A FIRM-LEVEL COMPARISON OF ALTERNATIVE INVESTMENT THEORIES

By

BIENVENIDO SANTOS CORTES

Bachelor of Science
University of the Philippines
Manila, Philippines
1977

Master of Science
Wichita State University
Wichita, Kansas
1980

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
July, 1987

A FIRM-LEVEL COMPARISON OF ALTERNATIVE INVESTMENT THEORIES

Thesis Approved:

Michael R. Edgmand
Thesis Adviser

John D. R

W. Gary Simpson

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

I must express my thanks and appreciation to my major adviser, Dr. Michael Edgmand, for proposing the idea of this study to me in the first place; for guiding me through the course of this work; and for having faith in my ability to accomplish the task.

For the idea of using a sequential methodology in the study, I must acknowledge my indebtedness to Dr. John Rea, who gave my many opinions regarding the econometric work and kept me busy in front of the computer terminal. I also owe much to the generous help and encouragement of the other members of my committee, Dr. David Bivin and Dr. Gary Simpson.

Thanks also goes out to Dr. Harry Comeskey, who helped me get started on the use of Compustat tapes and to Iris McPherson who helped me with the computer work. For their helpful comments, I wish to thank Charles Hegji of Clinch Valley College, Arthur Ekholm, Jr. of Texas Utilities Electric Company, and to the faculty and graduate students of the Economics workshop at Oklahoma State University. My heartfelt and warmest thanks also goes to my special friend, Paige Witt, who edited, typed, and corrected this manuscript.

Finally, I dedicate this work to my entire family, especially to my loving parents, Julian and Lina, and my grandparents, Bienvenido and Beatriz. My thanks to all of you.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Over the years, various theories of business investment behavior have been developed and tested. Despite numerous empirical studies, no single theory or combination of theories is widely accepted as the best explanation of investment behavior. Much of the disagreement arises because many of the previous empirical studies have used different sets of data. However, disagreement arises even among the studies which have utilized common sets of data.

The objective of this study is to examine five theories or models of investment behavior using a common body of firm data from the Standard and Poor's Compustat data bank for the 1956-84 period. The five models are: (1) accelerator; (2) accelerator-cash flow; (3) neoclassical; (4) modified neoclassical; and (5) securities-value or q. These models will be estimated and compared on the basis of the signs and level of significance of the individual coefficients and on each model's overall goodness of fit. By evaluating and comparing the estimated models, an attempt is made to determine the best or most useful theory of investment behavior.

The approach used in this study derives much from the work of Jorgenson and Siebert (1968a, 1968b, 1972) and Elliott (1973). Although the methodology is similar, there are some importance differences. First, the modified neoclassical and q models are included; Jorgenson and Siebert and Elliott did not include them in their studies. Second, this study covers a longer time span, 1956-84; Jorgenson and Siebert's study spans the 1937-41 and 1949-63 periods while Elliott's covers 1953-67. Finally, the procedure used in this study to test and compare different investment theories is superior to and more in line with current econometric practice than the procedures used by Jorgenson and Siebert and Elliott.

The dissertation is organized as follows. A survey of theoretical and empirical work on investment behavior is presented in Chapter II. Chapter III describes the alternative investment specifications, and the sequential procedure for selecting the best model. The results are reported and discussed in Chapter IV. It also discusses discriminant analysis which is used to determine whether there is a relationship between the investment models and the characteristics of the firms. Finally, Chapter V provides a summary of the conclusions, limitations of the study, and recommendations for further research.

CHAPTER II

REVIEW OF LITERATURE

This chapter covers the various theories of investment behavior and related empirical work. The original formulation of the theory will be reviewed, followed by modifications of the theory, and the relevant empirical evidence. The theories are discussed in the following order: accelerator, accelerator-cash flow, neoclassical, modified neoclassical, and q. A survey of the studies using common sets of data to test the alternative models follows the discussion of the theories.

Accelerator Model

Theoretical Work

The basic accelerator model was formulated by J. M. Clark (1917) and later modified by several economists, notably Chenery (1952) and Koyck (1954). Clark's original formulation of the theory suggests that investment or the demand for capital goods is positively related to the change in demand for output. The main assumptions of his hypothesis are: (1) there is a fixed ratio between capital stock and output; (2) the demand for capital is satisfied within the period in which the demand arises, that is, no lags or adjustment periods are assumed; and (3) firms are always operating at full capacity. The simple form of the accelerator model assumes that the capital stock K, at time t is a constant proportion of output, Y, at time t:

$$K_t = aY_t$$

where a is the accelerator coefficient. Net investment, I_{nt}, induced by changes in output can then be written as:

$$I_{nt} = K_t - K_{t-1} = a(Y_t - Y_{t-1}).$$

The simple accelerator model has been criticized and subsequently modified as a result of its rigid assumptions. First, the theory fails to recognize that the capital stock cannot be reduced as quickly as it can be expanded. Disinvestment depends on technological factors such as depreciation and obsolescence rates and age of the equipment. Kuznets (1935) argues that, if investment responds immediately and fully to changes in output, then capital stock will increase substantially during periods of expansion. Since the firm's ability to retire plant and equipment depends on the factors mentioned above, however, firms will eventually have overcapacity during periods of recession.

Second, the model assumes that the demand for capital goods is satisfied in the same period as the change in output. This assumption is unrealistic because of the lag in reaction of firms to changes in demand for their output. Moreover, idle capacity may exist because capital goods take some time to be fully utilized or depreciated away. Because of these limitations, Chenery (1952) introduces a lag in the simple accelerator model to reflect the time period between the change in demand and the new investment that results. He assumes that capital stock adjusts to output with a certain lag, i.e., $K_t = aY_{t-p}$ where p is the lag, and that investment is a function of the deviation of actual output from the desired output level. The resulting flexible accelerator equation is:

$$I_{nt} = b(K_t^* - K_t)$$

where K^* is the desired capital stock and b is the adjustment coefficient. Assuming that K^* is a fixed proportion of output, then the above equation can be rewritten as

$$I_{nt} = b(aY_t - K_t) = b(aY_t) - bK_t.$$

Thus investment is a function of the level of output instead of the change in output. Since the assumption of full capacity still holds, Chenery extends the model further by showing that cost-minimizing firms tend to increase their plant size ahead of changes in output (assuming economies of scale exist) and therefore possess some excess capacity. This capacity theory postulates that net investment is a function of the discrepancy between the amount of capital needed for output (aY_t) and the optimum degree of utilization of the existing capital stock (λK_{t-1}). Thus

$$I_{nt} = b(aY_t - \lambda K_{t-1}) = b(aY_t) - b(\lambda K_{t-1})$$

where λ is the degree of capacity utilization.

Koyck (1954) presents a more sophisticated version of the simple accelerator model. He criticizes the previous variants of the theory as assuming a lagless world or a world with only one or two period lags. He suggests a distributed lag function in which capital stock is a function of current and past levels of output. In particular, he assumes

$$K_t = a(\lambda Y_t + \lambda^1 Y_{t-1} + \lambda^2 Y_{t-2} + \ldots).$$

Using the Koyck transformation, capital stock is written as:

$$K_t = aY_t + \lambda K_{t-1}$$

and net investment is thus:

$$I_{nt} = (aY_t + \lambda K_{t-1}) - K_{t-1} = aY_t - (1-\lambda)K_{t-1}.$$

Another problem with the simple accelerator model is that it assumes an unlimited supply of capital funds to the firm such that any new investment expenditures induced by a change in output will not be restricted by available financing. Tsiang (1951), on the contrary, argues that the supply of funds faced by individuals firms is limited. For one thing, creditors will lend to any firm only a certain proportion of that firm's equity capital. For its part, the firm's desire to borrow is subject to certain limitations such as its perception of risk associated with too much indebtedness. Tsiang maintains that firms are more inclined to use internal financing such as profits and suggests that profits be incorporated into the accelerator model. The accelerator-cash flow model is discussed more fully in a subsequent section.

Another leading proponent of a more generalized form of the accelerator model that includes not only output but also profit variables is Eisner (1960, 1964, 1978). Eisner's major contribution, however, is in underscoring the role of expectations in investment analysis. He maintains that the firm's demand for new capital is a function of expected future output or sales, expected earnings, and future prices. In his 1967 study using survey data for 800 firms covering the 1955-62 period, Eisner finds that changes in current and past sales, serving as proxy variables for future demand for output, are significant determinants of investment spending. The market value of the firm, a proxy for expected profitability, is also found to be significant. Moreover, he finds support for a "permanent" theory of investment wherein firms respond slowly to changes in demand which they consider transitory.

In summary, the original accelerator model originated by Clark has been extended and improved in three ways: (1) the development of a capacity-oriented theory; (2) the introduction of distributed lags; and (3) the inclusion of profits or liquidity into the model.

Empirical Work

The empirical studies that followed Clark's formulation of the accelerator model fault its assumptions of a fixed ratio of capital to output and of the existence of full capacity. Kuznets (1935), Chenery (1952), and Hickman (1957), among others, show that the naive accelerator works during expansionary periods but not during contractionary periods. In his 1960 paper, Eisner lists several reasons why capital stock may not change immediately and fully in response to a change in output: (1) the change in output may be considered temporary; (2) there are lags from the time of the decision to invest to the time of actual investment; (3) there are limits on the rate at which existing capital stock can be reduced so that excess capacity may be present during recessionary periods; and (4) the accelerator may be nonlinear in nature so that even if output falls considerably, investment may not decrease beyond some minimum level. Eisner derived and tested several equations using a cross-section data base of 200 firms for the period 1953-55. He regressed capital expenditures divided by fixed assets on current and lagged sales change variables, a depreciation variable, and the ratio of net fixed assets to gross fixed assets. Eisner's sales change or accelerator coefficients are positive and significant with the sum of the coefficients amounting to 0.5, showing that half the changes in sales over the period is reflected in proportionate changes in capital stock. Moreover, the estimated coefficients are significant for firms with rising sales and high growth rates, but are insignificant for slow-growing firms, thus indicating the nonlinear nature of the accelerator process.[1]

Accelerator-Cash Flow Model

Theoretical Work

The accelerator-cash flow is an extension of the simple accelerator. A second explanatory variable, cash flow or liquidity, is added to output to comprise the determinants of desired capital stock. Tinbergen (1939) asserts that investment depends on expected profits which in turn are related to current and past profits. According to Tinbergen, it is almost a tautology to assume that investment depends on profit expectations. Since profit expectations are difficult to estimate, however, he uses the level of current profits as a proxy variable. Tinbergen also states that the possibility of financing is another important determinant of investment activity. This possibility of financing is affected by the amount of current profits of the firm. High current profits will indirectly increase the funds available to the firm in that investors will be attracted to the firm's high dividend or share yields and hence will buy stocks. Along with profits, Tinbergen includes the change in output (accelerator model) as an explanatory variable for investment expenditures of the firm.

---

[1] Recent surveys of the empirical evidence by Jorgenson (1971) and Naylor (1985) conclude that real output is the leading determinant of investment.

Empirical Work

Applying his profit and accelerator theory to the iron and steel industries for different countries and time periods, Tinbergen finds that the profit variable is more important than the accelerator variable in explaining investment behavior. In his study of investment in railway rolling stock, however, the accelerator variable proves to be more significant.

Unlike Tinbergen who used a single equation approach, Klein (1950) employs a system of equations to test the relation between investment and profits. He first develops a simultaneous equations model with three behavioral equations (demand for consumption goods, demand for capital goods, demand for labor) and three definitions. His investment equation regresses capital expenditures on current profits, the last period's profits, and the last period's capital stock. Testing the model on aggregate data for the period 1921-41, he obtains significant and positive profit coefficients. Estimating the investment equation separately using ordinary least squares yields the same results. Klein then combines both accelerator and profit variables in a demand for capital goods equation:

$$I_{nt} = b_0 + b_1(pY/g)_t + b_2(pY/g)_{t-1} + b_3K_{t-1} + b_4L_t + e_t$$

where p is output price, g the price of capital goods, L a liquidity variable defined as current assets minus current liabilities, and e the error term. Estimation results show significant accelerator variables (pY/g) but an insignificant liquidity variable with a wrong sign. Changes in the definition of L to cash balances plus marketable securities or to liquid funds less payments do not improve the results.

A major study evaluating and testing the accelerator-cash flow model is that of Meyer and Kuh (1957). Meyer and Kuh test alternative specifications of the accelerator and profit models on cross-section data for 600 firms during the 1946-50 period. Their most important finding is that the accelerator variable is the major determinant of investment for 1946-48 when the economy was expanding and capital funds were largely available. On the other hand, the accelerator variable does not perform as well as the profit variable during the contractionary years 1949 and 1950. In the short run, they find that liquidity factors are most important in explaining capital expenditures while in the long run, the capacity or output variable tends to dominate the investment decision. Meyer and Kuh organize and explain these empirical findings in an alternative theory they name the "residual funds theory". This theory assumes an economy characterized by large oligopolistic firms and imperfect equity and money markets. In the short run, expenditures for new capital stock are considered as a residual amount defined as the difference between the firm's total cash flow and its dividend payments. In the long run, investment is determined primarily by technological factors as defined by the capacity variable rather than by financial considerations.

Meyer and Glauber (1964) extend the residual funds theory. They present several versions of the accelerator-residual funds hypothesis based on the degree of capacity utilization and on the importance of depreciation charges as a source of internal funds. If capacity is fully or more than fully utilized, investment is a positive function of capacity utilization, depreciation, average change in sales over a period, and the change in the firm's share prices. If capacity is not fully utilized, investment is a function of net profits less dividend payments and the above mentioned variables except capacity. If depreciation is postulated to be of minor importance as an explanatory variable, investment is a function of profits plus depreciation less dividends paid, change in sales, and the change in share prices. These models are tested on a cross-section of large manufacturing firms for the period 1951-54, a sample very similar to the one used by Meyer and Kuh. The results are consistent with the Meyer-Kuh findings. Meyer and Glauber find that the capacity variable is statistically significant in explaining firm investment behavior during the boom years, while the profit and other "cash throw-off" variables are significant in the recessionary years. The most promising variable according to their analysis is the profits plus depreciation less dividends variable which, unlike the profit variable, is not closely correlated with sales and therefore can be included with sales in the same regression model.

A more recent combination of the accelerator with cash flow in the same model is by Eisner (1978). Eisner's basic relation involves gross investment as a function of current and past changes in slaes (reflecting the expected profitability of investment) and depreciation expenses (measuring the cost of replacing worn-out or obsolete physical capital). Although using a larger data base than that in his 1960 study, Eisner arrives at the same conclusions, namely, that the accelerator or sales change coefficients are positive and significant while the profit coefficients are small and have the wrong signs.[2]

---

[2] In his 1971 survey of investment studies, Jorgenson found that cash flow variables are insignificant in models that include both output and cash flow as variables (p. 1133).

Neoclassical Model

Theoretical Work

Both the accelerator model--simple and sophisticated forms--and the accelerator-cash flow model are incomplete since they fail to take into account the effect of the cost of capital on investment behavior. Jorgenson (1963, 1967) develops a theory of investment that considers not only the accelerator effect but also the influence of the rental price of capital services on investment decisions. The latter depends in turn on such factors as the interest rate, the rate of depreciation, and the tax treatment of business income.

The neoclassical theory of investment proposed by Jorgenson is based on the neoclassical assumptions that the firm's objective is to maximize the present value of its expected future returns and that the firm should hire labor and capital until their marginal productivities equal their respective real factor prices. Assuming that the firm produces only one homogeneous product, employs only labor and capital inputs, and has a Cobb-Douglas production function, the desired level of capital stock K* is proportional to the value of output in current prices divided by the user cost of capital c:

$$K_t^* = a(pY/c)_t$$

where a is the share of capital in output. The user cost of capital c is a composite of several factors including the tax, depreciation, and inflation rates. The equation is:

$$c = \frac{g_t}{1-u_t} \left[(1-u_t w_t)\delta + r_t - \frac{g_t - g_{t-1}}{g_t} \right]$$

where g is the price of capital goods, u the income tax rate, w the ratio of current depreciation cost to depreciation at replacement cost, δ the depreciation rate, and r the cost of capital.

Empirical Work

Jorgenson and Stephenson (1967) test the neoclassical theory of investment on quarterly data for fifteen U.S. manufacturing industries for the period 1947-60.[3] Before presenting their results, however, the derivation of the Jorgenson-Stephenson estimating equation will first be outlined. Jorgenson and Stephenson start with the definition of gross investment as the sum of net investment and replacement investment. They assume that net investment is a weighted average of current and past changes in desired capital stock and that replacement investment is a fraction of the capital stock available at the start of the period so that

$$I_t = u(L)\ (K_t^* - K_{t-1}^*) + \delta K_{t-1}$$

where $K^* = a(pY/c)$ and $u(L)$ is a power series in the lag operator, $u(L) = u_0 + u_1 L + \ldots$.

Using a distributed lag function of the "rational form" (Jorgenson, 1966), the above equation can be written as

$$I_t - \delta K_{t-1} = \frac{v(L)}{w(L)}\ (K_t^* - K_{t-1}^*)$$

where v(L) and w(L) are polynomials in the lag operator.

Multiplying both sides by w(L), we get the final form of the regression equation:

$$(1+w_1L+\ldots+w_nL^n)(I_t-\delta K_{t-1}) = (v_0+v_1L+\ldots+v_mL^m)(K_t^* - K_{t-1}^*)$$

or

---

[3] The Jorgenson-Siebert study which uses firm level data is discussed in a subsequent section.

$$(I_t-\delta K_{t-1})+w_1(I_{t-1}-K_{t-2})+\ldots+w_n(I_{t-n}-K_{t-n-1}) =$$
$$v_0(K^*_t-K^*_{t-1})+v_1(K^*_{t-1}-K_{t-2})+\ldots v_m(K^*_{t-m}-K^*_{t-m-1})$$

or

$$I_t = av(L)\left[(pY/c)_t-(pY/c)_{t-1}\right] + (1-w(L))(I_t-\delta K_{t-1}) + \delta K_{t-1}+e$$

Regression results for total manufacturing and for each industry show that the neoclassical model fits the historical data very well.

Eisner (1968, 1970, 1974) criticizes the basic assumptions of the Jorgenson neoclassical model. In particular, he questions Jorgenson's assumptions of a Cobb-Douglas production function and pure competition which give rise to an elasticity of demand for capital with respect to relative prices equal to one. He points to several empirical studies which show that this elasticity is less than one. In a study using Jorgenson's original data and functional form, Eisner and Nadiri (1968) find that the price elasticity of demand for capital is not significantly different from zero. They argue that a putty-clay hypothesis is more realistic than the putty-putty assumption made by Jorgenson. The putty-clay hypothesis states that a machine can be molded into any form (putty), but after it is built and installed, its technology and capacity are fixed (clay) and changes in relative factor prices have no influence on it. Thus, Eisner and Nadiri argue that investment responds more slowly to changes in relative prices than to changes in real output. Jorgenson, on the other hand, assumes that new equipment can respond immediately to changes in both output and relative prices. Eisner also disputes Jorgenson's assumption that replacement investment is a constant proportion of capital stock. He cites the study by Feldstein and Foot (1971) which finds that the ratio of replacement investment to capital stock varies considerably from year to year. Moreover, Feldstein and Foot show that this variation in the replacement-capital stock ratio can be explained by such factors as the availability of internal funds, the demand for expansionary investment, and capacity utilization. Finally, Eisner disagrees with Jorgenson's claim that only one stable lag structure exists for all variables determining investment. He notes Bischoff's 1971 study suggests that real output and the ratio of output price to the user cost of capital should have different lag distributions in explaining investment. Eisner also questions whether the various components of the user cost of capital should have identical lag structures.

Brechling (1974) disagrees with Jorgenson and Stephenson's analysis and argues that their empirical findings should be studied more carefully and not be used as a basis for implementing macroeconomic policies. Unlike Jorgenson and Stephenson who estimate a structural equation of investment, Brechling derives and tests the reduced form equation for the neoclassical model using quarterly industry data for 1949-69. Brechling's results were very unsatisfactory: wrong signs, unreasonable coefficient estimates, large standard errors. He maintains that applying Jorgenson's neoclassical theory of the firm to industry-level data may lead to aggregation problems. Tests on alternative specifications of the neoclassical reduced form equation--including tax variables and adjustment costs--do not give satisfactory results. Finally, Brechling suggests that supply factors must be taken into account in the model.

Modified Neoclassical Model

Theoretical Work

One important version of the neoclassical model is that of Bischoff (1969, 1971a, 1971b). Bischoff's modified neoclassical model specifies the determinants of desired productive capacity instead of desired capital stock as do the four previous theories. Moreover, unlike the standard neoclassical model which assumes that the capital-labor ratio associated or embodied in a physical asset responds freely and immediately to changes in relative prices, this model assumes that the capital-labor ratio is less variable after the fixed equipment has been installed. Thus, Bischoff argues that changes in relative prices and changes in output have different and independent effects on business investment. He hypothesizes that changes in relative prices affect investment spending with a longer lag than do changes in output.

According to Bischoff, planned investment expenditures are a function of past output levels and relative prices. To derive his investment equation, Bischoff begins by assuming that factor proportions (the variable that summarizes all relative price effects) at period t, V_t, is a distributed lag function of its past values,

$$V_t = \sum_{k=0}^{\infty} \chi_k V_{t-k}.$$

Next, he defines gross additions to capacity at time t as consisting of desired net additions to capacity at time t and replacement capacity. He assumes that net additions desired in the current period are a distributed lag function of past additions and that replacement is a constant proportion δ of the previous period's capacity stock,

$$I_{Yt} = \xi^* \sum_{k=0}^{\infty} \psi_k (Y_{t-k} - Y_{t-k-1}) + \delta\xi^* \sum_{k=0}^{\infty} \psi_k Y_{t-k-1}$$

$$= \xi^* \sum_{k=0}^{\infty} \psi_k (Y_{t-k} - (1-\delta) Y_{t-k-1})$$

where I_Y is gross additions to capacity and Y is productive capacity.

The final conceptual form of Bischoff's investment model shows planned investment expenditures, I_t^*, as a multiplicative function of V_t and I_{Yt},

$$I_t^* = \xi^* \sum_{k=0}^{\infty} \chi_k V_{t-k} \sum_{k=0}^{\infty} \psi \left[Y_{t-k} - (1-\delta) Y_{t-k-1} \right]$$

or in general form,

$$I_t^* = \xi^* \sum_{j=0}^{\infty} \sum_{i=0}^{\infty} \beta_{ij} V_{t-i} Y_{t-j} .$$

To reflect the difference in response of investment to changes in output and to changes in relative prices, Bischoff specifies the equation to be estimated to account for two sets of lag distributions,

$$I_t = \sum_{i=2}^{\infty} \beta_{i,i-1} V_{t-i} Y_{t-i+1} + \sum_{i=2}^{\infty} \beta_{i,i} V_{t-i} Y_{t-i} + e_t .$$

The second term on the right-hand side of the above equation is simply the standard neoclassical model since in this case output and relative prices will affect investment with the same time pattern. The addition of the first term, however, allows for investment to react differently to changes in output and to changes in relative prices. According to Bischoff, the row sums of the coefficient matrix β show the impact over time of relative prices on investment and these sums should all be positive. The column sums of the beta matrix, on the other hand, indicate the impact of output or capacity on investment; these values should be positive first and then negative. In other words, an increase in output initially results in a temporary rise or expansion in investment which eventually dies out. Changes in relative prices, however, have no similar influence on investment spending.

Empirical Work

In his 1971 study using quarterly data on aggregate equipment expenditures for the 1951-65 period, Bischoff tests his modified model against the Jorgenson neoclassical model and an accelerator model. He finds that the modified neoclassical model fits the historical data better than either the neoclassical model or the accelerator model. He concludes that relative prices are a crucial determinant of investment spending and that changes in relative prices affect investment with a much longer lag than do changes in output.[4]

Securities Value or q Model

Theoretical Work

In their 1968 paper, Tobin and Brainard state that the major determinant of firm investment is the market valuation of a firm's equity capital relative to the replacement cost of the physical assets that it represents. They argue that investment increases when capital stock is valued more than the cost of producing it, and decreases when its valuation is less than its replacement cost. They define q as the ratio of the market valuation of equity, V, to the replacement cost of

---

[4] Other comparative studies that include Bischoff's neoclassical variant are those of Bischoff (1971b) and Clark (1979). These studies will be discussed in a later section.

capital stock, RC. Alternatively, they define q as equal to the marginal product of capital, r, divided by the market yield on equity, r_e.

Ciccolo and Fromm (1979) explain the role of the q variable more rigorously as the link between the financial sector and real sector by using the neoclassical theory of investment as a starting point. Using the same assumptions as Jorgenson makes, i.e., that the firm is maximizing profits or, equivalently, the market value of the firm, they show that desired capital stock is equal to the product of q and the actual capital stock, i.e.,

$$K^* = qK = \frac{V}{P_k}$$

where V is the market value of the firm and P_k is the price of capital goods. Using the flexible accelerator form, gross investment is thus:

$$\begin{aligned} I = \Delta K + \delta K &= \lambda(K^* - K) + \delta K \\ &= \lambda(qK - K) + \delta K \end{aligned}$$

or

$$\frac{\Delta K}{K} = \lambda(q - 1).$$

Investment should therefore be stimulated if q is greater than 1, and discouraged if q is less than 1. Ciccolo and Fromm conclude that the q variable is a good indicator of expected future profitability of investment.

Empirical Work

Ciccolo (1975) derives and tests two equations which relate fixed nonresidential investment expenditures to q. The first equation shows gross fixed nonresidential investment divided by capital stock at the beginning of the period as a distributed lag function of q where q is defined as the ratio of the valuation of corporations in securities markets to the replacement cost of their physical assets. The second equation is a test of the q relation proposed by Tobin and Brainard, i.e., $q = r/r_e$ where r is the marginal product of capital and r_e is the required rate of return on equity. Since r and r_e are basic components of q, then gross investment is estimated as a distributed lag function of r and r_e, with the expectation that the sum of the r and r_e coefficients are equal in magnitude but opposite in sign. Estimating these models on quarterly macrodata for the 1953-73 period, Ciccolo demonstrates that investment is significantly related to q and its components, r and r_e. The equations also have good predictive performance.

A less aggregated analysis of the q theory is that of Von Furstenberg and others (1980). This study uses Compustat data for the 1956-76 period and computes q values for major manufacturing industries. The authors include changes in capacity utilization rates along with q as determinants of investment so that:

$$100\Delta(I/K)_i = a_{10i}\Delta(CU_i)_{-1} + a_{11i}\Delta(q_i/\overline{q_i})_{-1}$$

where CU is the Wharton index of capacity utilization in industry i divided by 100 and $\overline{q}_i$ is the q average over the period. Results show that the effects of the capacity variable and the q variable vary widely between industries; the q variable, however, is most frequently significant in explaining industry investment expenditures. Chappell and Cheng (1982) estimate Von Furstenberg's model for 287 manufacturing firms for the 1965-76 period and produced similar results. Contrary to Von Furstenberg, however, Chappell and Cheng found no evidence to support the claim that the q variable is more important than output in explaining investment activity.

Comparative Studies of Investment

A number of studies use a common set of data to estimate and compare alternative theories of business investment behavior. These studies differ with regard to the level of aggregation used, the time period under study, and the criteria for selecting the models to be evaluated and compared. Studies employing aggregate data include those by Bischoff (1971a), Clark (1979), and Kopcke (1982). Comparative studies using firm-level data include Jorgenson and Siebert (1968a, 1968b, 1972) and Elliott (1973). One industry-level study is that of Jorgenson, Hunter, and Nadiri (1970). These studies rank the significance of each theory based on certain criteria such as goodness of fit tests and predictive performance.

Clark estimates and compares five models of investment behavior: (1) accelerator; (2) accelerator-cash flow; (3) neoclassical; (4) modified neoclassical; and (5) q. He employs quarterly data of fixed nonresidential investment (equipment and structures) for the period 1954-73. His regression results indicate that the accelerator and modified neoclassical models fit the historical data very well while the neoclassical and q models do not. Simulation tests show that the accelerator model has the best forecasting performance followed by the q and accelerator-cash flow models. In a similar study using aggregate plant and equipment data for 1953-68, Bischoff finds that the accelerator and neoclassical models perform better than the q and accelerator-cash flow models. In his 1982 study, Kopcke tests five models--accelerator, modified neoclassical, time-series or naive, cash flow, and q--on quarterly aggregate data for 1954-81 and finds that all the equations tracked the historical data very well. The accelerator and time-series models, however, performed better than the other models during the forecast period.

Jorgenson, Hunter and Nadiri compare four models using a common body of data for 15 manufacturing industries for the 1949-64 period. The models are: (1) Anderson model; (2) Eisner model; (3) Jorgenson-Stephenson model; and (4) Meyer-Glauber model. Except for the Jorgenson-Stephenson model which is a neoclassical model, the other three are variants of the accelerator-cash flow model. These models were selected because they were previously tested by their respective authors on quarterly industry data and because they share common characteristics such as explanatory variables and distributed lag specifications. Ranking of the models based on goodness of fit statistics shows Jorgenson-Stephenson, Eisner, Meyer-Glauber, and Anderson in descending order of explanatory power. On the basis of forecasting performance, the ranking is as follows: (1) Eisner; (2) Jorgenson-Stephenson; (3) Meyer-Glauber; and (4) Anderson.

Jorgenson and Siebert estimate the neoclassical theory of investment for a sample of fifteen large U.S. manufacturing firms for the periods 1937-41 and 1949-63. They also estimate the generalized forms of the accelerator and liquidity models as well as the expected profits or market value model proposed by Grunfeld (1960). Starting with the flexible accelerator model, they treat net investment as a distributed lag function of changes in desired capital stock. The five models (including a second variation of the neoclassical model) therefore differ only in their determinants of desired capital stock.[5] Using a rational distributed lag function, Jorgenson and Siebert then select the best functional equation for each model for each of the fifteen firms based on goodness of fit tests. They also perform simulation tests and present the final ranking of the models: (1) neoclassical I (with capital gains); (2) neoclassical II (without capital gains); (3) expected profits; (4) accelerator; and (5) liquidity. Elliott repeats Jorgenson and Siebert's procedure on a much larger sample of 184 firms for 1953-67. He compares the same models (excluding the neoclassical model that contains capital gains) on both a time-series and cross-sectional basis. Using the same minimum standard error criterion employed by Jorgenson and Siebert, Elliott finds that the liquidity model is the best model of investment while the neoclassical model is the least useful.

Summary

Chapter II has outlined the major theoretical and empirical studies on investment behavior. It provides a historical survey of five theories of investment: accelerator, accelerator-cash flow, neoclassical, modified neoclassical, and q. It underscores the fact that no consensus exists regarding the determinants of investment spending. This lack of agreement is reflected in the differences in the empirical results and performances of the five models. Much of the debate arises because many of these empirical studies have used

---

[5] There are two versions of the neoclassical model: (1) neoclassical I which includes capital gains on assets as a component of the price of capital services; and (2) neoclassical II which does not consider capital gains.

different bodies of data. The different results of these studies can also be attributed to problems of aggregation. With aggregate data use, the investment objectives of individual firms are essentially summed or generalized to obtain investment behavior at the industry or economy-wide level. Since each theory is derived from assumptions about the goals, characteristics, and behavior of the individual business firm, the proper testing and comparison of these investment models should be carried out at the firm level. Chapter III presents the specifications of the five models to be estimated and compared. It discusses the firm-level data set and the econometric techniques that will be used to test and compare the various models of investment behavior.

CHAPTER III

METHODOLOGY

Introduction

The purpose of this chapter is to specify the alternative models of investment behavior and to discuss the econometric methodology used in estimating and evaluating these models. In developing the testable specifications, the flexible accelerator model is used as the framework within which each theory is estimated. The various theoretical models of investment spending will differ only in their specification of the determinants of desired capital stock. The following section discusses these alternative specifications, followed by the econometric techniques for estimating and comparing the models. A description of the sample, its general characteristics, and the criteria for selecting the firms are also presented.

Specification of the Alternative Models

In comparing and testing the different theories of firm investment behavior, the generalized form of the flexible accelerator model is used as the basic framework. In this model, gross investment is composed of net investment and replacement investment. Net investment is a weighted average of changes in desired capital stock K^* while replacement investment is a constant proportion δ of the capital stock at the beginning of the period. Gross investment at time t can then be written as

$$I_t = u(L) \left[K_t^* - K_{t-1}^* \right] + \delta K_{t-1} \tag{1}$$

where L is the lag operator. Following Jorgenson and Siebert (1968a, 1972), the distributed lag effect of desired capital stock on net investment is assumed to follow a rational distributed lag structure. Given the usual definition of a distributed lag function

$$Y_t = p_0 x_t + p_1 x_{t-1} + p_2 x_{t-2} + \dots .$$

we can rewrite this equation using the lag operator notation as

$$\begin{aligned} Y_t &= p_0 x_t + p_1 L x_t + p_2 L^2 x_t + \dots . \\ &= (p_0 + p_1 L + p_2 L^2 + \dots .)x_t \\ &= p(L) x_t \end{aligned}$$

where L is the lag operator.

Jorgenson (1966) showed that this function can be approximated by a rational form, i.e., it can be written as a ratio of two polynomials in L:

$$\begin{aligned} Y_t &= p(L) x_t = \frac{u(L)}{v(L)} x_t \\ &= \frac{u_0 + u_1 L + u_2 L^2 + \dots + u_m L^m}{v_0 + v_1 L + v_2 L^2 + \dots + v_n L^n} x_t \quad . \end{aligned}$$

Assuming that V_0 is unity and that U(L) and V(L) have no equal characteristic roots, we can then multiply both sides by V(L)

$$\left[1 + V_1 L + V_2 L^2 + \dots + V_n L^n \right] Y_t = \left[U_0 + U_1 L + U_2 L^2 + \dots + U_m L^m \right] x_t$$

and get the form of the rational distributed lag function

$$Y_t + V_1 Y_{t-1} + V_2 Y_{t-2} + \dots + V_n Y_{t-n} = U_o x_t + U_1 x_{t-1} \dots U_2 x_{t-2} + \dots + U_m x_{t-m} \quad .$$

The rational lag form is thus a flexible and general framework for representing the time structure of investment.

Thus equation (1) becomes

$$v(L)\left[I_t - \delta K_{t-1}\right] = u(L)\left[K^*_t - K^*_{t-1}\right] \tag{2}$$

Rewriting the above equation with current net investment as the dependent variable, the final form of the equation is

$$\begin{aligned} I_t - \delta K_{t-1} = {} & u_0(K^*_t - K^*_{t-1}) + U_1(K^*_{t-1} - K^*_{t-2}) + \ldots + \\ & u_m(K^*_{t-m} - K^*_{t-m-1}) - v_1(I_{t-1} - \delta K_{t-2}) \\ & - v_2(I_{t-2} - \delta K_{t-3}) - \ldots - v_n(I_{t-n} - \delta K_{t-n-1}). \end{aligned} \tag{3}$$

Up to three desired capital stock terms and up to two lagged net investment terms are included in the above equation. This is consistent with survey findings that the average time span of the investment process is two years (see Jorgenson, 1974). Thus the final estimating form of the flexible accelerator model becomes

$$\begin{aligned} NI_t = {} & b_0 + b_1\Delta K^*_t + b_2\Delta K^*_{t-1} + b_3\Delta K^*_{t-2} + b_5 NI_{t-1} \\ & + b_6 NI_{t-2} + e_t \end{aligned} \tag{4}$$

where NI is net investment and e is the random error term.[1] Equation (4) is the specific model used to compare the different theories of investment. Except for the modified neoclassical model, the investment models studied here are variants of the flexible accelerator equation and differ only in their specifications of the determinants of desired capital stock, K^*.

The accelerator model assumes a fixed relationship between the desired capital stock and real output Y,

$$K^* = aY$$

where a is the capital-output ratio. Output is measured by sales plus the change in inventories, both deflated by the producer price index for

---

[1] The variables discussed in this section are defined in the Appendix I.

the firm's industry group. Substituting this expression into equation (4) gives the specification for the accelerator model,

$$NI_t = b_0 + b_1\Delta Y_t + b_2\Delta Y_{t-1} + b_3\Delta Y_{t-2} + b_4 NI_{t-1} + b_5 NI_{t-2} + e_t. \quad (5)$$

Following Clark and others, a liquidity or cash flow variable is added to the accelerator model. Desired capital stock is postulated to be proportional to output and to cash flow L,

$$K^* = aY + dL$$

where d is the ratio of desired capital to the cash flow of the firm. Cash flow is defined as after-tax profits plus depreciation less dividends paid, all deflated by the nonresidential fixed investment deflator. Other definitions of cash flow tested by Jorgenson and Siebert (1968, p. 694) and by Meyer and Glauber (1964, pp. 92-103) suggest that this definition is best in terms of robustness of results. The specification for the accelerator-cash flow model is

$$NI_t = b_0 + b_1\Delta Y_t + b_2\Delta Y_{t-1} + b_3\Delta Y_{t-2} + b_4\Delta L_t + b_5\Delta L_{t-1} + \quad (6)$$
$$b_6\Delta L_{t-2} + b_7 NI_{t-1} + b_8 NI_{t-2} + e_t.$$

The q model (Tobin (1969) and Ciccolo and Fromm (1979)) hypothesizes a positive relationship between the desired capital stock of the firm and the ratio of the firm's market value, V, to the replacement cost of its assets, RC. Thus,

$$K^* = f(V/RC)K = f(qK).$$

where q is the ratio of market value to replacement cost and f is the ratio of desired capital to the product of q and capital stock. Market value of the firm, V, is defined as the sum of the market value of the firm's preferred and common stocks plus the book value of its short-term and long-term debt. It was necessary to take the book value of debt due to the considerable difficulties in measuring debt at market value.[2] Replacement cost is defined as total assets plus net plant and equipment at replacement cost less net plant at historical value plus inventories at replacement cost less inventories at historical value. Total assets represent the sum of current assets (cash, accounts receivables, inventories, etc.), net plant and other non-current assets. Gross plant refers to tangible fixed property such as land, buildings and capital equipment while net plant is gross plant less accumulated reserves for depreciation. Substituting the above expression for desired capital stock in equation (4) provides the specification of the q model of investment:

$$NI_t = b_0 + b_1\Delta(qK)_t + b_2\Delta(qK)_{t-1} + b_3\Delta(qK)_{t-2} + b_4NI_{t-1} + b_5NI_{t-2} + e_t \tag{7}$$

In the neoclassical model, the desired capital stock is proportional to the value of output divided by the rental price of capital c,

$$K^* = a(pY/c),$$

where p is the price of output measured by the producer price index for the firm's industry group. The user cost of capital, c, is defined as

$$c = \frac{g_t}{1-u_t}\left[(1-u_t w_t)\delta + r_t - \frac{g_t - g_{t-1}}{g_t}\right]$$

where g is the price of capital goods as measured by the nonresidential fixed investment deflator; u the corporate income tax rate which is equal to the ratio of profits before taxes less profits after taxes to profits before taxes; w the ratio of depreciation for tax purposes to

---

[2] For more detailed procedures for calculating the market value of debt, see Lindenberg and Ross (1981) and Brainard, Shoven and Weiss (1980).

depreciation at current replacement cost; δ the rate of depreciation; and r the cost of capital. Two formulations of the cost of capital, r, are used. First, the cost of capital is computed as profits after taxes plus depreciation for tax purposes less depreciation at current replacement cost plus interest payments deducted for tax purposes, all divided by the market value of the firm. Second, the cost of capital is calculated like the first plus all accrued capital gains on fixed assets and inventories. Thus, there are two versions of the neoclassical model. In the first version, accrued capital gains are excluded while in the second version capital gains are considered a part of the cost of capital. The specification of the standard neoclassical model is

$$NI_t = b_0 + b_1\Delta(pY/c)_t + b_2\Delta(pY/c)_{t-1} + b_3\Delta(pY/c)_{t-2} + b_4NI_{t-1} + b_5NI_{t-2} + e_t. \qquad (8)$$

The final model considered is Bischoff's modified neoclassical model. Unlike Jorgenson's formulation of the neoclassical model, Bischoff's neoclassical model is modified to account for separate effects of output and of the output price-user cost of capital ratio (p/c). According to Bischoff, the effect of changes in relative prices on investment is slower than the effect of changes in output. A specification that allows for this difference in responses and is similar in form to the previous models is

$$NI_t = b_0 + b_1\Delta(h_{t-1}Y_t) + b_2\Delta(h_{t-2}Y_{t-1}) + b_3\Delta(h_{t-1}Y_{t-1}) + b_4\Delta(h_{t-2}Y_{t-2}) + b_5NI_{t-1} + b_6NI_{t-2} + e_t \qquad (9)$$

where h equals p/c. There are also two versions of the modified neoclassical model to take into account the different measurements of the cost of capital.

Econometric Techniques

Estimation of the Depreciation Rate

Considerable experimentation preceded the final choice of the procedure for estimating the depreciation rate δ. Initially, different techniques were applied to a random sample (stratified by industry and asset size) of twenty firms. Several methods were considered but later rejected due to problems and limitations. The final method used in this study derives an estimate of the depreciation rate using a method proposed by Jorgenson and Siebert (1968, 1972). In this procedure, the depreciation rate can be determined by employing a mathematical iterative technique and solving for the value of δ in the expression:

$$K_t = (1-\delta)^t K_0 + (1-\delta)^{t-1} I_1 + (1-\delta)^{t-2} I_2 + \ldots + I_t$$

where K_0 and K_t are benchmark values for the capital stock and I is the gross investment time series.[3] Since K_t, K_0, and I are known and presetting δ as lying between 0 and 1, δ can then be calculated.[4] With the computed replacement rate, the rest of the capital stock series can be estimated using the formula:

$$K_i = (1-\delta)K_{i-1} + I_i$$

Alternative methods of estimating the depreciation rate were considered but none provided satisfactory results. One method defined

---

[3] The iteration procedure employed is called the Newton-Raphson Method. For a more detailed discussion of this method, see Wendell Grove, Brief Numerical Methods (New Jersey: Prentice Hall), 1966, pp. 9-14.

[4] By Descartes' law of signs, solving the polynomial equation provides a value of δ that is positive and unique. For explanation and proof of Descartes' law of signs, see A. D. Aleksandrov, A. N. Kolmogorov, and M. A. Lavrent'ev (eds.) Mathematics: Its Content, Methods and Meaning, Vol. I (Massachusetts: MIT Press), 1963, pp. 294-297.

the depreciation rate as the ratio of depreciation expense to capital stock. A major problem with this definition is that it provides a different depreciation rate estimate for each year in the sample period. Fluctuations in the calculated depreciation rate series could be attributed to changes in the firm's stock of fixed assets (acquired by either purchase or merger) or to changes in the accounting values of the assets or accounting practices of the firm. Nonetheless, given this definition of depreciation rate, ordinary least squares was applied to the following equation:[5]

$$I_t = b_0 + b_1\,\Delta K_t^* + b_2\,\Delta K_{t-1}^* + b_3\,\Delta K_{t-2}^* + b_4 NI_{t-1} + b_5 NI_{t-2} + b_6 K_{t-1} + e_t$$

The results of the regressions, however, produced equations that had either very large or very small coefficient values, inconsistent signs, and poor statistical fits.

Another approach used to estimate equation (4) was nonlinear least squares. Nonlinear regression was deemed a more appropriate estimation technique than ordinary least squares because of the nonlinear characteristic of equation (4):

$$I_t - \delta K_{t-1} = b_0 + b_1\,\Delta K_t^* + b_2\,\Delta K_{t-1}^* + b_3\,\Delta K_{t-2}^* + b_4\,(I_{t-1} - \delta K_{t-1}) + b_5\,(I_{t-2} - \delta K_{t-3}) + e_t$$

The equation is nonlinear because the depreciation rate δ is a scalar common to the net investment terms. Alternative plausible values were used as initial parameter estimates for the coefficients of desired capital stock and net investment as well as for δ, but most of the nonlinear regressions failed to converge.

---

[5] This equation is the same as equation (4) except that it has gross investment as the dependent variable and provides another estimate of the depreciation rate in the parameter b_6.

The depreciation rate was also defined as the reciprocal of the average length of life of the machines and equipment used in the firm's particular industry. The major problems encountered with this approach were determining the general types of machines and fixed assets that the firm uses, determining the date of acquisition or expected life of the asset, and selecting the appropriate fixed asset price deflator to use. Estimates of the average length of life of machines taken from secondary sources resulted in estimates of δ that were too small to be plausible.[6]

A final method of determining the depreciation rate was the grid search. Using ordinary least squares, attempts were made to search over a relevant range of values ($0.01 < \delta < 0.50$) to find the δ that maximized the likelihood function of the regression. This maximum likelihood search, however, often provided estimates of the depreciation rate beyond the range of "normal" values (for example, rates greater than 0.50).

In summary, the problems encountered with these alternative methods of calculating the depreciation rate made these methods inferior to the technique finally used in this study.

Serial Correlation

Serial correlation occurs when the error terms are correlated. With serial correlation, ordinary least squares estimates of the

---

[6] In Creamer, et al (1960), the authors provide estimates of the average length of life of machinery and equipment for a number of industries (see p. 23). For example, the average length of life of machines in the food sector is 15 years, textile industry 22 years, and chemicals 19 years. Taking the reciprocals, the range of values for the depreciation rate is from 0.04 to 0.08. For a more sophisticated discussion of the role of asset services lives in the computation of capital stock, see U.S. Dept. of Commerce, Fixed Nonresidential Business Capital in the U.S. (Washington, D.C.: U.S. GPO, 1974).

coefficients are unbiased and consistent, but inefficient. When the error terms are positively correlated, the standard error of the regression is biased downward so R^2 is biased upward; this leads to mistaken conclusions regarding the equation's goodness of fit. Moreover, when serial correlation and lagged dependent variables are present, the results of ordinary least squares are biased and inconsistent.

To check for first-order autocorrelation in models without lagged dependent variables as explanatory variables, the usual Durbin-Watson test is used. The standard rule is that if the Durbin-Watson test statistic is close to 2, no autocorrelation is present. When there are lagged dependent variables in the model, however, the Durbin-Watson test is no longer valid. The alternative test statistic is the Durbin h defined as

$$h = (1 - DW/2) \sqrt{\frac{T}{1 - T \operatorname{Var}(\hat{B})}}$$

where h is normally distributed with unit variance, T the number of observations, DW the Durbin-Watson statistic, and $\operatorname{Var}(\hat{B})$ the square of the standard error of the coefficient of the lagged dependent variable. Given the critical value of 1.645 (at five percent level of significance), the null hypothesis of no serial correlation cannot be rejected if the calculated h value is less than 1.645.[7]

If the term $T\operatorname{Var}(\hat{B})$ is greater than one, then the Durbin h test is no longer valid and another test is required. This alternative test first requires the calculation of the residual variable e_t and its

---

[7] Pindyck and Rubinfeld (1981).

lagged term e_{t-1} from the ordinary least squares estimation. Next, the test involves regressing e_t on its lagged term along with all the explanatory variables of the model, and finally, conducting a standard t test of the null hypothesis that the coefficient of e_{t-1} is equal to zero. Equations found to possess first-order serially correlated errors are re-estimated using the maximum likelihood iterative technique developed by Beach and MacKinnon (1978).

Estimation of the Investment Equation for a Firm

Using the estimates of the depreciation rate obtained from the Newton-Raphson method and using annual data from 1960 to 1984 (after adjustment for lags), ordinary least squares is initially applied to equation (4) for each of the investment specifications for each of the 104 firms. The estimated full models are checked for serial correlation and if found, are reestimated using an autoregressive model of order 1. Given the full equations (including those corrected for autocorrelation), a restricted form of each model is calculated using only those explanatory variables that are significant (the degree of significance used was 0.20). These restricted equations are then compared with the full equations using F tests for equations without autocorrelation and using log likelihood ratio tests for equations with autocorrelated disturbances. Detailed descriptions of the F and likelihood tests are provided in the Appendix II.

Selection of the Best Investment Model

Given the best form for each model, the next step in the sequential methodology is to check these equations for correctness with regard to the signs of the estimated coefficients. Only those models that have the correct a priori signs will be considered further. The model is said to be stable if changes in the ΔK^* variables induce a movement in net investment in the desired direction. Stability requires that the sum of the coefficients of the ΔK^* variables be positive.

Finally, given the list of acceptable models (that is, models that contain coefficients that have the right signs and are significant), the model with the lowest value of standard error of the regression is chosen as the best investment model for the firm.

Nonnested Tests

The standard error criterion for comparing models has one important limitation: it cannot test for significant differences between two or more models. When comparing two or more models, the standard error criterion will definitely select one model as superior even though the models may differ in prediction criterion values by only a very small amount. To solve this problem and supplement this minimum residual variance criterion, another technique of comparing and selecting the best model among a given set of competing alternatives is applied here. This method is the nonnested tests proposed by Davidson and MacKinnon (1981). Nonnested hypothesis testing or the comparison of different families of competing explanatory variables can be traced back to early works by Cox (1961, 1962) and later studies by Pesaran (1974) and Pesaran and Deaton (1978). Aside from the empirical tests conducted by Pesaran and Deaton and Davidson and MacKinnon on the same data and models of U.S. consumer behavior, econometric application of these tests has been limited. Recent applications on econometric models are that of Johannes and Nasseh (1985) and Wisley and Johnson (1985).

This section presents the J test developed by Davidson and MacKinnon for evaluating and comparing two or more rival linear models. Consider two linear, nonnested models H and H_1 explaining some dependent variable y:

$$H \ : \ y = XB + e$$

$$H_1 \ : \ y = Zv + e_1$$

where X and Z are observation matrices of exogenous variables which are not linear combinations of each other; B and v are the respective coefficient vectors to be estimated; and e and e_1 are the vectors of error terms assumed to have the usual classical regression properties of normal distribution, zero means and variance-covariance matrices of $\sigma^2 I$ and $\sigma_1^2 I$ respectively.

To test whether the first model H is true compared to H_1, the J test requires the following regression:

$$y = (1 - \alpha)\ XB + \alpha Z\hat{v} + u$$

where $Z\hat{v}$ are the fitted values from model H_1. If H is true, then $\alpha = 0$. The standard t test can then be used to test the hypothesis that H is valid. For pairwise comparisons, however, it is necessary to reverse the procedure by replacing XB with Zv and $Z\hat{v}$ with $X\hat{B}$ in the above equation and repeating the regression. This will test the validity of H_1 as opposed to H. Note that these pairwise tests can allow for the models to be both accepted or both rejected.

In cases of pairwise tests in which one of the equations has serial correlation, the J test is no longer valid since this now involves nonlinear regression. Following Wisley and Johnson, the alternative test when model H has serial correlation involves evaluating the parameter a in the regression,

$$y - X\hat{B} = a(Z\hat{v} - X\hat{B}) + XB + u.$$

The standard t statistic for a can then be computed and tested for a = 0. If the model H is true, then we can not reject the null hypothesis that a = 0. We then switch the models in H and H_1 to test the null hypothesis that the alternative model is true and repeat the procedure.

The Firm Sample

Annual data for the firm sample are drawn from the Standard and Poor's Compustat data bank and cover the period from 1956 to 1984. The Compustat files are computer tape libraries of financial and market information covering several thousand manufacturing and nonmanufacturing firms (including banks and public utilities) on annual and quarterly bases. The main Compustat tape used in this study is the Primary Industrial file which covers over 900 large firms including the Standard and Poor's 400 as well as various firms listed on the New York Stock Exchange.

The sample consists of 104 manufacturing firms representing 54 four-digit SIC industries. These firms were selected on the basis of the following criteria: (1) completeness of data for the 1956-84 time period; and (2) exclusion of nonmanufacturing and service firms such as mining companies, banks, and public utilities. The exclusion of the nonmanufacturing firms is due to the absence or lack of data on fixed capital expenditures. The 104 firms under study, their total assets, and their average values of capital expenditures as percent of total assets for the 1956-84 coverage period are presented in Table I. Although all the firms included in the sample are large, there is substantial variation among them with regard to size (as measured by

TABLE I

FIRMS INCLUDED IN THE ANALYSIS

FIRM	SIC CODE	TOTAL ASSETS (MILLIONS OF $)[a]	CAPITAL EXPENDITURES (MILLIONS of $)[a]	CAPITAL EXPENDITURES AS % OF TOTAL ASSETS	GROWTH RATE OF SALES (%)	GROWTH RATE OF CAPITAL EXPENDITURES (%)
AMF Inc.	3940	602.4	46.8	7.9	16.55	13.68
Air Products	2810	703.4	110.5	16.1	43.35	42.13
Alcan Aluminum	3330	2841.2	215.1	7.1	26.79	17.68
Allied Products	3460	100.5	4.6	5.2	31.46	21.62
Allis-Chalmers	3530	853.8	35.4	3.9	12.88	11.02
Aluminum Co.	3330	2961.6	262.7	8.7	19.78	17.41
American Brands	2111	2035.9	66.9	2.8	21.51	33.88
American Cyanamid	2800	1516.3	121.2	8.5	20.36	14.66
Anderson, Clayton	2000	492.9	15.0	2.9	7.52	10.43
Armstrong Rubber	3000	191.8	12.7	6.9	18.93	15.43
Atlantic Richfield	2911	6909.8	1039.0	13.0	47.81	44.71
Avon Products	2844	715.6	48.5	6.7	36.02	37.44
Bausch & Lomb	3851	199.1	9.4	5.0	25.92	20.48
Belding Heminway	2200	46.1	2.0	4.2	15.27	21.34
Bell & Howell	3861	248.4	11.1	4.3	24.14	24.85
Boise Cascade	2600	1344.9	126.3	9.4	43.58	47.88
Brown Group	3140	295.8	14.7	4.9	18.77	18.85
Brunswick	3510	595.9	34.0	5.2	24.14	27.06
Burlington	2200	1310.8	121.5	8.9	14.42	18.77
Burroughs	3680	1709.3	215.1	11.4	28.20	39.06
Caterpillar Tractor	3531	2709.8	258.4	9.6	27.44	28.47
Celanese	2820	1587.7	168.8	10.1	29.66	25.52
Cessna Aircraft	3721	260.7	11.4	4.4	26.04	27.12
Clark Equipment	3537	555.2	29.2	4.7	23.77	30.83
Cluett-Peabody	2300	253.9	7.8	2.9	21.42	23.54
Colgate-Palmolive	2841	1159.6	67.2	5.3	25.57	27.35
Collins & Aikman	2200	184.2	14.7	7.2	29.60	38.48
Conrac	3600	50.2	1.7	4.2	26.15	23.45
Cooper Inds	3610	527.5	35.2	5.6	39.96	51.11
Cooper Tire	3000	91.5	6.3	6.3	28.5	27.32
Crompton & Knowles	2860	75.9	2.9	3.7	24.82	17.14
Crown Zellerbach	2600	1283.2	129.6	9.5	19.98	18.82
Cummins Engine	3510	522.9	45.9	9.1	31.16	30.98
Dayco	3000	213.4	14.4	6.7	27.23	25.34
Diebold	3683	113.0	2.9	3.1	28.35	24.82
Dow Chemical	2800	4680.4	525.4	12.3	31.52	26.94
Emerson	3600	782.4	55.8	6.3	43.25	52.41
Emhart	3550	379.7	22.8	4.8	40.99	43.68

TABLE I (Continued)

FIRM	SIC CODE	TOTAL ASSETS (MILLIONS OF $)[a]	CAPITAL EXPENDITURES (MILLIONS of $)[a]	CAPITAL EXPENDITURES AS % OF TOTAL ASSETS	GROWTH RATE OF SALES (%)	GROWTH RATE OF CAPITAL EXPENDITURES (%)
Exxon	2911	27346.7	3001.8	10.0	28.71	24.11
FMC	2800	1303.4	115.7	8.5	25.05	27.61
Ferro	2890	171.0	11.5	6.5	27.50	24.97
Firestone	3000	2054.7	160.9	8.0	15.21	14.58
General Dynamics	3721	1287.2	95.8	7.2	12.38	18.22
General Electric	3600	9117.2	709.9	7.1	19.98	28.85
General Instrument	3670	308.8	27.1	7.8	32.28	44.68
General Motors	3711	20202.0	2540.5	10.7	19.73	28.47
General Refractories	3290	179.5	11.7	6.5	22.01	11.58
Georgia-Pacific	2400	2010.2	274.3	15.9	41.64	28.38
Gerber	2030	193.0	14.3	6.5	18.06	25.95
Goodrich	3000	1335.2	106.1	7.7	15.8	15.77
Goodyear Tire	3000	3111.1	232.9	7.7	20.64	18.03
Grace	2800	2148.9	212.9	9.4	29.39	24.94
Great Northern Nekoosa	2600	583.0	74.8	10.0	40.09	43.65
Honeywell	3680	1888.3	263.9	12.9	30.5	38.23
Inland Steel	3310	1573.3	131.3	8.8	17.22	10.08
Interco	2300	621.2	27.3	3.7	25.75	30.56
Interlake	3499	381.8	23.5	6.1	26.15	19.21
International Business Machines	3680	12614.7	2454.4	23.2	39.16	30.23
Kennametal	3540	114.5	8.4	6.7	30.44	33.60
Kerr-McGee	2911	1224.2	176.4	14.5	38.93	34.34
Kimberly-Clark	2600	1182.1	119.9	9.3	22.08	26.18
Koppers	2860	579.4	57.6	9.1	21.0	23.79
Lear Siegler	3728	386.4	23.8	5.4	37.82	40.77
Lone Star	3241	518.5	50.9	9.1	27.09	24.31
Manhattan Inds.	2300	91.8	3.6	3.1	29.03	37.40
Massey Ferguson	3520	1266.8	55.3	4.8	18.52	11.71
Minnesota Mining & Manufacturing	2649	2276.9	224.7	9.6	30.74	33.60
Mohasco	2270	243.6	14.9	5.4	23.20	24.88
Monsanto	2800	2894.3	326.2	11.2	24.45	21.42
Motorola	3662	1022.6	135.9	10.2	30.05	44.21
Munsingwear	2250	47.7	1.7	3.5	11.58	7.10
NCR Corp.	3680	1600.5	169.9	11.5	24.14	25.66
National Gypsum	3270	476.3	32.2	6.8	19.56	10.38
Northrop	3721	543.6	63.0	8.2	24.62	36.87
Olin Corp.	2800	1137.1	100.9	8.5	11.12	13.53
Outboard Marine	3510	306.6	15.3	5.3	19.34	16.63
PPG Inds.	2800	1566.8	162.0	9.6	19.45	22.55

TABLE I (Continued)

FIRM	SIC CODE	TOTAL ASSETS (MILLIONS OF $)[a]	CAPITAL EXPENDITURES (MILLIONS of $)[a]	CAPITAL EXPENDITURES AS % OF TOTAL ASSETS	GROWTH RATE OF SALES (%)	GROWTH RATE OF CAPITAL EXPENDITURES (%)
Pennwalt	2800	402.9	31.5	8.2	29.69	22.80
Pepsico	2086	1366.8	175.3	14.0	48.32	41.97
Pfizer	2834	1496.9	86.3	6.5	30.17	27.82
Pillsbury	2000	852.5	93.8	9.3	26.04	44.91
Pitney-Bowes	3570	438.6	46.2	11.5	37.78	32.37
Potlatch	2600	470.5	51.8	10.4	25.00	26.77
Procter & Gamble	2841	3067.6	268.7	7.9	24.59	30.44
Raytheon	2662	1144.3	95.5	6.7	30.95	44.71
Revlon	2844	723.6	37.4	4.2	34.15	50.73
Reynolds (R. J.)	2111	3255.0	310.7	6.8	30.11	49.55
Reynolds Metals	3330	1905.0	129.5	6.9	22.77	13.92
Riegel Textile	2200	137.8	10.7	7.0	17.49	25.0
Rohr	3728	184.2	8.4	4.4	14.92	22.77
Rubbermaid	3079	99.9	11.7	12.6	32.92	32.43
SCM Corp.	2850	506.0	35.8	6.2	40.18	41.81
Shell Oil	2911	7432.5	1211.0	15.8	27.03	27.61
Standard Oil	2911	4534.0	724.4	13.8	39.16	50.28
Stevens (J. P.)	2200	678.5	44.1	6.1	15.58	18.63
Sunstrand	3720	384.3	31.8	7.4	30.32	43.45
TRW	3662	1330.6	112.5	7.8	30.92	33.94
Texaco	2911	13026.4	1178.7	10.1	35.15	19.34
Texas Instruments	3674	921.3	152.3	14.8	42.17	45.21
Time	2721	933.8	81.6	6.8	25.83	32.53
Union Carbide	2800	4738.1	490.6	10.6	21.37	19.29
Uniroyal	3000	1192.9	70.5	6.0	10.28	9.60
Varian Associates	3670	226.2	13.9	7.8	37.03	23.82
Xerox	3861	2987.4	528.7	21.3	73.18	65.81

[a] Mean value during the 1956-84 period.

Source: Standard and Poor's Compustat Tapes total assets), the average investment rate during the period, and the growth rate of sales and capital expenditures. The total assets of the largest firm, Exxon Corporation, is almost 600 times greater than the assets of the smallest firm, Belding Heminway. In terms of average investment, Exxon also has the largest level with a little over $3 billion annually while Conrac Corp. and Munsingwear Inc. have the smallest mean investment levels of only about $2 million per year. The fastest-growing firm in terms of sales, Xerox Corporation, also has the highest growth rate of capital stock during the period while the slowest-growing firm, Anderson, Clayton and Co., has one of the lowest growth rates of capital stock. The specific industries and the number of companies per industry are given in Table II.

Summary

Chapter III has discussed the econometric techniques of estimating the final form of each investment model and the sequential methodology of comparing and selecting the best model among the alternative equations. It stresses the importance of determining an independent estimate of the depreciation rate for each firm since this variable creates nonlinearity in the parameters of the general investment specification and emphasizes the role of the correctly signed and significant coefficient criteria in selecting the models that will finally be compared and ranked.

Chapter IV presents the results of estimating the alternative model specifications and of implementing the sequential methodology to determine the best investment model for each firm.

TABLE II

CLASSIFICATION OF FIRMS BY INDUSTRY

INDUSTRY	NUMBER OF FIRMS
Food & Kindred Products (2000)	2
Canned-Preserved Fruits-Vegetables (2030)	1
Bottled-Canned Soft Drinks (2086)	1
Cigarettes (2111)	2
Textile Mill Products (2200)	5
Knitting Mills (2250)	1
Floor Covering Mills (2270)	1
Apparel and Other Finished Products (2300)	3
Lumber & Wood Products (2400)	1
Paper & Allied Products (2600)	5
Converted Paper-Paperboard (2649)	1
Periodicals & Publishing-Printing (2721)	1
Chemicals & Allied Products (2800)	9
Industrial Inorganic Chemicals (2810)	1
Plastic Material & Synthetic Resin (2820)	1
Pharmaceutical Preparations (2834)	1
Soap & Open Detergents (2841)	2
Perfumes, Cosmetics, Toilet Preparations (2844)	2
Paints, Varnishes, Lacquers (2850)	1
Industrial Organic Chemicals (2860)	2
Miscellaneous Chemical Products (2890)	1
Petroleum Refining (2911)	6
Rubber & Miscellaneous Rubber Products (3000)	7
Miscellaneous Plastic Products (3079)	1
Footwear Except Rubber (3140)	1
Cement Hydraulic (3241)	1
Concrete, Gypsum & Plaster (3270)	1
Abrasive Asbestos (3290)	1
Blast Furnaces & Steel Works (3310)	1
Primary Smelting-Refining (3330)	3
Metal Forgings & Stampings (3460)	1
Fabricated Metal Products (3499)	1
Engines & Turbines (3510)	3
Farm & Garden Machinery (3520)	1
Construction, Mining Material Handling Machinery (3530)	1
Construction Machinery (3531)	1
Industrial Trucks, Tractors, Trailers (3537)	1
Metalworking Machinery (3540)	1
Special Industry Machinery (3550)	1
Office Computing & Accounting Machinery (3570)	1
Electrical Marketing & Equipment (3600)	3
Electrical Transmission & Distribution Equipment (3610)	1
Radio-TV Transmitting Equipment (3662)	3
Electronic Components & Accessories (3670)	2
Semiconductors (3674)	1

TABLE II (Continued)

INDUSTRY	NUMBER OF FIRMS
Electronic Computing Equipment (3680)	4
Computer Terminals (3683)	1
Motor Vehicles (3711)	1
Aircraft & Parts (3720)	1
Aircraft (3721)	3
Aircraft Parts & Auxiliary Equipment (3728)	2
Ophthalmic Goods (3851)	1
Photographic Equipment (3861)	2
Toys & Amusement (3940)	1

CHAPTER IV

ECONOMETRIC RESULTS

Introduction

This chapter reports the results of applying the different econometric techniques to the five alternative investment models for each of the 104 firms in the sample. The functional forms of the five models will be presented, followed by the results of the sequential procedure used to determine the best model for each firm and for the sample as a whole, and finally, the results of applying chi square tests and discriminant analysis to the data.

Specifications

The five investment models and the relevant data variables are shown below:

Accelerator Model:

$$NI_t = b_0 + b_1 \Delta Y_t + b_2 \Delta Y_{t-1} + b_3 \Delta Y_{t-2} + b_4 NI_{t-1} + b_5 NI_{t-2} + e_1$$

Accelerator-Cash Flow Model:

$$NI_t = b_0 + b_1 \Delta Y_t + b_2 \Delta Y_{t-1} + b_3 \Delta Y_{t-2} + b_4 \Delta L_t + b_5 \Delta L_{t-1} + b_6 \Delta L_{t-2} + b_7 NI_{t-1} + b_8 NI_{t-2} + e_2$$

Neoclassical Model:

$$NI_t = b_o + b_1 \Delta(p/c)_t Y_t + b_2 \Delta(p/c)_{t-1} Y_{t-1} + b_3 \Delta(p/c)_{t-2} Y_{t-2} + b_4 NI_{t-1} + b_5 NI_{t-2} + e_3$$

Modified Neoclassical Model:

$$NI_t = b_0 + b_1\ \Delta(p/c)_{t-1}Y_t + b_2\ \Delta(p/c)_{t-2}Y_{t-1} + b_3\ \Delta(p/c)_{t-1}Y_{t-1} + b_4\ \Delta(p/c)_{t-2}Y_{t-2} + b_5NI_{t-1} + b_6NI_{t-2} + e_4$$

q Model:

$$NI_t = b_0 + b_1\ \Delta(qK)_t + b_2\ \Delta(qK)_{t-1} + b_3\Delta(qK)_{t-2} + b_4NI_{t-1} + b_5NI_{t-2} + e_5$$

Explanation of notation:

NI = net investment
Y = real output
L = cash flow
p = output price
c = user cost of capital
q = ratio of market value of the firm to replacement cost of assets
K = capital stock

Empirical Results

Minimum Standard Error Procedure

Ordinary least squares is used to estimate each of the five investment models for each of the 104 firms in the sample. The estimated equations are checked for serial correlation, and if present, are reestimated using Beach and MacKinnon's maximum likelihood technique. Given the possibility that some of the variables in the estimated models may be irrelevant, each full, unrestricted model is first examined for significance (at the 20 percent level) of the coefficients of the various explanatory variables and a restricted form of the model is then estimated. Some of these restricted models will have to be reestimated if other variables are still found to be insignificant. The final restricted models and their corresponding full equations are then compared using F tests and log likelihood tests (for models that have autocorrelated errors).

Given the best estimated form for each model, the regression coefficients are then checked to determine whether their signs are consistent with the underlying economic theory. From the set of acceptable and adequate models (i.e., equations with correctly signed and significant coefficient estimates), the best model of investment for each firm is then selected based on the minimum standard error criterion and on nonnested hypotheses tests.

Some representative results of the various tests conducted for one firm, AMF Inc., are presented in Table III. Beginning with the full unconstrained specification for each model, each estimated equation is checked for the presence of autocorrelated errors. Three of the seven models--both versions of the standard neoclassical model and the second version of the modified neoclassical--were found to possess serially correlated disturbances and were reestimated using an corrective autoregressive procedure. After correcting for autocorrelation, the full models are then examined for significance of the estimated coefficients. For example, the estimated full equation of the accelerator model for AMF Inc. is:[1]

$$NI_t = 2.54 + \underset{(0.49)}{0.01(Y_t - Y_{t-1})} + \underset{(-0.97)}{0.02(Y_{t-1} - Y_{t-2})} + \underset{(2.03)}{0.05(Y_{t-2} - Y_{t-3})}$$

$$+ \underset{(2.22)}{0.42NI_{t-1}} - \underset{(-2.62)}{0.59NI_{t-2}}$$

---

[1] The t-statistics are shown in parentheses.

TABLE III

RESULTS FOR AMC INC.**

Model	Constant	ΔK_t^*	Δk_{t-1}^*	Δk_{t-2}^*	ΔL_t	ΔL_{t-1}	ΔL_{t-2}	$\Delta(h_{t-1}y_{t-1})$	$\Delta(h_{t-2}y_{t-1})$	NI_{t-1}	NI_{t-2}	S.E.	R^2
Accelerator	2.67			0.04 (1.85)						0.39 (2.15)	-0.62 (-2.90)	8.56	0.39
Accelerator-Cash Flow													
q Model	2.64	0.06 (1.86)								0.38 (2.10)	-0.44 (-1.96)	8.55	0.39
Neoclassical I													
Neoclassical II													
Modified Neoclassical I	2.78			0.01 (1.30)					-0.01 (-1.51)			8.89	0.38
Modified Neoclassical II													

**t-statistics are in parentheses.

$$S.E. = 8.78$$

$$R^2 = 0.42$$

As can be seen from the above results, two of the explanatory variables are insignificant at the 20 percent level and hence can be removed. This leads to the restricted form of the accelerator model:

$$NI_t = 2.67 + \underset{(1.85)}{0.04}(Y_{t-2} - Y_{t-3}) + \underset{(2.15)}{0.39}NI_{t-1} - \underset{(-2.90)}{0.62}NI_{t-2}$$

$$S.E. = 8.56$$

$$R^2 = 0.39$$

Discriminating between the full estimated model and the restricted model using F test, it is shown that the latter equation is the best estimated form of the accelerator model for the firm. Similarly, the full equation for the q model is:

$$NI_t = 2.28 + \underset{(1.41)}{0.05}(q_t k_t - q_{t-1}k_{t-1}) - \underset{(-0.02)}{0.001}(q_{t-1}k_{t-1} - q_{t-2}k_{t-2})$$

$$- \underset{(-0.57)}{0.02}(q_{t-2}k_{t-2} - q_{t-3}k_{t-3}) + \underset{(1.87)}{0.40}NI_{t-1} - \underset{(1.40)}{0.38}NI_{t-2}$$

$$S.E. = 8.91$$

$$R^2 = 0.40$$

Given that two of the independent variables in the full q model can be omitted, the model can be reestimated to provide the following regression:

$$NI_t = 2.64 + \underset{(1.86)}{0.06}(q_t k_t - q_{t-1}k_{t-1}) + \underset{(2.10)}{0.38}NI_{t-1} - \underset{(-1.96)}{0.44}NI_{t-2}$$

$$S.E. = 8.55$$

$$R^2 = 0.39$$

After comparing the above alternative equations using F test, the final form of the q model selected is the second estimated equation. The estimated functional form for the modified neoclassical model (version

I) can be determined and written similarly. For AMF Inc., no cash flow variable, standard neoclassical variables (both versions), and modified neoclassical variables (version II) were found to be significant during the estimation procedure and hence no model results are presented.

Regression coefficients, t-statistics, goodness-of-fit data of the significant equations for AMF are presented in Table III. The columns in Table III contain estimates of the constant term, changes in desired capital stock (current and up to two-lagged terms), and two lagged net investment variables. Five additional columns representing the cash flow effects and two modified neoclassical terms are also included. The last columns provide the goodness-of-fit statistics. The rows correspond to the different alternative models. A blank row implies that none of the changes in desired capital stock variables were selected as a significant regressor based on a prespecified significance level of 0.20 for a two-tailed test.

Given the three competing models for AMF, the next step of the sequential procedure to select the best model of investment is to check the signs of the estimated coefficients for consistency with economic theory. The sum of the coefficients must have a positive impact on net investment. Based on this criterion, the modified neoclassical model I is dropped since it contains a negatively-signed desired capital stock variable. Finally, among the models with coefficient estimates which have the correct signs and are statistically significant, the model with the least standard error of the regression is chosen as the best explanatory model of investment. Based on this criterion, the q model is selected as the best estimated equation for AMF Inc.

To complement the standard error procedure, nonnested hypotheses tests are employed for AMF. Using Davidson-MacKinnon's J test, pairwise comparison tests are conducted on the accelerator and q models. The results of doing the pairwise tests are shown in Table IV.

TABLE IV

PAIRWISE NONNESTED TESTS: AMF

	H_1: Accept Accelerator	H_1: Accept q Model
H_0: Accept Accelerator		2.70
H_0: Accept q Model	2.70	

The above table gives the t-values for each pairwise test with H_0 as the null hypothesis and H_1 as the alternative. Using a critical t-value of 2.8 (at the one percent level of significance for a two-tailed test), both models are accepted. As pointed out earlier, nonnested tests may reject, or may not reject, in both pairwise tests. The t-values in this particular example are not necessarily the same and only indicate that the tests favor or support both the accelerator and q models.

The overall results of running this sequence of tests on the sample of 104 firms and selecting the best investment model on the basis of the minimum standard error criterion are shown in Table V. The first column shows for each model the number of firms for which the regression

TABLE V

SUMMARY RESULTS: STANDARD ERROR CRITERION

Model	Number of Equations with Significant Δk^* Coefficients	Number of Equations with Correct Signs of Δk^* and Significant Coefficients	Number of Equations Selected as Best Model	Percentage of Firms
Accelerator	82	74	18	17
Accelerator-Cash Flow	67	53	37	36
q Model	78	75	28	27
Neoclassical I	62	44	10	10
Neoclassical II	51	32	4	4
Modified Neoclassical I	57	35	5	5
Modified Neoclassical II	58	34	2	2

coefficients are statistically significant. For example, the accelerator model has significant coefficients for 82 of the 104 firms while the q model yields significant estimates for 78 of the 104 firms. Based on this criterion, the accelerator and q models are both satisfactory for a large number of firms (79 percent and 75 percent respectively). The liquidity model and each of the two versions of the standard neoclassical model and modified neoclassical model accounted for approximately 49 to 64 percent of the total sample in terms of possessing significant regression estimates.

The second column of Table V shows for each model the number of firms that have significant and correct-signed coefficients. On the basis of this second criterion, the accelerator model and q model each accounted for 74 firms or 71 percent of the total firm sample. The accelerator-cash flow model had both correctly signed and statistically significant coefficients for 52 percent of the firms. The standard neoclassical model I and model II accounted for about 42 percent and 31 percent respectively while the modified neoclassical I and modified neoclassical II were important in only 35 percent and 34 percent of the firms respectively.

The empirical results of the first two test criteria provide several important conclusions. First, for many firms, more than one model passes the tests of coefficient significance and hypothesized signs of the regressors; in particular, 90 have two or more such models. In fourteen firms, however, only one model passes the sign and significance tests. Second, the accelerator and q models pass the two test criteria most often with each model accounting for over 70 percent of the total firms. This suggests that the accelerator and q models become candidates for the best model of investment approximately three-fourths of the time. Finally, the liquidity model comes in third with 52 percent while each of the neoclassical models yield acceptable regression estimates for no more than 42 percent of the firm sample.

Given the models for each firm that pass both the signs and significance criteria, the standard error criterion is used to select the best investment model; the results are given in the third column of Table V. As can be seen from the results, no single theory consistently outperforms the others. The best performance is given by the accelerator-cash flow model which is chosen as the best model in 36 percent of the firms, followed by the q model which is selected 27 percent of the time. The accelerator model is selected in 17 percent of the firms while both versions of the standard neoclassical model taken together account for 13 percent. Finally, both forms of the modified neoclassical model explained only seven percent of the firms.

To summarize, no single theory does very well in all the tests as to be considered "the" theory of investment. Although the accelerator-cash flow and q models perform better than the other models, they are selected as the best model for only about a third of the firms. Another interesting finding is that out of the 37 firms explained by the accelerator-cash flow model, 24 of those cases, or about 65 percent, contain accelerator variables thereby confirming the relative importance of such variables. Finally, the two versions of the modified neoclassical model can be removed from contention as satisfactory models of firm investment since they yield only a small number of acceptable equations and are selected the best model in only seven percent of the total firm sample.

Results of Nonnested Tests

Pairwise nonnested tests are applicable to 89 of the 104 firms. The fifteen firms not tested are excluded on either of the following grounds: (1) the firm had only one model with the right signs and significant coefficients; (2) the firm had only the accelerator model and the accelerator-cash flow as competing models; since both models are nested, it is only necessary to test the cash flow variables for significance and, if they pass, then the accelerator-cash flow model is accepted and the accelerator model rejected. The summary results of the pairwise tests shown in Table VI indicate that the accelerator-cash flow model is definitely chosen in 19 of the 89 firms while the q model is selected in 11 firms. The accelerator model and the neoclassical model I tie for third with seven firms each. The last three models explain only one to two firms. Combining both versions of the standard neoclassical model result in eight firms while the modified neoclassical models taken together only account for three firms out of 89.

Table VII gives a more detailed picture of the determinate pairwise nonnested test results. For example, row 1 states that in the number of times the accelerator model was tested against the q model, the accelerator model is selected the best model four times. Conversely, the q model is selected the best model over the accelerator eight times in pairwise tests. The accelerator-cash flow model dominates the pairwise tests, winning over the q model 13 times, over the accelerator model five times, and over the combined neoclassical models and combined modified neoclassical models 13 and 12 times respectively.

TABLE VI

SUMMARY RESULTS: PAIRWISE NONNESTED TESTS

Model	Number of Firms Explained by Model
Accelerator	7
Accelerator - Cash Flow	19
q Model	11
Neoclassical I	7
Neoclassical II	1
Modified Neoclassical I	1
Modified Neoclassical II	2
Indeterminate/Inconclusive*	36
No Model Accepted	5

*Number of firms for which two or more models are accepted.

TABLE VII

DETERMINATE CASES: NUMBER OF TIMES THE COLUMN MODEL IS REJECTED IN PAIRWISE TESTS IN FAVOR OF THE ROW MODEL

	Accelerator	Cash Flow	q	Neoclassical I	Neoclassical II	Modified I	Modified II
Accelerator		0	4	6	1	6	3
Cash Flow	5		13	8	5	6	6
q Model	8	5		3	4	4	7
Neoclassical I	2	3	7		3	1	1
Neoclassical II	0	0	1	0		0	0
Modified I	0	1	1	1	1		0
Modified II	2	1	2	0	1	2	

Finally, the neoclassical model II and both versions of the modified neoclassical model win at best only two pairwise tests against any of the other alternative models.

The very small numbers of definite or determinate cases resulting from the pairwise nonnested tests are due to the large number of indeterminate cases where more than one model is accepted as the best model for the firm. Thirty-six firms or 40 percent of the firms tested provide inconclusive results. Of these 36 indeterminate cases, 25 are consistent with the q model, 19 with the accelerator, and 18 with each of the combined standard and modified neoclassical models. Only 15 firms are compatible with the accelerator-cash flow model. Table VIII provides additional results of the indeterminate cases wherein no model could be adequately chosen over another model or set of models. The table shows that the q model is compared and selected with the accelerator model 12 times out of 25 indeterminate cases, against the accelerator-cash flow and against neoclassical II eight times each, and against the other models five times each case. Of the 15 cases consistent with the accelerator-cash flow, it shares the explanation for firm investment most of the time with the q and accelerator models. The same can be said for both versions of the standard and modified neoclassical models.

Chi Square Tests for Independence

Given the theory classifications of the firms, an interesting point to examine is whether the choice of best investment model for a firm is related to the characteristics of the firm. For example, is there a relation between the type of product produced by a firm and that firm's investment model? Is a particular industry dominated by a particular

TABLE VIII

INDETERMINATE CASES: NUMBER OF TIMES THE ROW MODEL IS COMPARED AND ACCEPTED WITH THE COLUMN MODEL

	Accelerator	Cash Flow	q	Neoclassical I	Neoclassical II	Modified I	Modified II
Accelerator		5	12	5	5	5	7
Cash Flow	5		8	0	2	3	3
q Model	12	8		5	8	5	5
Neoclassical I	5	0	5		4	3	3
Neoclassical II	5	2	8	4		3	4
Modified I	5	3	5	3	3		5
Modifed II	7	3	5	3	4	5	

group? Is it possible to significantly distinguish one model group of firms from another based on certain qualitative characteristics of the firms? These relationships between model types and qualitative attributes of firms can be determined using the chi square test statistic.

The chi square statistic is used to test for significance between two classifications. Generally speaking, independence implies that the probability of one variable occurring is not affected by the occurrence (or nonoccurrence) of the other variable. The observed frequencies of the two variables are entered in a two-way cross-classification table or contingency table. The dimension of a contingency table is given by i x j where i is the number of row variable and j is the number of column levels of the column variable.

To test the null hypothesis of independence between the two variables, we need to estimate the expected frequencies for each cell of the contingency table, that is,

$$f_e = \frac{\Sigma i \; \Sigma j}{n}$$

where n is the total number of observations. These expected frequencies are then compared with the actual observed frequencies, f_o. This is done by computing the chi square test statistic,

$$\chi^2 = \Sigma \frac{(f_o - f_e)^2}{f_e}$$

with degrees of freedom v = (i - 1) (j - 1). If this computed statistic is greater than the critical tabulated chi square value at a specific significance value, then the null hypothesis of independence is rejected and we conclude that the two variables are related to one another.

The chi square tests, however, are subject to certain limitations.[2] The most important limitation is sample size. The larger the sample size, the better the fit. A safe rule of thumb is that the sample size should be large enough such that the expected frequency at each cell is greater than five. Another limitation is that the chi square test only measures the differences between the observed and expected frequencies. A rejection of the null hypothesis of independence implies a relation between the variables but does not say anything about the direction of the relationship or causation.

Results of Chi Square Tests for Independence

The model classifications used for these tests are the four major theory groups--accelerator-cash flow, q, accelerator, and standard neoclassical--based on the results of the minimum standard error sequential procedure. The few firms explained by the two versions of the modified neoclassical theory are excluded because of the unsatisfactory performance of these models based on the sequential procedure of selecting the best model. The qualitative firm characteristics tested here include: (1) industry; (2) consumer vs. producer good; (3) durable vs. nondurable good; and (4) single vs. diversified product line. The four model types are tested for independence against each of these four firm attributes. The methods of classifying the firms using the last three characteristics is based on available information regarding the background and current operations of each firm (for example, see latest issues of Moody's Investors Service, Moody's Handbook of Common Stocks) and admittedly suffers from some

---

[2] Reynolds (1977), pp. 9-11.

degree of arbitrariness on the part of the author. The distinction between whether the firm is producing capital goods (used in production of other goods) or consumer goods (bought by consumers or final users) becomes unclear especially when the firm has a diversified product line, i.e., the firm is expanding into other unrelated markets. For example, AMF Inc. has two main operating lines: recreational products (consumer goods) and industrial technology products (producer goods). In this case, the traditional product line or the dominant line in terms of sales is the basis used for classifying the firm in either consumer or producer good type.

Classifying the industries by two-digit SIC codes results in nineteen industry levels. A majority of the cells, however, have observed frequencies of less than five firms thereby making the results of the chi square tests untenable. To solve this problem, some industries are combined to produce the contingency table presented in Table IX. The chi square test statistic is 23 and significant at the 10 percent level, implying a relation between the model groups and the industry classifications. Examination of the cell chi square values shows that the accelerator group explains a large number of firms in the hardware and machinery industries and only one firm in the food and textiles industries. On the other hand, the q model group has many firms in the food and textiles sectors and only about half the number of firms as the accelerator model in the machinery and hardware sectors. Such extreme cases are not evident in the accelerator-cash flow group although it seems to dominate in the lumber and paper industries. Moreover, the accelerator-cash flow and q models account for almost the same number of firms in several industry groups.

TABLE IX

CONTINGENCY TABLE TO TEST INDEPENDENCE OF FIRM CLASSIFICATIONS BY INDUSTRY AND MODEL

Industries[a]	Accelerator[b]	Accelerator-Cash Flow[b]	q model[b]	Neoclassical I and II[b]	Total
Food (20); Cigarettes (21); Textiles (22); Apparel (23)	1 (0.98)	3 (1.03)	7 (2.17)	3 (0.48)	14
Lumber (24); Paper (26); Printing (27)	1 (0.16)	5 (1.25)	1 (0.74)	1 (0.02)	8
Chemicals (28); Petroleum Refining (29)	2 (1.21)	11 (0.57)	5 (0.41)	5 (0.85)	23
Rubber (30); Cement (32); Iron and Steel (33)	2 (0.32)	8 (0.59)	6 (0.41)	0 (2.31)	16
Hardware (34); Machinery (35); Electrical Machinery (36)	11 (7.16)	7 (1.06)	6 (0.41)	3 (0.21)	27
Transport Equipment (37); Instruments (39); Recreational (39)	1 (0.27)	3 (0.05)	3 (0.06)	2 (0.38)	9
Total	18	37	28	14	97

[a] The members in parentheses are SIC codes.

[b] The first member in each cell is the number of firms. The second number in parentheses is the cell X^2 value. The sum of the cell X^2's equals the X^2 statistic for independence.

Similar tests between the model types and each of the remaining qualitative firm variables failed to produce significant results. For example, testing the null hypothesis that the model type and type of good (consumer vs. producer) produced by the firm are independent of each other resulted in an estimated chi square statistic of 0.1, insignificant at the five percent level.

Discriminant Analysis

Another technique for distinguishing between the different model groups of firms on the basis of firm characteristics is discriminant analysis. It differs from the previous chi square tests in that it involves quantitative variables while the latter use qualitative variables. Unlike the chi square tests which determine the relation between two factors, discriminant analysis determines the relation between a specific theory classification and a combination of firm variables. Moreover, this method is not limited by sample size or cell frequency requirements.

Discriminant analysis is concerned with the problem of assigning or classifying an individual or observation to one of several groups, classes, or populations. For example, an international aid organization, in determining its development aid policy, might want to discriminate among different countries as between those which are considered "under-developed" and those that are not.[3] The central idea is the existence of some classification rule such that after observing a certain set of characteristics, traits, or attributes, one can decide to

---

[3] For a good discussion of the application of discriminant analysis to selected groups of countries, see Adelman and Morris (1968).

which group the individual or observation possessing such characteristics should belong. The approach of discriminant analysis can be decomposed into two main steps: (1) differentiate or distinguish between a number of groups or populations according to some predetermined set of X characteristics; and (2) then assign or classify an individual or observation to a specific group on the basis of some selection criterion.

Although different authors published papers on discriminant analysis at about the same time, the most important was by R. A. Fisher in 1936.[4] Fisher argued that before one can classify an individual observation, one must first distinguish between the various groups or classes. To do this, it is necessary to select a set of discriminating variables on which the groups are expected to differ. The objective of discriminant analysis is to form a linear function or combination of these variables in such a way that the groups or populations are forced to be as distinct from one another as possible. This "discriminant function" proposed by Fisher can be written as

$$Z = u_1X_1 + u_2X_2 + \;.\;.\;.\;.\; + u_pX_p$$

where

Z = discriminant score or index of differentiation

X_j = discriminating variable, $j = 1,2,\ldots p$

u_j = weight or coefficient of discrimination, $j = 1,2,\ldots,p$

Fisher only studied the case of two groups although the analysis can be extended to the general case of G number of groups. For the 2-group case, we can write the above discriminant function for Group 1 as

---

[4] Hotelling (1931) and Mahalanobis (1936) provided similar methods of analysis although their test procedures and initial objectives may be different.

$$Z_{i1} = u_1X_{i11} + u_2X_{i21} + \ . \ . \ . + u_pX_{ip1}$$

where Z_{i1} is the discriminant score for the ith individual where $i = 1,2,\ldots,n_1$. Similarly, the discriminant score for the ith individual in Group 2 is

$$Z_{i2} = u_1X_{i12} + u_2X_{i22} + \ . \ . \ . + u_pX_{ip2}.$$

The weights, u_j, are derived such that the distinction between the two groups is maximized. According to Fisher, the groups will differ on the basis of the means of their discriminant functions. Define the group means, $\overline{Z}_1$ and $\overline{Z}_2$, as

$$\overline{Z}_1 = \frac{\sum_{i=1}^{n_1} Z_{i1}}{n_1} = u_1\overline{X}_{11} + u_2\overline{X}_{21} + \ . \ . \ . + u_p\overline{X}_{p1}$$

$$\overline{Z}_2 = \frac{\sum_{i=1}^{n_2} Z_{i2}}{n_2} = u_1\overline{X}_{12} + u_2\overline{X}_{22} + \ . \ . \ . + u_p\overline{X}_{p2}$$

If we let $d_j = \overline{X}_{j1} - \overline{X}_{j2}$ signify the difference between group means on the discriminating variable X_j and let $D = \overline{Z}_1 - \overline{Z}_2$, then

$$D = u_1d_1 + u_2d_2 + \ . \ . \ . + u_pd_p$$

is the value that we want to maximize. Since D is a random variable whose value depends on the variability of the discriminant scores, Z_{i1} and Z_{i2}, Fisher proposed that in order for two groups to significantly differ from each other, we should maximize the ratio

$$\frac{D^2}{SS_w}$$

where SS_w stands for the within-group sum of squares of the variable Z. This ratio is also called the discriminant criterion. It can then be shown that there exists a unique vector of weights, u's, which will maximize Fisher's criterion.[5] Since the two groups differ only in their vectors of weights, u, we can test the significance D (the difference between the group means) by testing the null hypothesis,

$$H_0 : u^1 = u^2$$

against the alternative,

$$H_1 : u^1 \neq u^2$$

using an F test statistic with p and $n_1 + n_2 - p$ degrees of freedom.[6]

For the general case where there are more than two groups under consideration, Fisher argued that there would be G-1 discriminant functions where G is the total number of groups. For the G-group case, the discriminant criterion is the ratio of the sum of squares or covariance between group means to the sum of squares within group means,

$$\frac{SS_b}{SS_w} .$$

Again the objective is to find the vector of weights, u's, that will maximize this criterion. It can be shown that this analysis results in a specific number of discriminant functions (the smaller the G-1 and p or the total number of discriminating variables) each with its own set of discriminating variables and weights. Moreover, these functions are all uncorrelated with one another and are ordered from highest to lowest in terms of their power to discriminate between the groups. As such, the first estimated discriminant function defines a dimension consisting of a set of discriminating variables on which the groups differ the most. The second derived function is uncorrelated with the first and defines a dimension on which group differences are second to the highest

---

[5] For a rigorous discussion, see Lindeman, et al. (1980), pp. 171-173.

[6] See Dhrymes (1970), p. 74.

and so forth. This G-group discriminant analysis where a number of discriminant equations representing different dimensions in the discriminating variables are determined is a special case of canonical correlation analysis.[7]

The significant discriminant functions that are derived can be used to assign individuals or observations to the different groups. An individual is classified to that particular group which it resembles the most. There are several methods of classifying individuals but we do not intend to discuss all these procedures here.[8] Such an attempt would involve an entire literature survey altogether. Moreover, different computer packages on discriminant analysis may vary on the classification procedures used. The computer algorithm on discriminant analysis used in this study assigns individuals to groups on the basis of two decision rules: (1) the generalized squared distance between an individual and a particular group; and (2) the prior and posterior probabilities of membership.[9] The first classification rule is credited to C. R. Rao (1973) who extended Mahalanobis' 1936 work on discriminant analysis. Rao integrated the original idea of Mahalanobis' D^2 statistic (which is a measure of the distance or resemblance of an individual to a particular group) and the idea of a probability of membership estimated after the discriminant function is known. The decision rule based on Rao's procedure is to classify an individual to that group for which its generalized squared distance is the smallest.

---

[7] Lindeman, et al. (1980), p. 195.

[8] See Lindeman, et al. (1980), pp. 196-214, for a brief survey.

[9] SAS DISCRIM procedure (1982).

The second classification rule takes into account the individual's prior probability of membership in a specific group. This prior probability is based on the relative sizes of the groups to which the individual might belong. For instance, given three groups or classes of size 100, 200, and 500, then the three prior probabilities would be 0.125, 0.25, and 0.625. This procedure of using prior probabilities computes a posterior probability of membership, posterior in the sense that such a probability is conditional on having known the individual's discriminant score on the discriminating variables. The decision rule is to assign an individual to the group for which its posterior probability of membership is the highest.

Procedure of Discriminant Analysis

The first step in the discriminant analysis is to classify the firms into five groups representing the five models of investment according to their performance in the standard error criterion. Next, a set of discriminating variables or firm characteristics must be selected. The original set of discriminating variables consists of 56 firm characteristics. This set does not presume to be a comprehensive list of discriminating variables. The list contains both quantitative as well as qualitative characteristics and can be grouped in the following categories: rates of return, turnover rates, financial risk, stock performance, income and balance sheet data, operating characteristics, growth, and product characteristics. Except for the growth measures, standard deviations, coefficients of variation, and concentration ratios, all the variables are average values over the

1956-84 period. Definitions of these discriminating variables are given in Table X.

Rather than using all 56 variables in the analysis, only the most useful discriminating factors are included. Preliminary investigation showed that the product characteristics are insignificant for our purposes and hence dropped. These qualitative variables, however, are used in chi-square tests of independence in another analysis. The remaining variables are selected for entry on the basis of their contribution to the discriminatory power of the function as measured by the value of the stepwise selection criterion. In the stepwise procedure used in this study, Wilk's lambda is the test criterion for significance.[10]

Given a specified level of significance, the stepwise selection method begins by choosing the first variable which has the highest discriminatory power as indicated by Wilk's lambda. After this variable is entered, the procedure checks over the remaining variables and enters each significant one. At each step, each variable already in the model is tested for significance given the other variables now in the model. This is done because as more variables are selected for inclusion, some variables previously selected may lose their discriminatory power. This loss in power occurs since the information that a variable contains may now be available in another variable or combination of variables. Such redundant variables are thus removed. When all variables in the model meet the criterion to stay and no other variables can be further added based on the selection criterion, then the stepwise procedure stops.

---

[10] For discussion of the stepwise (STEPDISC) procedure, see SAS (1982).

TABLE X

DISCRIMINATING VARIABLES

Rates of Return

1. Return on assets (net income/assets)
2. Return on equity (net income/equity)
3. Margin on sales (net income/sales)
4. Earnings per share (net income/total shares outstanding)
5. Return on capital (net income/net capital)

Turnover Rates

6. Sales-asset ratio (sales/assets)
7. Sales-capital ratio (sales/net capital)
8. Assets per working capital liabilities (assets/(current assets-current liabilities))

Financial Risk

9. Current ratio (current assets/current liabilities)
10. Liability to equity ratio (total liabilities/equity)
11. Current liabilities-equity ratio (current liabilities/equity)
12. Capital to equity ratio (net capital/equity)
13. Long-term debt to equity ratio (long-term debt/equity)
14. Debt-equity ratio (total debt/equity)
15. Debt to asset ratio (total debt/total assets)
16. Current assets-Total assets ratio (current assets/total assets)

Stock Performance

17. PE ratio (price per common share/earnings per share)
18. Dividend ratio (dividend per common share/price per share)

Income, Expenses and Balance Sheet Data

19. Total assets
20. Total liabilities
21. Equity
22. Invested capital (long-term debt plus preferred stock plus common equity plus minority interest)
23. Sales
24. Gross income
25. Research and development expenditures
26. Advertising expenditures
27. Net income
28. Net plant

TABLE X (Continued)

Operating Statistics

29. Labor productivity (sales/number of employees)
30. Number of employees
31. Total wages
32. Capital-labor ratio (net plant/number of employees)
33. Asset employee ratio (total assets/numbers of employees)
34. Wage rate
35. R&D per worker (research and development expenditures/number of employees)
36. Depreciation rate
37. Corporate income tax rate ((gross income-net income)/gross income)
38. Gross investment to assets (gross investment/total assets)
39. Capital expenditures
40. Gross investment (capital expenditures/price index)
41. Capital stock
42. Interest expense
43. Interest income
44. Inventory

Growth, Variance, and Concentration Ratios

45. Growth rate of sales
46. Growth rate of capital expenditures
47. Standard deviation of sales
48. Standard deviation of net income
49. Standard deviation of capital expenditures
50. Standard deviation of gross investment
51. Coefficient of variation of sales
52. Coefficient of variation of net income
53. Coefficient of variation of capital expenditures
54. Coefficient of variation of gross investment
55. Industry concentration ratio (1972)
56. Industry concentration ratio (1982)

Initial experimentation used different levels of significance. Caution must be exercised here since increasing the significance level increases the number of discriminating variables included in the model but does not significantly raise the overall discriminatory power of the selected variables. For example, at a significance level of 0.50, more than 20 variables are entered but the overall fit as measured by the canonical correlation is low indicating that some included variables contribute little or no discriminating power to the model. Hence, the recommended range is from 0.10 to 0.25.

Given the significant discriminant variables, the discriminant functions can now be determined. The maximum number of functions that can be derived is one less the number of groups or the number of discriminant variables, whichever is smaller. As mentioned earlier, the discriminant analysis procedure (called DISCRIM) to be used in this study calculates discriminant equations on the basis of a resemblance measure of generalized squared distance. Each firm is assigned to that theory group from which it has the smallest distance D^2. This procedure also assumes prior capabilities of membership. Along with the discriminant functions, the DISCRIM procedure produces posterior probabilities and prints the results of classifying observations in the groups. To check the adequacy of the discriminant analysis results, the study proposes to:

(a) count the number of times each firm is correctly classified into its group, that is, compare the predicted firm classification with the actual, original classification;

(b) analyze the relevant statistics such as Wilk's lambda and the canonical correlation; and

(c) cross-check or cross-validate the results of the discriminant analysis (DISCRIM) procedure with a sample procedure for canonical correlation analysis (the SAS program is called CANDISC).

A brief explanation of canonical correlation analysis is in order. This technique was developed by Hotelling (1935, 1936) and is another way of determining discriminant functions. Given a variable Y (usually a dummy variable to represent the different groups or populations) and a set of quantitative variables X, canonical correlation analysis derives linear combinations of the X's (called canonical variables) that are highly correlated with the dummy variable Y. The first linear combination or canonical variable has the highest possible multiple correlation with Y (or essentially the groups under study). The second canonical variable is not correlated with the first and has the second highest correlation with Y and so on. It is important to remember that the discriminant functions derived by the CANDISC procedure is different from those estimated by the DISCRIM method. The usefulness of the CANDISC procedure, however, lies in the fact that each canonical variable represents a set of discriminating variables used in DISCRIM and hence we can compare the discriminatory and classification powers of these two procedures. Moreover, CANDISC provides a plot of the firms by theory groups and we can see how distinct or separated the groups are from one another.

Results of Discriminant Analysis

Considerable experimentation was conducted on the different model groups and the level of significance used in the discriminant analysis procedure. Beginning with the original model groups (with each firm initially assigned to a specific theory class based on the minimum residual variance criterion), the stepwise procedure of selecting significant discriminating variables was applied using various significance levels in entering and retaining variables. Results showed that the number of relevant variables increased from six at the 0.10 significance level to 24 variables at the 0.50 level. Even so, the average squared canonical correlation, a measure of the discriminatory power of these variables, increased only slightly from 0.14 with six variables to 0.35 with 24 variables. Moreover, using 25 percent level yielded the same six variables obtained at the 10 percent level. Hence, increasing the significance level in order to add more explanatory variables in the model does not substantially raise the discriminatory power. The recommended range of the significance level is 10 to 25 percent.

As mentioned earlier, given a significance level of 0.10, the discriminant stepwise procedure resulted in the selection of six discriminating variables with an overall canonical correlation of 0.14. The variables included a profitability measure, a dividend yield measure, the depreciation rate variable, the gross investment variable, invested capital variable, and the total liabilities variable. As discussed earlier, the stepwise method selects a variable according to its contribution to the discriminatory power of the model as measured by Wilk's lambda. Wilk's lambda is an inverse measure; the smaller lambda is, the greater the discriminatory power. In the case of the six variables, although the lambda value decreased in magnitude as variables were entered in the function (0.89 to 0.53), Wilk's lambda was still large indicating that the discriminating power of these variables is low. Nevertheless, given these six variables, the discriminant (DISCRIM) procedure was applied to the sample assuming prior probabilities based on model group size so as to derive the discriminant functions. Results show that 58 percent of the 104 firms are correctly classified in the five theory groups. This prediction performance is greater than the 20 percent expected forecast performance had the assignments been randomly made.[11] Moreover, the proportion of firms classified in the q model group after the discriminant functions had been considered increased dramatically over the prior probabilities, and dropped for the other groups. A look at the pairwise generalized squared distances between model groups reveals that the accelerator, q, accelerator-cash flow, and modified neoclassical groups are closely related and as a group tend to be distinct or separate from the standard neoclassical theory group.

To cross-validate these results, the canonical discrimination procedure CANDISC was also run. CANDISC produced four canonical variables (linear combinations of the six discriminating variables) but only the first two are significant based on their canonical correlation of 0.48 and 0.47 respectively (significant at the five percent level). Although these correlations are significant, they are still small implying low discriminatory power. This result is supported by a large Wilk's lambda. A glance at the plot of the two significant canonical variables shows no distinct separation between the different model groups although data observations of the standard neoclassical firms were located apart from the main cluster of data points.

---

[11] Klecka (1980), p. 50.

This Stepwise-DISCRIM-CANDISC procedure was repeated using the four theory groups: accelerator, accelerator-cash flow, q, and standard neoclassical. The modified neoclassical group was excluded from the analysis because of the very few firms assigned to this group as per the standard error criterion. The stepwise method selected eight discriminating variables from the initial list of variables at the 25 percent level of significance. These variables were: (1) depreciation rate; (2) dividend yield; (3) net fixed assets or net plant; (4) price-earnings ratio; (5) ratio of fixed assets to equity; (6) ratio of current assets to current liabilities; (7) the coefficient of variation of net income; and (8) standard deviation of gross investment. The average squared canonical correlation is still low but significant.

The results of applying DISCRIM to the four theory groups given the eight discriminating variables were: (1) the generalized squared distances between the groups indicated a close resemblance between the accelerator, accelerator-cash flow, and neoclassical groups while the q model group was distinct from the other three; (2) all four groups were found to have approximately equal covariance matrices, an important assumption in discriminant analysis[12]; (3) the number of correctly classified observations amounted to 55 percent of the total 97 observations (greater than the expected percentage of correct classifications of 25 percent); (4) the proportion of firms classified into the accelerator group is now 25 percent (the prior proportion was 19 percent), the proportion of firms assigned to the accelerator-cash flow group after DISCRIM is now 50.5 percent (prior proportion was 38 percent), the percentage of firms now in the q model group is now only

---

[12] See Klecka (1980), pp. 9-11.

11 percent when before it was 29 percent, and the percentage of firms in the neoclassical group also dropped from 14 to 13 percent.

Canonical discriminant analysis of the same four groups produced two significant canonical variables with canonical correlation values of 0.58 and 0.49 and a Wilk's lambda of 0.49. A look at the plot of these canonical variables show that the data points for the accelerator, accelerator-cash flow, and neoclassical groups are clustered together while the data cases for the q model group are somewhat separated, thereby supporting the DISCRIM results on the distances between theory groups. Because of this high degree of relatedness between the accelerator, accelerator-cash flow, and neoclassical firms, the accelerator and neoclassical firms were dropped and the rest of the analysis was continued using only the accelerator-cash flow and q model groups. Besides, these two remaining theories together account for over 60 percent of the total firm sample under study.

Applying stepwise discriminant procedure to the accelerator-cash flow and q model groups at the 15 percent level of significance lead to five discriminant variables being selected. These variables are: (1) depreciation rate; (2) ratio of net income to sales; (3) ratio of total liabilities to equity; (4) coefficient of variation of gross investment; and (5) coefficient of variation of sales. Running the DISCRIM procedure on the two theory groups given these five variables resulted in a successful classification rate of 80 percent, with the accelerator-cash flow group now accounting for 68 percent to the total firms (ten out of the original 28 q model firms are reclassified into the accelerator-cash flow group). To cross-check these results, the CANDISC procedure was applied resulting in one significant canonical variable with a correlation of 0.62. A plot of the canonical variable shows a clear distinction between the two groups with a slight overlap in some of the data cases. These results indicate that the five discriminating variables are sufficient to distinguish between the two model groups. A look at the standardized canonical coefficients of these variables show that the variability of sales is the most important variable, followed by the variability of gross investment, then the ratio of net income to sales, the rate of depreciation, and finally the liability to equity ratio. Finally, an examination of the class means reveal that the accelerator-cash flow group of firms is more profitable, has a lower degree of business risk, and a higher sales variability than the q model firms. The q model firms generally have a lower depreciation rate and lower variability in terms of gross capital expenditures than their accelerator-cash flow counterparts.

CHAPTER V

CONCLUSIONS

This chapter enumerates the main findings of the study, its limitations, and directions for further inquiry.

Main Findings

The main conclusion of this study is that the accelerator-cash flow and q models are best in explaining investment behavior for the firms examined here and that both models perform about equally well based on the different sets of comparison criteria employed in the study. The performance of both models is surprising considering that previous studies have found conflicting results. Comparative studies by Bischoff and Clark have shown that the accelerator-cash flow and q models perform very poorly relative to other investment theories. On the other hand, studies by Elliott and Ciccolo have found empirical support for the accelerator-cash flow model and the q model respectively.

The accelerator model ranks third to the accelerator-cash flow and q models in terms of overall significance, followed closely by the standard neoclassical model. The performance of the accelerator model confirms earlier findings of comparative investment studies using aggregate (Bischoff, Clark, Kopcke) and firm (Kuh, Eisner) data. The average performance of the accelerator model is partly due to the fact that the relative influence of the accelerator variables seems to be obfuscated or obscured by the effects of the cash flow variables. Of the 37 firms explained by the accelerator-cash flow model, 24 of those firm equations contain accelerator variables. However, an inspection shows that the parameter estimates of the accelerator variables are smaller in magnitude than those of the cash flow variables. This is consistent with Kuh's (1963) finding that when both output and profit variables are included in the same model, the profit or cash flow variable tends to be more statistically significant than the output variable. This finding, however, contradicts Jorgenson's (1971) conclusion that cash flow variables are insignificant in models that also include output as an explanatory factor.

Although the standard neoclassical model ranks closely with the accelerator model, its overall performance is relatively poor. This sharply contradicts the findings of Jorgenson and Siebert. The unsatisfactory performance of this model may be attributed to the formulation and implementation of the user cost of capital. This variable is not only difficult to measure but is also a composite of many independent variables and influences (inflation rates, depreciation rates, taxes, etc.) so that its significance as an explanatory variable is unclear or doubtful. Two versions of the neoclassical model are used in the study to account for two different formulations of the user cost of capital. Our results show that version I of the neoclassical model which defines cost of capital without accrued capital gains performs better than the other model version.

Both versions of the modified neoclassical model are inferior in terms of explanatory power compared to the other four theories. This finding contradicts Bischoff's earlier studies.

Finally, the sequential methodology employed in this study to test and compare alternative theories of investment expenditures is superior to the procedures used by Jorgenson and Siebert and Elliott. The procedure used here eliminates problems of coefficient sign inconsistencies and insignificance in the final models or equations compared. Elliott (1973) complained, on the other hand, that his regression equations were plagued with variables that had inconsistent hypothesized signs, and attributed the inconsistency to problems of multicollinearity. The use of nonnested hypotheses tests complemented our sequential procedure of choosing the best investment model on the basis of minimum standard error.

Although this study presents interesting findings, it is not conclusive. First, despite the fact that the accelerator-cash flow and q models perform well, each accounts for only about a third of the entire firm sample studied. Consequently, this study concludes that there is no single theory that is dominant or superior. This study claims only that, based on the assumptions and various criteria used for discriminating among the five investment models, output, cash flow, and q variables are the most important determinants of firm investment behavior.

Taking the two primary theories, accelerator-cash flow and q, discriminant analysis is used to determine whether there are any significant relationships between the choice of the best model and the different characteristics of the firms. The results indicate that five firm variables (sales variability, gross investment variability, ratio of net income to sales, depreciation rate, ratio of total liabilities to equity) can be used to distinguish between the accelerator-cash flow model firms and the q model firms. On the average, the accelerator-cash flow firms are more profitable and less risky and possess a higher sales variability than the q firms. The q firms have lower depreciation rates and lower investment variability.

Limitations and Suggestions for Further Research

One suggestion for further research is to conduct the comparison of the different investment models using combined time-series and cross-sectional data. This method is attractive in that it could provide useful insights especially with regard to inter-industry effects as well as policy decisions. The pooled data set carries much information that could be used to make statements or conclusions about the economy as a whole. Combined cross-sectional and time-series analysis of individual firm data is subject to problems however. The dual problems of heteroscedasticity and autocorrelation occur due to the pooling of data. Nevertheless, these problems may be solved by employing procedures such as time-series autocorrelation model and seemingly unrelated regression.[1]

Another important aspect of this study involves the assumption regarding the lag structure of the investment process. This study uses the rational distributed lag structure to represent the investment process. In his 1971 study of three types of lag functions (finite, geometric, rational), Jorgenson found that rational distributed lags are more consistent with the survey results of the average two-year time span of the investment process. Moreover, the rational lag form is a

---

[1] See Drummond and Galant (1977) for a description of the procedure for analyzing time-series and cross-sectional data.

general structure in that it allows for a wide range of different lag patterns to be represented. For instance, the Koyck geometric lag model is a special case of the rational distributed lag function.[2] The lag shape indicated by the rational distributed lag function is first rising and then falling; this shape is more appropriate and useful than the geometric lag shape that is always falling. Finally, the rational distributed lag function is computationally easier to estimate than other types of lag distributions. Despite all these advantages, however, it should be noted that other formulations of the time structure of investment should be tested and compared.

In a similar vein, other procedures should be devised and tested in order to determine the depreciation rate for a firm. Although several methods were pretested and evaluated earlier, and a final procedure was chosen, other formulations may be more appropriate. In addition, as pointed out by Eisner and Feldstein and Foot, the assumption used in this study of a constant ratio of replacement investment to capital stock may be unrealistic.

Finally, another possibility for further research would be to improve the measure of the q variable (especially with regard to the market value of the firm) and to conduct a comparative study of the three significant models: accelerator-cash flow, q, and accelerator.

---

[2] See Griliches (1967).

SELECTED BIBLIOGRAPHY

Adelman, Irma and Cynthia T. Morris. "Performance Criteria for Evaluating Economic Development Potential: An Operational Approach." Quarterly Journal of Economics, 1968, pp. 260-280.

Alexandrov, A. D., A. N. Kolmogorov, and M. A. Lavrent'ev (eds.). Mathematics: Its Content, Methods and Meaning, Vol. I, Mass: MIT Press, 1963.

Beach, Charles M. and James J. MacKinnon. "A Maximum Likelihood Procedure for Regression with Autocorrelated Errors." Econometrics, 1978, pp. 51-58.

Bischoff, C. W. "Business Investment in the 1970s: A Comparison of Models." Brookings Papers in Economic Activity, 1971a, 1, p. 13-63.

____________. "The Effect of Alternative Lag Distributions." Tax Incentives and Capital Spending. Ed. Gary Fromm. Washington: Brookings Institute, 1971b, pp. 61-125.

____________. "Hypothesis Testing and the Demand for Capital Goods." Review of Economics and Statistics, 51, August 1969, pp. 354-368.

Brainard, William C., J. Shoven, and L. Weiss. "Financial Valuation of the Valuation of the Return to Capital." Brookings Papers on Economic Activity, 1980, pp. 453-511.

Brechling, Frank R. "Monetary Policy and Neoclassical Investment Analysis." in Johnson, H. G. and Nobay, A. R., eds., Issues in Monetary Economics. Oxford: Oxford University Press, 1974.

____________. Investment and Employment Decisions. Manchester: Manchester University Press, 1975.

Chappell, Henry W., Jr. and David C. Cheng. "Expectations, Tobin's q and Investment: A Note." The Journal of Finance, 37(1), March 1982, pp. 231-36.

Chenery, Hollis B. "Overcapacity and the Acceleration Principle." Econometrics, January 1952, pp. 1-28.

Ciccolo, John Henry, Jr. "Four Essays on Monetary Policy." (Unpub. Ph.D. dissertation, Yale University, 1975.)

____________ and Gary Fromm. "'q' and the Theory of Investment." J. Finance, 34, 2 (May 1979), pp. 535-47.

Clark, J. Maurice. "Business Acceleration and the Law of Demand: A Technical Factor in Economic Cycles." Journal of Political Economy (March 1917), pp. 217-235.

Clark, Peter. "Investment in the 1970s: Theory, Performance, and Prediction." BPEA, 1:1979, pp. 73-113.

Conte, S. D. Elementary Numerical Analysis: An Algorithmic Approach. (New York: McGraw Hill), 1965.

____________ and Carl de Boor. Elementary Numerical Analysis: An Algorithmic Approach. (New York: McGraw Hill), 1972.

Cox, D. R. "Tests of Separate Families of Hypotheses." Proceedings of the Fourth Berkeley Symposium on Mathematical Statistics and Probability, Vol. 1, Berkeley: University of California Press, 1961.

____________. "Further Results on Tests of Separate Families of Hypotheses." Journal of the Royal Statistical Society, 1962, 406-424.

Creamer, Daniel B., Sergei P. Dobrovolshy and Israel Borenstein. Capital in Manufacturing and Mining: Its Formulation and Financing. (Princeton: Princeton University Press), 1960.

Davidson, R. and J. G. MacKinnon. "Several Tests for Model Specifications in the Presence of Alternative Hypotheses." Econometrica, September, 1981, pp. 781-793.

Davidson, Signey and Roman L. Weil. "Inflation Accounting: What Will General Price Level Adjusted Income Statements Show?" Financial Analysts Journal, January-February, 1975, pp. 27-31, 70-84.

Dhrymes, Phoebus J. Econometrics: Statistical Foundations and Applications. New York: Springer-Verlag, 1974.

Drummond, Douglas and A. Ronald Galant. "TSCSREG: A SAS Procedure for the Analysis of Time Series Cross-Section Data." Mimeo Series #1107, Institute of Statistics, North Carolina State Univ., Raleigh, Feb. 1977.

Eisner, Robert. "A Distributed Lag Investment Function." Econometrica, January, 1960, pp. 1-29.

____________. "Investment Plans and Realizations." American Economic Review, 52, 1 (1962), 190-203.

____________. "Investment: Fact and Fancy." American Economic Review, May, 1963, pp. 237-246.

____________. "A Permanent Income Theory for Investment: Some Empirical Explorations." American Economic Review, June, 1967, pp. 363-390.

____________. "Tax Policy and Investment Behavior: Comment." American Economic Review, 59 (3), June, 1969, pp. 378-387.

____________. "Neoclassical Theory of Investment Behavior: A Comment." Review of Economics and Statistics, May, 1970, 52 (2), pp. 216-222.

____________. "Econometric Studies of Investment Behavior." Economic Inquiry, March, 1974, 12, pp. 91-104.

____________. Factors in Business Investment. Cambridge, Mass.: Ballinger Publishing Company, 1978.

____________ and M. I. Nadiri. "Investment Behavior and Neoclassical Theory." Review of Economics and Statistics, August, 1968, pp. 369-382.

____________ and Robert H. Strotz. "Determinants of Business Investment." Impacts of Monetary Policy. Ed. Commission on Money and Credit. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963, pp. 59-233.

Elliott, J. W. "Forecasting and Analysis of Corporate Financial Performance with an Econometric Model of the Firm." Journal of Finance and Quantitative Analysis, March, 1972, pp. 1499-1526.

____________. "Theories of Corporate Investment Behavior Revisited." American Economic Review, 63, 1 (March, 1973), 195-207.

Falkenstein, Angela and Roman L. Weil. "Replacement Cost Accounting: What Will Income Statements Based on the SEC Disclosures Show? Part II." Financial Analysts Journal, March-April, 1977, pp. 48-56.

Feldstein, Martin S. and David K. Foot. "The Other Half of Gross Investment: Replacement and Modernization Expenditures." Review of Economics and Statistics, February, 1971, pp. 49-58.

Fisher, R. A. "The Use of Multiple Measurements in Taxonomic Problems." Annals of Eugenics, Vol. 7, 1936, pp. 179-188.

Griliches, Z. "Distributed Lags: A Survey." Econometrica, Vol. 35, 1967, pp. 16-49.

Grove, Wendell. Brief Numerical Methods. New Jersey: Prentice Hall, 1966.

Grunfeld, Yehuda. "The Determinants of Corporate Investment." The Demand for Durable Goods. Chicago: University of Chicago Press, 1960, pp. 211-266.

Hall, Robert E. "Investment, Interest Rates and Effects of Stabilization Policies." Brookings Papers on Economic Activity, 1977, pp. 61-103.

____________ and D. W. Jorgenson. "Tax Policy and Investment Behavior." American Economic Review, June, 1967, pp. 391-414.

____________ and D. W. Jorgenson. "Application of the Theory of Optimum Capital Accumulation," in Tax Incentives and Capital Spending. Ed. Gary Fromm. Washington: Brookings Institute, 1971, pp. 9-60.

Herbener, Jeff. "Demand for Money by Firms." (Unpub. Ph.D. dissertation, Library, Oklahoma State University, 1982).

Hickman, Bert G. "Capacity, Capacity Utilization and the Acceleration Principle." NBER Studies in Income and Wealth. NBER Monograph, No. 19. Princeton: NBER, 1957, pp. 419-50.

Hotelling, H. "The Generalization of Student's Ratio." Annals of Mathematical Statistics, 1931, 2, pp. 360-378.

____________. "The Most Predictable Criterion." Journal of Educational Psychology, 1935, 26, pp. 139-142.

____________. "Relations Between Two Sets of Variates." Biometrika, 1936, 28, pp. 321-377.

Johannes, James M. and Ali Reza Nasseh. "Income or Wealth in Money Demand: An Application of Non-nested Hypothesis Tests." Southern Economic Journal, 1985, pp. 1099-1106.

Jorgenson, Dale W. "Capital Theory and Investment Behavior." American Economic Review, 53, 2 (May, 1963), 247-259.

____________. "Rational Distributed Lag Functions." Econometrica, 32, 1 (January, 1966), 135-149.

____________. "The Theory of Investment Behavior." The Determinants of Investment Behavior. Ed. R. Ferber. New York: NBER, 1967.

____________. "Econometric Studies of Investment Behavior: A Survey." Journal of Economic Literature, 9, 4 (1971), 1111-1147.

____________, J. Hunter, and M. I. Nadiri. "A Comparison of Alternative Econometric Models of Quarterly Investment Behavior." Econometrica, March, 1970, pp. 187-212.

____________ and Calvin B. Siebert. "A Comparison of Alternative Theories of Corporate Investment Behavior." American Economic Review, 58, 4 (September, 1968a), pp. 681-712.

____________ and Calvin B. Siebert. "Optimal Capital Accumulation and Corporate Investment Behavior." Journal of Political Economy, November-December, 1968b, 76 (6), pp. 1123-1151.

____________ and Calvin B. Siebert. "An Empirical Evaluation of Alternative Theories of Corporate Investment." Current Econometric Practice. Ed. Karl Brunner. Columbus, Ohio: Ohio State University Press, 1972, pp. 155-218.

____________ and J. A. Stephenson. "Investment Behavior in U.S. Manufacturing, 1947-60." Econometrica, April, 1967, pp. 169-220.

Klecka, William R. Discriminant Analysis. (Beverly Hills, CA: Sage Publications), 1980.

Klein, Lawrence R. Economic Fluctuations in the U.S., 1921-41. Cowles Commission for Research in Economics Monograph No. 11, 1950.

____________. "A Study of Investment." Conference on Business Cycles. New York: NBER, 1951, pp. 233-303.

Kopcke, Richard W. "The Behavior of Investment Spending During the Recession and Recovery, 1973-76." Federal Reserve Bank of Boston, New England Economic Review, November/December, 1977, pp. 5-41.

____________. "Forecasting Investment Spending: The Performance of Statistical Models." Federal Reserve Bank of Boston, New England Economic Review, November/December, 1982, pp. 13-29.

____________. "The Determinants of Investment Spending." Federal Reserve Bank of Boston, New England Economic Review, July/August, 1985, pp. 19-35.

Koyck, L. M. Distributed Lags and Investment Analysis. Amsterdam: North Holland Publishing Co., 1954.

Kuh, Edwin. Capital Stock Growth: A Micro-Econometric Approach. Amseterdam: North Holland Publishing Co., 1963.

Kuznets, Simon. "Relation Between Capital Goods and Finished Products." Economic Essays in Honor of Wesley Clair Mitchell. New York: Columbia University Press, 1935, pp. 209-269.

Lindeman, Richard H., Peter Merenda and Ruth Gold. Introduction to Bivariate and Multivariate Analysis. Illinois: Scott, Foreman and Co., 1980.

Lindenberg, E. and S. Ross. "Tobin's q Ratio and Industrial Organization." Journal of Business, January, 1981, pp. 1-32.

Mahalanobis, P. C. "On the Generalized Distance in Statistics." Proceedings of the National Institute of Science, India, 1936, 12, pp. 49-55.

Malkiel, Burton G., George M. Von Furstenberg, and Harry S. Watson. "Expectations, Tobin's q and Industry Investment." Journal of Finance, May, 1979, pp. 549-561.

Mallows, C. L. "Choosing Variables in a Linear Regression: A Graphical Aid." (Paper presented at the Central Regional Meeting of the Institute of Mathematical Statistics, Manhattan, Kansas, May, 1964).

____________. "Some Comments on C_p." Technometrics, November, 1973, pp. 661-676.

Meyer, J. R. and R. R. Glauber. Investment Decisions, Economic Forecasting and Public Policy. Cambridge, MA: Harvard University Press, 1964.

____________ and Edwin Kuh. The Investment Decision. Cambridge, MA: Harvard University Press, 1957.

Mueller, D. "The Firm Decision Process: An Econometric Investigation." Quarterly Journal of Economics, February, 1967, pp. 58-87.

Naylor, John A. "A Survey of Post-1970 Empirical Studies of Investment Expenditures." Modern Concepts in Macroeconomics. Ed. Thomas M. Havrilesky. Arlington Heights, IL: Harlan Davidson, Inc., 1985, pp. 27-55.

Parker, James E. "Impact of Price-Level Accounting." The Accounting Review, January, 1977, pp. 69-95.

Pesaran, M. H. "On the General Problem of Model Selection." Review of Economic Studies, 1974, pp. 153-171.

____________ and A. S. Deaton. "Testing Non-nested Linear Regression Models." Econometrica, May, 1978, pp. 677-694.

Pindyck, Robert and Daniel Rubinfeld. Econometric Models and Economic Forecasts. New York: McGraw-Hill, 1981.

Rao, C. R. "The Utilization of Multiple Measurements in Problems of Biological Classification." Journal of the Royal Statistical Society, 1948, 10, pp. 159-193.

____________. Linear Statistical Inference and its Applications. New York: John Wiley and Sons, 1973.

Resek, Robert. "Investment by Manufacturing Firms: A Quarterly Time Series Analysis of Industry Data." Review of Economics and Statistics, August, 1966, pp. 322-333.

Reynolds, H. T. The Analysis of Cross-Classifications. New York: The Free Press, 1977.

Rowley, J. C. R. and P. K. Trivedi. Econometrics of Investment. London: 1975.

SAS User's Guide: Statistics. Cary, NC: SAS Institute, Inc., 1982.

Standard and Poor's Compustat Tape, 1956-1982. Standard Statistics Division, New York.

Theil, Henri. Economic Forecasts and Policy. 2nd Amsterdam: North-Holland Publishing Co., 1961.

____________. Principles of Econometrics. New York: John Wiley and Sons, Inc., 1971.

Tinbergen, J. "A Method and Its Application to Investment Activity." Statistical Testing of Business Cycle Theories. Vol. I., Geneva: League of Nations, 1939.

____________. Statistical Testing of Business Cycle Theories. New York: Agathon Press, Inc., 1968.

Tobin, James. "A General Equilibrium Approach to Monetary Theory." Journal of Money, Credit, and Banking, 1, 1 (February, 1969), pp. 15-29.

____________ and William C. Brainard. "Asset Markets and the Cost of Capital." Economic Progress, Private Values, and Public Policy: Essays in Honor of William Fellner. Eds. Bela Balassa and Richard Nelson. Amsterdam: North-Holland Publishing Co., 1977, pp. 235-262.

____________ and William C. Brainard. "Pitfalls in Financial Model Building." American Economic Review, 58, May, 1968, pp. 99-122.

Tsiang, S. C. "Accelerator, Theory of the Firm and the Business Cycle." Quarterly Journal of Economics, August, 1951, pp. 325-341.

U.S. Department of Commerce. Fixed Nonresidential Business Capital in the U.S.. Washington, D.C.: U.S. GPO, 1974.

Von Furstenberg, George M. "Corporate Investment: Does Market Valuation Matter in the Aggregate?" Brookings Papers on Economic Activity, 1977, pp. 347-397.

____________, Burton G. Malkiel, and Harry S. Watson. "The Distribution of Investment Between Industries: A Microeconomic Application of the "q" Ratio." Capital, Efficiency, and Growth. Ed. George M. Von Furstenberg. Cambridge, MA: Ballinger Publishing Co., 1980, pp. 395-460.

Wisley, T. O. and S. R. Johnson. "An Evaluation of Alternative Investment Hypotheses Using Non-nested Tests." Southern Economic Journal, 52, October, 1985, pp. 422-30.

APPENDIX I

DEFINITIONS

Gross investment (I) - current capital expenditures of the firm deflated by the nonresidential fixed investment deflator.

Capital stock (K) - the capital stock series is computed by first solving for the (economic) depreciation rate α in the equation

$$K_t = (1 - \delta^t K_0 + (1 - \delta)^{t-1} I_1 + (1 - \delta)^{t-2} I_2 + \ldots + I_t,$$

where K_0 and K_t are net fixed assets deflated by the nonresidential fixed investment deflator for 1956 and 1982, respectively. Given the estimate for μ, the rest of the capital stock series is calculated using the equation $K_t = (1 - \delta)K_{t-1} + I_t$.

Output (Y) - (sales plus change in inventories) deflated by the producer price index for the firm's industry.

Cash flow (L) - (profits after taxes plus depreciation less dividends paid) deflated by the nonresidential fixed investment deflator.

Price of output (P) - the producer price index of the firm's industry.

Price of capital goods (g) - nonresidential fixed investment deflator.

Corporate income tax rate (u) - ratio of profits before taxes less profits after taxes to profits before taxes.

(w) - ratio of depreciation for tax purposes to depreciation at replacement cost.

Depreciation rate (δ) - obtained from the computation of the capital stock series.

Cost of capital (r) - (profits after taxes plus depreciation for tax purposes less depreciation at current replacement cost plus capital gains on depreciable and depletable assets and inventories) divided by the market value of the firm.

Market value of the firm (V) - market value of common stock and preferred stock plus long-term debt plus short-term debt.

Replacement cost (RC) - total assets plus net plant at replacement cost minus net plant at historical value plus inventories at replacement value minus inventories at historical value.

Market value of common stock is calculated by multiplying the year-end closing price of common stock by the total number of common shares outstanding. The market value of preferred stock is equal to total preferred dividends divided by Moody's preferred stock yield average. It was necessary to take the book value of firm debt instead of its market value because of the considerable difficulties in measuring debt at market value. For more detailed discussions of the calculating procedure for the market value of the firm, see Lindenberg and Ross (1981), Brainard, Shoven, and Weiss (1980), Von Furstenberg (1977), and Tobin and Brainard (1977).

With regard to the replacement cost variable, different procedures are used to calculate the replacement cost of net plant (and depreciation) and inventories.

Computation of the replacement cost of net plant requires the following steps. First, net plant is subtracted from gross plant to get accumulated depreciation. Second, the accumulated depreciation is divided by the depreciation expense to get the average age of the firm's assets. Third, this age is subtracted from the current year to get the acquisition date of the firm's assets. Fourth, the nonresidential fixed investment deflator of the current year is divided by the nonresidential fixed investment deflator of the acquisition year to determine the adjustment factor. Finally, the adjustment factor is applied to the historical net plant (and depreciation) to get the replacement cost values (see Parker, 1977 and Falkenstein and Weil, 1977).

With regard to the replacement value of inventories, certain assumptions are made. First, if the firm uses the first in-first out (FIFO) method of inventory valuation, real inventory equals the reported or historical inventory. Second, if the method is last in-first out (LIFO), the replacement cost of inventories is given by

$$\mathrm{RINVTY}_t = \left[\frac{\mathrm{HINVTY}_{t-1}}{\mathrm{IPDINV}_{t-1}}\right] \frac{\mathrm{IPDINV}_t}{\mathrm{IPDINV}_{t-1}} + (\mathrm{HINVTY}_t - \mathrm{HINVTY}_{t-1}) \left[\frac{0.5\ (\mathrm{IPDINV}_t + \mathrm{IPDINV}_{t-1})}{\mathrm{IPDINV}_{t-1}}\right]$$

where RINVTY is inventory at replacement cost, HINVTY is inventory at historical cost, and IPDINV is the implicit price deflator for inventories. Third, all other methods except for LIFO are treated as FIFO. Finally, when several methods are used, the method cited as dominant (Compustat lists them in descending order of importance) is used (see Lindenberg and Ross, 1981).

The producer price indexes for the major industry groups as well as the implicit price deflators for gross national product are obtained from the 1985 Economic Report of the President. The implicit price deflators for inventories are taken from the U.S. Department of Commerce National Income and Product Accounts of the United States, 1929-76 Statistical Tables and from various issues of the Survey of Current Reviews. Finally, the preferred stock yield indexes are taken from Moody's Industrial Manual, 1985.

APPENDIX II

F TEST AND LOG LIKELIHOOD RATIO TEST

Given an equation or model containing a number of explanatory variables, one can test whether a group or subset of these variables is significant in explaining the variation in the dependent variable by using an F test. Consider the equation

$$Y = \beta_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \text{error}$$

which contains K independent variables, including the constant term. Thus the full, unrestricted equation UR, unrestricted because no assumptions are made regarding any of the regression coefficients of the K variables. The problem is to test the null hypothesis H_0 that a subset of the estimated coefficients is jointly equal to zero. For example, assume that the last q parameters (q<k) equal zero, that is,

$$H_0: \ \beta_{k-q+1} = \ldots = \beta_k = 0.$$

If the null hypothesis is accepted, then the correct equation is now a restricted (by assumption that q coefficients are zero) form of the unrestricted equation UR:

$$Y = \beta_1 + \beta_2 X_2 + \ldots + \beta_{k-q} X_{k-q} + \text{error}$$

Thus, if the null hypothesis is true, then dropping the q variables from the original specification UR will have little or no effect on the explanatory power of the equation.

The test statistic is

$$\frac{(ESS_R - ESS_{UR})/q}{ESS_{UR}/(N-k)}$$

where ESS is the error sum of squares and N is the total number of observations and its distribution is F (q, N-k). If this computed test statistic is larger than the critical value at some specified level of significance, then one rejects the null hypothesis and concludes that the subset of q variables is statistically significant, i.e., the UR model is the correct one. On the other hand, if the computed test statistic is less than the critical F value, then one accepts the null hypothesis and concludes that the UR and R models are statistically the same, i.e., the R model is the correct one since dropping the q variables from the equation has little or no impact on the model's explanatory power.

The F joint tests for discriminating between unrestricted and restricted versions of a model or equation are applicable only in the absence of serial correlation. If the equation possesses autocorrelated error terms, then the appropriate test is the log likelihood ratio test. Assuming the residuals are autocorrelated, the logarithm of the likelihood function is

$$\log L = \frac{-N}{2} \log \sigma_e^2 + \frac{1}{2} \log (1 - \rho^2) - \frac{N}{2}$$

where ρ is the autocorrelation coefficient and N the total number of observations. Now suppose that the null hypothesis implies that q variables are insignificant. In order to discriminate between the UR (unrestricted) and R (restricted) models, one has to compute the values of the log-likelihood functions for these models. Indicating the log L value for the unrestricted model as L_{UR} and for the restricted model as L_R, then the test statistic is

$$-2(L_R/L_{UR})$$

and is asymptotically distributed as χ^2 (q).

If the computed test statistic is less than the critical value at a specified significance level, then one accepts the null hypothesis and concludes that dropping the q variables has little or no effect on the explanatory power of the equation, i.e., R model is the correct one.

VITA

Bienvenido Santos Cortes

Candidate for the Degree of

Doctor of Philosophy

Thesis: A FIRM-LEVEL COMPARISON OF ALTERNATIVE INVESTMENT THEORIES

Major Field: Economics

Biographical:

Personal Data: Born in Manila, Philippines, August 17, 1956, the son of Julian and Lina Cortes.

Education: Graduated from Ateneo de Naga High School, Naga City, Philippines, in April, 1973; received Bachelor of Science degree in Business Economics from the University of Philippines in April, 1977; received Master of Arts degree from Wichita State University in May, 1980; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in July, 1987.

Professional Experience: Research Assistant, Philippine Center for Advanced Studies, June, 1977 to December, 1978; Teaching Assistant, Department of Economics, Wichita State University, January, 1979 to May, 1980; Teaching Assistant/Associate, Department of Economics, August, 1980 to August, 1986; Assistant Professor, Department of Economics, Pittsburg State University, August, 1986 to present.