on the coefficient of variation of the distribution of rates of return earned from an investment in the firm's stock. ($CV_{test} = CV_{control}$)

Unlike the above absolute measures of risk, the coefficient of variation is a relative dispersion measure. It adjusts for the scale of various investments by showing the amount of risk (as measured by the standard deviation) per unit of expected return. This allows decision-makers to simultaneously consider both risk and expected return. The coefficient of variation (CV) is defined as

$$CV = \frac{\sigma}{\overline{R}}$$

Even if risk as tested above is different for firms which invest in an information system, it is not definite that investor wealth is affected. Changes in average market rates of return and interest rates affect all investments. For investor wealth to be different from what it would have been without the information system investment, beta must change also.

Hypothesis IV:

H_o: An investment in an information system has no effect on the beta of a firm. ($\beta_{test} = \beta_{control}$)

Beta is a standard measure of the relationship between returns on an individual asset and returns on the market portfolio. A change in beta following an information system investment would have more meaning than a change in the coefficient of variation, because beta measures only the systematic risk of the investment. According to current financial theory, this systematic risk is the only type of risk an investor must be subject to and therefore is the only type of risk which affects an asset's price. Beta (β) is defined as

$$\beta = \frac{COV(R_i, R_m)}{\sigma^2 \ R_m}$$

Hypothesis V

H_o: An investment in an information system has no effect on various measures of the firm's operational efficiency. ($Ratio_{test} = Ratio_{control}$)

Operational efficiency is measured in this manuscript using a selection of accounting and financial ratios. These ratios are chosen to measure the firm's operating and financing characteristics over the information system investment timeperiod.

Research Methodology

The dissertation will begin with a survey of the relevant literature dealing with the evaluation of management information systems. Attention will be given to theoretical and empirical research dealing with evaluation methodologies and why an information system investment is expected to change the value of the firm.

A sample of firms which have undertaken major investments in information systems will be collected. The sample will be based on the text of the 1988 or 1989 annual report and Form 10-K for each firm. The majority of firms do not disclose the amount of their information systems investment in the annual report or Form 10-K. For this analysis, the investment is considered as constituting a significant change in operations if the company considers it important enough to disclose in this manner.

Collecting data on the amount of the information system investment would be preferable, but outside of a few industries (such as banking and insurance) this information is not available. The majority of the firms in the test sample refer to investments as being significant but do not disclose dollar amounts. The president's letter to the shareholders of Claire's Stores Inc. for example, stated in 1988:

> Recognizing that heavy investment in information systems was essential to building a solid foundation for the company's

> dramatically expanding business base, we installed a state-of-the-art point-of-sale systems at all out store locations.

The president's letter in the 1988 annual report published by Clayton Homes Inc. mentions that:

> Our highly computerized management information system gives us another competitive advantage. With operating statements produced within three days after the end of each accounting period, the company can quickly identify and respond to new trends and expectations. This year, in a move to increase sales productivity and improve management response time, the retail division began closing its books 24 times each year.

Kimmins Environmental Service Corporation informs stockholders that during 1988, "we also expanded our management information system, enabling the company to operate at an even higher level of efficiency." Munsingwear Inc. stated that a fall in gross profit was the result of changes in the corporate information system:

> The gross profit as a percent of sales decreased to 17.7% in 1987 compared to 29.4% in 1986. The uncompleted modification of our new management information systems, especially in production planning, prevented the smooth production process and timely shipment of finished products to customers. This created increased manufacturing variances and markdowns, which were the primary reasons for the decrease. With the addition of a Vice President, Management Information Systems, an increase of our information system staff and assistance of outside consultants, major improvements have been made to these systems.

A pair-matched control group will also be collected. This control group will be selected based on SIC industry classifications and systematic risk measured by beta.

To test for the effect of the information system on the risk of the firm, various risk measures will be calculated to compare firms which invested in an information system to those which did not invest in an information system. The tests will be conducted using data for the fiscal years prior to and following the announcement year for each firm in the sample.

Outline of Following Chapters

Chapter II reviews previous literature relevant to the study. After a discussion of the role of information systems in organizations, previous research on the evaluation of information systems is summarized. The relationships between information systems and firm performance is also examined in this chapter. Following this, the concept of risk in financial theory, particularly the Capital Asset Pricing Model, is analyzed. This leads to a review of the relationship between risk and value followed by an examination of risk measures which may be affected by an information system investment. Throughout the chapter, particular attention is given to the previous research dealing with information system evaluation and the manner in which information systems may affect firm risk.

Chapter III describes the methodology used in the study. This involves the selection of the test and control groups and the calculation of the various risk measures which may be affected.

Chapter IV presents the results of the empirical tests of the hypotheses being questioned. Chapter V contains the summary and conclusions of the study along with recommended areas for further research.

CHAPTER II

LITERATURE REVIEW

The development of computer technology affects both individuals and corporations. The ability of a correctly designed and implemented information system to organize and report the numerous events in an organization make the effective use of computer technology a prime concern for most businesses. This ability is not without its potential liabilities. The results of using computers to organize a company depend on how the computer system is designed and the way the change to computers is implemented.

Several attempts have been made to define an information system. At the first International Conference on Information Systems, Peter Keen defined management information systems as "the effective design, delivery, and use of information systems in organizations" (1980). This early definition depends on one aspect of information systems that is still being considered today. Of the many groups involved with the system, who decides whether the "design, delivery, and use" are effective? Hamilton and Chervany content that "evaluating system effectiveness in meaningful terms has been one of the most difficult aspects of the management information system implementation process" (1981a, p. 61).

A system may be judged effective by the programmers if it operates without problems. The people who work with the same system on a daily basis may consider it a failure if it is too complicated to use or if they have not been effectively trained in the operation. Auditors are concerned that the system performs as designed and that the resulting infomation is reliable.

Information System Evaluation

Hamilton and Chervany (1981a, p. 61) list the following four problems in evaluating information system effectiveness:

1. Objectives and measures of accomplishments are often inadequately defined initially.
2. Efficiency-oriented and easily quantified objectives and measures are typically employed.
3. Objectives and measures used to evaluate the system are not the same as those defined initially.
4. Individual perceptions may differ on what the objectives and measures are.

Two views of information system effectiveness and how it should be measured are discussed by Hamilton and Chervany (1981a). The goal-centered view looks at how the system meets the stated objectives set out in the initial design. The system resource model considers the stated objectives as well as incidental benefits that accrue to the company as a result of the information system. These changes may not follow directly from the information system but they may be attributed to system use and resulting changes in the organization.

A management information system is a system which attempts to organize the information a firm has into a systematic, useable format. A management information system is not a single, comprehensive, integrated system to control the business or meet everyone's information needs.

David Kroenke (1989) stated that "the purpose of organizational information systems is to integrate the activities of different departments into a single business system that produces coordinated, integrated responses to its environment" (p. 454). The modern corporation must deal with both internal and external forces on a daily basis. The actions of individuals and workgroups combine to determine the actions of the organization. Workgroups are groups of individuals whose jobs are interrelated through directly working together or the exchange of information or goods in process. Each of these groups can benefit from the appropriate use of a management information system.

Each individual has roles, duties and responsibilities which determine how they interact with others. These constraints may be formal, such as a job description, or informal group expectations. An information system can enhance both the individual's internal activity and the external products which are supplied to vertical or horizontal elements of the organization.

The workgroup has roles, duties and responsibilities which are recognized (formally or informally) by other elements of the organization. At the workgroup level, information systems must support the internal activity of group members and the productive services the group provides to others within the organization.

The sum of all the workgroups is the organization. The organization does not have a formal job description in the same sense that individuals and workgroups do, but is usually defined by a stated goal, purpose or mission. This is accomplished by individuals and workgroups interacting with each other and external forces. An organization's information system helps in the coordination of internal activities as well as the creation and delivery of the final product.

Externally, the organization must deal with customers, suppliers, regulatory agencies and competitors (Dill, 1958). Duncan (1972) adds the element of technology to this list. The needs and viewpoints of each of these groups may change. Figure 1 presents an overview of some of the various groups which must interact internally and externally within modern corporations.

Given the number of clients and complexity of these relationships, it is apparent that information may have some value. The purpose of an information system is to support decision making within the organization. Van De Ven and Ferry (1980) suggest that as communication increases in situations with high task interdependence, there are also increases in interunit awareness and consensus. The purchase of a management information system should make it possible for a company to organize and use the information it has. A more

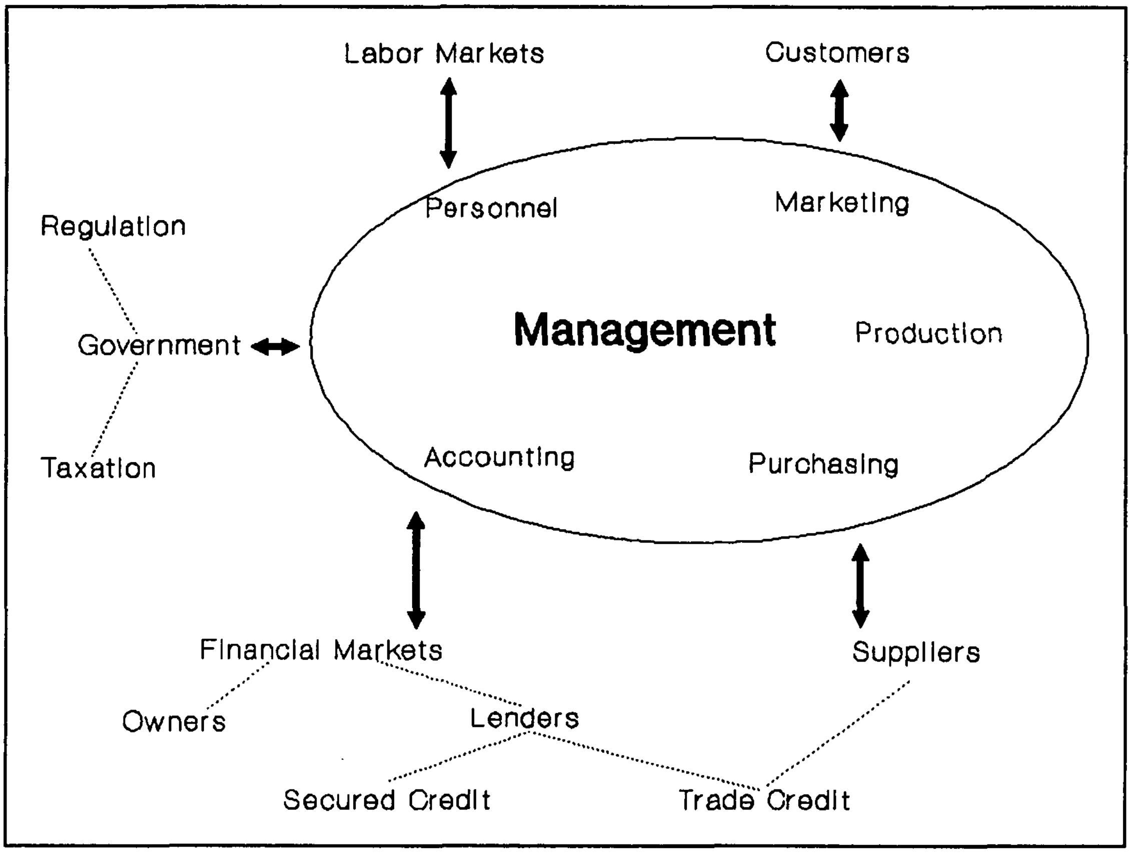

Figure 2.1. Groups which interact in modern corporations.

complete information set to base decisions on should improve forecasting and daily operations which will make the firm more valuable to its owners.

Development of Information System Evaluation Theory

The question of whether to invest in an information system is not as well-defined as other investment decisions made by business firms. Information systems by their nature and potential impact do not lend themselves well to traditional investment analysis methods.

> For investment decisions, evidence has shown that businesses have difficulty in evaluating when to use information technology. This problem really is fundamental to the continuing application of information technology in business and government. (Clemons, 1991, p. 24)

There was a great deal of uncertainty when American Airlines first began to market their Sabre travel agent reservation system. A dozen years after it was developed, Sabre was valued at $1.5 billion, at the same time that AMR, the parent company of American Airlines, was valued at only $2.9 billion (Clemons, 1991). The use of information systems to keep track of passengers changed the airline business. This in only one example of the often unexpected impact on an industry when information systems are introduced. This possibility exists in many applications, but it is difficult, if not impossible, to estimate the current dollar value of an extreme outcome such as this.

> There are other, more fundamental difficulties with strategic innovations, not tied to problems with accounting. Often the strategic programs being undertaken have extremely long lead times. In particular, during the time between making the investment decision and the strategic program coming on-line, the environment itself may have changed, confounding analysis and adding considerable uncertainty. This problem is particularly acute in rapidly changing, newly deregulated industries. And often the technologies involved are so new that not even the experts are certain about what their implications will be. The affected managers are often without the experience, information, or methodology needed to evaluate their programs. (Clemons, 1991, p. 25)

The evaluation of information systems begins with identifying the correct person, group or groups who determine whether the system is successful. The next question is how to correctly evaluate the investment. Traditional investment analysis techniques, such as value analysis, cost/benefit analysis and net present value analysis have been applied with mixed success to information systems. Some general guidelines for evaluation are available to guide investors in arriving at a decision or identifying the available options to consider.

Evaluator Groups and Interrelationships

Hamilton and Chervany (1981a,b) provide a comprehensive review of the literature up to 1981 on the evaluation of management information systems. They list four main internal groups who are responsible for judging the effectiveness of the information system (1981b, p.79):

1. **User personnel** are the primary and secondary users of the completed system. These are the decision makers who rely on the information and personnel who are responsible for the upkeep of the system.
2. **System development personnel** are the personnel who develop and implement the system.
3. **Management personnel** are responsible for overall organization and control of the system and the associated workers.
4. **Internal audit personnel** evaluate the effectiveness of the system from a compliance with application controls viewpoint.

Hamilton and Chervany (1981b) discuss the differing evaluation viewpoints of these groups and provide a review of the literature on the interrelationships between these groups up to 1981. Users tend to value accuracy more than do system development personnel, who are concerned with the modifiablility, compatibility and responsibility of the system. Empirical work on management and internal auditors is limited, but they appear to view the system similarly, but not identically to, the way users view the system.

King and Schrems (1978) suggest combining these differing views by measuring benefits as the sum of net benefits for all independent users weighted by the importance of each user group. Hamilton and Chervany (1981b) suggest that validated instruments for measuring user satisfaction be given to several functional groups within the organization so that differing viewpoints will be considered when evaluating the system (p. 84).

Problems with Value Analysis

Keen (1981) argues that value analysis is the appropriate decision criteria for evaluating information systems. He suggests a two stage decision-making process involving prototyping the system. Instead of weighing benefits against costs, value analysis identifies relevant benefits and compares them to their market price: "Would I be willing to pay $X to get this capability" (p. 12)?

Several attempts have been made to measure the effectiveness of an information system using proxies such as user satisfaction indexes or measures of system use. Banker Kauffman and Morey (1990) focused on operational efficiency as a measure of the value of a management information system. Money, Tromp and Wegner (1988) used conjoint analysis to measure the perceived benefits of information systems. They develop and test an evaluation methodology which "emphasizes value rather than cost, focuses on intangible benefits, and is applicable to a single investment proposal" (p. 224). These measures focus on specific areas of the organization without fully considering the overall impact of the information system. Problems exist with both the validity of the measures and their relationship to the company's financial performance (Alpar and Kim, 1990).

Problems with Cost/Benefit Analysis

Carlson (1974) reviews six selection and evaluation techniques for information system projects. He concluded that cost-benefit analysis would provide more meaningful results than other available techniques but that project benefits are often difficult to measure. Knutsen and Nolan (1974) argue for the rejection of cost-benefit analysis because of these measurement problems. The contend that the focus on monetary measures will bias the technique in favor of clerical tasks where savings can be easily measured. Non-clerical projects are more likely to be rejected because of the difficulty in measuring their benefits.

Attempts to apply economic cost/benefit analysis to information systems have generally been unacceptable because of the nature of the benefits involved. Keen (1981), Oxenfeldt (1979), Melone and Wharton (1984), and Money, Trump and Wegner (1988) support the argument that cost/benefit analysis is inadequate for the evaluation of information systems.

It is difficult to measure these benefits because of their unique nature. The benefits provided by the typical information system tend to be qualitative gains such as the ability to examine more alternatives or offer a more detailed analysis of a situation. Additionally, information systems tend to evolve over time (Nolan, 1973). Successful implementation in one unit of a business often leads to use in other units and/or additional investment to upgrade the existing system. The gains from such growth are likely to result from interactions among a number of different projects.

Dos Santos (1991) has suggested the use of option pricing theory to value information technology investments. "It is asserted that a new IT project gives the firm the ability to undertake future projects using the new IT and that it is the potential value of these future projects that accounts for a major portion of the value of the initial project" (p. 73). Treating future investment in the system as optional can increase the pre-investment estimated value of an information system project.

Although they favor cost-benefit analysis, King and Schrems (1978) list several problems with valuing project benefits. Among these are:

1. The natural unit of measurement may not be comparable across all benefits.
2. Some benefits will be of different value to different users of the system.
3. The quantification of some benefits is highly subjective and subject to great uncertainty.
4. The benefits actually obtained may depend on the operating environment of the system.
5. Benefits are estimated at the start of the project but may change during the life of the system.

Hirsch (1968) was one of the first to attempt to measure the value of the information directly obtained from an information system. Emery (1971) recognized that both tangible and intangible costs and benefits are involved in the information system decision. He defined intangible costs as those costs which are difficult or impossible to estimate. These intangible costs are particularly important in the case of information systems since many of them are designed to control costs and standardize routine tasks. "Subsequent research on measuring the intangible benefits of strategic systems has not kept up, and shortcomings still exist" (Clemons and Weber, 1990, p. 11).

Keim and Janaro (1982) attempt to attribute cost savings or increased revenue to specific tasks such as the reduction in interest expense associated with a computerized accounts receivable system. Wilkerson and Kner (1987) concentrated on the expected reduction in manpower costs resulting from the introduction or expansion of an information system.

Keen (1981) states that the decision to invest in an information system seems to be based on expected value rather than the initial cost.

> In few of the DSS case studies is there any evidence of formal cost-benefit analysis. In most instances, the system was built in response to a concern about timeliness or scope of analysis, the need to upgrade management skills, or the potential opportunity a computer data resource or modeling capability provides. Since there is little *a priori* definition of costs and benefits, there is little *a posteriori* assessment of gains. (Keen, 1981, p. 9)

"In many organizations, information technology is the second largest expense (after personnel), and yet the benefits of this investment are extremely difficult to measure, or even to demonstrate informally" (Clemons, 1990, p. 6). Lederer, Mirani, Neo, Pollard, Prasad, and Ramamurthy (1990) examine Robey and Markus' (1984) Rational and Political models of information system development by conducting a case study using the information systems department at a large chemicals manufacturing firm. Both models were supported and political factors appear to play a significant role in the cost estimating process.

Problems with Net Present Value Analysis

Financial theory suggests that Net Present Value (NPV) techniques are appropriate when considering new capital projects. Mason and Merton (1985) report that some form of discounted cash flow analysis is widely used by practitioners for project evaluation. Cooper and Kaplan (1988) and Kaplan (1986,1988) noted that the uncertainty involved increases when decision-makers must value risky and intangible benefits using NPV analysis. An investment in an information system includes both the system under consideration and possible future uses of the system or related technological developments. "The system itself may so radically alter the industry that prior assumptions are invalidated" (Clemons and Weber, 1990, p. 10). The uncertainty in predicting the future of computer technology makes selecting appropriate inputs for the NPV process difficult.

Strategic necessity may be a key reason for a firm's decision to invest in an information system, even though it is difficult to place a dollar value on the need to stay competitive within an industry. Clemons and Weber (1990) suggest that discount cash flow evaluation methods have a bias toward conservative decisions and risk aversion that is not appropriate for evaluating an information system investment. In some areas of the information systems literature, the use of discounted cash flows is not recommended (Cash, McFarlan, McKenney and Vitale, 1988) and reported to be seldom used (Raho, Belohlav and Fiedler, 1987).

Guidelines for Evaluation

Clemons and Weber (1990, p. 18-24) provide the following seven guidelines which may be considered before making an information system investment. Although these do not give a simple "yes or no" answer to the investment question, they are valuable because they lead the decision maker to consider some of the possible changes in the company or industry that may result from the information system decision.

1. Investment decisions can be made on a rational analytical basis, even when the numbers required for discounted cash flow analyses cannot be obtained
2. Thresholds established by sensitivity analysis can be used as trigger points for fine-tuning a project once it is initiated.
3. Advantage results from unique assets and resources of the implementing firm.
4. Several types of risk exist and must be recognized early in the evaluation of an information technology development.
5. Technology investments may have option and timing value, and unexpected upside benefits.
6. Downside risk exists in reflected information technology programs, which then may become strategic necessities through another firm's initiative.
7. Cooperation may be the dominant investment alternative under conditions of strategic necessity.

The advancement of computer technology and the impact of the management information system of another company on the overall industry must also be considered. Simple measures of association or correlation between management information systems investment and firm performance do not capture the pressures from competitors and suppliers on the firm's cost and profit structures. There are situations in which a firm has no choice but to invest in a management information system if it is going to stay competitive in the industry. Barwise, Marsh and Wensley (1989) point to a failure to correctly identify what will happen if no action is taken as a major flaw in most investment decisions.

Hamilton and Chervany (1981a, p. 63) offer four recommendations for evaluating system effectiveness. These items along with a brief discussion of the effects of evaluating the system from the owner's viewpoint include:

1. **Define and/or derive appropriate system objectives and measures**. As discussed above, if an information system does not have a beneficial effect on owner's wealth, it is not successful. Treynor (1981) provides a well-written justification for shareholder wealth maximization as the goal of publicly held firms.
2. **Enlarge the range of performance being evaluated.** Observing the change in the value of the firm as a result of the information system reveals the value owners place on the change. These changes are reflected in the stock price (or total market value of the company) for publicly traded firms.
3. **Recognize the dynamic nature of the MIS implementation process**. The addition of an information system has the potential to affect every aspect of the firm. Focusing on cost savings or improved efficiency only in the areas directly affected ignores part of the overall impact on day-to-day operations and profitability.
4. **Account for differing evaluator viewpoints**. Although it is good for all the people involved to agree that the system is a success, if the owners do not feel that they are earning a fair return for their investment in the system, the system is a failure. Rational owners will not continue to invest in or

> support an information system that does not add to their wealth.

These guidelines call for an overall measure of how the firm is affected by the information system. The principle concept of financial theory is that the goal of the firm should be to maximize shareholder wealth. Any action which truly affects the firm will have some effect on the wealth of the owners of the firm. If the information system benefits the owners of the firm, it will be encouraged. If there are no benefits to the owners, further investment is unlikely and the existing system is likely to be phased out.

Relationships Between Information System Investment and Firm Performance

There is a need for a better understanding of the relationship between information systems and firm performance. This study addresses that need and adds to the knowledge in the field. "While businesses are investing enormous resources in information technology, there is little evidence linking IT investment to organizational performance" (Weill and Olson, 1989, p. 3).

Bender (1986) divided information system investment into components and finds that expenditures on people, hardware, and environment are significantly related to performance but that software is not related to performance. His conclusions suggest that keeping the ratio of information processing expenses to total premium income at 15-20 percent is the optimum level of information system investment in the insurance industry.

Harris and Katz (1988) analyzed 40 insurance firms over a four year period and concluded that the most profitable firms tend to spend a significantly higher proportion of their non-interest operating expenses on information systems. A follow-up article by Harris and Katz (1991) found that small firms spend a higher proportion of total expenses on information technologies than do large firms.

Weill and Olson (1989) cite two articles (PIMS Program, 1984; Harris and Katz, 1988) suggesting that high-performing companies spend a higher percentage of their revenue on information systems than lower-performing companies.

Cron and Sobol (1983) focused on firms in the warehousing industry. They report that firms which made extensive use of computers were either very strong or very weak financial performers. It has been suggested that the strategic position of the firms was partially accountable for this finding. The PIMS investigation (1984) used market share as a measure of performance. They found that firms with superior strategic position which increased investment in information systems technology annually increased management productivity three times more than other firms in the sample (p. 35). If a firm has a strong strategic position to build from, an information system may have more value than to a firm in a weak strategic position.

Cecil and Hall (1988) also argue for the consideration of organizational structure and strategy as part of the information systems decision. Barva, Kriebel and Mukhopadhyay (1991) have developed a formal economic model of the strategic impacts of information technology investments in a duopoly setting.

Das, Zahra and Warkentin (1991) have developed a framework which combines competitive strategy, strategic MIS planning and company financial performance. This article presents an extremely through review of previous research in the areas of corporate strategy and information systems. The organized presentation of one hundred eighteen articles is accomplished by the use of tables and careful categorization of research findings.

Debate still exists regarding the specific benefits associated with an investment in an information system. Malone, Yates and Benjamin (1987) contend that information systems reduce transactions costs from an economy-wide viewpoint and that this will lead to a more efficient market system. Knutsen and Nolan (1974) suggest that the following benefits may arise from an information system:

1. equipment displacement,
2. reduction of personnel in data processing tasks,
3. increased operational efficiency in functional areas,
4. increased sales,
5. better managerial planning and control, and
6. other organizational impacts, such as flexibility.

Theoretical Justification

Financial Theory and the Capital Asset Pricing Model

One of the central issues in the field of finance is determining value. Value is based on a combination of three factors:

1. The amount of future cash flows.
2. The date at which these cash flows will be received.
3. The risk involved that they will or will not be received as anticipated.

The currently used models are variations of the "risk-premium model" (Harrington, 1987, p.2). The basis of the risk-premium model is that higher returns are associated with higher levels of risk. Portfolio theory was an early and widely accepted application of the risk-premium model to actual markets. Portfolio theory eventually evolved into the Capital Asset Pricing Model (CAPM) which is unique in that only systematic risk is considered in establishing value.

Systematic risk is that portion of total risk which is caused by socioeconomic and political events and affects all market assets. Unsystematic risk is the portion of total risk which is specifically related to the investment under consideration. By proper diversification, investors can remove the effects of unsystematic risk from their portfolios. Given diversification, the only risk which an investor must be subject to is systematic risk. That is why the CAPM focuses on systematic risk exclusively.

Portfolio Theory

Harry Markowitz (1952) was one of the first researchers to popularize portfolio theory as a means of choosing which asset, or combination of assets, to invest in. Prior to the work of Markowitz, the field of finance concentrated on selecting securities likely to perform better than the stock market in general (Smith, 1990). Markowitz recognized that it is not always enough to select likely winners. As long as there is some uncertainty in the outcome, risk is a factor investors consider but which had been largely ignored by financial theory up to that time.

The basics of portfolio theory are a combination of elementary statistics and economic theory. Any normal distribution can be described by two measures, the mean and the standard deviation. Any investment has some set of possible outcomes and a probability associated with each outcome. For a financial asset, the mean would be the most likely, or expected, rate of return (E(R)) the investor may earn from the investment:

$$E(R) = \frac{\textit{Sales price} + \textit{Payments} - \textit{Purchase price}}{\textit{Purchase price}}$$

If an investor knows what a given asset can be purchased for today and can estimate the amount of cash payments it will generate and how much it can be sold for, the rate of return expected from the investment can be computed. This expected rate of return will have some element of uncertainty in it as long as the future cash payments and sales price are not known with certainty.

Standard deviation and variance are commonly used measures of how results tend to cluster around the average value (or mean) if a large number of tests are run. Standard deviation is the square root of variance and has the advantage of being in the same units as the mean.

Markowitz recognized that investors tend to be risk averse. A risk averse investor faced with a choice between assets A and B in figure 2 will always choose A. This is because both assets offer the same expected rate of return but asset B has a higher standard deviation than investment A. The risk averse investor will not take on the additional risk without some compensation, which would mean a higher expected rate of return in this case. If offered a choice between assets C and B, the risk averse investor will always choose C, because it offers a higher expected rate of return and less risk than asset B.

The problem arises when the investor is offered a choice between assets A and C. It is true that C has more risk than A, but C also offers a higher expected rate of return. Each investor has to make an individual value judgement to decide whether the extra expected rate of return is enough to offset the extra risk. This value judgement can be expressed using the indifference curves in figure 3. Each curve represents a combination of points that an investor is equally happy with. The amount of utility associated with each curve is reflected in its subscript (i.e. $U_3 > U_2 > U_1$). The rational investor is indifferent between points on indifference curve U_3 because all points along U_3 offer the same level of satisfaction. The investor whose indifference

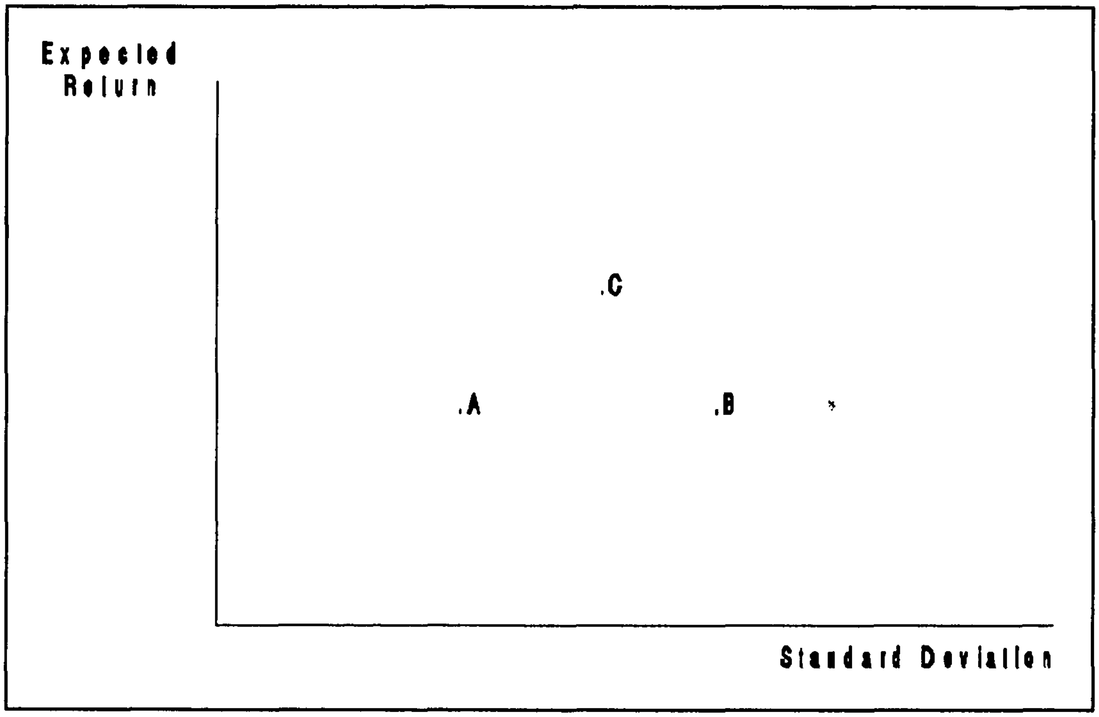

Figure 2.2. Three assets plotted on their risk/return characteristics.

curves are pictured here would invest in asset C because U_3 is the highest level of utility possible in this situation.

Markowitz (1952) realized that as long as investors are risk averse and consider both risk and return as discussed above, their investment decision can be graphed as shown in figure 4. The collection of individual points represents all possible individual assets. If investors are allowed to freely combine these assets into portfolios of assets, the outer limits of all possible investments will be along the curved line shown in figure 4.

If investors are risk averse and rational, they will hold investments which lie somewhere along the curved line in figure 4. This is the set of investments

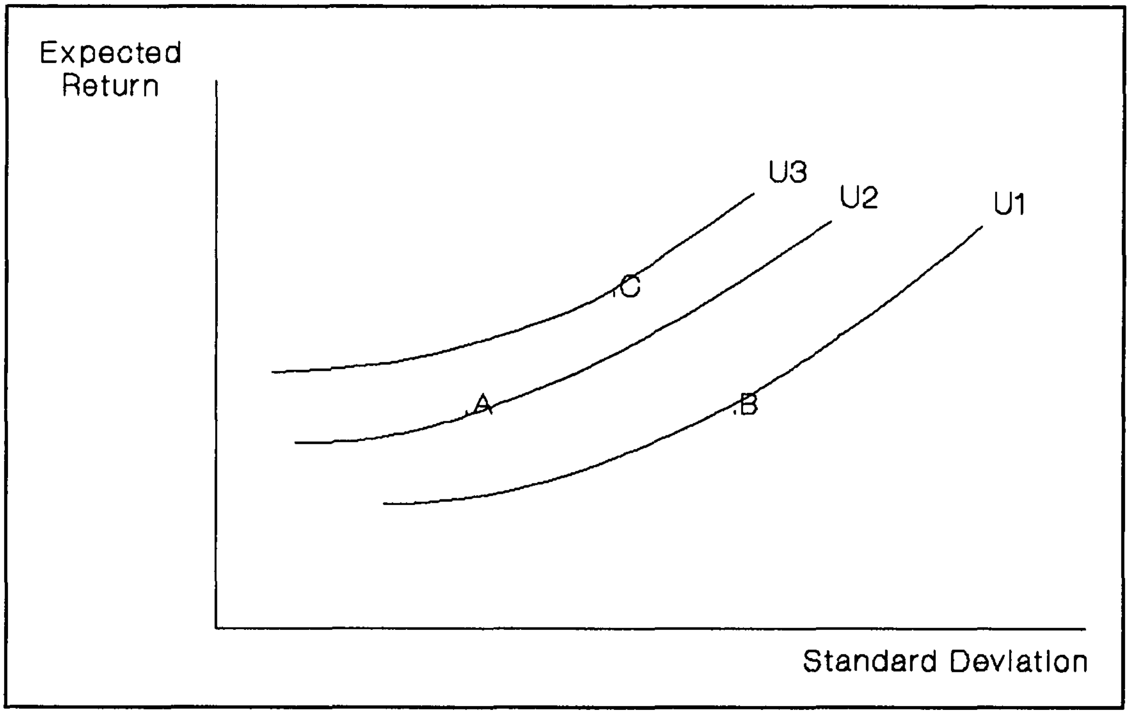

Figure 2.3. Indifference curves used to choose between risky assets.

offering the maximum expected rate of return for a given amount of risk or the minimum risk for a given expected rate of return. Markowitz (1952) referred to this set as the efficient frontier.

Markowitz portfolio theory was an important step in the development of financial theory because it defined the possible portfolios which rational, risk averse investors will choose among. In the example presented here, no one will place all of their investment funds in asset D as shown in figure 5. By investing in some portfolio which lies along the efficient frontier, the investor can have a higher expected rate of return for the same level of risk or less risk for the same expected rate of return as any given asset under the efficient frontier.

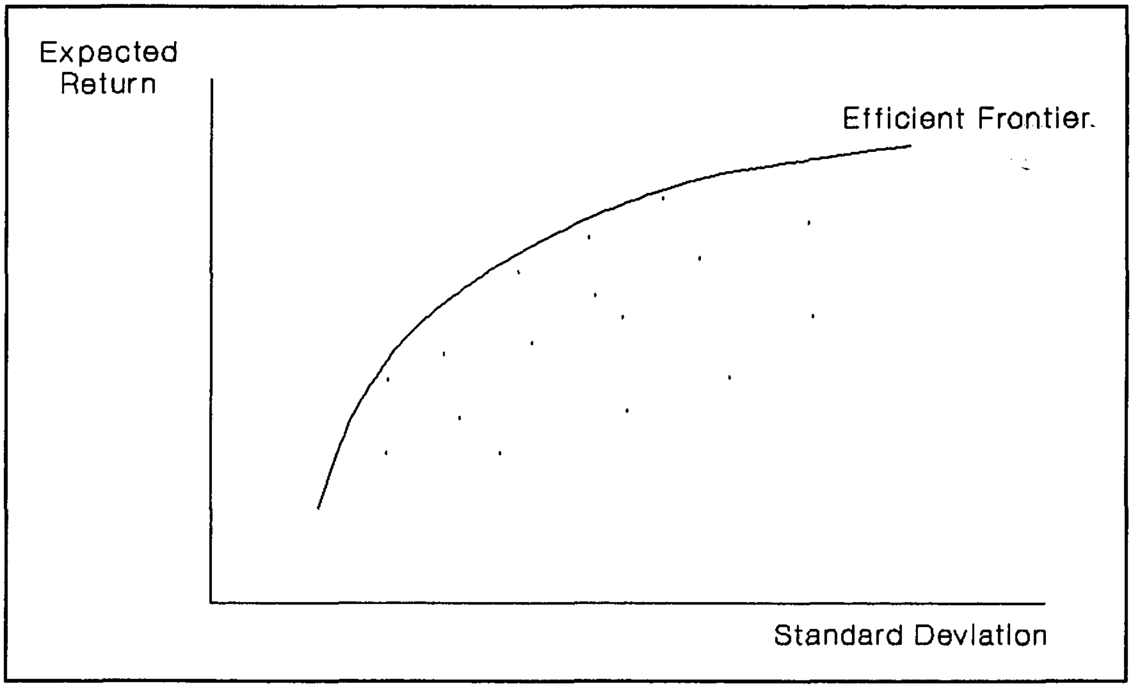

Figure 2.4. The Markowitz efficient frontier.

An investor who would have been happy with 100 percent of their funds invested in asset D alone will be better off by investing along the efficient frontier at any point between the dotted lines shown in figure 5. The exact point on the efficient frontier would be determined by the investor's indifference curves. A very risk averse investor would tend to be closer to the horizontal dotted line whereas a more risk tolerant investor is likely to be near the vertical dotted line.

While Markowitz portfolio theory does allow investors to identify the efficient frontier, there are some computational problems. For the simplest case of two possible assets to choose between, an investor would have to forecast returns for each asset and estimate the variance (or standard deviation) of each

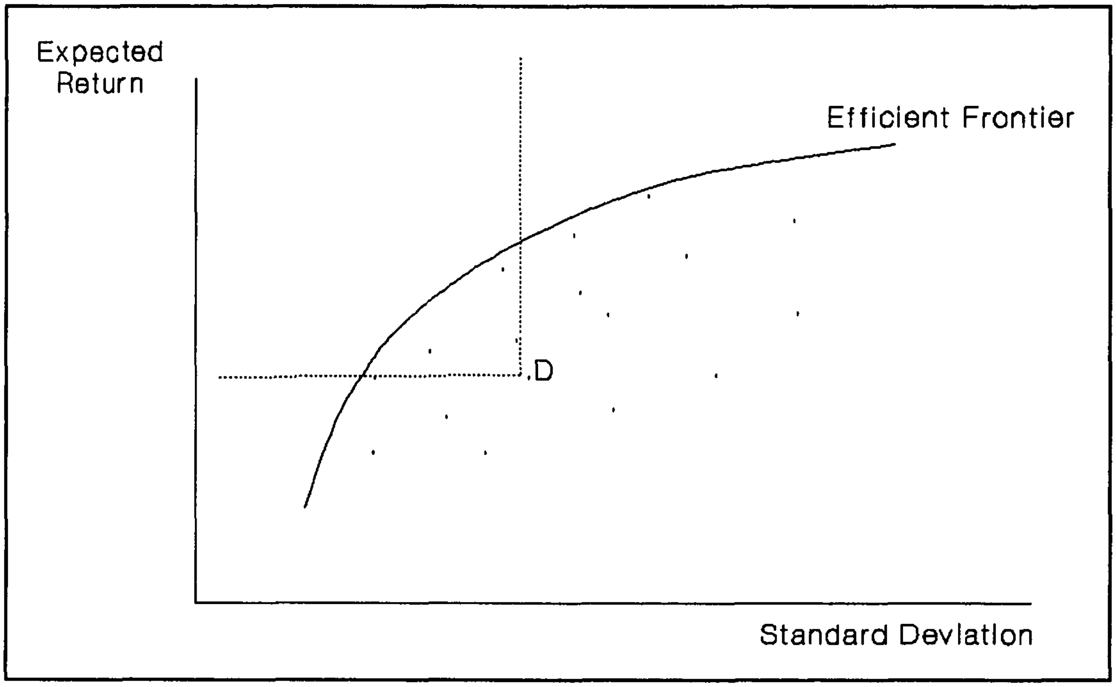

Figure 2.5. Positions on the efficient frontier which dominate point "D".

asset, the correlation between the assets' returns, and both the variance and expected rate of return of the portfolio. The number of calculations increases as more asset combinations become possible. For N assets, N(N-1)/2 correlations must be calculated. Thus, 2,566,245 correlations would have to be calculated by an investor in order to choose among the 2,266 domestic stocks trading on the New York Stock Exchange on December 31, 1984. These correlations have some element of uncertainty in themselves, because the first step would be to estimate the expected rates of return and variance of the returns for each asset being considered.

Development of the CAPM

Although Markowitz portfolio theory was difficult to implement, especially before computers became commonplace, it did inspire related work in the theory of valuation. Several variations were published in the early 1960s which eventually were merged into the CAPM. The CAPM is a mathematical extension of portfolio theory. The influential work in the development of the CAPM was done by Sharpe (1963), Lintner (1965) and Mossin (1966).

The difference between portfolio theory and the CAPM is the addition of another asset to the set the investor must choose from in the CAPM. This is the risk-free asset (R_f) which appears along the vertical axis in figure 6. The risk-free asset, by definition, has no risk and no covariance with any other asset or portfolio. It offers investors a small return as compensation for temporary illiquidity.

The addition of the risk-free asset changes the efficient frontier faced by investors. A straight line drawn from the risk-free rate will lie tangent to portfolio theory's efficient frontier at a point known as M, the market portfolio. This line is the Capital Market Line. The market portfolio contains all possible assets which originally existed. Assuming investors are allowed to buy or sell the risk-free asset, any investor who was not originally investing in the market portfolio can move along the Capital Market Line to reach a higher level of utility.

To illustrate, assume an investor originally selected the portfolio at point E as shown in figure 7. This point lies on indifference curve U_1 and represents

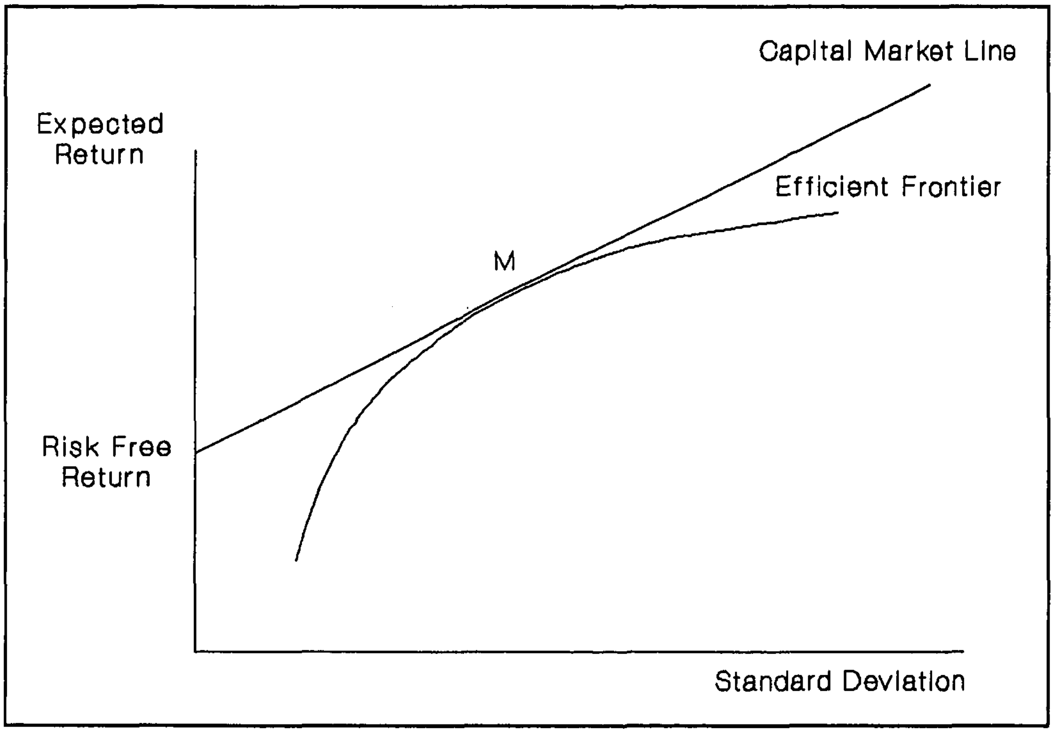

Figure 2.6. The Capital Market Line drawn tangent to the efficient frontier in risk/return space.

the highest possible utility level the investor can reach if limited to the original set of investments bounded by the efficient frontier.

When the risk-free asset is added to the investor's opportunity set, the efficient frontier is dominated by the Capital Market Line, as discussed above. The investor who was holding portfolio E will now sell E and invest part of his wealth in the market portfolio (M) and the rest in the risk-free asset. By combining M with either buying or selling the risk-free asset, an investor can reach any point which lies along the Capital Market Line. This investor would invest a portion of his wealth in the market portfolio and buy into the risk-free

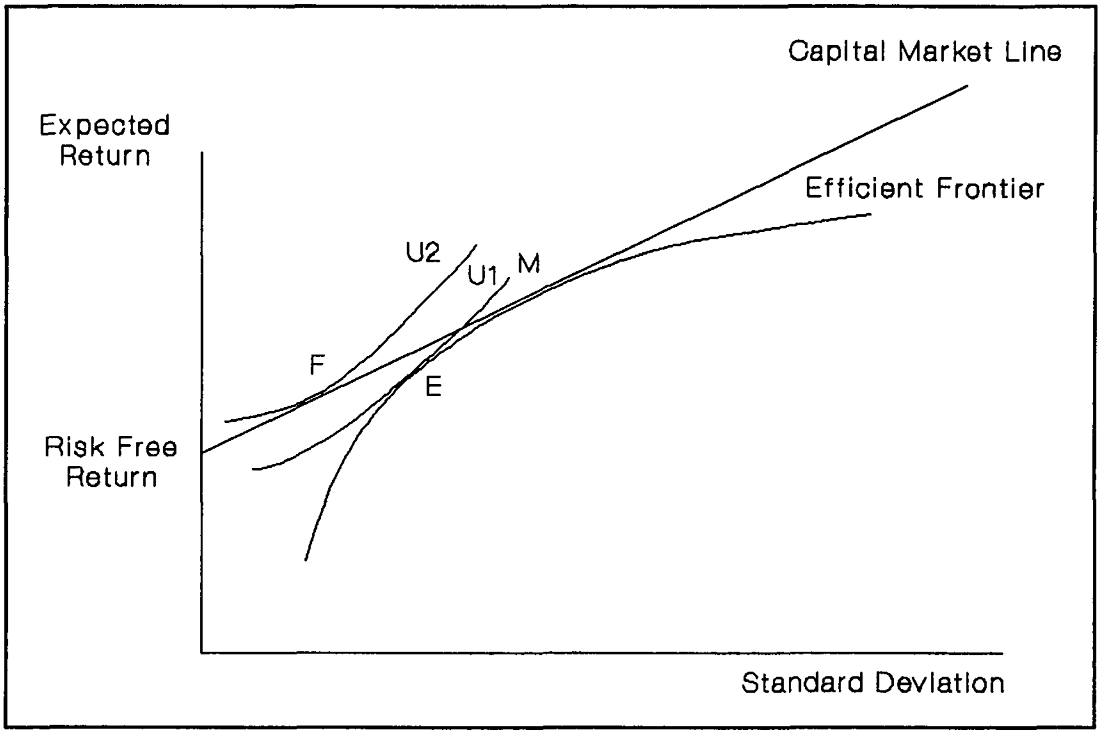

Figure 2.7. The use of indifference curves to select the investor's optimal portfolio on the Capital Market Line.

asset with the remainder. The proper combination of M and R_f will allow the investor to reach point F, which lies on indifference curve U_2 and provides more utility to the investor than the original investment in portfolio E.

All investors now invest in only two assets, the market portfolio and the risk-free asset. Investment in the risk-free asset can be thought of as allowing all individuals to borrow or lend at the risk-free rate of return. An investor who desires a portfolio which lies on the Capital Market Line between the market portfolio and the risk-free asset will invest a portion of their wealth in the risk-free asset. This would be the same as lending that amount of wealth at the risk-free rate of return. An investor who desired to invest along the Capital Market Line at a point to the right of the market portfolio would be selling short the market portfolio, in effect borrowing at the risk-free rate in order to invest some amount greater than 100 percent of current wealth in the market portfolio.

This result leads us to the formal statement of the CAPM. In order to value individual assets, we look at how an individual asset will affect the portfolio, so begin by assuming that the investor has "a" percent invested in risky asset "i" and "1-a" percent is invested in the market portfolio "m". The expected rate of return and variance of the investor's portfolio are now:

$$E(R_p) = aE(R_i) + (1-a)E(R_m)$$

$$\sigma(R_p) = [a^2\sigma_i^2 + (1-a)^2\sigma_m^2 + 2a^2(1-a)^2\sigma_{im}]^{1/2}$$

Now take the partial derivatives of the expected rate of return and variance of the portfolio with respect to the amount invested in the risky asset.

$$\frac{\partial E(R_p)}{\partial a} = E(R_i) - E(R_m)$$

$$\frac{\partial \sigma(R_p)}{\partial a} = 1/2\ [a^2\sigma_i^2+\sigma_m^2 - 2a\sigma_m^2+a^2\sigma_m^2+2a\sigma_{im}-2a^2\sigma_{im}]^{-1/2} * [2a\sigma_i^2-2a\sigma_m^2+2a\sigma_m^2+2\sigma_{im}-4a\sigma_{im}]$$

Taking the limits of the above equations as "a" approaches zero

$$\frac{\partial E(R_p)}{\partial a}\lim_{a\to 0} = E(R_i) - E(R_m)$$

$$\frac{\partial\sigma(R_p)}{\partial a}\lim_{a\to 0} = \frac{\sigma_{im}-\sigma_m^2}{\sigma_m}$$

Setting the slope of this relationship equal to the slope of the Capital Market Line;

$$Slope = \frac{Rise}{Run} = \frac{E(R_i)-E(R_m)}{\frac{\sigma_{im}-\sigma_m^2}{\sigma_m}} = \frac{E(R_m)-R_f}{\sigma_m}$$

Cross multiply by each denominator

$$[E(R_i)-E(R_m)](\sigma_m) = [E(R_m)-R_f]\frac{\sigma_{im}-\sigma_m^2}{\sigma_m}$$

Cross multiply by σ_m

$$[E(R_i)-E(R_m)](\sigma_m^2) = [E(R_m)-R_f][\sigma_{im}-\sigma_m^2]$$

Multiply to combine terms

$$\sigma_m^2 E(R_i)-\sigma_m^2[E(R_m)] = \sigma_{im}E(R_m)-\sigma_{im}R_f-\sigma_m^2 E(R_m)+\sigma_m^2 R_f$$

Cancel out $\sigma_m^2(E(R_m))$ term

$$\sigma_m^2 E(R_i) = \sigma_{im}E(R_m)-\sigma_{im}R_f+\sigma_m^2 R_f$$

Factor covariance terms out

$$\sigma_m^2 E(R_i) = \sigma_{im}[E(R_m)-R_f]+\sigma_m^2 R_f$$

Divide by σ_m^2

$$E(R_i) = \frac{\sigma_{im}[E(R_m)-R_f]+\sigma_m^2 R_f}{\sigma_m^2}$$

Separate terms

$$E(R_i) = \frac{\sigma_{im}[E(R_m)-R_f]}{\sigma_m^2}+\frac{\sigma_m^2 R_f}{\sigma_m^2}$$

Cancel out σ_m^2 to leave R_f

$$E(R_i) = R_f+\frac{\sigma_{im}}{\sigma_{m^2}}[E(R_m)-R_f]$$

Define beta (β)

$$\beta = \frac{\sigma_{im}}{\sigma_m^2}$$

Resulting in the Capital Asset Pricing Model

$$E(R_i) = R_f+\beta[E(R_m)-R_f]$$

Tests of CAPM Assumptions

The CAPM is based on eight assumptions. The first five are required for the development of Markowitz portfolio theory and the remaining three are required for portfolio theory to be extended into the CAPM. These assumptions are:

1. The investor's only desire is to maximize the utility of terminal wealth.
2. Investors make choices based on risk and return, which can be measured as mean portfolio return and variance of these returns.
3. Investors have homogeneous expectations regarding risk and return.
4. Investors have identical time horizons.
5. All information is freely and instantly available to all investors.
6. A risk-free asset exists which all investors may buy or sell short.
7. There are no taxes, transactions costs, restrictions on selling short, or other market imperfections.
8. Total asset quantity is fixed and all assets are marketable and divisible. (Harrington, 1987, p. 26)

To various degrees, all of the above assumptions are violated in the real world. These violations and their impact on the assumptions are discussed individually in the following sections.

<u>The investor's only desire is to maximize the utility of terminal wealth</u>. This first assumption is perhaps the most straightforward. To develop a theory of valuation, we begin by specifying the investor's objective.

<u>Investors make choices based on risk and return, which can be measured as mean portfolio return and variance of these returns</u>. If returns are normally distributed, the expected value and variance of returns are the only measures necessary to describe the distribution of expected returns. Returns in the stock market cannot be perfectly normally distributed because (given limited

liability for investors) the limit on losses is 100 percent of the initial investment. Fama (1965a) tested the distribution on daily returns of the NYSE and reported that they are symmetrically distributed but that the empirical distribution has fat tails and no finite variance. In a related article, Fama (1965b) shows that as long as the distribution of returns is stable and symmetric, investors can make choices using measures of dispersion other than variance (such as the semiinterquartile range) and portfolio theory will remain valid.

Investors have homogeneous expectations regarding risk and return. This assumption requires that all investors agree on (and face) the same opportunity sets, efficient portfolio and capital market line. Lintner (1969) argues that the existence of heterogeneous expectations will cause the terms of the CAPM to be expressed as complex weighted averages of investor expectations but that the basic model is not changed.

Investors have identical time horizons. This assumption is the presumption that all investors desire to achieve their terminal wealth at a single, common date. Although not realistic, the variables in the CAPM are the best estimates possible today regarding future conditions. Merton (1973) has derived a version of the CAPM which relaxes this assumption and is essentially unchanged.

All information is freely and instantly available to all investors. This assumption is another way of stating that no investors have privileged information that allows them to consistently earn higher rates of return than average investors. This is naturally violated in the case of specialists who make a market for stocks on organized exchanges and for inside traders, but it appears that overall, markets are efficient in this regard.

A risk-free asset exists which all investors may buy or sell short. This assumption is critical to the development of the CAPM from Markowitz portfolio theory. The risk-free asset is needed to reduce the complex pairwise covariances of the Markowitz model into the simpler and intuitively appealing CAPM. If all investors may borrow or lend at the risk-free rate, the curved efficient frontier developed by Markowitz is transformed into the linear efficient frontier found in the CAPM. This assumption rests on two conditions. Does a risk-free asset exist, and if so, can investors both borrow and lend at this rate?

The rate of return on U.S. Treasury securities is commonly used in empirical studies as a proxy for the risk-free rate of return. Black (1972) has developed a version of the CAPM which uses a zero-beta portfolio in place of the risk-free asset. The zero-beta portfolio is a portfolio which has zero covariance with the market portfolio and the same systematic risk as the market portfolio. This portfolio can be constructed through short selling risky assets. Because inflation still affects the zero-beta portfolio, the Security Market Line in this version of the CAPM has a higher intercept and less steep slope than the theoretical model. Other forms of the CAPM which explicitly consider inflation have been developed by Biger (1975), Hagerman and Kim (1976) and Friend, Landskroner and Losq (1976).

The assumption that all investors have access to the risk-free rate clearly does not hold true in the real world. Although all investors have the option of purchasing U.S. Treasury securities (lending at the risk-free rate) they surely cannot borrow at the same rate of return. Relaxing this assumption leads at least to a capital market line with an angle where the different borrowing and lending rates intersect. "The borrowing-lending assumption is critical to the model's integrity, and its relaxation causes changes that we are not yet able to describe well" (Harrington, 1987, p. 42).

There are no taxes, transactions costs, restrictions on selling short, or other market imperfections. Brennan (1970) has investigated the effects of different tax rates on capital gains and dividends. His model suggests that the CAPM should include an additional term to measure the tax effect.

The CAPM relies heavily on the ability of investors to sell short. Both Ross (1977) and Roll (1977) have shown that a risk-free asset or a portfolio of short-sold securities must exist in order for the capital market line to be straight. In the real world, restrictions on short-selling vary among investors.

Total asset quantity is fixed and all assets are marketable and divisible. This assumption implies that the liquidity of an asset does not have to be explicitly considered when an investor is determining an appropriate required rate of return. Liquidity refers to the ease of converting an asset to cash at a fair market value.

This assumption also ignores the existence of nonmarketable assets. Most people have an investment in personal skills which can be rented (for wages) but not permanently sold. In some cases, this may represent a large amount of an individual's total wealth in the form of a nonmarketable asset.

Mayers (1972) has derived an alternative form of the CAPM which includes the existence of nonmarketable assets. It suggests investors will hold different risky portfolios because of their different human capital. The market price of a risky asset can still be determined without the use of the investor's utility curves and the appropriate measure of risk is now the covariances between the risky asset and two portfolios, one of marketable and another of nonmarketable assets.

The Firm Size Effect

Several researchers have reported that adding firm size to the model increases the predictive power of the CAPM. It appears that small firms have higher average returns than large firms even after returns are adjusted for firm risk as measured by the CAPM (Reinganum, 1983, p. 36). Harrington (1983, p. 83) reports that it would have been possible to increase returns by almost twenty percent per year from 1963 to 1977 if an investor had concentrated on investing in the stocks of small firms. The largest abnormal returns occur for firms that recently became small, (i.e. declined in price) did not pay a dividend or have high dividend yields, low prices, or low P/E ratios (Keim, 1986).

Rolf Banz (1981) published one of the first empirical articles on the size effect as part of a special edition of the Journal of Financial Economics devoted to market anomalies in 1981. He examined the relationship between the total market value of the common stock of a firm and the rate of return earned by investors for the 1936-1975 period. This study was a cross-sectional test of the CAPM relationship using the same model as Black (1972) with an additional term added to measure the size of the firm relative to the size of all other firms in the market. The final model used was

$$R_{it} = \hat{\gamma}_{0t} + \hat{\gamma}_{1t}\,\beta_{it} + \hat{\gamma}_{2t}\,\frac{\theta_{it} - \theta_{mt}}{\theta_{mt}}$$

Where:

R_{it}	=	the rate of return on security "i" at time "t"
$\dot{\gamma}_{0t}$	=	the rate of return on a zero-beta portfolio at time "t"
$\dot{\gamma}_{1t}$	=	the market risk premium at time "t"
θ_{it}	=	the market value of security "i" at time "t"
θ_{mt}	=	the average market value at time "t"
$\dot{\gamma}_{2t}$	=	a measure of contribution of θ_i to the rate of return associated with a security at time "t"

If there is no observable relationship between θ_{it} and R_{it} ($\hat{y}_{2t}$ is not statistically significant) then the model collapses into the Black (1972) version of the CAPM. Prior to testing, securities were placed in portfolios, using the same technique as Black and Scholes (1974).

> The securities are assigned to one of twenty-five portfolios containing similar numbers of securities, first to one of five on the basis of the market value of the stock, then the securities in each of those five are in turn assigned to one of five portfolios on the basis of their beta. (p. 7)

Five years of data were used to estimate security betas and the following five years were used to estimate portfolio betas. Price and number of shares outstanding at the end of the five year periods are used to calculate firm size.

Banz's (1981) results suggest that, on average, small NYSE firms had significantly higher risk adjusted returns than large NYSE firms over the test period. This effect was not linear or stable through time and was most pronounced in the smallest firms in the sample. When Banz plotted the mean residual return for each of the twenty-five portfolios he found that the majority of the firm size effect was associated with the smallest firms in his sample.

The portion of returns not explained by the CAPM are commonly referred to as "excess returns". The average excess return for holding very small firms long and very large firms short was 1.52 percent per month (19.8 percent annually). Although this strategy would suggest large arbitrage profits to investors, it would leave them with a poorly diversified portfolio and the strategy would not have been successful in each five year sub-period.

Reinganum (1981) attempted to test the information content of firm size relative to P/E ratios (in this article, the P/E ratio was calculated as an E/P ratio). Using quarterly data, he ranked firms into two portfolios, each with twenty securities and an estimated portfolio beta equal to one. One was formed with the twenty securities with the highest E/P ratios and the other contained the twenty lowest E/P ratios. The securities in each portfolio were weighted so that the portfolio would have a beta equal to one. If the CAPM fully explains returns there would have been equal returns for the portfolios. The high E/P portfolio consistently had excess returns which were positive and statistically significant. Reinganum repeated his tests using different market indexes and yearly data with approximately the same results.

After establishing the existence of an E/P effect, the same data set was used to test for the existence of a firm size effect (which was referred to as market value). Reinganum (1981) formed ten portfolios based on the market values of the securities. The portfolio with the lowest total market value had a mean daily abnormal return of 0.05 percent, more than twelve percent annually. the second lowest total market value portfolio had mean daily abnormal returns of 0.02 percent, slightly over four percent per year. Both were statistically significant. Reinganum concluded that "one can earn 'abnormal' returns that persist for at least two years by forming portfolios based on the market value of the stock" (1981, p. 41).

After validating both an E/P and a firm size effect on the same data set, Reinganum began to study the interactions between the two. Casual examination of a matrix classifying firms on both their market value and E/P ratio revealed a slightly positive correlation between low E/P ratios and high market values and that only a few firms in the sample have both high market values and high E/P ratios.

Next the firms were grouped into twenty-five portfolios by forming a 5 x 5 matrix with the highest E/P ratio on the left going to lowest on the right and the highest market value at the top going down to the lowest at the bottom. "The smallest firms in a given E/P quintile systematically outperform the high market value firms in that quintile,and this result is true for each of the five E/P quintiles" (p. 42). A test based on Zellner's Seemingly Unrelated Regression methodology was used to test the hypothesis that the mean excess returns of the lowest market value portfolios are equal to the mean excess returns of the highest market value portfolios within each E/P group. The difference between the means is statistically significant at the one percent level. "Thus, the evidence indicates the presence of a substantial value effect irrespective of a security's E/P ratio" (p.43).

> The evidence in this study strongly suggests that the simple one-period capital asset pricing model is misspecified. The set of factors omitted from the equilibrium pricing mechanism seems to be more closely related to firm size than E/P ratios. The misspecification, however, does not appear to be a market inefficiency in the sense that 'abnormal' returns arise because of transaction costs or informational lags. Rather, the source of the misspecification seems to be risk factors that are omitted from the CAPM as evidenced by the persistence of 'abnormal' returns for at least two years. (Reinganum, 1981, p. 44)

The P/E anomaly was no longer significant after controlling for the size effect. This suggests that the two anomalies are related to the same subset of factors and that these factors are more closely related to firm size then P/E ratios.

Richard Roll (1981) presents evidence that these unknown factors are partially an auto-correlation in portfolio returns caused by infrequent trading. "Because small firms are traded less frequently, risk measures obtained from short interval returns data (such as daily), seriously understate the actual risk from holding a small firm portfolio, whatever the model investors use to assess risk" (p. 879).

Instead of testing portfolios formed with individual securities of different sizes, Roll used equally-weighted and value-weighted market indexes. A value-weighted index is influenced more by large firms than an equally-weighted index. Roll used Standard and Poor's 500 Index to proxy for large firms and an equally-weighted index of NYSE and AMEX common stocks for the period July 1962 through December 1977 as a proxy for small firms. (The value weighted index of the NYSE and AMEX was also used and produced results which were similar but not presented in detail.)

When returns were calculated based on daily holding periods, Roll supported Reinganum's (1981) finding that small firms have higher rates of return than large firms, holding risk constant. Roll then when on to calculate returns using weekly, bi-weekly, monthly, bi-monthly, quarterly and semi-annual holding periods. As longer holding periods were used, the risk (measured by variance and the market model beta) increased for the equally-weighted index more than for the value-weighted index while the difference in mean returns between two only went from 12.56 percent annually to 12.20 percent annually.

Roll explained both the small firm and P/E effects as being caused by errors in the variables. He stated that Reinganum (1981) had "demonstrated convincingly that the P/E effect is attributable to P/E and size being strongly related" (p.886). This was to be expected since size and P/E ratios are correlated and size is the better proxy for infrequent trading. Roll went on to suggest that the small firm effect is caused by a "rather horrendous bias" associated with the use of daily data even though small firms may not trade daily:

> The effect is easy to see when an entire day passes without a trade; then that day's implicit return will be recorded on the day when its first subsequent trade takes place. This return is correlated, of course, with the returns of other firms which did register trades on the first day. The auto-correlation thereby induced in a portfolio of such securities is completely spurious and is simply the result of a defect in our record of prices. A similar spurious auto-correlation is induced even if firms trade every day but not continuously. The longer the average time between trades, the greater the induced auto-correlation in portfolios of such firms (p. 884).

Reinganum (1982) responded to Roll's (1981) criticism by testing Roll's ideas using portfolios of actual securities instead of market indexes. He applied Roll's corrections to the same data set used for testing the size effect in the Arbitrage Pricing Theory model

Ten portfolios were formed on the basis of firm size at the end of each year. Individual securities were weighted equally to calculate portfolio returns.

Both ordinary least squares and the Dimson aggregated coefficients method were used to estimate portfolio betas. The CRSP value-weighted NYSE-AMEX market returns were used as a market index. The Dimson method involves summing the slope coefficient of a regression of leading, lagged, and contemporaneous market returns on the portfolio returns. This method was suggested by Roll (1981) as a possible solution to the auto-correlation problem.

Betas estimated with Dimson's method support the hypothesis that small firms are more risky than large firms. Portfolios of small firms are associated with higher Dimson betas, as Roll (1981) had predicted. However, these larger betas are not enough to explain the differences in return between the portfolios.

> While the OLS estimates seem to understate the betas of small firms, the excess returns not explained by the misestimation could easily exceed twenty percent per year on average. Thus, one can conclude with confidence that the small firm effect is still a significant economic and empirical anomaly (p. 35).

Reinganum further supported his point by directly testing for a size effect after controlling for the Dimson portfolio betas. He estimated the following model for each of the 180 months from 1964 through 1978

$$R_{pt} = \gamma_{0t} + \gamma_{1t}\hat{\beta}_{py} + \gamma_{2t}S_{py} + e_{pt}$$

Where

R_{pt}	=	return in month "t" on market value portfolio "p"
$\hat{\beta}_{py}$	=	estimated Dimson beta for portfolio "p" during year "y"
S_{py}	=	logarithm of median firm size in portfolio "p" at end of year "y-1"
e_{pt}	=	disturbance term

This model is applied to ten and thirty market value portfolios. The estimates "are virtually the same regardless of whether ten or thirty portfolios are used" (p. 33). Overall, firm size displays a statistically significant negative relationship with portfolio rates of return. The risk premiums associated with the Dimson betas were small during this period. After controlling for size effects, the Dimson betas are able to explain only a portion of the differences in average portfolio returns.

Roll's final response in this series of articles was published in 1983. This article dealt with various methods of calculating the mean return for the portfolios being tested and how these might contribute to a possible size effect.

Roll drew a distinction between two main methods of computing mean returns. The arithmetic computational method consists of averaging returns across both firms and days to obtain the mean daily return for the portfolio. The mean daily return is then compounded to obtain the return over the period being tested. The buy-and-hold method involves calculating the individual stock return for the full period, then the mean return of the portfolio is found by averaging the security returns. The buy-and-hold method is said (by Roll) to be a better approximation of investor behavior.

Roll (1983) demonstrates that the arithmetic method produces higher average returns for small firms when applied over periods of one year or more. The reason he offers is that individual assets may not trade continuously and significant transactions costs may exist. Roll also states that this problem is not limited to firm size, but that "dividend yield, price/earnings ratio, and beta, could also present similar empirical difficulties" (p. 372).

After making these statistical corrections, Roll is forced to admit that a firm size effect is still statistically significant, although no longer as large as originally thought. Referring specifically to Banz's (1981) size effect article and the related price effect articles of Blume and Husic (1973) and Bachrach and Galai (1979) he admits that "it seems unlikely that the results presented in those papers will be much affected by the problem investigated here" (p. 383).

Following this series, Roll seems to have become a reluctant convert to the existence of market anomalies. His 1983 article argues for the existence of an annual pattern in stock prices, in addition to a size effect. Roll (1983) tested for data errors, listing, delisting, and outliers in this article, but was unable to find a reason for the pattern he observed. In an article he had authored following the development of the CAPM, Roll (1977) had argued that the CAPM was untestable because the market portfolio cannot be observed. All tests of the CAPM are joint tests of the efficiency of the proxy selected for the market portfolio. If this proxy is not efficient (and this cannot be tested), the results will be biased. Roll updated his reasoning to allow for the existence of anomalies at the conclusion of his 1983 article. After admitting that he was unable to explain away the seasonal and size effects in his data set, Roll states that "the presence of the seasonality creates a substantial econometric problem in measuring systematic risk and in testing risk/return relationships" (p.26).

Keim (1983) followed Roll's 1983 article by further investigating the connection between firm size and seasonal market returns. Keim used a data set containing all firms listed on the NYSE or AMEX and on the CRSP tapes from 1963 to 1979. After controlling for the influence of the January seasonal, it appeared that the size effect can be broken down "into two distinct components: a large premium every January and a much smaller and, on average, positive differential between risk-adjusted returns of small and large firms in every other month" (p. 14). Approximately fifty percent of the size effect was explained by controlling for the January effect in Keim's study.

Kothari and Wasley (1989) found different results regarding the interaction of the firm size and January effects. They tested four different abnormal return measures using a combination of simulated and empirical data. Their results suggest that a firm size effect does exist and that controlling for firm size removes the January effect. Both Kothari and Wasley (1989) and Demson and Marsh (1986) recommend using a size adjustment when calculating excess returns. Demson and Marsh (1986) specifically refer to the case of event studies while Kothari and Wasley (1989) suggest the use of a size control portfolio or size model abnormal performance measure in order to reduce the probability of incorrectly rejecting the null hypothesis.

Lamoureux and Sanger (1988) extended both the size and January effects into the Over-the-Counter (OTC) market. They listed five reasons for using the OTC market as a data base.

1. The presence of a large sample of small firms.
2. Small OTC firms are less likely to have recently performed poorly.
3. To test the robustness of the effects in different market structures.
4. To include bid and ask spreads and trading volume in cross-sectional analysis of the size and January effects.
5. Returns on OTC stocks which are not listed on the National Market System are computed from successive midpoints of bid and ask prices which reduces "measurement error caused by a shift in order flow from trades at the bid price to trades at the ask price as a possible explanation for any observed effects" (pp. 1120-1121).

Their database was from December 1972 to December 1985 and size was adjusted for using the Scholes-Williams beta measure rather than Dimson.

Friend and Lang (1988) used Standard & Poor's Quality Rank for Stocks in an effort to see if some measure other than beta "can be used to explain all or a large part of the variation in return of stock among different size groups which cannot be explained by the more objective measures of risk commonly used" (p. 14). This risk measure did remove the majority of the firm size effect, however, the Standard & Poor's Quality Rank includes a firm size variable in some years. Prior to 1975, the rank was determined by the stability and growth of earnings and dividends, modified as needed by industry and special circumstances, from 1976 to 1979, a minimum size criteria existed for the top three ranks. Beginning in 1978, minimum size criteria exist for all ranks. One interesting change here is that firm size is defined in terms of corporate sales volume instead of total market capitalization. Assuming that there is a high correlation between total market capitalization and sales, this result is to be expected. Shelor and Cross (1990) directly used sales to measure firm size in a test of insurance firm response to California Proposition 103. They found that small firms (firms with sales less than $200 million) had greater reaction to the passage of Proposition 103 than large firms.

The Relationship Between Risk and Value

There is a positive relationship between an investor's required rate of return and the riskiness of the investment. A decrease in risk reduces the investor's required rate of return which causes cash flows to be discounted at a lower rate and increases the total value of the firm.

The required rate of return is the minimum rate of return which an investment must earn in order for its market price to remain unchanged. The capital asset pricing model (CAPM) defines the required rate of return for asset "i" as

$$R_i = R_f + \beta_i (R_m - R_f)$$

Where

R_i	=	Required rate of return on asset *i*
R_f	=	Rate of return on a risk-free asset
R_m	=	Rate of return on the market portfolio
B_i	=	Beta of asset *i*

If an investment in an information system allows a firm to act faster and/or in a more appropriate manner than the groups that it must interact with, this will reduce the risk to investors. In the framework above, the information system would merely have to reduce the variance of the rate of return on the asset in order to reduce total risk.

Given the number of assets in the market portfolio, a reduction in the variance of one asset would have a negligible effect on the variance of the market portfolio. If the variance of the rate of return on the individual asset decreases and the variance of the rate of return on the market portfolio is unchanged, the asset's beta will decrease. This will occur because beta is the covariance between the rates of return on the individual asset and the market portfolio divided by the variance of the rate of return on the market portfolio. This beta reduction would lead to a reduction in an investor's required rate of return. To phrase it another way, the company's investment in an information system reduces investor's perceived risk and they will to accept a lower rate of return because of the reduced risk.

The only service provided by a financial asset is a claim to some stream of future cash flows. The market value of any financial asset is the present value of the future cash flows it is expected to provide. Mathematically, this is

$$PV = \sum_{t=1}^{n} \frac{CF_t}{(1+i)^t}$$

where *n* is the number of periods in the investment horizon, CF_t is the cash flow (positive or negative) for period *t* and Σ denotes the summation of the discounted cash flows for periods 1 through *n*. If the discount rate which investors apply to these expected cash flows decreases, the present value of the asset must increase. This is because the interest rate, *i* is in the denominator of the above equation. A decrease in the denominator of a fraction must cause an increase in the value of the fraction. The relationship between present value and the discount rate must be inverse because the partial derivative of present value with respect to the interest rate has a negative value

$$\frac{\partial PV}{\partial i} = \frac{-CF}{(1+i)^{n-1}}$$

If the information system investment reduces the firm's risk but does not decrease the stream of future cash flows, the total present value of the firm must increase. This occurs because the same stream of expected cash flows are now being discounted at a lower rate.

To illustrate, an investor with a required rate of return of 15 percent annually will value the right to receive $1,000.00 in five years at $497.18 today. If that same investor reconsiders the riskiness of the investment and chooses to accept a 10 percent annual rate of return, the asset is now worth $620.92. This increase in the value of the asset occurs because of the change in the investor's required rate of return.

Risk Measures Which may be Affected

It is believed that one of the benefits of investing in an information system is the ability of the firm to react faster. If true, this will reduce the risk investors are subject to. Specifically, the theory is tested that an information system allows a firm to reduce various risk measures which are reflected in the market.

Several risk measures are used because one measurement which perfectly describes risk in every situation is not available. Investors tend to look at various risk measures and then aggregate the information content of each measure. The theory that information systems reduce risk by improving a firm's ability to react to it's environment is examined by testing the following hypothesists.

Hypothesis I:

> H_o: An investment in an information system has no effect on the mean of the distribution of rates of return earned from an investment in the firm's stock. ($\mu_{test} = \mu_{control}$)

The mean is the expected value of a distribution. In this study, it is the rate of return earned by an investor who purchased and held the stock for a one-year period. The purpose of this first test is to determine whether there is a statistically significant difference between the test group and the pair-matched control sample in the year following the announcement of an information system investment. This test includes an implied assumption that the returns have a statistically normal distribution.

Hypothesis II:

> H_o: An investment in an information system has no effect on the semivariance of the distribution of rates of return earned from an investment in the firm's stock. ($SV_{test} = SV_{control}$)

Semivariance is similar to standard deviation but it concentrates on the risk of returns below the mean. Standard deviation assumes a normal distribution and assigns equal importance to outcomes above and below the mean. The test for semivariance change follows Hypothesis I because it relaxes the assumption of a normal distribution of returns. If the distribution of returns is skewed, semivariance can be used to compare the distributions. Proponents of semivariance also argue that focusing on downside risk is appropriate because investors are assumed to be risk averse.

Hypothesis III:

> H_o: An investment in an information system has no effect on the coefficient of variation of the distribution of rates of return earned from an investment in the firm's stock. ($CV_{test} = CV_{control}$)

Unlike the above absolute measures of risk, the coefficient of variation is a relative dispersion measure. It adjusts for the scale of various investments by showing the amount of risk (as measured by the standard deviation) per unit of expected return. This allows decision-makers to simultaneously consider both risk and expected return.

Hypothesis IV:

> H_o: An investment in an information system has no effect on the beta of a firm. ($\beta_{test} = \beta_{control}$)

Beta is a standard measure of the relationship between returns on an individual asset and returns on the market portfolio. A change is the beta following an information system investment would have more meaning than a change in the coefficient of variation. This is because beta measures only the systematic risk of the investment. According to current financial theory, this systematic risk is the only type of risk an investor must be subject to and therefore is the only type of risk which affects an asset's price.

Hypothesis V

H_0: An investment in an information system has no effect on various measures of the firm's operational efficiency. ($Ratio_{test} = Ratio_{control}$)

Operational efficiency is measured in this manuscript using a selection of accounting and financial ratios. Unfortunately there does not seem to be agreement in the literature as to which ratios best measure firm performance and some of the intangible constructs which may be important in this case are not appropriately measured by financial ratio analysis.

Pinches, Mingo and Caruthers (1973) developed a seven-factor classification based on principal component analysis of financial ratios across a selection of industries. Their classification system was stable during the 19-year period used for testing. A follow-up study by Pinches, Eubank, Mingo and Caruthers (1975) demonstrated that the factors are also stable for short-term tests. Principle component analysis of financial ratios has also been performed by Pinches and Mingo (1973), Stevens (1973) and Libby (1975).

Chen and Shimerda (1981) provide a review of the financial ratios which were found to be useful in 26 earlier empirical studies. They concentrated on the major financial areas developed by Pinches, Mingo, and Caruthers (1973) as the seven factors best representing the variables used in other studies. Following a principal components analysis of 39 ratios for 1,053 firms they identified a selection of financial ratios which loaded on the factors identified in the earlier studies. They conclude that "the question of which ratio should represent a factor has yet to be resolved" (p. 59).

The du Pont model is another commonly used method of organizing financial ratios (Brigham, (1992); Weston and Copeland, (1992)). This model provides a logical basis for considering profitability in terms of the firm's ability to control costs and manage assets. The upper section of the model focuses on cost management while the lower section focuses on asset management. Items identified by the above researchers and the components of the du Pont model are used to measure operating efficiency in this manuscript.

Summary

This chapter begins with an overview of the development of information systems as an important, although somewhat intangible, asset of modern organizations. As the importance of information system investment increases, the need for and complexity of information system investment evaluation increases. A review of the theoretical reasons for the use of accounting and financial measures to determine the effect of information system on shareholders has been presented. Finally, appropriate measures of this effect on the firm's risk levels and measures of operating efficiency are discussed.

CHAPTER III

METHODOLOGY

The purpose of this chapter is to describe and provide theoretical support for the methodological procedures used in the research. Following a list of the steps taken during the research, the sample collection methodology is discussed. An explanation of the methods used to calculate beta, semivariance and coefficient of variation is followed by the methodology for testing the hypothesists. The final section of the chapter discusses the computation of the measures of operating efficiency and the appropriate tests.

Steps in the Research Process

1. Select a test group of firms which undertook significant information system investments in 1988 or 1989 based on their annual reports.
2. Calculate beta based on daily rates of return for the year prior to the year in which the information system investment was announced for all firms in the test group.
3. Calculate beta based on 1987 and 1988 rates of return for all firms listed on the CRSP database.
4. Select a pair-matched control sample matching each firm in the test sample with one other firm in the CRSP database based on the SIC industry code and pre-investment beta.
5. Calculate post-investment beta, semivariance and coefficient of variation for all firms in the test and control groups.
6. Calculate measures of operational efficiency for all firms in the test and control groups.
7. Perform appropriate tests of hypotheses.

Sample Collection

Sample collection began with the selection of a group of companies which had made significant information system investments in 1988 or 1989. For each year of interest, a search was made of the Compact Disclosure database. The key words used in this search were "information system," "information systems" and "computer." All firms which contain at least one of these key words in the text of the annual report or Form 10-K were selected. This list was then matched with the CRSP database in order to eliminate those firms for which rate of return data was not available. Following the reduction of the list to firms with data available, the annual report and Form 10-K text for each firm in the reduced sample were read to determine which firms indicated making information systems investments.

As discussed in chapter II, the great majority of firms did not divulge the value of their information systems investment in the annual report or Form 10-K. For this manuscript, it is assumed that the investment is expected to have a significant impact of operations or else it would not be mentioned in the documents. Table 3.1 shows the reduction in the number of firms in the sample at each stage of this process for each year.

Table 3.1

Reduction in Sample Size during Selection Process

Selection Criteria	1988	1989
Initial key word search	2,473	2,417
Match with CRSP database	497	670
Information system investment mentioned	105	157

This selection process left a total of 262 possible test firms. The next criteria which had to be met was the availability of data on Standard & Poor's Compustat tapes. It was also necessary for three full years of data to available on the CRSP tape to calculate market risk measures. The necessity to combine three separate databases limited the number of companies in the final sample. The final test group contained 162 companies for a total of 324 firms after the pair-matched sample had been collected.

The selection of a control group is the next step in the research process. A pair-matched sample is preferable to a randomly selected control group in this situation. In a study of accounting changes, Abdel-khulik and McKeown (1978) explained this preference for a pair-matched sample as follows:

> In selecting the control sample, we preferred to use pairwise matching over a random sample for a simple but important reason. Since the analysis of the behavior of rates of return is performed over a period of time surrounding the date of the announcement of the accounting change, and since the control firms did not change accounting method, the need to preserve a consistency in the timing of the analysis required pairwise matching of the switch firms with control firms on the basis of

> certain similarity criteria. Utilizing a random control sample would have made this alignment of dates arbitrary and would have rendered any statistical tests of significance very difficult... Since the experimental sample was not randomly selected, other variables were not randomized and the choice of a matched-pair control sample was necessary. (p. 855, 857)

The control group selection techniques used in Abdel-khulik and McKwoen (1978), Abdel-khulik and Ajinkya (1982) and Ricks (1982), formed a basis for the selection of the control group used in this study. The control sample was selected based on the industry code and pre-investment beta of the firms in the test sample. Tables 1 and 2 in the appendix show the distribution of the firms in the sample groups by two-digit SIC code and beta, respectively.

Calculation of Risk Measures

In addition to comparing mean rates of return, three measures of risk (semivariance, coefficient of variation and beta) were tested to determine whether a difference exists between the test group and the control sample. The mean rates of return used in these tests are the one-year average of the daily rates of return in the stock market.

The test of the mean rates of return is designed to determine whether the stock of the firms which did invest in an information system performed differently from the stock of the firms which did not invest. A statistically significant difference implies that a real difference exists in the rates of returns earned by the companies in the test group relative to the control sample.

Semivariance is related to standard deviation with the difference that it concentrates on the risk of returns below the mean. Standard deviation assumes a normal distribution and assigns equal importance to outcomes above and below the mean. The test for semivariance change relaxes the assumption of a normal distribution of returns which is implicit in the comparison of means. If the distribution of returns is markedly skewed, the semivariance can be used to compare the distributions. Proponents of semivariance also argue that focusing on downside risk is appropriate because financial theory assumes that investors are risk averse. Semivariance (SV) is defined as

$$SV = \sum_{j=1}^{K} P_j (R_j - \bar{R})^2$$

where

j	=	the set of all values of the random variable which are less than the expected value
K	=	number of outcomes in set j

The mean and semivariance are absolute measures of a distribution. Unlike them, the coefficient of variation is a relative dispersion measure. It adjusts for the scale of various investments by showing the amount of risk (as measured by the standard deviation) per unit of expected return. This allows decision-makers to simultaneously consider both risk and expected return. The coefficient of variation (CV) is defined as

$$CV = \frac{\sigma}{\overline{R}}$$

Beta is a standard measure of the relationship between returns on an individual asset and returns on the market portfolio. A change is the beta following an information system investment would have more meaning than a change in the coefficient of variation. This is because beta measures only the systematic risk of the investment. According to current financial theory, this systematic risk is the only type of risk an investor must be subject to and therefore is the only type of risk which affects an asset's price. Beta (β) in this manuscript is calculated using the market model form of the CAPM (Copeland and Weston, 1990, p.362). In this model, beta is the slope coefficient on the rate of return on the market portfolio (R_m) as shown below

$$R_i = \alpha_i + \beta_{iR_m} + e_i$$

As discussed in Chapter II, there is considerable evidence that firm size affects investment performance in the stock market. Several variables have been used as proxies for size with similar empirical results and high correlations among the variables. Firm size has been measured in the financial literature by using sales as a cut off between large and small firms (Shelor and Cross, 1990). This practice is followed in this manuscript.

Statistical Analysis Method

The hypotheses of interest were tested using an Analysis of Variance (ANOVA) model to compare the test sample to the control group while controlling for firm size. Iversen and Norpoth (1989) state that the ANOVA method is appropriate "when the groups of observations are created by a categorical independent variable" (p. 8). The objective of this study was to determine whether an information system investment had a statistically significant effect on the risk levels of the investing firms relative to the control sample. Because it was also necessary to control for the effects of company size, a fixed-effects, two-factor ANOVA model was appropriate for use.

Because both factors are considered fixed, three types of effects must be considered in this manuscript (Kleinbaum and Kupper, 1978, p. 332). First, row-factor main effects are the differences between the various row means and the overall sample mean. Second, column-factor main effects are the differences between the various column means and the overall sample mean. Finally, an interaction effect will be tested.

Each model of interest in this manuscript is a 2x2 factorial design as shown below

		Size Factor	
		Small	Large
Information System Investment Factor	Yes	*X*	*X*
	No	*X*	*X*

The two factors of interest are firm size and the presence or absence of a recent information system investment. The group mean for each variable being tested (mean rates of return, etc.) is *X*. The row-factor main effect shows the difference in *X* related to the information system investment decision. The column-factor main effect shows the difference in *X* related to firm size. The interaction effect shows the degree to which the scores for a given factor depend on the other factor.

The common form of the two-way fixed-effect analysis of variance model is

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_{ij} + E_{ijk}$$

Where

$\mu = \mu_{..}$ = overall mean

$\alpha_i = \mu_{i.} - \mu_{..}$ = effect of row *i*

$\beta_j = \mu_{.j} - \mu_{..}$ = effect of column *j*

$\gamma_{ij} = \mu_{ij} - \mu_{i.}\ \ \mu_{.j} + \mu_{..}$ = interaction effect of cell *ij*

$E_{ijk} = Y_{ijk} - \mu - \alpha_i - \beta_j - \gamma_{ij}$ = error of observation *k* in cell *ij*

Procedure for Data Analysis and Findings Identification

The following assumptions are part of the development of the ANOVA model. The first step in the research was to determine the degree to which the data conform to these assumptions. Neter, Wasserman, and Kutner (1985) note that it is not essential that the ANOVA model fits the assumptions perfectly because the model is robust regarding certain departures form the assumptions (see also Meyers (1975) and Winer (1962)). The major purpose for testing the assumptions of the model is to identify serious departures form the assumptions which would limit or invalidate conclusions drawn from the research.

The ANOVA assumptions which are tested in this manuscript are summarized in table 3.4.

Table 3.2

Tests Employed for ANOVA Assumptions

Assumption	Test
Homoscedasticity	1. Visual inspection of residual plots. 2. White (1980) test.
Normal distribution of error terms	1. Visual examination of normal probability plots of residuals. 2. Studentized residual test.
No outliers	1. Visual inspection of residual plots. 2. Studentized deleted residuals test. 3. Cook's distance measure

Each of these assumptions was examined for the models developed in the present study. The first assumption, homoscedasticity, requires that the residuals have constant variance for all factor levels. If this condition is met, the residual plots will show the same dispersion of the residuals around zero for each factor level. White's (1980) test was also applied to determine whether the data confirm to this assumption. Rejection of the null hypothesis in this test suggests that the data is homoscedastic and also that the model is correctly specified.

Because the basic ANOVA model is robust regarding departures form normality, the assumption that the error terms are normally distributed does not have to be perfectly satisfied provided the model is applied to sample sizes of 20 or more for each factor level (Kleinbaum and Kupper, 1978). The distribution of the error terms may be tested by inspecting a normal probability plot of the residuals. Additionally, the standardized residuals can be examined to test this assumption. When normality exists and the number of residuals is sufficiently large, it is expected that approximately 95 percent of the standardized residuals will fall between +2 and -2 standard deviations from the mean. Visual and formal tests were conducted for each of the ANOVA models in the present study. The visual test consists of graphing the standardized residuals for each factor by observation number. The formal test involves calculating the percentage of the residuals which are outside the acceptable range. If the unacceptable group is under five percent of the total, the data are assumed to be normally distributed.

The presence of outliers was tested for in each of the models in the present study using both a visual examination of the residual plots and the Studentized Deleted Residuals test to identify possible outliers. After the possible outliers had been identified, Cook's Distance Measure was used to measure the individual observation's influence on the results of the model. Although Cook's Distance measure does not follow a true F-distribution, it is commonly assigned the percentile-value of the corresponding F-distribution. A percentile of fifty percent or more suggests substantial influence by that specific observation.

After all of the models were examined for their aptness, the results of the ANOVA technique were analyzed as follows. Testing of each hypothesis was conducted in terms of sub-hypotheses for each job. The sub-hypotheses deal with the main and interaction effects present in the model. The appropriate F-tests from a series of ANOVA models were used to test the sub-hypotheses for each of the four risk measures. The F-test statistic calculated using the ANOVA technique was compared to the F-test statistic (given the degrees of freedom and the selected α level) contained in the percentiles of the F-test distribution table. This comparison indicated whether each sub-hypothesis should be accepted or rejected. The p-value (probability of a greater F statistic) was used to assess the appropriateness of the decision rules used in testing the stated hypotheses. The conclusions for the present manuscript were drawn from the results of the statistical tests applied.

Calculation of Measures of Operational Efficiency

In this dissertation, operational efficiency is measured using a selection of financial and accounting variables. There does not seem to be widespread agreement regarding which variables are best used to measure firm performance. In addition, some of the intangible constructs which are assumed to be important in this case are not appropriately measured through the use of financial and accounting variables.

Pinches, Mingo and Caruthers (1973) developed a seven factor classification system based on principal component analysis of financial ratios across a selection of industries. This framework was stable during the 19-year period used for testing. A follow-up study by Pinches, Eubank, Mingo and Caruthers (1975) found the factors to also be stable for short-term tests. Principle component analysis of financial ratios has also been performed by Pinches and Mingo (1973), Stevens (1973) and Libby (1975).

Chen and Shimerda (1981) provide a review of the financial ratios which were found to be useful in 26 earlier empirical studies. They concentrated on the major financial areas developed by Pinches, Mingo, and Caruthers (1973) as the seven factors best representing the variables used in other studies. Following a principal components analysis of 39 ratios for 1,053 firms they identified a selection of financial ratios which loaded on the factors identified in the earlier studies. They conclude that "the question of which ratio should represent a factor has yet to be resolved." (p. 59) Table 3.3 contains the financial ratios which were used in this manuscript to test for changes in operational efficiency. The related factors, based on previous research, are also presented.

Table 3.3

Measures of Operational Efficiency

Factor	Ratio
Return on Equity	Net Income/Common Equity
Capital Turnover	Sales/Total Assets
Financial Leverage	Long-Term Debt/Current Assets
Short-Term Liquidity	Current Assets/Current Debt
Cash Position	Cash/Current Liabilities
Inventory Turnover	Inventory/Sales
Receivables Turnover	Quick Assets/Sales

The du Pont model is another commonly used method of organizing financial ratios (Brigham, (1992); Weston and Copeland, (1992)). The du Pont model is presented in figure 3.1. This model provides a logical basis for considering profitability in terms of the firm's ability to control costs and manage assets. The upper section of the model focuses on cost management while the lower section focuses on asset management. In addition to the measures of operating efficiency discussed above, several components of the du Pont model are tested in this manuscript.

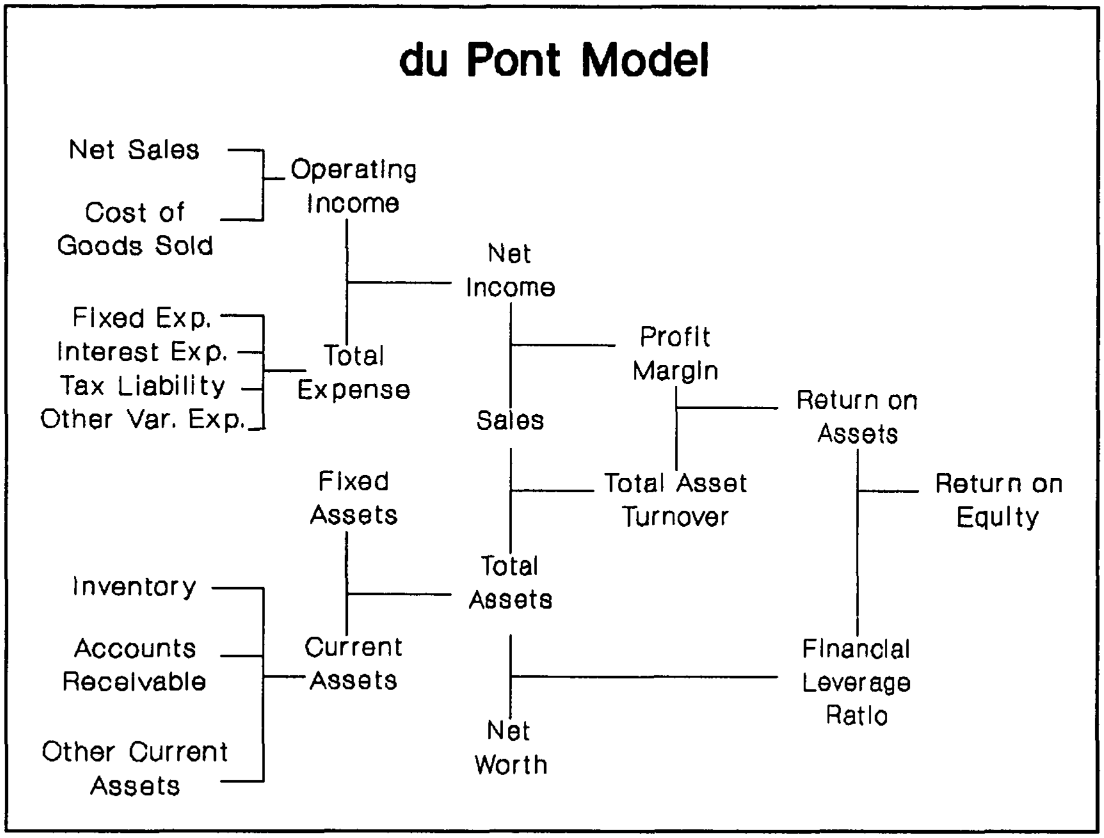

Figure 3.1. The du Pont Model illustrates the relationships between a company's financial ratios.

Summary

This chapter has described and provided theoretical support for the methodological procedures used in the manuscript. The sample collection methodology was the first step discussed. Next, an explanation of the methods used to calculate beta, semivariance and coefficient of variation was followed by the methodology for testing the hypothesists. The final section of the chapter discusses the selection of the measures of operating efficiency and the appropriate tests conducted.

CHAPTER IV

EMPIRICAL RESULTS

This chapter presents the results of the empirical analysis conducted for each hypothesis. As discussed in the preceding chapter, a fixed-effects, two-factor ANOVA model was used in testing the first four hypotheses. This model attempts to account for the fact that the experimental units (the subjects) are not homogeneous with regard to factors that are likely to affect the response variable. The fifth hypothesis was evaluated using a series of T-tests.

Because the first four hypotheses consist of an identical series of tests on four different response variables, a standard format is used to report the results of each. The first section of this chapter presents the results of the tests of assumptions for each model. This is followed by an interpretation of the ANOVA model results for each hypothesis. First, the cell means for the model are presented in table form and discussed. This is followed by examination of the model for main (row and column) and interaction effects on the response variable. F-tests are employed to determine the significance of differences.

The dependent (response) variables used are identified in each stated hypothesis. The independent variables are the information system investment factor and the firm size factor. Both of the independent variables are classification variables with two levels each. The information system investment factor equals 1 for firms which announced an information system investment (the test group) and 0 for firms in the control group. Net sales were used as a proxy for size. Size groups were determined by dividing the full sample into two equal groups based on size. The interaction term was created by multiplying the information system factor by the size factor.

Tests of ANOVA Model Assumptions

ANOVA Model Assumptions for Hypothesis I

Homoscedasticity

The assumption of homoscedasticity is the requirement that the residuals have constant variance for all factor levels. This assumption is violated if the data are heteroscedastic, meaning the variance of the error terms for at least one factor level is different from other factors. Plots of the residual against the expected response variables and the independent variables are used as a measure of the model's ability to meet this assumption. A visual examination of the residual plots for the above model suggests the residuals have equal variance for each factor level. The residuals tend to fall within a horizontal band centered around zero, and display no systematic tendencies to be positive and negative. A formal examination for the presence of heteroscedasticity was conducted using the White (1980) test. The test statistic produced is 5.5293, leading to rejection of the null hypothesis regarding heteroscedasticity at the .1369 level.

Normal Distribution of Error Terms

The basic ANOVA model is robust against departures from the assumption that the error terms are normally distributed. Kleinbaum and Kupper (1979) state the normality assumption does not have to be exactly satisfied provided that sample sizes of 20 or more are used for each factor level. Given the size of the data set which this manuscript is based on, this assumption is not critical. This assumption was tested with a normal probability plot and studentized residual test.

The normal probability plot, which is a plot of the residuals against their expected value under normality, was visually inspected. Normally distributed error terms will cluster in a straight line pattern with a mean of zero. Error terms for the model are distributed in this pattern.

A formal examination of this assumption is a check of the studentized residuals. For a normal distribution with a large sample size, 95 percent of the studentized residuals will fall within $\mp$ 2 standard deviations from the mean. This may be tested two ways. The visual test involves graphing the studentized residuals against the dependent variable and examining the chart for abnormal points. The second test involves counting the number of observations which are outside the acceptable range. If less than 5 percent of the observations are outside the acceptable range, the data set is assumed to be normally distributed.

A visual examination of the normal probability plots indicated that the data was normally distributed. Eleven observations fell outside the ∓ 2 standard deviation range. This is 3.4 percent of the total sample. The model appears to have normally distributed error terms.

<u>Outliers</u>

The final assumption tested is that no extreme or outlying observations exist. Outlying observations add to the total variation in the data set and may cause statistically significant differences to appear, or not appear, incorrectly. The studentized deleted residuals test was used to identify potential outliers. Cook's distance measure was then used to determine the amount of bias the observation exerts on the estimated regression coefficients. An F-distribution is used to determine the percentile value for each observation. Although the Cook's Distance measure does not follow a true F-distribution, this approximation is robust and commonly used. If the percentile value is less than 20 percent, the observation has little influence on the model parameters. A percentile value of 50 percent or more indicates substantial influence.

The studentized deleted residual test for this model revealed 11 potential outliers. The Cook's Distance Measure for each observation shows that none of the observations have a statistically significant effect on the model. The maximum value for Cook's D is .1430. No valid reason exists for eliminating observations as potential outliers.

ANOVA Model Assumptions for Hypothesis II

Homoscedasticity

Plots of the residual against the expected response variables and the independent variables are used as a measure of the model's ability to meet this assumption. A visual examination of the residual plots for the above model suggested that the residuals have equal variance for each factor level. The residuals tend to fall within a horizontal band centered around zero, and display no systematic tendencies to be positive and negative. A formal examination for the presence of heteroscedasticity was conducted using the White (1980) test. The test statistic produced is 8.0197, with the probability of a greater Chi-square being 0.0456., indicating heteroscedasticity.

Although a slight departure from this assumption was identified, it is not serious enough to eliminate the use of the fixed-effects ANOVA model. Neter, Wasserman, and Kutner (1985) state that so long as the number of observations in the sample are equal, the F-test is robust with respect to moderate variations of this assumption. This has been confirmed by Schmidt (1979) who notes that it is permissible to use the ANOVA model without perfectly meeting this assumption given equal sample sizes.

Normal Distribution of Error Terms

This assumption was tested with a normal probability plot and studentized residual test. The normal probability plot was visually inspected. An examination of the normal probability plots indicated that the data was normally distributed. Based on the studentized residual values, 14 observations fell outside the ∓ 2 standard deviation range. This is 4.32 percent of the total sample. The model appears to have normally distributed error terms.

Outliers

The studentized deleted residual test for this model revealed 14 potential outliers. The Cook's Distance Measure for each observation shows that none of the observations have a statistically significant effect on the model. The maximum value for Cook's Distance Measure is .2510, followed by .1324. No valid reason exists for eliminating observations as potential outliers.

ANOVA Model Assumptions for
Hypothesis III

Homoscedasticity

Plots of the residuals against the expected response variables and the independent variables are used as a measure of the model's ability to meet this assumption. A visual examination of the residual plots for the above model suggested that the residuals have approximately equal variance for each factor level. The residuals tend to fall within a horizontal band centered around zero, and display no systematic tendencies to be positive and negative. A formal examination for the presence of heteroscedasticity was conducted using the White (1980) test. The test statistic produced is 10.5019, with the probability of a greater Chi-square being 0.0147, indicating a statistically significant degree of heteroscedasticity.

Normal Distribution of Error Terms

This assumption was tested with a normal probability plot and studentized residual test. The normal probability plot was visually inspected. An examination of the normal probability plots suggested the data was normally distributed. Based on the studentized residual values, 18 observations fell outside the $\mp$ 2 standard deviation range. This is 5.56 percent of the total sample. This assumption appears to also be violated to a slight degree.

Outliers

The studentized deleted residual test for this model revealed 18 potential outliers. The Cook's Distance Measure for each observation shows that none of the observations have a statistically significant effect on the model. The maximum value for Cook's Distance Measure is .0859. No valid reason exists for eliminating observations as potential outliers.

ANOVA Model Assumptions for Hypothesis IV

Homoscedasticity

Plots of the residual against the expected response variables and the independent variables are used as a measure of the model's ability to meet this assumption. A visual examination of the residual plots for the above model suggested that the residuals have equal variance for each factor level. The residuals tend to fall within a horizontal band centered around zero, and display no systematic tendencies to be positive or negative. A formal examination for the presence of heteroscedasticity was conducted using the White (1980) test. The test statistic produced is 6.0187, with the probability of a greater Chi-square being 0.1107, leading to a rejection of the null hypothesis concerning heteroscedasticity.

Normal Distribution of Error Terms

This assumption was tested with a normal probability plot and studentized residual test. A visual examination of the normal probability plot indicated that the data was normally distributed. Based on the studentized residual values, 15 observations fell outside the $\mp$ 2 standard deviation range. This is 4.63 percent of the total sample. The assumption of normally distributed error terms does not appear to be violated.

Outliers

The studentized deleted residual test for this model revealed 15 potential outliers. The Cook's Distance Measure for each observation shows that none of the observations have a statistically significant effect on the model. The maximum value for Cook's Distance Measure is .1161, followed by .0188. No valid reason exists for eliminating observations as potential outliers.

Test of Hypothesis I

H_O: An investment in an information system has no effect on the mean of the distribution of rates of return earned from an investment in the firm's stock. ($\mu_{test} = \mu_{control}$)

Examination of Cell Means for Hypothesis I

Kleinbaum and Kupper (1978) state that "an important first step in examining a two-way layout should always be the construction of a table of cell means"(p. 317). The cell means for the ANOVA model using mean annual rates of return as the response variable are presented below.

		Size Factor		
		Small	Large	Row Totals
Information System Investment Factor (Group)	Control	.21	.16	.19
	Test	.13	.15	.14
Column Totals		.17	.16	.16

From the cell means, it appears that an announced information system investment has little if any effect on the mean rate of return earned by investors in the following year. Looking only at the row means, firms in the control group had higher mean annual rates of return than firms in the test group. The difference is only .05 and may not be statistically significant. The size of the firm appears to have no effect on the mean rate of return which investors in the firm's common stock earn the following year. The column means for small and large firms are .17 and .16 respectively. An interaction effect, in which the announced information system investment seems to have a stronger relationship with mean rates of return when combined with the firm size, may be present. This is suggested by the fact that mean daily rates of return for the test group increase from .13 to .15 as we move from small to large firms but firms in the control group decrease from .21 to .16 as a result of the same change.

Test of Estimated Regression Coefficients

Three hypotheses exist for a two-way ANOVA model. These may be considered sub-hypotheses of the main hypotheses tested in this manuscript. Kleinbaum and Kupper (1978) state the general hypotheses in the following manner:

1. $H_0(R)$: There is no row-factor (main) effect (i.e., there are no differences among the effects of the levels of the row factor).

2. $H_0(C)$: There is no column-factor (main) effect (i.e., there are no differences among the effects of the levels of the column factor).
3. $H_0(RC)$: There is no interaction effect between rows and columns (i.e., the row-level effects within any one column are the same as within any other column, and the column-level effects within any one row are the same as within any other row) (p. 328).

The row-factor of interest is whether the company in the sample announced an investment in an information system during fiscal 1988 or 1989.

Kleinbaum and Kupper (1978) state that "an interaction effect exists between two factors if the relationship among the effects associated with the levels of one factor differs according to the levels of the second factor (p. 333). The presence of an interaction effect in this instance would mean that the size of the firm is correlated with the effects of an announced information system investment on market returns.

The results of the ANOVA model using mean annual rate of return as the response variable are presented below.

Source	DF	Sum of Squares	F Value	PR > F
Model	3	0.3331	0.24	.8683
Error	320	147.9899		
Corrected Total	323	148.3231		

For the purposes of illustration, the above hypotheses will be discussed below. Realistically, their interpretation in this case is not valid because the ANOVA model using mean annual rates of return is not significant. For this manuscript, a value of .05 or less is required in order for a variable to be considered statistically significant.

The null hypothesis associated with the information system investment factor (row) is that the mean annual rates of return earned by investors are equal regardless of the information system decision. The alternative hypothesis is that the mean annual rates of return earned by investors in each group are not equal.

The F statistic for the row effect is calculated to be 0.24, which is not statistically significant. The F-test did not lead to rejection of the null hypothesis. Based on the sample evidence, there is no significant difference in the mean annual rate of return earned by investors in the test and control groups.

The null hypothesis associated with the firm size factor (column) is that the mean annual rates of return earned by investors are equal regardless of firm size. The alternative hypothesis is that the mean annual rate of return earned by investors in each size group are not equal.

The calculated F-statistic for the column effect is 0.23, which is not statistically significant. The F-test conducted did not lead to the rejection of the null hypothesis. The column factor, firm size, is not statistically significant in its impact on the mean annual rate of returns earned by investors.

The null hypothesis associated with the interaction effect is that the mean annual rates of return earned by investors in the information system investment groups are equal regardless of firm size. The alternative hypothesis is that the mean annual rates of return earned by investors in the test and control groups are related to firm size.

The F-test conducted did not lead to the rejection of the null hypothesis. The calculated F-statistic was .23, which is not statistically significant. Based on the sample evidence, there is no significant interaction effect involving the decision to invest in an information system and the size of the investing firm.

Test of Hypothesis II

H_O: An investment in an information system has no effect on the semivariance of the distribution of rates of return earned from an investment in the firm's stock. (SV_{test} = $SV_{control}$)

Examination of Cell Means for Hypothesis II

The cell means for the ANOVA model using the semivariance of annual rates of return as the response variable are presented below.

		Size Factor		
		Small	Large	Row Totals
Information System Investment Factor (Group)	Control	.20	.06	.13
	Test	.12	.07	.09
Column Totals		.16	.06	.11

From the cell means, it appears that an announced information system investment effects the semivariance of the daily rates of return on common stock earned by investors in the following year. The average semivariance of the daily rates of return on the firms which announced an information system investment is .09, versus .13 for firms in the control group. As discussed earlier, this reduced semivariance risk means that the firms announcing an information system investment have less downside risk than the firms in the pair-matched control group. The test group has only 70 percent of the downside risk, or potential loss, of the control group.

The size of the firm also appears to have a statistically significant effect on the semivariance of the daily rates of return which investors earn the following year. Smaller firms show more downside risk (.16 compared to .06) than large firms. Given the body of Accounting and Financial literature supporting higher returns for small firms, this is not unexpected.

Finally, an interaction affect may be present, in which a announced information system investment seems to have a stronger relationship with the semivariance of rates of return for small firms than for large firms. Comparison of the mean semivariance of rates of return between individual cells suggests this possibility. The difference between the average semivariance of rates of return for the control and test groups is .08 when only the small firms are considered. For only large firms, the difference is .01, for all firms it is .04. Based on this model, small firms may be able to reduce downside risk through information systems projects more than large firms.

Test of Estimated Regression
Coefficients

The results of the ANOVA model using the semivariance of the annual rate of return as the response variable are presented below.

Source	DF	Sum of Squares	F Value	PR > F
Model	3	.9602	8.37	.0001
Error	320	12.2383		
Corrected Total	323	13.1985		

Unlike the model estimated for Hypothesis I, this model is statistically significant. The calculated F-statistic is 8.37. This is significant at the .0001 level. Some statistically relationship exists between the semivariance of the annual rates of return as the response variable, and either (or both) the information system investment and firm size.

The null hypothesis associated with the information system investment factor (row) is that the semivariance of the annual rates of return earned by investors is equal regardless of the information system decision. The alternative hypothesis is that the semivariance of the rates of return earned by investors in each group is not equal.

The F-test conducted led to the rejection of the null hypothesis, indicating that, based on the sample evidence, there is a significant difference in the semivariance of the annual rate of return earned by investors in the test and control groups. The F statistic is significant at the .0110 level.

The null hypothesis associated with the firm size factor (column) is that the semivariance of the annual rate of return earned by investors is equal regardless of the firm size. The alternative hypothesis is that the semivariance of the annual rate of return earned by investors in each size group is not equal.

The F-test conducted led to the rejection of the null hypothesis, indicating that, based on the sample evidence, there is a significant difference in the semivariance of annual rates of return earned by investors based on the size of the firms they invest in. The column factor, firm size, is highly significant in that its calculated value is significant at an alpha level of .0001.

The null hypothesis associated with the interaction effect is that the semivariance of the annual rates of return earned by investors in the information system investment groups are equal regardless of firm size. The alternative hypothesis is that the semivariance of the annual rates of return earned by investors in the test and control groups is related to firm size.

The calculated F-statistic is 4.21, which is significant at the .0409 level. This led to a rejection of the null hypothesis, indicating that, based on the sample evidence, there is a significant interaction effect involving the decision to invest in an information system and the size of the investing firm. These two factors appear to have a combined effect on the semivariance of the annual rate of returns earned by investors, in addition to their separate effects. It appears that small firms which announce an information system investment are able to reduce the semivariance risk of their stock to a lower level than large firms.

Test of Hypothesis III

H_O: An investment in an information system has no effect on the coefficient of variance of the distribution of rates of return earned from an investment in the firm's stock. (CV_{test} = $CV_{control}$)

Examination of Cell Means for Hypothesis III

The cell means for the ANOVA model using the coefficient of variance on annual rates of return as the response variable are presented below.

		Size Factor		
		Small	Large	Row Totals
Information System Investment Factor (Group)	Control	1788.51	1775.45	1781.90
	Test	-2123.92	-682.32	-1412.02
Column Totals		-191.85	561.74	184.94

From the cell means, an announced information system investment appears to have a strong effect on the coefficient of variance of the rates of return earned by investors in the following year. The average coefficient of variance is 1781.90 for the control group and -1412.02 for the test group. Firm size also appears to have a definite effect on the coefficient of variance of the rate of return which investors in the firm's common stock earn the following year. An interaction affect may be present, in which the announced information system investment seems to have a stronger relationship with the coefficient of variance of the rates of return when combined with the firm size.

It is apparent that the means in the above table have larger absolute values and a much larger range than all other response variables. Human error was the first possibility investigated. All coefficients of variance used in this manuscript were calculated by an option of the SAS software system. The reliability of this option (and the author's programming ability) was tested by outputting the mean and standard deviation of the data and creating a check figure for the coefficient of variance. This revealed that the SAS-generated variable was in percentage form while the check figure was in decimal notation.

Test of Estimated Regression
Coefficients

The results of the ANOVA model using the coefficient variance of annual rates of return as the response variable are presented below.

Source	DF	Sum of Squares	F Value	PR > F
Model	3	910,451,386	0.84	.4704
Error	320	115,020,859,910		
Corrected Total	323	115,931,311,297		

This model is not statistically significant. The calculated F-statistic is 0.84. No statistically relationship exists between the coefficient of variance of the annual rates of return as the response variable, and either or both the information system investment and firm size. The individual row, column and interaction effects are not significant in this model.

Test of Hypothesis IV

H_0: An investment in an information system has no effect on the beta of a firm. ($\beta_{test} = \beta_{control}$)

Examination of Cell Means for Hypothesis IV

The cell means for the ANOVA model using beta as the response variable are presented below.

		Size Factor		
		Small	Large	Row Totals
Information System Investment Factor (Group)	Control	.51	.98	.75
	Test	.62	.92	.76
Column Totals		.56	.95	.76

From the cell means, it appears that an announced information system investment has no effect on beta in the following year. The average beta of firms which announced an information system investment is .76, versus .75 for firms in the control group.

As in the existing literature, firm size appears to have a definite effect on beta. Larger firms have beta values which are closer to the market average, one, than small firms. This is means that large firms are closer to the average market risk as measured by beta. An interaction affect does not appear to be present.

Test of Estimated Regression
Coefficients

The results of the ANOVA model using beta as the response variable are presented below.

Source	DF	Sum of Squares	F Value	PR > F
Model	3	12.6049	17.36	.0001
Error	320	77.4470		
Corrected Total	323	90.0519		

This model is statistically significant. The calculated F-statistic is 17.36 and the model is significant at the .0001 level. Some statistically significant relationship exists between beta as the response variable, and either or both the information system investment and firm size.

The null hypothesis associated with the information system investment factor (row) is that the beta of all firms in the sample is equal regardless of the information system decision. The alternative hypothesis is that the beta for the firms in each group is not equal.

The F-test conducted did not lead to the rejection of the null hypothesis, indicating that there is no significant difference in the betas of the firms in the test and control groups in the year following the information system investment. The calculated F-statistic is 1.74.

The null hypothesis associated with the firm size factor (column) is that the betas of all firms are equal regardless of firm size. The alternative hypothesis is that averages betas in each size group are not equal.

The F-test conducted led to the rejection of the null hypothesis, indicating that, based on the sample evidence, there is a significant difference in firm beta based on firm size. The column factor, firm size, is highly significant in that its calculated value of 36.87 is significant at an alpha of less than .0001. Given the existing literature, this result was to be expected.

The null hypothesis associated with the interaction effect is that the betas of firms in the information system investment groups are equal regardless of firm size. The alternative hypothesis is that the beta of firms in the test and control groups is related to firm size.

The calculated F-statistic is 2.38, which is not statistically significant. Based on this data set, there is no significant interaction effect involving the decision to invest in an information system and the size of the investing firm.

Test of Hypothesis V

Hypothesis V deals with the existence of measurable changes in operating efficiency characteristics of the test and control group firms. This is an attempt to identify the changes which are common to the investing firms. Because a diversified sample is the basis for this manuscript, the following results are more applicable to the population of publicly traded firms than previous studies. Such knowledge would be useful in assessing the probable impact of information systems in general.

The measures of operating efficiency selected for this manuscript are discussed in Chapter III. The following tables present the results of an F-test for a significant difference between the measures one year prior to and one year following the information system investment. This information is presented for both the test and control groups.

The purpose of the above tests was to identify systematic changes in operating efficiency measures between the test and control groups. None of the above measures are statistically significant at a .10 or less level. Therefore, both the test and control groups appear not to have significantly changed these characteristics during the period one year prior to and one year following the information system investment.

Table 4.1

Differences in Operating Efficiency Measures for the Test Group

Measure	T-Value	Prob > T	Before	After
Asset Turnover	-.4405	.6599	1.40	1.35
Cash	.2229	.8238	475.55	578.93
Cash Position	-.2806	.7792	.5149	.4968
Common Equity	.2767	.7822	546.94	588.18
Cost of Goods Sold	1.0386	.2999	852.34	1078.91
Current Assets	-.3505	.7262	783.15	774.92
Current Debt	.6456	.5192	292.88	468.14
Current Liabilities	.1717	.8646	547.57	603.28
Financial Leverage	1.5597	.1203	.7548	1.0351
Inventory	.4196	.6751	158.30	176.68
Inventory Turnover	-.2055	.8374	18.11	17.24
Leverage Ratio	-.6953	.4875	3.0043	2.3740
Long-Term Debt	1.5951	.1119	373.067	567.685
Net Income	-.8821	.3784	76.246	56.670
Net Equity	1.0386	.2999	852.34	1078.91
Operating Income	.7026	.4829	148.44	174.03
Profit Margin	.8338	.4057	-0.0132	3.2303
Receivables Turnover	-.0371	.9704	.2792	.2742
Return on Assets	-1.5259	.1290	0.0371	-0.0290
Return on Equity	1.1677	.2448	.1279	2.4489
Sales	.8711	.3844	1588.51	1948.96
Short-Term Liquidity	.5115	.6095	118.44	173.43
Total Assets	.4792	.6322	3755.29	4878.26
Total Expense	1.5125	.1315	72.19	117.36

Table 4.2

Differences in Operating Efficiency Measures for the Control Group

Measure	T-Value	Prob > T	Before	After
Asset Turnover	.0612	.9512	1.307	1.314
Cash	.0871	.9306	142.342	147.024
Cash Position	-1.0230	.3078	.4263	.2796
Common Equity	-.0753	.9401	554.32	541.87
Cost of Goods Sold	.3449	.7304	1345.78	1524.09
Current Assets	.4924	.6228	429.69	487.09
Current Debt	.2206	.8255	230.00	265.64
Current Liabilities	.8735	.3831	267.82	331.10
Financial Leverage	.1844	.8539	1.07	1.03
Inventory	.3124	.7550	222.27	240.03
Inventory Turnover	.0336	.9733	15.21	15.31
Leverage Ratio	.1168	.9071	2.60	2.67
Long-Term Debt	.7708	.4415	380.79	472.28
Net Income	-.0665	.9470	86.65	84.98
Net Equity	.3449	.7304	1345.78	1524.10
Operating Income	-.1778	.8590	211.61	202.34
Profit Margin	-1.2609	.2084	.0313	.0140
Receivables Turnover	-1.3400	.1813	.2166	.1806
Return on Assets	-.7174	.4737	.0264	.0177
Return on Equity	-.7573	.4495	.0054	.1050
Sales	.3241	.7461	2033.6	2235.7
Short-Term Liquidity	-.9868	.3246	43.59	33.63
Total Assets	.4135	.6795	2357.62	2743.26
Total Expense	-.2122	.8321	124.95	117.35

Summary

This chapter provided results of the study, including descriptive statistics and tests of hypotheses. The following chapter is concerned with implications.

The following results are apparent related to the hypotheses tested. No reliable conclusion can be drawn regarding mean daily returns and the coefficient of variance because the ANOVA models estimated for these variables were not statistically significant. Both an information system investment and firm size, as well as an interaction term, have a statistically significant correlation with the semivariance of daily rates of return. When beta is used as the response variable, only firm size has a statistically significant correlation.

An investment in an information system seems to reduce downside risk as measured by semivariance. This finding supports the idea that information system investments are made for defensive purposes. If this investment allows the firm to reduce its downside risk it makes the firm a more attractive target for investors.

A selection of operating efficiency measures were examined in an attempt to identify the causes of the effects noted above. None of the operating efficiency measures were statistically significant at the .10 level or below.

The fact that the operating efficiency measure were not significant does not detract from the study. This finding supports the assumption that a random sample was used. Business firms invest in information systems for different reasons. Some firms invest in information systems to reduce inventory costs, some to speed up collections and others for different reasons. Not all of the firms in the test group invested in an information system for the same purpose. If the results had shown a statistically significant change in the test group but not the control group, it could be interpreted that an information system gave the same type of benefit to all investing firms, regardless of their reason for investing. The firms in this sample did not invest for a common reason and a common change in operations was not evident.

The following chapter discusses the practical implications of these findings in more detail. Directions for related work are also presented.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

This chapter provides a discussion and interpretation of the empirical results presented in Chapter IV. The chapter begins with a discussion of the research which was conducted and the conclusions drawn form the tests of hypothesis. Possible implications of this area of research to financial policy-makers and investors are considered in the next section. The third section of the chapter discusses potential directions for future research. Finally, contributions of the study are presented.

Research Findings and Conclusions

Findings of this research investigating relationships between information system investments and risk are discussed initially in this section. Conclusions drawn from the research are also presented.

For this sample, no conclusions can be drawn regarding the relationship between information systems investment and either daily rates of return or the coefficient of variance for those returns. These relationships are not statistically significant using this data set.

Statistically significant relationships do exist for models using the semivariance of daily rates of return and beta as response variables. An investment in an information system is associated with a reduction in semivariance risk and the firm size effect is significant. A statistically significant interaction effect is present. The small firms in the sample exhibit a reduction of semivariance risk to a lower level than larger firms which also invested in an information system. This finding implies that an information system investment is correlated to reduced downside risk for the firm. Small firms, which appear to have some extra component of risk reflected in the firm size effect, benefit more from the information system' correlation with reduced semivariance risk. This is not to say that total risk has changed, only that the portion of risk caused by potential returns below the average is less. As stated before, this is the same as truncating the negative tail of a two-tailed normal distribution.

The model using beta as a response variable is statistically significant and the firm size effect is present. This is as expected. If the model using beta as the dependent variable had not been significant, or if the firm size effect had not been significant, it would be likely that this data set does not represent the population of publicly traded firms. Beta and size are consistently significant in the existing literature. The information system investment is not significant in this model.

The above results support the idea that defensive investments exist and that information systems are one example. The information system investment is associated with reduced downside risk (semivariance) but not with a change in beta. Of the two, only beta is explicitly priced in the market. If the information system investment is undertaken because it is needed for defensive purposes, beta will not always change. This is a case of the company doing what it should be doing to reduce risk. The market will not reward the company by reducing beta when the company is only doing what is expected.

The risk change is not priced by individual investors who have the ability to diversify their portfolios. The company does not, and should not, be attempting to diversify for its investors. The Fisher Separation Theorem states that the objective of the firm should be to maximize investor's end-of-period wealth. Investors can diversify without the assistance of the company. Through the use of a defensive investment, the company has reduced some of the risk it faces and reduced investor risk to a small degree. The fact that the firm size effect is significant confirms the similarity of this data set to the data used in the established literature.

Measures of operating efficiency were examined for both the test and control groups. Although none of these measures were statistically significant, this result was consistent for both groups. This suggests that the groups did not change during the sample period.

In summary, both groups did not change their operating efficiency measures or their betas. The only difference of interest is that those firms which invested in information systems had a lower and statistically significant difference in their semivariance risk compared to firms which did not invest in an information system.

Implications

A number of important implications for business firms and academic researchers can be drawn from the findings of this study. One such implication is that a special class of investments may exist which have received little formal attention from the academic community. Investments can be made for defensive purposes as well as to increase cash flow. Different objectives for the different investments imply a different set of considerations for the investment decision-making process.

Investments solely for protective purposes provide different benefits which may not be adequately measured using traditional capital budgeting techniques. This is not intended to downplay the benefits of cash flow analysis. It is the recognition that a defensive investment may serve its purpose even if the operating characteristics of the firm do not change. They may be different from what they would have been without the investment and, most importantly, cash flows are not the only important characteristic to be considered.

Directions for Future Research

The research conducted in this study is exploratory in that it identified and tested a subset of the risk measures which might be affected as a result of an information system investment.

Consistent with this exploratory design, other risk measures should be identified and tested. Suggestions for potential risk measures which may reflect the effects of an information system investment include a more detailed examination of the components of total risk. The reduction in semivariance reported in this manuscript is only part of the unsystematic risk of the firm. It is likely, although not definite, that the change in semivariance risk is accompanied by a statistically significant change in unsystematic risk or in variance.

More sophisticated statistical methods seem to be appropriate to testing this relationship. It has been suggested that the Data Envelope Analysis methodology be used to compare the test and control groups. The estimation of a structural equation model also has potential benefits for better understanding these relationships.

Contributions of the Study

The purpose of this exploratory study was to investigate the interrelationships between information systems and risk. This investigation made a number of significant contributions to the research literature regarding investments and information systems.

First, the possibility that investments are made for multiple purposes, namely defensive and offensive, was discussed. This suggests that two companies may make the same investment, get identical results, and have different opinions as to their success or failure as a result of their reason for making the investment.

The possibility that these investments exist across a wide range of industries was tested using information systems as a defensive investment. This in the only known research in which information systems are tested as a type of defensive investment. The purchase of an information system reduces the downside risk of the firm but does not have a significant effect on shareholder wealth, using beta as a proxy for shareholder wealth. The argument that an information system investment is successful at protecting the company's competitive position and that the market (beta) does not react because the company is only doing what it should do cannot be rejected.

APPENDIX

Table A.1

Sample Firm Distribution by 2-Digit SIC Code

SIC Code	Control Group	Test Group
1300	5	5
1500	2	2
1600	2	2
1700	1	1
2000	5	5
2200	1	1
2300	4	4
2500	2	1
2600	4	5
2700	8	8
2800	4	4
3000	2	2
3100	2	2
3200	1	1
3300	3	3
3400	5	5
3500	10	10
3600	8	8
3700	2	2
3800	6	6
3900	4	4
4000	1	1
4200	1	1
4500	2	1
4700	0	1

Table A.1 (Continued)

SIC Code	Control Group	Test Group
4800	1	1
4900	9	9
5000	5	4
5100	4	4
5200	1	2
5300	7	7
5400	4	4
5500	0	1
5600	2	1
5700	1	1
5800	2	2
5900	6	7
6000	1	0
6200	4	4
6300	8	8
6400	0	2
6500	1	2
6700	6	6
7000	4	4
7300	3	3
7800	1	1
7900	0	1
8000	4	3
8700	1	1
8900	2	2

Table A.2

Sample Firm Pre-Announcement Beta Distribution

Beta	Control Group	Test Group
-0.3	1	0
-0.1	1	1.0
0	4	5
0.1	13	16
0.2	15	16
0.3	13	12
0.4	19	12
0.5	12	17
0.6	10	12
0.7	12	10
0.8	11	13
0.9	11	9
1	14	11
1.1	7	14
1.2	10	7
1.3	1	4
1.4	3	1
1.5	4	2
1.6	1	0

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