DYNAMIC INVESTMENT BEHAVIOR:

A COMPARISON OF MODELS

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INTRODUCTION

Motivation

Business fixed investment is critical not only because of its magnitude, but also because of its volatility which can make aggregate private spending exhibit marked and persistent fluctuations. For forecasting and economic policy purposes, it is therefore very important to predict investment accurately.

Objective of the Study

Previous studies have failed to discriminate among the alternative theories of investment. Empirically, no one model consistently outperforms the others. Thus, none can be regarded as "the" theory of investment.

The objective of this study is to estimate and evaluate alternative investment models, with a view to comparing them both within and beyond the estimation period. Quarterly aggregate data for the 1947-85 period are used. We consider five models of investment behavior. They are: (1) accelerator; (2) accelerator-cash flow; (3) neoclassical; (4) modified neoclassical; and (5) securities value or q. In addition, we consider a time series (ARIMA) model. The alternative models are estimated for constant dollar gross investment in producer's durable equipment and in nonresidential structures. The models will be compared on the basis of the signs and level of significance of the individual coefficients, on each model's overall goodness of fit, and on their ability to predict investment both within and beyond the sample period. By evaluating and comparing the estimated models, an attempt is made to determine the best or most useful theory of investment behavior.

Contributions to the Literature

This dissertation contributes to the literature in several ways. First, an ARIMA model is included and estimated using the Box-Jenkins methodology. Second, a new quarterly "tax-adjusted" q series is used. Third, several specification diagnostics are used in comparing the alternative investment models. Among the diagnostics, we report the Wallis-DW statistics as a measure of fourth order autocorrelation. The Theil inequality proportions--bias, variance, and covariance--are also presented for each model as a decomposition of the mean squared error. Fourth, combinations of forecasts are used in order to improve the forecasting ability of the models.

Outline of the Dissertation

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 models and statistical techniques. The results are reported and discussed in Chapter IV. Finally, Chapter V provides a summary of the conclusions as well as recommendations for further research.

CHAPTER II

SURVEY OF LITERATURE

Introduction

In this chapter, six models of investment behavior are reviewed. They are: (1) accelerator; (2) accelerator-cash flow; (3) neoclassical; (4) modified neoclassical; (5) q; and (6) ARIMA. The chapter is divided into three sections. In the first section, the original formulation of each theory will be reviewed, followed by modifications of the theory, and the relevant empirical evidence. The second section reviews some recent studies that compare alternative theories of business investment behavior. The third section presents some concluding remarks.

Review of Investment Models

Accelerator Model

Accelerator models of investment in fixed capital have their origins in work done by J. M. Clark (1917) with subsequent modifications by Chenery (1952) and Koyck (1954). The original theory suggested that demand for capital goods is related to the change in demand for output. It assumed: (1) a fixed ratio between capital stock and output; (2) no lags or adjustment periods; and (3) full utilization of productive capacity. In its simplest form, the accelerator model assumes that:

(1) $K_t = a\ Y_t$,

where a is the accelerator coefficient, K_t is the capital stock, and Y_t is output. This relationship can be used to obtain an equation for net investment I_{nt}. Since a is assumed constant,

(2) $K_{t-1} = a\ Y_{t-1}$.

After subtracting (2) from (1), net investment is a function of a change in output:

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

This elementary statement of the acceleration principle has been strongly challenged over the years on the basis of the empirical observation that capital stock does not show the same swings as output over time. In addition, it fails to recognize that the capital stock cannot be reduced at the same rate at which it can expand. Technological factors such as depreciation, obsolescence, and age of the equipment have a measurable impact on disinvestment. Also, it is not realistic to assume that the demand for capital goods is satisfied in the same period as the change in output because it takes time for firms to react to changes in demand for their output. Another criticism is that idle capacity may exist because capital goods are not fully utilized or depreciated instantaneously. To overcome these limitations, Chenery (1952) introduced a lag to reflect the time period between change in demand and implementation of new investment. With this lag the model took the form of:

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[1] Note that if $Y_t = Y_{t-1}$, net investment = 0, however, there will be gross investment to replace plant and equipment that is depreciating.

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

where K^* is the desired capital stock and b is the adjustment coefficient. Assuming that K^* is a fixed proportion of output, then equation (4) can be rewritten as

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

In this manner investment became a function of the level of output rather than changes in output.

Koyck suggested that a distributed lag function, in which capital stock is a function of current and past levels of output, be added to the model. The function is:

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

Using the Koyck transformation,

(7) $\lambda K_{t-1} = a\ (\lambda^1\ Y_{t-1} + \lambda^2\ Y_{t-2} + \lambda^3\ Y_{t-3} + \ldots)$.

After subtracting (7) from (6) and rearranging terms, the capital stock may be written as:

(8) $K_t = aY_t + \lambda K_{t-1}$.

Net investment is thus:

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

Tsiang (1951) argued that the supply of funds faced by individuals firms is limited, contrary to the model's assumptions. He suggested that profits should be incorporated into the accelerator model. A more generalized form of the accelerator model was postulated by Eisner (1960, 1974, 1978). After surveying data for 800 firms covering the 1955-62 period, Eisner found that changes in current and past sales, serving as proxy variable for future demand for output, were significant determinants of investment spending. The market value of the firm, a proxy for expected profitability, was also found to be significant.

With these contributions the original accelerator model was modified to include distributed lags and profits or liquidity.

Empirical studies showed that the accelerator model was appropriate during expansionary periods (Kuznets 1935, Chenery 1952, Hickman 1957, and Eisner 1960). Using cross section data from 200 firms for the period 1953-55, Eisner 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 accelerator coefficients were positive and significant with the sum of the coefficients amounting to 0.5, showing that half the changes in sales over the period was reflected in proportionate changes in capital stock. He also found that the estimated coefficients were significant for firms with rising sales and high growth rates, and insignificant for slow-growth firms. This finding indicated the nonlinearity of the accelerator process. Surveys of the empirical evidence by Jorgenson (1971) and, more recently, Naylor (1985) concluded that real output is the main determinant of investment.

Accelerator-Cash Flow Model

In 1939 Tinbergen added cash flow as a determinant of the desired capital stock. His explanation falls into two broad categories. First, changes in profits convey information about the future profitability of the firm. Second, the financing is an important determinant of investment activity. While the accelerator model assumes that firms' demand for investment goods depend on changes in the demand for business products, the cash flow approach assumes that the supply schedule of investment funds rises sharply at the point where internal funds are exhausted. Hence, additional investment beyond that supported by internal funds is not optimal as the marginal cost of capital would be above the projects' rate of return. From these arguments came the view that the firm's desired stock of capital would be a function of cash flow.

Empirical application of the accelerator-cash flow theory to the iron and steel industries for different countries and time periods was undertaken by Tinbergen. He found that the profit variable was more important than the accelerator variable in explaining investment behavior. However, when the same was done for railway rolling stock, the accelerator variable appeared more important.

In 1950, Klein tested the relation between investment and profits. This was determined by developing a simultaneous equations model which addressed the demand for consumption goods, the demand for capital goods, and the demand for labor. His investment equation regressed capital expenditures on current profits, last period's profits, and last period's capital stock. By testing the model on aggregate data for the period 1921-41, he obtained significant and positive profit coefficients. The same results were obtained by estimating the investment equation separately using ordinary least squares. Klein combined the accelerator and profit variables in a demand for capital goods which can be expressed in the following equation:

$$(10) \quad I_{nt} = b_0 + b_1(pY/g)_t + b_2(pY/g)_{t-1} + b_3K_{t-1} + b_4L_t + e_t,$$

where p is output price, g the price of capital goods, Y output, L a liquidity variable defined as current assets minus current liabilities, and e the error term.

A major study of the accelerator-cash flow model was conducted by Meyer and Kuh in 1957 using cross-section data for 600 firms during the 1946-50 period. This study revealed that the accelerator variable was 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 did not perform as well as the profit variable during the contractionary years 1949 and 1950. They found that liquidity factors were most important in explaining capital expenditures in the short run while in the long run the capacity or output variable tended to dominate the investment decision. These empirical findings led to the development of the "residual funds theory" which 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.

The residual funds theory was extended by Meyer and Glauber (1964). Their theory was based on the degree of capacity utilization and on the importance of depreciation changes 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, 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 profit plus depreciation less dividends paid, change in sales, and the change in share prices. These models were tested using data from large manufacturing firms for the period 1951-54. The results indicated that the capacity variable was statistically significant in explaining firm investment behavior during the boom years, while the profit variables were significant in the recessionary years. The profits plus depreciation less dividends variable was not closely correlated with sales and, unlike the profit variable, can be included with sales in the same regression model.

Jorgenson (1971) found that cash flow variables were insignificant in models that include both output and cash flow as explanatory variables. A more recent combination of the accelerator with cash flow in the same model was investigated by Eisner (1978). His basic relation involves gross investment as a function of current and past changes in sales (reflecting future profitability of the firm) and depreciation expenses (measuring the cost of replacing obsolete physical capital). Eisner concluded that the accelerator or sales change coefficients were positive and significant while the profit coefficients were small and had the wrong signs. Bar-Yosef, Callen, and Livnat (1987) examined the linkage between corporate earnings and corporate investment based on Granger (1969) causality. They concluded that corporate earnings is a determinant of corporate investment.

The cash flow model has been augmented also by the q model.

Kopcke (1977, 1982) employed a cash flow-security value version of the investment model. His mathematical representation of such a model is expressed in the following equation:

(11) $I_t = a + \sum b_i \ (q)_{t-i} \ (F/C)_{t-i} + c \ K_{t-1}$,

where I is real investment, q the ratio of financial market valuation of net business assets to replacement costs, F cash flow, C price index for capital goods, K real stock of capital, and the a, b's, and c coefficients to be estimated.

By introducing the Tobin's q ratio, Kopcke argued that the model may not only capture the interaction between the cost of funds and the return to capital, but it may incorporate some of the more subtle effects of business risk and general investors' uncertainties. These interactions are not captured by the cash flows, but reflected in the market's valuation of the firm, and hence in q.

Neoclassical Model

The investment models reviewed so far lack a feature that most economists consider crucial, the user cost of capital. This cost may be interpreted as either the direct cost of actually renting capital goods, or an implicit cost associated with a firm renting capital services to itself. In either case, the higher the rental price relative to the price of output, the lower is the level of desired capital.

Jorgenson and a number of colleagues --Jorgenson and Stephenson (1967), Jorgenson and Siebert (1968), Hall and Jorgenson (1971)-- have attempted to remedy this defect by developing a more complete model based on the theoretical framework of optimal capital accumulation. The accelerator model becomes a complete theory of investment behavior by proposing that the prospective return to capital essentially depends on size of the capital stock relative to output. The neoclassical model, unlike the accelerator model, admits that the demand for plant and equipment depends on more than the quantity of sales. Optimal capital/output ratios may vary with prices, interest rates, and tax laws. Specifically each firm selects a production plan to maximize its net present value, defined to be the sum of discounted future revenues less future outlays, including taxes.

In order to obtain a complete description of the investment behavior, it is necessary to specify the firm's production function relating the flow of output to the flow of factor inputs including the flow of capital services. Then, in the context of the production technology, the firm determines its optimal investment program based on its forecasts of the demand for its output, relative prices, and the tax laws.

Assuming that the firm produces only one homogeneous product and employs only labor and capital inputs, the general neoclassical model as proposed by Jorgenson and others can be developed as follows: The firm's objective is to maximize the present value of its expected future returns, i.e., the sum of discounted future cash flows. That is,

$$(12) \quad \text{Max} \quad V_0 = {}_0\int^{\infty} [R_t - D_t] \exp(-rt)\, dt,$$

where R_t and D_t are revenues and outlays respectively and defined as

$$(13) \quad R_t = p_t Y_t - w_t L_t - S_t I_t .$$

$$(14) \quad D_t = Z(p_t Y_t - w_t L_t - V\mu\, S_t K_t - C\, S_t K_t + \acute{S}_t K_t).$$

In the above two expressions, p_t is the price of the firm's output (Y_t), w_t the wage rate of the labor input (L_t), S_t the price of investment good (I_t), Z_t the corporate income tax rate, V the ratio of depreciation for tax purposes to depreciation at current replacement cost, μ the economic depreciation rate, K_t flow of capital services, and C the cost of capital. The symbol $\acute{S}$ denotes the time derivative of the variable S.

The firm faces the production function

(15) $F(Y_t, K_t, L_t) = 0$

If replacement investment is a constant multiple μ of the capital stock, then K_t is constrained by

(16) $d/dt\,(K_t) = I_t - \mu K_t$.

In this context, firm's optimal behavior would be defined by maximization of (12) subject to (15) and (16).

The problem in (12)-(16) is a standard calculus of variations problem. With some manipulation of the first order conditions, the following results can be obtained:

(17) $dY_t/dL_t = w_t/p_t$

(18) $dY_t/dK_t = r_t/p_t$

where

(19) $r_t = [S_t/(1-Z)][(1-ZV)\mu + C - \acute{S}_t]$.

Equation (17) is the marginal productivity condition for labor input which says that, at the margin, the revenue product of labor must be equal to its rental price (w_t). Equation (18) then, if interpreted in the same way, gives a meaning to variable r_t, defined in (19), similar to the price of labor services. That is, r_t is the price of the capital services flow. If the firm rented the equipment used in production process from an outside source, it should not pay a price higher than r_t to the supplier of the capital services. In other words, in deciding upon how much capital to employ for production, the firm should behave as though it was paying r_t for capital services.

To proceed with the analysis and derive the investment demand function, the production function must be specified. Assuming a Cobb-Douglas production function, the desired level of capital stock K^* is proportional to output Y deflated by the real rental price of capital (r/p). Thus,

(20) $K^*_t = \alpha \ (p_t Y_t \ / \ r_t)$.

where α is the elasticity of output with respect to the capital services input.

Jorgenson and Stephenson (1967) developed the empirical form of the neoclassical investment function by starting with the definition of gross investment as the sum of net investment and replacement investment. They assumed 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:

(21) $I_t = U(L) \ (K^*_t - K^*_{t-1}) + \mu K_{t-1}$.

where $K^*_t = \alpha \ (p_t Y_t / r_t)$; and U(L) is a power series in the lag operator, $U(L) = u_0 + u_1 L + u_2 L^2 + \ldots$

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

(22) $I_t - \mu K_t = [V(L) \ / \ W(L)](K^*_t - K^*_{t-1})$.

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:

$$(23) \quad (1 + w_1L + w_2L^2 + \ldots + w_nL^n)(It - \mu K_{t-1}) = (v_0 + v_1L + v_2L^2 + \ldots)(K^*_t - K^*_{t-1}).$$

or

$$(24) \quad (I_t - \mu K_{t-1}) + w_1(I_{t-1} - K_{t-2}) + \ldots + w_n(I_{t-n} - K_{t-n-1}) = v_0(K^*_t - K^*_{t-1}) + v_1(K^*_{t-1} - K^*_{t-2}) + \ldots + v_m(K^*_{t-m} - K^*_{t-m-1}).$$

or

$$(25) \quad I_t = \mu\, v(L)[(pY/r)_t - (pY/r)_{t-1}] + (1 - w(L))(I_t - \mu K_{t-1}) + \mu K_{t-1} + e_t.$$

Where e_t represents the disturbance term in the regression equation.

Jorgenson and Stephenson tested the above empirical form of the neoclassical investment function by quarterly data for 15 U.S. manufacturing industries for the period 1947-60. The results for total manufacturing and for each industry showed good agreement between the neoclassical model and the historical data.

Eisner (1970, 1974) criticized the assumptions of a Cobb-Douglas production function and pure competition which gave rise to an elasticity of demand for capital with respect to relative price equal to one. He demonstrated that this elasticity was less than one in several empirical studies. Eisner and Nadiri (1968) used Jorgenson's original data and functional form and claimed that the price elasticity of demand for capital is not significantly different from zero. Their argument was that investment responds more slowly to change in relative prices than to changes in real output. In contrast, Jorgenson assumed that new equipment can respond immediately to changes in both output and relative prices. Eisner also disputed Jorgenson's assumption that replacement investment is a constant proportion of capital stock. He adopted the findings of Feldstein and Foot (1971) that the ratio of replacement investment to capital stock varies considerably from year to year. It was argued that this variation in the replacement-capital stock ratio can be explained by the availability of internal funds, the demand for expansionary investment, and capacity utilization. Eisner also questioned the validity of using one stable lag structure for all variables determining investment. In 1971, Bischoff provided supporting evidence that the real output and the ratio of output price to the user cost of capital should have different lag distribution in explaining investment.

Another criticism was posed by Brechling in 1974, who challenged the accuracy of the Jorgenson and Stephenson analysis. Unlike Jorgenson and Stephenson who estimate a structural equation of investment, Brechling derived and tested the reduced form equation for the neoclassical model using quarterly industry data for 1949-69. The model produced unsatisfactory results: wrong signs, unreasonable coefficient estimates, and large standard errors. He advocated that the application of Jorgenson's neoclassical theory of the firm to industry-level data may lead to aggregation problems.

In the studies of Feldstein and Foot (1971), Eisner (1972), and Feldstein (1974), the proportion of capital to be replaced was considered as a function of several variables including profits and capacity utilization. Both variables generally had coefficients which were statistically significantly different from zero. Jorgenson (1971, 1974) criticized these results on the grounds that the capital stocks were not treated in a theoretically consistent manner. Recently Bischoff and Kokkelenberg (1987) argued that the same criticism may be applied to later research on the subject. To provide an answer to Jorgenson's objection, Bischoff and Kokkelenberg estimated depreciation-in-use using a dynamic cost-of-adjustment model of factor demand in which labor, energy and capacity utilization are instantaneously variable factors and capital is a quasi-fixed factor. Unlike earlier studies by Epstein and Denny (1980) and Kollintzas and Choi (1985), the initial capital stock was made consistent with the depreciation parameters. They concluded that the estimated depreciation-in-use was both a statistically and an economically significant factor in the production process.

Modified Neoclassical Model

Bischoff (1969, 1971a, 1971b) revised the neoclassical model by assuming that the capital-labor ratio is less variable after the equipment has been installed. Unlike Jorgenson's formulation of the neoclassical model, Bischoff permitted the firm to respond differently to a change in output than to a change in interest rates, taxes, or prices. According to Bischoff, firms adjust to a change in the price of output relative to the user cost of capital by changing the capital intensity of new projects rather than the whole capital stock. The change in desired capital stock can be shown as:

$$(26) \quad \Delta K^* = b_1 (p/r)_{t-1} Y_t + b_2 (p/r)_{t-1} Y_{t-1}.$$

Bischoff's modified neoclassical model of investment thus incorporates two separate lag distributions, one showing the effect of changes in relative prices, tax rates, and interest rates embodied in the (p/r) variable; and the other showing the effect of the output variable on investment.

Bischoff tested his modified model in 1971 using quarterly data on aggregate equipment expenditures for the 1951-65 period. His model obtained a better fit than the neoclassical model. Bischoff concluded 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.

Q Model

As opposed to the explicit equilibrium analysis in the neoclassical model, the q model is explicitly a disequilibrium model. This model is based on the portfolio balance of the firm, with q being the ratio of the market value of existing assets to the replacement costs of those assets. This relationship between investment and the q ratio have been proposed by a number of authors, particularly Tobin and Brainard (1968) and Ciccolo and Fromm (1979). Following a line of argument presented by Keynes (1936), they based their approach on the adjustment cost literature developed by Eisner and Strotz (1963), Lucas (1967a, 1967b), Gould (1968), and Treadway (1969).

In equilibrium, and assuming perfectly competitive markets, the market value of the firm (the market value of its assets) and the replacement of its assets should be equal, thus yielding a q equal to 1. But in disequilibrium the value of q may be different from 1, resulting in increases or decreases in the desired capital stock, and thus in increases or decreases in investment. Lindenberg and Ross (1981) provide a detailed explanation of why q may not equal 1.

The q model is basically a restatement of the neoclassical theory of corporate investment which is based on the assumption that management seeks to maximize the present net worth of the firm, the market value of outstanding common stocks. Ciccolo and Fromm used this assumption and showed that desired capital stock was equal to the product of q and the actual capital stock, as explained by the following equation:

(27) $K^* = qK,$

where q is the ratio of market value to replacement cost. Using the flexible accelerator form, gross investment can be formulated as:

(28) $I = \Delta K + \mu K = \lambda(K^* - K) + \mu K = \lambda(qK - K) + \mu K$

or

(29) $\Delta K / K = \lambda(q - 1).$

On this basis investment is stimulated if q is greater than 1, and discouraged if q is less than 1. Ciccolo and Fromm concluded that the q variable is a good indicator of expected future profitability of investment.

In empirical implementation of the q theory researchers face the problem that only average q could be observed from available data while it is marginal q that really matters for investment. Tobin and Brainard write (1977, pp. 243)

> "..... the forces of continuity in the economy are strong. Especially for short-run variation of aggregate demand, we can expect that the same factors which raise or lower q on the margin likewise raise or lower q on average."

Thus Tobin and Brainard justify the use of average q to study investment behavior. In addition, Hayashi (1982) showed that under certain linear homogeneity and price-taking assumptions, the shadow price of installed capital is equal to the market value of the firm divided by the replacement cost of its capital; that is, marginal q equals average q. More recently, Abel and Blanchard (1986) constructed a series for marginal q and investigated the relation between it and investment. Their finding were very similar to the results obtained relating investment to average q and they concluded that average q is a good proxy for marginal q.

In 1975, Ciccolo derived and tested two equations which relate fixed nonresidential investment expenditures to q. The first equation showed 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 tested the q relation proposed by Tobin and Brainard. Ciccolo estimated these models using quarterly macrodata for the 1953-73 period. He found the equations to have good predictive performance, and concluded that investment is significantly related to q. Also, work done by Yoshikawa (1980) showed that the rate of investment of a share-value-maximizing firm is indeed a function of q. On the other hand, von Furstenberg (1977), Summers (1981), and Blanchard and Wyplosz (1981) found that q does not explain a large part of the variation in investment and that the unexplained movement in investment is highly serially correlated.

In 1980, von Furstenberg included changes in capacity utilization rates along with q as determinants of investment. Using data for major manufacturing industries during the 1956-76 period, he demonstrated that the effects of the capacity variable and the q variable vary widely between industries. His results, however, showed that the q variable was most frequently significant in explaining industry investment expenditures. Chappell and Cheng (1982) estimated von Furstenberg's model for 287 manufacturing firms for the 1965-76 period and produced similar results. In contrast to von Furstenberg, they found no evidence to support the claim that the q variable was more important than output in explaining investment activity. Ueda and Yoshikawa (1986) claimed that an investment equation including only q's was shown to be mis-specified, and either the profit or the discount rate, when added to the equation, would turn out to be significant.

The studies mentioned above developed the q theory in a deterministic framework with adjustment costs. Lucas and Prescott (1971), and Hartman (1972) developed stochastic models of investment in the presence of adjustment costs. Using a discrete-time stochastic model, Hartman showed that for a competitive firm with constant returns to scale, increased uncertainty about future output prices or factor prices leads to increase current investment. More recently, Pindyck (1982) and Abel (1983, 1985) demonstrated that Hartman's results carry to continuous time when several variable factors of production, with stochastic prices, were incorporated to the model.

The literature cited above indicated that Tobin's q theory has gained substantial popularity as a theory of investment in recent years. One reason for this popularity is that a single variable "q" conveniently summarizes all the information relevant for investment decisions. This variable can be constructed by using asset prices observable in the market. Thus the q approach has the merit of possessing a simple theoretical structure, and it also easily lends itself to empirical implementation.

ARIMA Model

In contrast to the other models, the time series model does not use output, or other variables to determine investment expenditures. Instead, investment is explained by a distributed lag over past investment expenditures and/or by a distributed lag of random disturbances. The former distributed lag represents an autoregressive process; the latter represents a moving average process. Combining the two types of influences of the past on investment expenditures, I_t, gives a mixed autoregressive-moving average process.

Box and Jenkins (1976) popularized the abbreviation ARIMA, which stand for "autoregressive integrated moving average model". They have effectively put together in a comprehensive manner the relevant information required to understand and use univariate time series ARIMA models. They summarized certain useful techniques to help specify (in their terminology, identify) the order of a model and to estimate its parameters, and suggested certain ways of checking the appropriateness of the model for final adoption. They consider model building as an iterative process which can be divided into three stages--identification, estimation, and diagnostic checking.

Using the lag operator, L, the general form for the process ARIMA (p,d,q) can be written as:

$$(30) \qquad \Phi(L)\ (1 - L)^d\ I_t = \Theta(L)\ \epsilon_t$$

with $\Phi(L) = 1 - \phi_1 L - \phi_2 L^2 - \ldots - \phi_p L^p$

and $\Theta(L) = 1 - \theta_1 L - \theta_2 L^2 - \ldots - \theta_q L^q$

where $\Phi(L)$ is the autoregressive operator and $\Theta(L)$ is the moving average operator. The number of differencing required so that the series will be stationary is denoted by d. The random disturbance ϵ_t is assumed to be generated by a white noise process. In particular, each disturbance term ϵ_t is assumed to be a normal random variable with mean 0, variance σ^2_ϵ, and covariance $\gamma_k = 0$ for $k \neq 0$.

Thus, models of the ARIMA type do not represent structural relationships. They consist of a set of reduced-form equations wherein lagged values of the model's variables and/or disturbances are used to explain current values of the variables.

Empirically, models of the autoregressive type were estimated using ordinary least squares by Jorgenson and Siebert (1972) and Kopcke (1985). Although the autoregressive models were criticized by Webb (1984) for their lack of theoretical content and their small number of variables, proponents frequently justify its approach by noting that such models avoid controversial restrictions and the use of exogenous variables. Autoregressive models also provide coefficients that change over time. Kopcke's 1985 study suggested that the autoregressive model produced the most accurate forecast of investment in structures. Jorgenson and Siebert fitted two autoregressive models as a standard for evaluating of the performance of the other models. Both of the above two studies used ordinary least squares in estimating their autoregressive models rather than applying a more sophisticated approach such as the Box-Jenkins method. This study will include ARIMA models that may outperform the competition. Specifically, forecasts of investment based on a time series ARIMA model may prove to be more accurate than those based on existing theories of investment behavior.

Comparative Studies of Investment

Some recent comparison studies of quarterly investment behavior in U.S. manufacturing are reviewed in this section. 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.

At the aggregate level comparative studies of quarterly investment expenditures in the United States were undertaken by Bischoff (1971), Clark (1979), Kopcke (1977, 1982, 1985), and Wisley and Johnson (1985). In these studies, investment was disagregated into structures and equipment, Although all the studies used the Almon polynomial distributed lag function, lag specification among them was different. Bischoff used a third degree polynomial with no end-point restriction except in one case and allowed the length of lag up to 23. Clark's lagged variables have been fitted by using a sixth-degree polynomial with no end-point constraint, the length of lag was allowed to reach 20. Kopcke's lag coefficients were constrained to lie along fourth degree polynomial without any end-point restriction, and the maximum number of lags was 13. The typical models selected in the above studies were accelerator, accelerator-cash flow, neoclassical, modified neoclassical, and Tobin's q. Both Clark and Bischoff concluded that output-based models (accelerator and neoclassical) fit the investment time series better than non-output models (cash-flow and q). They also found that the accelerator model outperforms the neoclassical and generates superior forecasts of investment. Kopcke concluded from predictive performance of the models for the 1978-81 period that "there may be no best model of investment" (p. 28). Wisley and Johnson reached a similar conclusion using non-nested tests. More recently, Bernanke, Bohn, and Reiss (1988) extended the non-nested testing procedures of Pesaran (1974), Fisher and McAleer (1981), and Davidson and MacKinnon (1981) to situations involving first-order serially correlated errors. They then compared net investment equations (instead of the gross investment equations that are usually estimated) and concluded that no model uniformly outperformed the other models.

At the industry level, Jorgenson, Hunter, and Nadiri (1970a, 1970b) fitted four alternative quarterly econometric models of investment behavior to a common set of data for individual manufacturing industries in the United States for the 1949-64 period. The four models included in their studies were those of Anderson (1964), Eisner (1962), Jorgenson and Stephenson (1967), and Meyer and Glauber (1964). Jorgenson and Stephenson's model was based on the neoclassical theory of investment which combined the effects of past changes in output levels with changes in the price of capital services, and employed the rational distributed lag function with the Koyck distributed lag as a special case. Eisner's model, representing the flexible accelerator, based its explanation of investment expenditure on past changes in sales, was modified by the effects of past changes in profits as an indicator of changes in profit expectations, and uses a Koyck distribution lag function with first and second period lagged independent variables. Anderson's model was similar in the use of the marginal efficiency of investment schedule to Meyer and Glauber's. The determinants of investment expenditure in both models included capacity utilization, profit, and interest rates. Anderson included the Koyck distributed lag as one of three possible characterizations of the lag structure underlying investment behavior but this specification was not used by Jorgenson, Hunter, and Nadiri. Meyer and Glauber used Koyck distributed lag function, but the dependent variable was lagged two periods. On the bases of the goodness of fit and absence of autocorrelation of errors in the sample period, the ranking of the alternative models was: (1) Jorgenson-Stephenson; (2) Eisner; (3) Meyer-Glauber; (4) Anderson. On the basis of predictive performance which included prediction errors for a period of prediction and a test for structural change between sample period and sample plus predictive period, the ranking of the alternative models was: (1) Eisner; (2) Jorgenson-Stephenson; (3) Meyer-Glauber; (4) Anderson. Thus, Jorgenson, Hunter, and Nadiri found some evidence supporting the superiority of the neoclassical model. Loeb (1976, 1986) provided additional evidence of the superior ranking of the Jorgenson-Stephenson model over the Eisner, Meyer-Glauber, and Anderson models.

Jorgenson and Siebert (1968a, 1968b, and 1972) reached a similar conclusion using firm-level data. Using a common body of data for a sample of 15 large U.S. manufacturing firms for the periods 1937-41 and 1949-63 resulted in the following ranking scheme: (1) neoclassical I (with capital gains on assets as a component of the price of capital services); (2) neoclassical II (without capital gains); (3) expected profits; (4) accelerator; and (5) liquidity. In contrast, Elliott (1973) found the cash-flow model superior using the same models and the same minimum standard error criterion employed by Jorgenson and Siebert. Elliott, however, repeated the procedure on a much larger sample of 184 firms for 1953-67. In 1988 Cortes, Edgmand, and Rea compared the explanatory power of five theories of business fixed investment--accelerator, accelerator-cash flow, q, standard neoclassical, and modified neoclassical. Using a common body of data for a sample of 104 manufacturing firms, they compared the estimated models not only on the basis of the minimum residual variance criterion as used by Jorgenson and Siebert and Elliott, but also upon non-nested hypothesis tests. Their conclusion was that the accelerator-cash flow model provided the most satisfactorily estimated model.

Concluding Remarks

In conclusion, this chapter has outlined the major theoretical and empirical studies of investment behavior. A historical survey of six models was provided. They are: (1) accelerator; (2) accelerator-cash flow; (3) neoclassical; (4) modified neoclassical; (5) Tobin's q; and (6) ARIMA. The above discussion indicates the spectrum of thoughts on determinants of investment behavior. While each one of the theories presents convincing arguments regarding the variables and the mechanisms through which those variables affect investment process, the empirical evidence does not provide a clear picture of which one of the theories is an adequate representation of the investment process. The past studies do not reveal which model of investment behavior is best and suggest the need for further study. Chapter III presents the specifications of a six models to be estimated and compared. It discusses the econometric and time series techniques that will be used to test and compare the various models of investment behavior.

CHAPTER III

INVESTMENT MODELS AND STATISTICAL TECHNIQUES

Introduction

This chapter describes the alternative models of aggregate investment demand. It also discusses both the econometric and the time series techniques used in estimating, forecasting, and evaluating these models. In developing the testable econometric specifications, the flexible accelerator model is used as the framework within which each theory is estimated. The various theoretical models of investment spending differ only in their specification of the determinants of desired capital stock. In the generalized form of the flexible accelerator model, gross investment is composed of net investment and replacement investment. Net investment is a distributed lag function of changes in the desired capital stock K^* while replacement investment is a constant proportion, γ, of the lagged capital stock K_{t-1}. Gross investment at time t can then be written as

$$I_t = U(L)(K^*_t - K^*_{t-1}) + \gamma K_{t-1},$$

where L is the lag operator. The following section describes first the alternative specifications of K^*, then the statistical techniques. Appendix A provides a complete description of the variables and data sources.

Description of The Models

Accelerator Model

The accelerator model assumes that the desired capital stock is proportional to the current level of output, Y_t; or, equivalently (assuming initial equilibrium), that the desired rate of net investment is proportional to the first difference of output. A strict application of the accelerator principle implies a greater volatility of investment spending than what has been observed. Hence, a cost-of-adjustment argument is usually invoked [see Clark (1979)] to support the assumption that actual investment is linked to desired investment via a distributed lag. This leads to a specification for gross investment, I_t, of the form

$$(1) \quad I_t = \alpha + \sum_{s=0}^{N} \beta_s \, \Delta Y_{t-s} + \gamma \, K_{t-1} + u_t,$$

where N is the lag length, α and β_s's are scaler parameters to be estimated, Δ is the first-difference operator, and u_t is an additive random disturbance. In estimating this model, as well as the other models, we follow Clark in including a constant term. Also following Clark's specifications, the dependent and independent variables are divided by a measure of potential output (potential real GNP) to adjust for residual heteroscedasticity.

Accelerator-Cash Flow Model

Following Clark and others, a liquidity or cash flow variable, F, will be added to the accelerator model. This variable can be justified on the grounds that due to inefficiencies in financial markets, internal financing of capital expansion is less costly than external financing. Thus, empirical specification of the accelerator-cash flow model is identical to the accelerator, except that an additional distributed lag on the level of cash flow is included as an explanatory variable:

(2) $I_t = \alpha + \sum \beta_{1s} \Delta Y_{t-s} + \sum \beta_{2s} F_{t-s} + \gamma K_{t-1} + u_t$,

where F is the real cash flow of nonfinancial corporations. Nominal cash flow is the sum of after-tax profits, capital consumption allowances without capital consumption and inventory valuation adjustments. The investment deflator for equipment or structures (whichever is appropriate) is applied to nominal cash flow to derive the variable F.

Neoclassical Model

The neoclassical investment equation represented by Jorgenson and others is based on a term representing the user cost of capital on the assumption that the best use of factor inputs in production is a function of the relative prices of those inputs. Unlike the accelerator model, the neoclassical model admits that the demand for plant and equipment depends on more than the quantity of output. Optimal capital/output ratios may vary with prices, interest rates, and tax laws.

Assuming that the aggregate production function is Cobb-Douglas, and defining the desired capital stock as the level at which the marginal product of capital services equals their rental price, the specification of actual gross investment is

(3) $I_t = \alpha + \sum \beta_s \Delta(pY/c)_{t-s} + \gamma K_{t-1} + u_t$,

where p is the price of output, and c is the rental price of capital services. The rental price of capital is the cost of using one unit of capital goods for one year. Thus, in various forms, it includes terms for the interest rate, depreciation, various tax parameters, and inflation. The variant of the rental price of capital is derived according to Clark's (1979, app. B) procedure using the formula

$$c = p_E\ (\delta_E + r)(1 - ITC_E - D\ .\ ZE\ .\ U\ .\ ITC_E - ZE\ .\ U)\ /\ (1-U)$$

for equipment and

$$c = p_S\ (\delta_S + r)(1 - ITC_S - ZS\ .\ U)\ /\ (1-U)$$

for structures, where δ_E and δ_S are the economic rates of depreciation for equipment and structures, respectively, p_E and p_S are the deflators for non-financial business investment, and U is the corporate tax rate, defined as the highest marginal rate on corporate income. ZE and ZS are the present values of a dollar's worth of depreciation on equipment and structures, respectively, ITC_E and ITC_S are the rates of investment tax credit, and D is a dummy variable, equal to 1.0 when the Long Amendment to the Revenue Act of 1962 was in effect in 1962 and 1963, and zero thereafter. The discount rate r is constructed as in Clark (1979, fn. 40).

Modified Neoclassical Model

The modified neoclassical model is a variant of the neoclassical model due to Bischoff (1971a, b). Unlike the standard neoclassical approach, Bischoff's model allows for putty-clay capital. That is, he acknowledges the possibility that it may be easier to modify factor proportions and thus the capital-output ratio *ex ante*. Bischoff's modified neoclassical model of investment thus incorporates two separate lag distributions, one showing the effect of changes in relative prices, tax rates, and interest rates embodied in the (p\c) variable; and the other showing the effect of the output variable on investment.

$$(4) \quad I_t = \alpha + \sum \beta_{1s} (p/c)_{t-s-1} \cdot Y_{t-s} + \sum \beta_{2s} (pY/c)_{t-s-1} + \gamma K_{t-1} + u_t$$

A major difference between equation (4) and the neoclassical equation (3) is that Y_{t-s} is divided by c_{t-s-1} instead of c_{t-s}, an alteration that makes investment a function of the level of the rental price of capital services, rather than a function of differences.

Q Model

In contrast to the preceding four output-based models, the q model attempts to explain investment in terms of portfolio balance. It posits that the rate of net investment should depend on the ratio of the market value of capital to its replacement cost (Tobin's q). Although a strict interpretation of the theory suggests that current investment should depend only on beginning of period value of q, it is well known that investment is related to lagged q as well. Thus the standard empirical specification is

$$(5) \quad I_t = \alpha + \sum \beta_s q_{t-s} + \gamma K_{t-1} + u_t.$$

In his study of the securities-value, Clark used a quarterly q series constructed by von Furstenberg (1977). However, Summers (1981) has shown that adjustment of annual q data to reflect corporate, dividend, and capital gains taxes improve the performance of the model. In this study, the q series is taken from Bernanke, Bohn, and Reiss (1988) who used Summers' general form and constructed a quarterly tax-adjusted q variable:

$$q = [1/(1-U)]\ [((V-B)/K) - 1.0 + b + ITC + (U\ .\ Z)],$$

where U is the corporate tax rate, V is the nominal market value of the firms, defined as the ratio of dividends paid by the non-financial corporate sector to dividend yield, B is the present value of depreciation allowances on the existing capital of non-financial corporations, and K is the nominal capital stock. The investment tax credit, ITC, and the present value of a dollar's worth of depreciation, Z, are investment-weighted averages of the relevant variables.

ARIMA Model

In contrast to the above models, the time series model does not use output, or other variables to determine investment expenditures. Instead, investment is explained by a distributed lag over past investment expenditures and/or by a distributed lag of random disturbances. The former distributed lag represents an autoregressive process; the latter represents a moving average process. Combining the two types of influences of the past on investment expenditures, I_t, gives a mixed autoregressive-moving average process.

Using the lag operator, L, the general form for the process ARIMA (p,d,q) can be written as:

(6) $\Phi(L)\ (1 - L)^d\ I_t = \Theta(L)\ \epsilon_t$

wit $\Phi(L) = 1 - \phi_1 L - \phi_2 L^2 - \ldots\ldots - \phi_p L^p$

and $\Theta(L) = 1 - \theta_1 L - \theta_2 L^2 - \ldots\ldots - \theta_q L^q$

where $\Phi(L)$ is the autoregressive operator and $\Theta(L)$ is the moving average operator. The number of differencing required so that the series will be stationary is denoted by d. The random disturbance ϵ_t is assumed to be generated by a white noise process. In particular, each disturbance term ϵ_t is assumed to be a normal random variable with mean 0, variance σ^2_ϵ, and covariance $\gamma_k = 0$ for $k \neq 0$.[1]

Thus, models of the ARIMA type do not represent structural relationships. They consist of a set of reduced-form equations wherein lagged values of the model's variables and/or disturbances are used to explain current values of the variables.

The following section discusses the statistical techniques that will be used to estimate the models.

The Statistical Techniques

Almon Polynomial Distributed Lag

Distributed lags occur when the effect on a dependent variable of a change in the independent variable is not instantaneous. The effect is spread over a period of time because of such factors as uncertainty, costs of adjustment, and technological restraints. The accelerator investment equation, which asserts that the required physical investment cannot be achieved instantaneously, can be rewritten in a general form of distributed lag function as

$$I_t = U(L)\ \Delta K^* + \mu K_{t-1},$$

where U(L) is any particular polynomial in the lag operator, L. There have been many suggestions in the literature about ways to

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[1] The autocorrelation function for a white noise process is simply

$$\rho_k = \begin{cases} 1 & \text{for } k = 0 \\ 0 & \text{for } k \neq 0 \end{cases}$$

impose some "structure" on the L's. A great difficulty in studies of investment demand is that of deciding upon the appropriate lag structure. Virtually all aggregate studies use Almon's Polynomial Distributed Lag Function (PDL) because of its flexibility.[2] The general form of a bivariate distributed lag model is:

$$(7) \quad Y_t = \alpha_0 + \beta_0 X_t + \beta_1 X_{t-1} + \ldots + \beta_n X_{t-n} + e_t.$$

or

$$(8) \quad Y_t = \alpha + \sum_{i=0}^{N} \beta_i X_{t-i} + e_t.$$

One problem in estimating the lag coefficient β_i is that there may be an almost linear dependence between the columns of the X matrix. In such cases, the least squares estimators of individual coefficients may be very imprecise. Almon suggests using polynomials to reduce the parameter space. The polynomial degree may be substantially lower than N if the points lie approximately on a smooth curve. Under Almon's scheme, the restrictions on the β's specify a polynomial lag structure so that:

$$(9) \quad \beta_n = f(n) = \sum_{j=0}^{k} \alpha_j i^j,$$

where $k < n$; $n = 0,1,2,\ldots,N$.

Under the above scheme, the direct approach of attempting to estimate all N β's is ruled out. The basis of the approximation given by (8) is Weierstrass's theorem, which states that a function continuous in a closed interval may be approximated over the whole interval by a

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[2] Jorgenson and Stephenson (1967) used rational distributed lags. Meyer and Glauber (1964) and Eisner (1962) used Koyck lags.

polynomial of suitable degree, which differs from the function by less than any given positive quantity at every point of the interval. Substituting for β's from (9) in (7) gives:

$$(10) \quad Y_t = \alpha_0 X_t + (\alpha_0 + \alpha_1 + \ldots + \alpha_k) X_{t-1} + \ldots$$
$$+ (\alpha_0 + N \alpha_1 + N^2 \alpha_2 + \ldots + N^k \alpha_k) X_{t-N} + e_t.$$

Rearranging terms:

$$(11) \quad Y_t = \alpha_0 (X_t + X_{t-1} + \ldots + X_{t-N}) + \alpha_1 (X_{t-1} + \ldots + N X_{t-N})$$
$$+ \ldots + \alpha_k (X_{t-1} + \ldots + N^k X_{t-N}) + e_t.$$

or

$$(12) \quad Y_t = \alpha_0 Q_{t0} + \alpha_1 Q_{t1} + \ldots + \alpha_k Q_{tk},$$

with $Q_{t0} = (X_t + X_{t-1} + \ldots + X_{t-N})$,

$Q_{t1} = (X_{t-1} + \ldots + N X_{t-N})$,

and $Q_{tk} = (X_{t-1} + \ldots + N^k X_{t-N})$.

The new regressors (Q_{t0}, Q_{t1}, ... , Q_{tk}) are formed as linear combinations of the lagged X's. The regression of Y on these variables yields estimates of the α's, which in turn yield estimates of the β's from the relationship between the α's and β's.

These estimates are better than the unrestricted OLS estimates of the β_n from the model given by (7) for two reasons. First, the specifications given by (9) reduce the number of parameters (since $K < N$). The attraction of this proposal is that a great variety of shapes for the weights of the lag distribution may be considered, while preserving some parsimony in the number of independent parameters so that fewer degrees of freedom are lost. Second, since the number of lagged explanatory variables is reduced, the multicollinearity problem of distributed lag is reduced, and precise parameter estimates are obtained.

Predetermining the lag structure is not an easy task, however, because the researcher does not know the true lag structure. In the case of Almon lags the length of the lag, the endpoint constraints, and the degree of the polynomial which the lag pattern follows are all determined by the researcher. Frost (1975) in particular goes into detail on the difficulty of this problem and on the sensitivity of the coefficient estimates to these parameter selections. Most of the recent studies of investment demand have used lag lengths of from 5 to 22 quarters, although there has been even less agreement as to the degree of the polynomial or the endpoint constraints. Frost shows that when a model is incorrectly specified, due to, say, incorrect *a priori* assumptions about the degree of the polynomial and the lag length, the estimates may be biased. As the degree of the polynomial increases, however, the probability of bias decreases from misspecifying the polynomial. In addition, he shows that constraining the endpoints incorrectly can cause large biases. He also shows that a search procedure to find the best specification by minimizing the residual variance also causes biased parameter estimates in the lag.

In this study, all models are estimated using different polynomial degrees and different lags with no endpoint constraints. The final models are selected on the basis of the signs and level of significance of the individual coefficients.

Correction for Serial Correlation

Serial correlation occurs in time-series studies when the errors associated with observations in a given time period carry over into future time periods. As a general rule, the presence of serial correlation will not affect the unbiasedness or consistency of the ordinary least-squares regression estimators, but it does affect their efficiency. In the case of positive serial correlation, this loss of efficiency will be masked by the fact that the estimates of the standard errors obtained from the least-squares regression will be smaller than the true standard errors. In other words, the estimates of the standard errors will be biased downward. This will lead to the conclusion that the parameter estimates are more precise than they actually are. There will be a tendency to reject the null hypothesis when, in fact, it should not be rejected. Moreover, when serial correlation and lagged dependent variables are present, the results of ordinary least squares are biased and inconsistent.

The solution to the serial-correlation problem requires transforming the original equation with the autoregressive disturbance term into a nonautoregressive disturbance term so as to permit the use of OLS procedures. Two methods of correcting for serial correlation are generally used. One method is the Cochrane-Orcutt method. The other is the Hildreth-Lu method, and involves performing a series of regressions conditional upon a set of given values of the autoregressive parameters of the error term.

The Cochrane-Orcutt method essentially involves a three step iterative procedure: OLS estimation of the parameters of a particular equation and the subsequent computation of the residuals of that regression. Initially, this equation is estimated using untransformed observations on variables, y, x_1, x_2, ... , x_n. After the first iteration, the data are transformed as indicated below.

If u denotes the regression residuals, the direct estimation of the auroregression parameter, ρ:

(13) $u_t = \rho\ u_{t-1} + v_t$

in the case of the first-order autoregressive scheme, or the parameters ρ_1, ρ_2, in the case of a second order scheme:

(14) $u_t = \rho_1\ u_{t-1} + \rho_2\ u_{t-2} + v_t$

The transformation of the original regression variables are obtained using the estimates of the unknown parameters ρ's as:

(15) $y_t = \rho\ y_{t-1}$

(16) $x_t = \rho\ x_{t-1}$

or

(17) $y_t = \rho_1\ y_{t-1} + \rho_2\ y_{t-2}$

(18) $x_t = \rho_1\ x_{t-1} + \rho_2\ x_{t-2}$

depending upon the autorgressive scheme chosen. These transformed data are then used to create the dependent variable and regressor variable for the next iteration regression. The iterative process of estimation continues until the change in the autoregression parameter estimates from iteration to iteration is less than a specified small amount. This process can be shown to result in convergence to a local minima.

Both the Hildreth-Lu and Cochrane-Orcutt procedures lead to consistent estimates of the regression parameters, as does OLS. In large samples these new procedures are more efficient than OLS. In small samples the new procedures are biased, while OLS is not. The new procedures provide a better basis for carrying out hypothesis tests, although the validity of the tests strictly holds for large samples.[3]

In this study, we assumed, after the original tests, a first order autoregressive process in the errors. Following earlier studies, we used the Cochrane-Orcutt procedure for autoregressive corrections.

Box-Jenkins Methodology

The Box-Jenkins approach for analyzing time series data consists of extracting the predictable movements from the observed data. The time series is decomposed into several components, sometimes called filters. The Box-Jenkins approach primarily makes use of three linear filters: autoregressive, integration, moving average.

Box and Jenkins (1976) popularized the abbreviation ARIMA, which stand for "autoregressive integrated moving average model". They have effectively put together in a comprehensive manner the relevant information required to understand and use univariate time series ARIMA models. They summarized certain useful techniques to help specify (in their terminology, identify) the order of a model and to estimate its parameters, and suggested certain ways of checking the appropriateness of the model for final adoption. They consider model building as an iterative process which can be divided into three stages--identification, estimation, and diagnostic checking.

At the stage of identification, the autoregressive order, p, and the moving-average order, q, in a univariate ARMA model will be chosen. The differencing operations are used to produce a

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[3] Mirer, Thad W. <u>Economic Statistics and Econometrics</u>, second edition. New York: Macmillan Publishing Company, 1988.

covariance-stationary time series. If the autocorrelations taper off slowly or do not die out, nonstationarity is indicated and differencing (usually not more than once or twice) is suggested until stationarity is obtained. Then an ARMA model is identified for the differenced series. To determine the autoregressive order, *p*, and the moving average order, *q*, the sample autocorrelation function (acf) and the sample partial autocorrelation function (pacf) are used. The characteristics of these two functions can reveal the order of an ARMA (*p*,*q*) process. A model is then tentatively selected for estimation. For an autoregressive (AR) processes the theoretical acf's taper off toward zero with some type of exponential decay or a damped sine wave pattern; and theoretical pacf's cut off to zero after lag *p* (the AR order of the processes). For a moving average (MA) processes the theoretical acf's cut off to zero after lag *q* (the MA order of the processes); and theoretical pacf's taper off toward zero with some type of exponential decay or a damped sine wave pattern. A mixed ARMA processes will be adequate if neither the autocorrelations nor the partial autocorrelations have a cutoff point. A mixed ARMA processes is usually characterized by having theoretical acf that taper off toward zero after the first *q*-*p* lags; and theoretical pacf that taper off tower zero after the first *p*-*q* lags

In the estimation stage, point estimates of the coefficients can be obtained by the method of maximum-likelihood, or approximations thereof. The parameters of pure AR processes can be estimated using regression methods. If MA terms are involved, the minimization of the sum of squared errors or the maximization of the likelihood function requires nonlinear optimization methods.

To put this another way, rewriting Eq. (6) above in terms of the error term series ϵ_t:

(19) $\epsilon_t = \Theta^{-1}(L)\ \Phi(L)\ w_t$,

where $w_t = (1 - L)^d I_t$. The objective in estimation is to find a vector of autoregressive parameters $\Phi = (\Phi_1, \ldots, \Phi_p)$ and a vector of moving average parameters $\Theta = (\Theta_1, \ldots, \Theta_q)$ that minimize the sum of square errors

(20) $S(\Phi,\Theta) = \sum \epsilon_t^2$.

Under the assumption of normally distributed and independent errors with zero mean and constant variance, the maximum-likelihood estimate is the same as the least-squares estimate. When utilizing these assumptions, the conditional log likelihood function associated with the parameter values $(\Phi,\Theta,\sigma_\epsilon)$ is given by

(21) $L(\Phi,\Theta,\sigma_\epsilon) = -T \log \sigma_\epsilon - [S(\Phi,\Theta)/2\sigma_\epsilon^2]$.

Thus, to maximize $L(\Phi,\Theta,\sigma_\epsilon)$ is the same as to minimize $S(\Phi,\Theta)$. We say that $L(\Phi,\Theta,\sigma_\epsilon)$ is the conditional log likelihood function because the sum of squared errors $S(\Phi,\Theta)$ depends on the past and unobservable values of w_t and ϵ_t. Because the sum-of-squares function $S(\Phi,\Theta)$ and thus the likelihood function $L(\Phi,\Theta,\sigma_\epsilon)$ are both conditional on the past unobservable values of w_t and ϵt, the least squared estimates must choose initial starting values for them. A reasonably good approximation to the correct procedure is attainable if the actual values of $\Phi_1, \ldots, \Phi_p$ are not very close to one and if the number of observations T is large relative to p and q.

Before a nonlinear estimation can be performed on Eq. (19), an initial guess must be made for the parameter values. The sample autocorrelation function can sometimes be used to help produce the initial guess. If the initial guess cannot be determined by simply inspecting a correlogram, the numerical values for the sample autocorrelation function can still be used to obtain the initial guess. The theoretical autocorrelation function can be related to the theoretical parameter values through a series of equations, the Yule-Walker equations. If these equations are inverted, they can be used to solve for the parameter values in terms of the autocorrelation function. Only when a moving average part is contained in a time series model will the Yule-Walker equations not be linear. To get initial estimates for a moving average model of order q, it is necessary to solve q simultaneous nonlinear equations. Along with the estimates of the coefficients, the associated standard errors can be obtained suggesting which coefficients could be dropped.

In the stage of diagnostic checking, additional autoregressive and moving-average variables can be added to the model and their statistical significance can be examined. Since the random error terms in the actual process are assumed to be normally distributed and independent of each other, then for the model to be specified correctly the residuals (which are estimates of the unobservable error terms) should have close to the same properties; i.e., they should resemble a white noise process. In particular, we would expect the residuals to be nearly uncorrelated with each other, so that a sample autocorrelation function of the residuals would be close to zero for displacement k greater than, or equal to, one. A very convenient test, based on statistical results obtained by Box and Pierce (1970), can be applied to this sample autocorrelation function. If the model is correctly specified, then for large displacements *k* the residual autocorrelations are themselves uncorrelated, normally distributed random variables with mean zero and variance equal to (1/T), where T is the number of observations in the time series. This fact makes it possible to devise a simple diagnostic test.

Once a time series model has been estimated and its original specification checked, a fourth step, forecasting, generates predictions of future values of the time series. These four steps, identification, estimation, diagnostic checking, and forecasting, complete the Box-Jenkins methodology. Although ARIMA models embody measurement without economic theory, they attempt to avoid difficulties in model-building by analyzing the underlying dynamics embedded in an economic indicator.

Concluding Remarks

This chapter has described the various models of investment demand and discussed the econometric and time series techniques of estimating the final version of each model.

The next chapter presents the results obtained by estimating the various models. It also reports the results obtained by applying the Box-Jenkins methodology to the ARIMA model. An evaluation and comparison of the alternative specifications will be offered to determine the best investment model.

CHAPTER IV

EMPIRICAL RESULTS

The first section of this chapter reports the results obtained applying the Almon Polynomial Distributed lags (PDL) technique to the five models. The five models are estimated using quarterly aggregate data for the United States. The sample period is 1947:I-1982:IV. Separate equations are estimated for equipment and structures. The functional forms of the five models will be presented, followed by an explanation of the notation. Detailed empirical results are reported in Appendix C.

In the second section, the results of applying the Box-Jenkins methodology to the time series model will be reported. The ARIMA model will be used to generate a forecast beyond the estimation period, specifically from 1983:I to 1985:IV. After analyzing the four stages--identification, estimation, diagnostic checking, and forecasting--an evaluation of the generated forecast will be provided to test the adequacy of the model, and, if need be, to suggest potential improvement. The adequacy of the model depends upon whether there is a systematic error or not. After the evaluation, selected statistics of the final forecast will be offered.

The third section will provide a within-sample comparison of the alternative models. Summary tables for selected statistics for the estimation period will be presented.

The fourth section will discuss and compare the out-of-sample performance of the alternative forecasts for the period 1983:I-1985:IV generated by the five alternative econometric models as well as by the ARIMA model. Summary tables for selected statistics, explained in Appendix B, of the forecasts will be presented.

In the last section, combinations of forecasts (for each pair) will be considered as an attempt to improve the forecasting ability of the models. A concluding remark will come at the end of this chapter.[1]

Specification and Results of the Econometric Models With PDL

In our analysis, we considered different polynomial degrees and lag lengths. The final models were selected on the basis of the signs and level of significance of the individual coefficients. After the original tests, we assumed a first order autoregressive process in the errors, and used the Cochrane-Orcutt procedure. The functional forms of the alternative models are stated below. Tables I and II summarize selected statistics for the equipment and structures models, respectively. The detailed regression results are provided in Appendix C.

A. The functional forms of the five alternative specifications of the econometric models for producer durable equipment are shown

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[1] In this study the goodness of fit and forecasting accuracy criteria are used to compare the explanatory power of the alternative models. In a recent study by Bernanke and others (1988), non-nested tests were used in comparing alternative investment models. They found that these non-nested tests can have significant finite-sample size and power biases.

below:[2]

Accelerator model:

GIE = F(IPGNP, ACC <D = 4, L = 15>, L1KE)

Accelerator-Cash Flow Model:

GIE = F(IPGNP, ACC <D = 4, L = 14>, CFE <D = 4, L = 16>, L1KE)

Neoclassical Model:

GIE = F(IPGNP, NE <D = 4, L = 14>, L1KE)

Modified Neoclassical Model:

GIE = F(IPGNP, MNE1 <D = 4, L = 14>, MNE2 <D = 4, L = 14>, L1KE)

Q Model:

GIE = F(IPGNP, Q <D = 4, L = 9>, L1KE)

B. The functional forms of the five alternative specifications of the econometric models for nonresidential structures are shown below:[3]

Accelerator model:

GIS = F(IPGNP, ACC <D = 3, L = 11>, L1KS)

Accelerator-Cash Flow Model:

GIS = F(IPGNP, ACC <D = 3, L = 5>, CFS <D = 3, L = 5>, L1KS)

Neoclassical Model:

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[2] Note the use of the angle brackets; these specify that the variable enters with a polynomial distributed lag. The degree of the lag is specified by D = k, where k is an integer number stating the degree of the polynomial. The length of the lag is specified by: L = n, where n is an integer number defining the length of the lag.

[3] Higher lag lengths were ruled out. The general criteria was to select the final models on the basis of the signs and level of significance of the individual coefficients.

GIS = F(IPGNP, NS <D = 3, L = 11>, L1KS)

Modified Neoclassical Model:

GIS = F(IPGNP, MNS1 <D = 3, L = 6>, MNS2 <D = 3, L = 5>, L1KS)

Q Model:

GIS = F(IPGNP, Q <D = 3, L = 5>, L1KS)

C. The variables are as follows:

ACC	is change in real output divided by potential real GNP.
CFE, CFS	are real cash flow for equipment and structures, respectively.
GIE, GIS	are real gross private domestic investment for equipment and structures, respectively, divided by real potential GNP.
IPGNP	is the inverse of potential real GNP.
L1KE, L1KS	are first lags of real net capital stock for equipment and structures, respectively, divided by potential GNP.
MNE1, MNS1	represent desired capital stocks for equipment and structures, respectively, divided by potential GNP.
MNE2, MNS2	represent lagged desired capital stocks for equipment and structures, respectively, divided by potential GNP.
NE, NS	represent first differences of desired capital stocks for equipment and structures, respectively, divided by potential GNP.
Q	is the tax-adjusted Tobin's Q.

Identification and Estimation of the ARIMA Models

The first step in any time series analysis should be to plot the available observations against time. This is often a very valuable part of any data analysis since qualitative features such as trend, seasonality, discontinuities and outliers will usually be visible if present in the data. Examining the plot of the data, for both investment in producer durable equipment and nonresidential structures, we observed that the series trend upward over time. This observation indicated that the means of the series were nonstationary. Also, the slow decay of the estimated autocorrelations for the undifferenced data supported our observation. Taking the first differences produced stationary series.

The next step in the identification stage was whether we should estimate an autoregressive (AR), moving average (MA), or a mixed ARIMA model. At this step, we used the autocorrelations and other properties introduced in Chapter III.

For equipment, a multiplicative ARIMA model is selected. The nonseasonal variation is identified as an ARIMA (2,1,2), while the seasonal variation is identified as an AR (2). Next, we subject the residuals to autocorrelation analysis to test whether the shocks of the model are independent. The chi-squared statistics is small enough to allow acceptance of the null hypothesis that the shocks are independent as a set. The critical chi-squared statistic for 17 degrees of freedom at the 5 percent level is 28.87 compared with the calculated value of 14.69. Furthermore, the residual autocorrelation function reveals no significant residual autocrrelation coefficients. The conclusion is that an ARIMA (2,1,2) provides an adequate representation of the observed investment in equipment.

For structures a multiplicative ARIMA model is selected. The nonseasonal variation is identified as an ARIMA (1,1,0), while the seasonal variation is identified as an AR (1). Next, we subject the residuals to autocorrelation analysis to test whether the shocks of the model are independent. The chi-squared statistics is small enough to allow acceptance of the null hypothesis that the shocks are independent as a set. The critical chi-squared statistic for 21 degrees of freedom at the 5 percent level is 33.92 compared with the calculated value of 14.05. Furthermore, the residual autocorrelation function reveals no significant residual autocorrelation coefficients. The conclusion is that an ARIMA (1,1,0) provides an adequate representation of the observed investment in structures.

After the above models had been estimated, quarterly forecasts for the 1983-85 period were generated for both equipment and structures. Finally, an evaluation of the forecasts was considered. One consideration to test the adequacy of the models is to test whether we have a biased systematic errors. A second consideration is to test for efficiency of the forecasts. Both tests supported the adequacy of the models. Selected statistics for both estimation and forecast periods are reported in Tables I through IV. Detailed statistical results are provided in Appendix C.

Estimation Results: 1947:I to 1982:IV

In this section we compare the alternative specifications to determine which model best fits the path of the dynamic behavior of investment. Summary tables for selected statistics of the models within the sample period are provided for both equipment and structures. Appendix C presents the detailed regression results of the investment equations. Viewed in isolation, each of the models appears "successful" with high adjusted R squared. The estimated coefficients are significant and have the right signs.

To compare different specifications, we calculated several conventional specification diagnostics. These diagnostics are reported in Table I for equipment and in Table II for structures. Among the diagnostics, we report the Wallis-DW statistics as a measure of fourth order autocorrelation.[4] Wallis derives upper and lower bounds for the test at the 5 percent level. Further significance points at 0.5, 1.0, and 2.5 percent levels are provided by Giles and King.[5]

We look first at the estimation results for equipment. The various Durbin-Watson (DW) and Wallis-DW statistic does not indicate residual serial correlation after the initial correction. All of the estimated alternative models explain a high percentage of the variance of the dependent variable as indicated by the adjusted R squared. On the basis of goodness of fit, indicated by the adjusted R squared, and the root mean squared error reported in Table I, the ranking of the alternative models is as follows: (1) accelerator-cash flow; (2) accelerator; (3) modified neoclassical; (4) neoclassical; (5) q; (6) ARIMA. This finding is consistent with

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[4] Wallis, K. F. "Testing for Fourth Order Autocorrelation in Quarterly Regression Equations." <u>Econometrica</u>, 40, 1972, pp. 617-36.

[5] Giles, D. E. A. and King, M. L. "Fourth-Order Autocorrelation: Further Significance Points for the Wallis Test." <u>Journal of Econometrics</u>, 8, 1978, pp. 255-59; King, M. L. and Giles, D. E. A. "A Note on Wallis' Bounds Test and Negative Autocorrelation." <u>Econometrica</u>, 45, 1977, pp. 1023-26.

TABLE I

SELECTED STATISTICS FOR THE ESTIMATION PERIOD

Models for Producer Durable Equipment[a]						
	ACC	ACCF	NEOC	MNEOC	Q	ARIMA
Adjusted R Squared	0.978	0.978	0.963	0.976	0.960	0.957
Standard Error[b]	0.153	0.153	0.198	0.159	0.201	0.228
Percent Error[c]	2.4	2.4	3.1	2.5	3.2	3.6
Root Mean Squared Error[b]	0.149	0.145	0.193	0.152	0.196	0.228
Durbin-Watson (DW)	2.15	2.18	1.66	1.93	1.80	---
Wallis-DW[d]	1.95	1.91	1.87	1.85	2.03	---
Autocorrelation Coefficient	0.83	0.84	0.92	0.74	0.96	---
Box-Pierce[e]	---	---	---	---	---	14.69

[a] ACC ≡ Accelerator, ACCF ≡ Accelerator-Cash Flow, NEOC ≡ Neoclassical, MNEOC ≡ Modified Neoclassical, Q ≡ q Model, ARIMA ≡ Autoregressive Moving Average.

[b] Multiplied by 100

[c] Percent of the dependent variable mean represented by the standard error.

[d] Computed as a measure of forth order autocorrelation.

[e] Distributed as a Chi-Square with T-(p+q) degrees of freedom.

Clark's results in which he concluded that output-based models (accelerator and neoclassical) fit investment time series better than non-output models. Like Clark, we also found that the accelerator models outperform the neoclassical models.

We now turn to the results for structures. The various Durbin-Watson (DW) and Wallis-DW statistics do not indicate residual serial correlation after the initial correction. As shown in Table II, however, the autocorrelation coefficients for the structures equations are higher than those for the equipment. On the basis of goodness of fit, indicated by the adjusted R squared, and the root mean squared error reported in Table II, the ranking of the alternative models is: (1) modified neoclassical; (2) accelerator; (3) accelerator-cash flow; (4) q; (5) neoclassical; (6) ARIMA. Unlike the results obtained from the equipment equations, the modified neoclassical model is ranked ahead of the accelerator models. Also, the q model is ranked ahead of the neoclassical model. Statistics provided in Table II indicate that the accelerator, accelerator-cash flow, and q models all did about the same, with a slight edge to the accelerator over the accelerator-cash flow and q. Out-of-sample comparison may, of course, widen up the gap between these models. Although the ARIMA models ranked last in both equipment and structures, we cannot rule out the possibility of a better performance during the forecast period.

The next section discusses and compares the out-of-sample performances of the alternative forecasts for the period 1983:I-1985:IV generated by the five alternative econometric models as well as by the identified ARIMA model.

TABLE II

SELECTED STATISTICS FOR THE ESTIMATION PERIOD

	Models for Nonresidential Structures[a]					
	ACC	ACCF	NEOC	MNEOC	Q	ARIMA
Adjusted R Squared	0.931	0.928	0.926	0.934	0.928	0.923
Standard Error[b]	0.101	0.103	0.106	0.098	0.102	0.107
Percent Error[c]	2.2	2.3	2.3	2.2	2.3	2.4
Root Mean Squared Error[b]	0.099	0.099	0.103	0.095	0.100	0.106
Durbin-Watson (DW)	1.53	1.47	1.49	1.55	1.80	---
Wallis-DW[d]	1.98	2.06	1.89	2.01	2.03	---
Autocorrelation coefficient	0.96	0.97	0.95	0.94	0.98	---
Box-Pierce[e]	---	---	---	---	---	14.05

[a] ACC ≡ Accelerator, ACCF ≡ Accelerator-Cash Flow, NEOC ≡ Neoclassical, MNEOC ≡ Modified Neoclassical, Q ≡ q Model, ARIMA ≡ Autoregressive Moving Average.

[b] Multiplied by 100.

[c] Percent of the dependent variable mean represented by the standard error.

[d] Computed as a measure of forth order autocorrelation.

[e] Distributed as a Chi-Square with T-(p+q) degrees of freedom.

Forecast Results: 1983:I to 1985:IV

The forecasts are generated using the values for the independent variables that were actually observed for the 1983-85 period. These ex post forecasts give an indication of how precise ex ante forecasts by the models would be. Tables III and IV provide selected statistics for the forecast period for equipment and structures, respectively. In addition to the average absolute error and the root mean squared error of forecast, the Theil inequality proportions are presented for each model. The root mean squared error are of particular importance since it implicitly weights large forecast errors more heavily than small ones. The Theil inequality proportions are computed as a decomposition of the square of the root mean squared error. The proportions are termed as the bias, the variance, and the covariance. The bias is zero if and only if the mean predicted value equals the mean actual value, and therefore its value reflects errors in central tendency. The variance is zero if and only if the standard deviations of the predicted and actual values are the same; it therefore measures errors of unequal variation. Finally, the covariance equals zero if the actual and predicted values are perfectly correlated, or (equivalently) if and only if the covariance of the predicted and realized values ($r\sigma_a\sigma_p$) takes its maximum value.[6]

Looking first at the forecast errors for equipment, the root mean squared error reported in Table III suggests that the

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[6] See Appendix B for more explanation; for further details see Theil (1974).

TABLE III

SELECTED STATISTICS FOR THE FORECAST PERIOD

	Models for Producer Durable Equipment[a]					
	ACC	ACCF	NEOC	MNEOC	Q	ARIMA
Root Mean Squared Error[b]	0.34	0.35	0.57	0.46	0.60	0.96
Root Mean Squared Percent Error	4.5	4.7	8.2	5.9	7.4	11.8
Average Absolute Error[b]	0.28	0.28	0.45	0.38	0.46	0.73
Average Absolute Percent Error	3.8	3.8	6.2	5.0	5.8	9.1
Theil Inequality Proportions[c]						
Bias	0.701	0.671	0.612	0.699	0.474	0.554
Variance	0.072	0.044	0.010	0.159	0.444	0.346
Covariance	0.227	0.285	0.378	0.142	0.082	0.100

[a] ACC ≡ Accelerator, ACCF ≡ Accelerator-Cash Flow, NEOC ≡ Neoclassical, MNEOC ≡ Modified Neoclassical, Q ≡ q Model, ARIMA ≡ Autoregressive Moving Average.

[b] Multiplied by 100.

[c] See Appendix B for explanation.

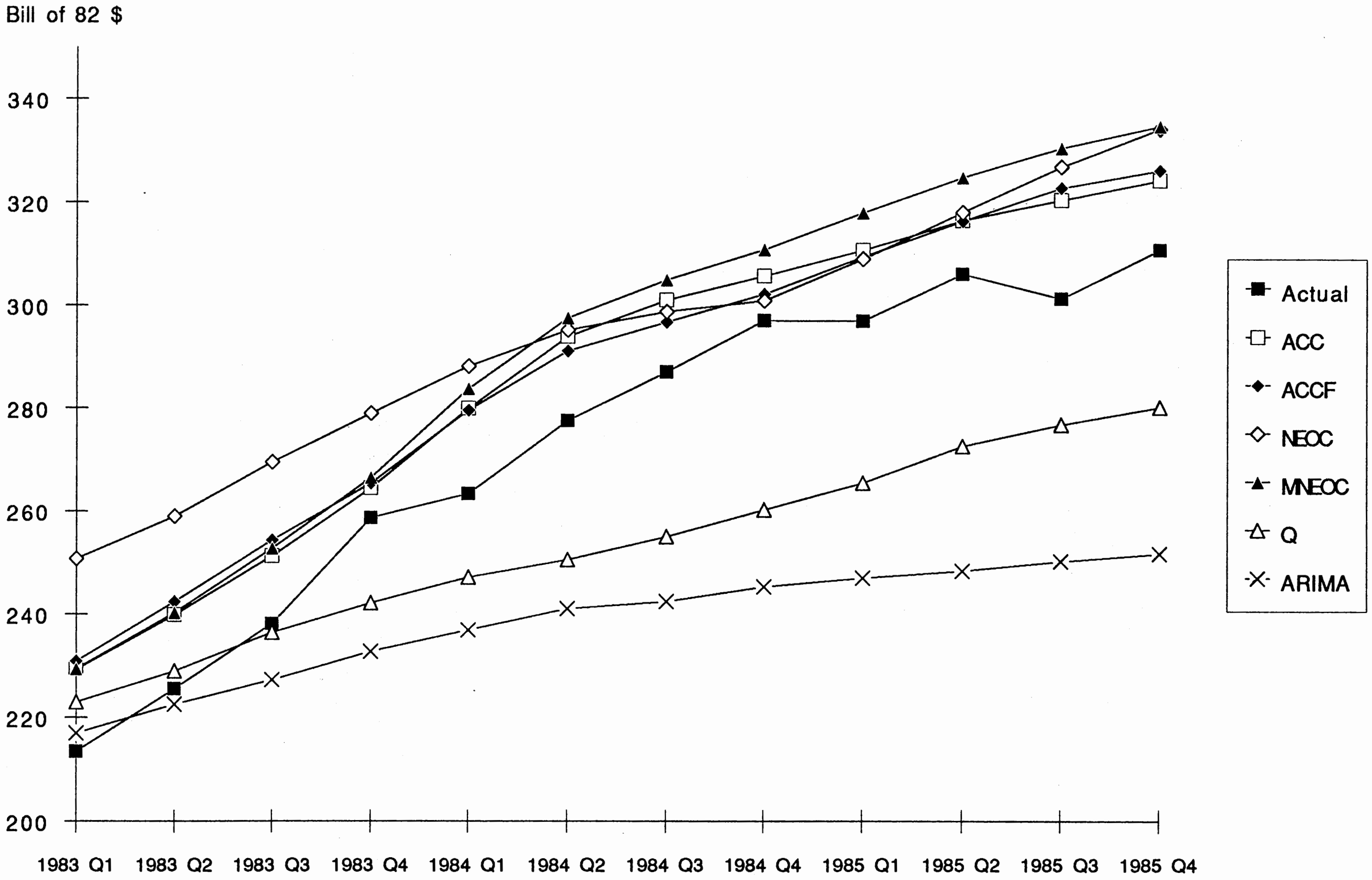

Figure 1. Forecast of Investment in Producers' Equipment, Alternative Models, and Actual Investment

performances of the investment models are worse during the forecast period than during the period of estimation. However, the ranking of the alternative models is almost the same. Based on the root mean squared error, the ranking is as follows: (1) accelerator; (2) accelerator-cash flow; (3) modified neoclassical; (4) neoclassical; (5) q; (6) ARIMA. The Theil inequality proportions indicate that the variance proportion is closer to zero than both the bias and covariance proportions for the first three models--accelerator, accelerator-cash flow, and neoclassical. The covariance proportions is closer to zero than both the bias and the variance proportions for the modified neoclassical, q, and ARIMA models.

The predictive performance for the six models of investment behavior is compared in Figure 1. The ARIMA, and the q models underpredict observed values; the modified neoclassical, neoclassical, accelerator-cash flow, accelerator models forecast equipment investment higher than its actual value.

Looking next at the forecast errors for structures, the root mean squared error reported in Table IV also suggests that the performances of the investment models are worse during the forecast period than during the period of estimation. Moreover, the ranking of the alternative models during the forecast period is not the same as in the estimation period. Based on the root mean squared error, the ranking is as follows: (1) q; (2) ARIMA; (3) modified neoclassical; (4) neoclassical; (5) accelerator; (6) accelerator-cash flow. The performance of the ARIMA model indicates that forecasts of investment in nonresidential structures based on such model may prove to be more accurate than those based on most of the existing theories

TABLE IV

SELECTED STATISTICS FOR THE FORECAST PERIOD

Models for Nonresidential Structures[a]	ACC	ACCF	NEOC	MNEOC	Q	ARIMA
Root Mean Squared Error[b]	0.38	0.47	0.35	0.35	0.17	0.25
Root Mean Squared Percent Error	9.8	12.3	9.4	9.2	4.6	6.7
Average Absolute Error[b]	0.32	0.40	0.27	0.30	0.11	0.16
Average Absolute Percent Error	8.2	10.3	7.1	7.7	3.0	4.3
Theil Inequality Proportions[c]						
Bias	0.717	0.721	0.599	0.715	0.347	0.393
Variance	0.058	0.035	0.178	0.065	0.352	0.298
Covariance	0.225	0.244	0.223	0.220	0.301	0.309

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[a] ACC ≡ Accelerator, ACCF ≡ Accelerator-Cash Flow, NEOC ≡ Neoclassical, MNEOC ≡ Modified Neoclassical, Q ≡ q Model, ARIMA ≡ Autoregressive Moving Average.

[b] Multiplied by 100.

[c] See Appendix B for explanation.

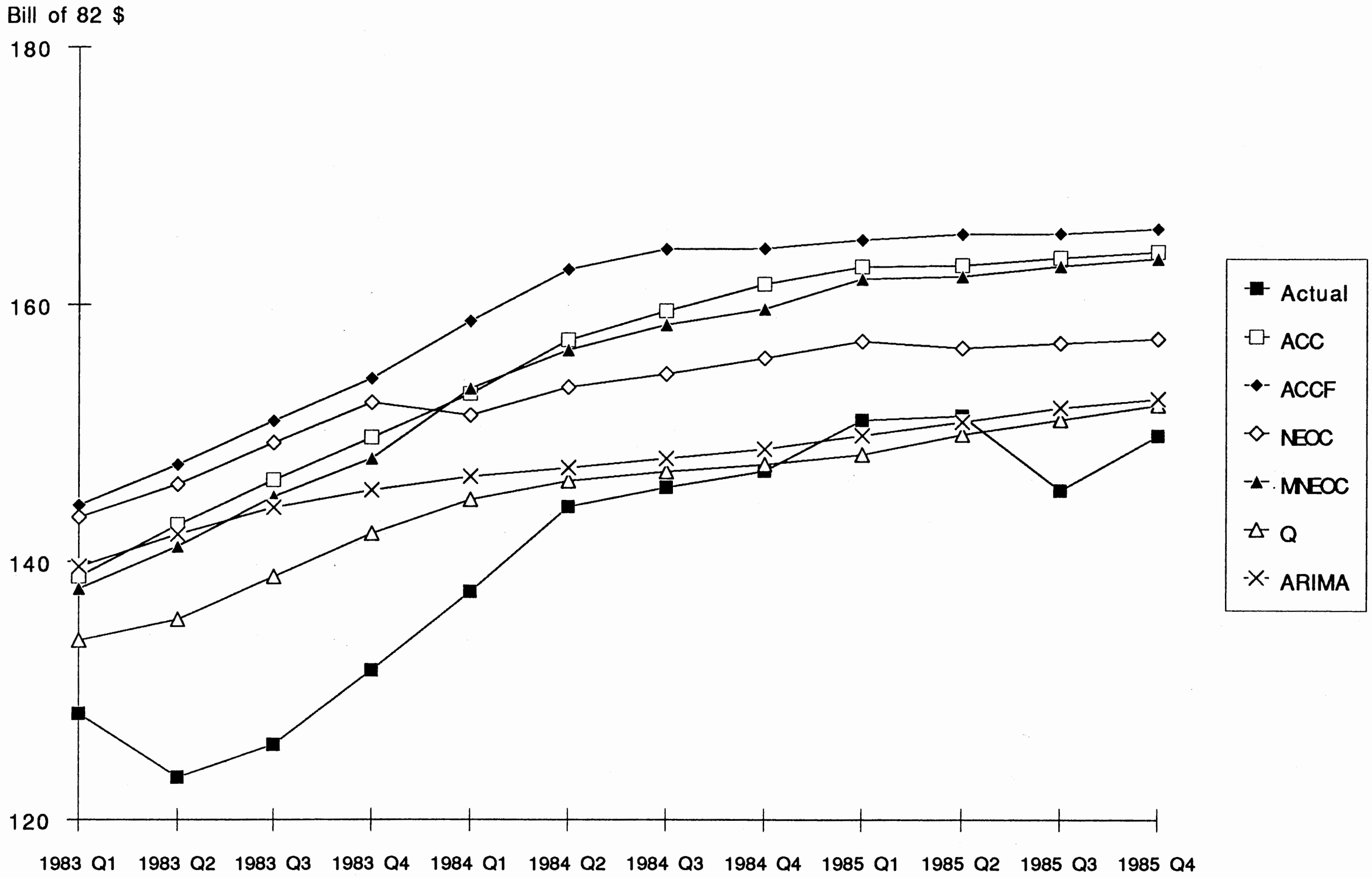

Figure 2. Forecast of Investment in Nonresidential Structures, Alternative Models, and Actual Investment

of investment behavior. Kopcke's 1985 study suggested also that the autoregressive model produced the most accurate forecast of investment in structures. The Theil inequality proportions indicate that the variance proportions is closer to zero than both the bias and the covariance proportions for all models except the q model. For the q model the three proportions are almost the same.

The predictive performance for the six models of investment behavior is compared in Figure 2. Generally all models overpredict observed values; only during the 1984:IV-85:II period do the ARIMA and the q models forecast structures investment lower than its actual value.

Combination of Forecasts

One way to perhaps improve the forecasting ability of the alternative models is to combine the forecasts.[7]

There are several methods of combining forecasts generated by different models. A simple method is to give equal weights to the alternative forecasts by taking the average.[8]

Another way of combining forecasts, one that has been shown to be superior to equal weights, is to regress the actual value on its

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[7] Combinations of models were also estimated. The additional variables, however, reduced the explanatory power of the initial variables.

[8] See Granger, C. W. J. Forecasting in Business and Economics. 2nd ed. San Diego: Academic Press, Inc., 1989; Granger, C. W. J., and Newbold P. Forecasting Economic Time Series. 2nd ed. New York: Academic Press,Inc., 1986.

forecasts and a constant.[9] We applied this approach to the econometric models and combined the forecasts of each pairs. Tables V and VI report the root mean squared error for the combined forecasts for equipment and structures respectively.

For equipment, the combinations of forecasts from the accelerator-cash flow and either the q or the neoclassical model provided a set of forecasts that is superior to the best individual one (generated by the accelerator model). The root mean squared error of these two combinations equals 0.15 (see Table V), whereas the root mean squared error of the forecasts generated by the accelerator model equals 0.34 (see Table III).

For structures, however, no combination of forecasts was superior to that of the q model. All the entries in Tables VI are higher than 0.17 (the root mean squared error of the forecasts generated by the q model). This was expected since, unlike the case for equipment, all models overpredict observed values.

Concluding Remark

This chapter reported the results obtained using the Almon Polynomial Distributed lags (PDL) technique to the five econometric models as well as the results of applying the Box-Jenkins methodology to the time series model. Separate equations were estimated for equipment and for structures. Both within-sample comparison and out-of-sample performance of the alternative models were discussed.

Of the six models, the accelerator and modified neoclassical

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[9] See Granger, C. W. J. and Ramanathan, R. "Improved Methods of Combining Forecasts." Journal of Forecasting. 3, 1984, pp. 197-204.

TABLE V

ROOT MEAN SQUARED ERROR FOR COMBINED EQUIPMENT MODELS

	Pairwise Combination[a]				
	ACC	ACCF	NEOC	MNEOC	Q
ACC	----	0.19	0.35	0.42	0.22
ACCF		----	0.15	0.26	0.15
NEOC			----	0.47	0.30
MNEOC				----	0.32
Q					----

[a] ACC ≡ Accelerator
ACCF ≡ Accelerator-Cash Flow,
NEOC ≡ Neoclassical
MNEOC ≡ Modified Neoclassical,
Q ≡ q Model

TABLE VI

ROOT MEAN SQUARED ERROR FOR COMBINED STRUCTURES MODELS

	Pairwise Combination[a]				
	ACC	ACCF	NEOC	MNEOC	Q
ACC	----	0.43	0.37	0.36	0.25
ACCF		----	0.44	0.38	0.31
NEOC			----	0.35	0.22
MNEOC				----	0.28
Q					----

[a] ACC ≡ Accelerator
ACCF ≡ Accelerator-Cash Flow,
NEOC ≡ Neoclassical
MNEOC ≡ Modified Neoclassical,
Q ≡ q Model

appear to be the best models of the equipment series in both within-sample comparison and out-of-sample performance. The combination of forecasts from the accelerator cash flow and either the q or the neoclassical model provided a set of forecasts that is superior to the best individual one which was generated by the accelerator model.

For structures, the ranking of the models is less clear. While the modified neoclassical and the accelerator predicted actual investment rather well within the estimation period, the q and the ARIMA models provided the best forecasts over the 1983:I-1985:IV interval. Unlike equipment, no combination of forecasts was superior to the best individual one which was generated by q model.

For equipment, the combination of forecasts from the accelerator-cash flow and either the q or the neoclassical model provided a set of forecasts that is superior to the best individual one. The root mean squared error of the combined forecasts was about 57 percent less than that of the accelerator. For structures, however, no combination of forecasts was superior to that of the q model.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Five different sets of econometric equations explaining investment behavior were considered in this study. This selection is representative of five theoretical positions on the demand for fixed capital goods. In addition, an ARIMA model was considered. In each case we separated investment in equipment from investment in nonresidential structures, primarily because of differences in tax policies applied to these assets.

In developing the testable econometric specifications, the flexible accelerator model was used as the framework within which each theory was estimated. The various theoretical models of investment spending differed only in their specification of the determinants of desired capital stock. The Almon Polynomial Distributed Lag technique was used in estimating the equations. The Box-Jenkins methodology was applied in estimating the ARIMA model.

We evaluated the alternative investment models by comparing them both within and beyond the estimation period. By evaluating and comparing the estimated models, an attempt is made to determine the best or most useful theory of investment behavior. Combinations of forecasts (for each pair) was considered as an attempt to improve the forecasting ability of the models.

Conclusions

The main conclusion of this study is that output is clearly the primary determinant of investment in producers' durable equipment and that the q model has the best forecasting performance for investment in nonresidential structures followed by the ARIMA model.

Among the equipment equations, the accelerator equation has the lowest estimated forecast error. The accelerator-cash flow model (with its extra variable) fits the historical data better. Although the performance of the models was worse during the forecast period than during the period of estimation, the ranking of the alternative models was almost the same. For the accelerator, accelerator-cash flow, and the neoclassical models, the Theil inequality proportions indicate that the standard deviations of the actual and predicted values are almost the same. For the modified neoclassical, q, and ARIMA models, the Theil inequality proportions indicate that the actual and predicted values are highly correlated.

The forecasts for structures tell a different story. The ranking of the alternative models during the forecast period is not the same as in the estimation period. The q model is ranked fourth during the estimation period, but first during the forecast period. The ARIMA model is ranked last during the estimation period, but second during the forecast period. This indicates the usefulness of such a model in forecasting investment in nonresidential structures. The Theil inequality proportions favor the equality of the standard deviation of the actual and predicted values of all models except q and ARIMA whose three proportions are close to each other.

Although the performance of the neoclassical equations is somewhat disappointing, it should not imply a rejection of the role of prices in the determination of business investment. The effect of interest rates and tax changes must be estimated with more comprehensive data, and that these effects are likely to be felt only gradually, over long period of time.

Because all common statistical models are simple approximations of very complex relationship, the ranking of these models might change as the pattern of economic development, the prospects for growth, or the motives of investors are altered by the evolution of future economic conditions.

For equipment, combination of forecasts from the accelerator-cash flow with that from either the q or the neoclassical model provided a set of forecasts that is superior to the best individual one. The root mean squared error of the combined forecasts was about 57 percent less than that of the accelerator. For structures, however, no combination of forecasts was superior to that of the q model.

Suggestions for Future Research

Our conclusion must be tempered by the specificity of our sample models, and our restriction to models with only first-order serially correlated errors. In practice, investigators may wish to extend these to more general serial correlation processes. Recent work by King (1983) and King and McAleer (1984) provide useful steps in these directions.

The work reported here is confined to a very high degree of aggregation, which limits the possibility of sharp discrimination among models. Investment arises from different motives, and these apply differently in different industries. Hence, it would be useful to disaggregate the investment data and develop investment functions by sector. Recent data for investment in nonresidential structures shows a sharp decline since the second quarter of 1986. The declines were concentrated in petroleum manufacturing and mining firms--apparently in response to the sharp decline in petroleum prices--and in commercial buildings. Consideration of the structures investment data on a disaggregated basis may help explain the behavior of investment in structures since the second quarter of 1986.

As in most other studies, equipment and structures investment are separated. This disaggregation is useful in determining the effects that the variables in the equations have on equipment and structures investment separately, and also in determining the differential effects of tax policy. However, this dichotomy is artificial, as many business investment decisions are not made by separating equipment and structures needs. To some extent they are needed jointly in the production process. Greenspan in particular goes into this problem, stressing the interdependence of equipment and structures investment.[1] The problem then is how to model this interdependence while still keeping the equations separate. The determinants of investment which are not, or cannot be, included in the separate equipment and structures equations are likely to be correlated in the disturbance terms.

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[1] See Greenspan's comments on pages 114-17 of Clark (1979).

If it can be assumed that the disturbance terms of the equipment and structures equations are correlated, and that this is the only way in which these equations are linked, then the correct method of analysis is to estimate the equations as a set of seemingly unrelated regressions. The estimation procedure is the one developed by Zellner (1962) and is based on the fact that the sample variance and covariance are unbiased and consistent estimators of the population variance and covariance.

Finally, to gain an improved forecast, different combination schemes is worth considering. Combining forecasts might be successful when using constituents based on quite different philosophies, such as those using a time series Box-Jenkins model and regression models .

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APPENDIX A

DESCRIPTION OF THE VARIABLES AND THE DATA

The Dependent Variable

The dependent variable is gross private domestic fixed investment. Data are from U.S. Bureau of Economic Analysis, National Income and Product Accounts (*NIPA*), and was retrieved from the CITIBASE: Citibank economic database. Separate estimates are made for the two major components of real investment, producers' durable equipment and expenditures on nonresidential structures, both measured in 1982 dollars.

In estimating the investment models described in Chapter III, the gross investment series were divided by potential output, following Clark. The potential output series is provided in Gordon (1984 and 1987).

The Independent Variables

Most of the independent variables used in this study were also retrieved from the CITIBASE: Citibank economic database. The output variable, Y_t, is the *NIPA* real gross domestic product of non-financial businesses, nonfarm less housing in 1982 dollars. The quarterly real (1982 dollars) net stock of nonresidential equipment and structures were linearly interpolated from the annual data. The annual data for 1947-1963 are from Musgrave (1981), and then updated from DRI/McGraw-Hill, U.S. Long-Term Review. The cash flow variable, F_t, is the real cash flow of nonfinancial corporations. Nominal cash flow is the sum of after-tax profits, capital-consumption allowances without capital-consumption and inventory valuation adjustments. The investment deflator for equipment or structures (whichever is appropriate) is applied to nominal cash flow to derive F.

In the neoclassical model, the variable, p_t, is the deflator corresponding to the output variable, Y_t. The economic rate of depreciation for equipment is estimated at 0.15 and structures 0.05 (Clark (1979), and Kopcke (1985)). The corporate tax rate, U, is the highest marginal rate on corporate income from Seater (1982), and was updated from DRI/McGraw-Hill, U.S. Long-Term Review. The present value of a dollar's worth of depreciation allowances (ZE, ZS) used the formula given in Hall and Jorgenson (1967). Data on the average lifetime of investment are from Jorgenson and Sullivan (1982), and updated from Wharton Econometric Forecasting Associates Inc., Wharton long-Term Forecast. The BAA bond rate (from the CITIBASE) was used in the discounting. The rates adopted for the investment tax credit, ITC_E and ITC_S, were also taken from Jorgenson and Sullivan (1982), and updated from Wharton Econometric Forecasting Associates Inc.

In the tax-adjusted Q variable (Bernanke 1988), the taxable capital stock, *KTAX*, was derived as the capitalized difference of the value of total investment (equipment and structures) minus capital consumption allowances, *CCA* (excluding capital consumption adjustment, from NIPA). To reduce the effect of an inaccurate initial value, *KTAX* was set equal to the actual capital stock in 1931:4 and capitalization was started from that date. *B* is then the present value of reduced taxes due to depreciation of the current taxable capital stock,

$$B = U * [\ \delta_d /(\delta_d + r_B(1\text{-}U))] * KTAX,$$

where $r_B(1\text{-}U)$ is the quarterly, risk-free, after-tax interest rate (on long term government bonds, Standard and Poor), and $\delta = CCA/KTAX$ is the rate of tax depreciation.

APPENDIX B

PREDICTION ERROR STATISTICS

The prediction error statistics reported in this study include the mean square prediction error, the root mean square percent error, The average absolute error, and the average absolute percent error. In addition, the Theil error decomposition statistics is also reported. These statistics are defined as follow:

$$\text{RMSE} = [1/N \sum_{i=1}^{N} (P_i - A_i)^2]^{1/2},$$

where RMSE stands for root mean square error, P denotes the predicted value, A the realized value, and N is the number of prediction periods.

$$\text{AAE} = 1/N \sum_{i=1}^{N} |P_i - A_i|,$$

where AAE stands for average absolute error. The root mean square percent error and average absolute percent errors are computed in the same way, except that the errors are computed as a percent of the realized values period by period.

The Theil inequality proportions are computed as a decomposition of the square of the root mean square error. This square, the mean square error, can be decomposed:

$$\text{MSE} = \text{UM} + \text{US} + \text{UC},$$

where: $\text{UM} = (\bar{P} - \bar{A})^2$, $\text{US} = (\sigma_p - \sigma_a)^2$, $\text{UC} = 2(1 - r)\sigma_p\sigma_a$, and $\bar{p}$, $\bar{A}$ denote the means of the predictions and realized values; σ_a, σ_p

denote their respective standard deviations; and r the correlation coefficient of the predicted and actual values. Defining: U1 = UM/MSE, U2 = US/MSE, AND U3 = UC/MSE, it follows immediately that: U1 + U2 + U3 = 1.

Note that U1 is zero if and only if the mean predicted value equals the mean actual value, and therefore its value reflects errors in central tendency. The second term, U2 is zero if and only if the standard deviations of the predicted and actual values are the same; it therefore measures errors of unequal variation. Finally, U3 equals zero if the actual and predicted values are perfectly correlated, or (equivalently) if and only if the covariance of the predicted and realized values ($r\sigma_a\sigma_p$) takes its maximum value. These proportions are sometimes termed the bias, variance, and covariance proportions, respectively.[1]

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[1] For further details see Theil (1974).

APPENDIX C

DETAILED REGRESSION RESULTS

Models For Producer Durable Equipment

(1) The Accelerator Model:

```
     SAMPLE PERIOD: 195101-198204
     NUMBER OF OBSERVATIONS: 128
     ORDINARY LEAST SQUARES
     POLYNOMIAL DISTRIBUTED LAG
     AUTOREGRESSIVE CORRECTIONS: COCHRANE-ORCUTT TECHNIQUE

GIE=C1*IPGNP+L1*ACC<D=4,L=15>+C2*L1KE

              PARAMETER     T-STATISTIC    STD ERROR
     C1)        -23.805     -5.29374        4.49689
     C2)        0.16755     30.76784         .00545
    RHO( 1)=  .83058
    VARIANCE=  .23517303E-05         DEPENDENT MEAN= .62979E-01
    STANDARD ERROR=      .00153354     PERCENT ERROR=  2.4
    R-SQUARE=  .9790           R-BAR-SQUARE=  .9778
    F TEST(  7,120)=     792.7698

    LAG WEIGHTS
    PERIOD       WEIGHT    T-STATISTIC
    T- 0        .10015      6.83685
    T- 1        .14731     11.92628
    T- 2        .17288     12.83906
    T- 3        .18206     12.92757
    T- 4        .17937     12.66418
    T- 5        .16870     11.81959
    T- 6        .15331     10.51209
    T- 7        .13579      9.13237
    T- 8        .11810      7.94790
    T- 9        .10152      6.99963
    T-10        .08673      6.19232
    T-11        .07372      5.41640
    T-12        .06187      4.66257
    T-13        .04988      3.97450
    T-14        .03583      3.09871
    T-15        .01713      1.22112
            ------------- -----------
    SUM       1.78435     32.24841     MEAN LAG  5.69
    DW STATISTIC=  2.15045  WALLIS-DW( 4) STATISTIC=  1.95049
```

(2) The Accelerator-Cash Flow Model

```
     SAMPLE PERIOD: 195101-198204
     NUMBER OF OBSERVATIONS: 128

     ORDINARY LEAST SQUARES
     POLYNOMIAL DISTRIBUTED LAG

     AUTOREGRESSIVE CORRECTIONS: COCHRANE-ORCUTT TECHNIQUE

GIE=C1*IPGNP+L1*ACC<D=4,L=14>+L2*CFE<D=4,L=16>+C2*L1KE

             PARAMETER     T-STATISTIC    STD ERROR

    C1)        -25.573      -4.10245        6.23369
    C2)        0.14520       4.73074         .03069

    RHO( 1)=  .84467

    VARIANCE=  .23350437E-05        DEPENDENT MEAN= .62979E-01
    STANDARD ERROR=     .00152808     PERCENT ERROR=  2.4

    R-SQUARE=  .9800            R-BAR-SQUARE=  .9779
    F TEST( 12,115)=    466.0675

    LAG WEIGHTS:  L1

    PERIOD      WEIGHT    T-STATISTIC

    T- 0        .09282      4.77645
    T- 1        .14830      6.80135
    T- 2        .17744      7.20119
    T- 3        .18658      7.34896
    T- 4        .18132      7.32715
    T- 5        .16650      7.05398
    T- 6        .14620      6.51770
    T- 7        .12375      5.81249
    T- 8        .10174      5.05982
    T- 9        .08198      4.33466
    T-10        .06554      3.67343
    T-11        .05275      3.12946
    T-12        .04314      2.78312
    T-13        .03554      2.60401
    T-14        .02800      1.84953

            ------------- -----------

    SUM       1.63162     20.63675    MEAN LAG  5.22
```

```
LAG WEIGHTS:  L2

PERIOD       WEIGHT    T-STATISTIC

T- 0        .02291       .49223
T- 1       -.01633      -.56627
T- 2       -.02852     -1.19601
T- 3       -.02317     -1.07520
T- 4       -.00828      -.44434
T- 5        .00963       .59397
T- 6        .02556      1.62484
T- 7        .03599      2.16813
T- 8        .03892      2.26378
T- 9        .03384      2.02922
T-10        .02174      1.40403
T-11        .00512       .34055
T-12       -.01203      -.74250
T-13       -.02421     -1.36952
T-14       -.02442     -1.40508
T-15       -.00417      -.24012
T-16        .04654      1.48760
        ------------- -----------
SUM         .09911      1.08393    MEAN LAG 10.57

DW STATISTIC=  2.18486  WALLIS-DW( 4) STATISTIC=  1.91534
```

(3) The Neoclassical Model

```
     SAMPLE PERIOD: 195004-198204
     NUMBER OF OBSERVATIONS: 129

     ORDINARY LEAST SQUARES
     POLYNOMIAL DISTRIBUTED LAG

     AUTOREGRESSIVE CORRECTIONS: COCHRANE-ORCUTT TECHNIQUE

GIE=C1*IPGNP+L1*NE<D=4,L=14>+C2*L1KE

             PARAMETER     T-STATISTIC     STD ERROR

     C1)       -12.988      -1.12673        11.52707
     C2)       0.16520      11.95959          .01381

    RHO( 1)=  .91868

    VARIANCE=  .39337025E-05         DEPENDENT MEAN= .62984E-01
    STANDARD ERROR=      .00198336     PERCENT ERROR=  3.1

    R-SQUARE=  .9646           R-BAR-SQUARE=  .9626
    F TEST(  7,121)=    467.4880

    LAG WEIGHTS

    PERIOD       WEIGHT     T-STATISTIC

    T- 0        .00778       2.91231
    T- 1        .01503       5.66586
    T- 2        .01898       6.26489
    T- 3        .02054       6.53875
    T- 4        .02048       6.54116
    T- 5        .01945       6.17409
    T- 6        .01795       5.59623
    T- 7        .01635       5.05667
    T- 8        .01490       4.66845
    T- 9        .01369       4.39415
    T-10        .01268       4.12784
    T-11        .01171       3.82924
    T-12        .01047       3.56964
    T-13        .00852       3.29416
    T-14        .00529       1.90525

             ------------- -----------

    SUM         .21383      18.37702    MEAN LAG  6.19

    DW STATISTIC=  1.65860  WALLIS-DW( 4) STATISTIC=  1.87149
```

(4) Modified Neoclassical Model:

```
     SAMPLE PERIOD: 195004-198204
     NUMBER OF OBSERVATIONS: 129

     ORDINARY LEAST SQUARES
     POLYNOMIAL DISTRIBUTED LAG

     AUTOREGRESSIVE CORRECTIONS: COCHRANE-ORCUTT TECHNIQUE

GIE=C1*IPGNP+L1*MNE1<D=4,L=14>+L2*MNE2<D=4,L=14>+C2*L1KE

             PARAMETER     T-STATISTIC    STD ERROR

     C1)       -28.671     -6.27867        4.56639
     C2)       0.13463      5.72107         .02353

     RHO( 1)=  .74285     ACCURATE TO 3 DIGITS.

     VARIANCE=  .25454349E-05        DEPENDENT MEAN= .62984E-01
     STANDARD ERROR=     .00159544     PERCENT ERROR=  2.5

     R-SQUARE=  .9781           R-BAR-SQUARE=  .9758
     F TEST( 12,116)=    427.1450

     LAG WEIGHTS:  L1

     PERIOD       WEIGHT    T-STATISTIC

     T- 0        .02694      5.80422
     T- 1        .03802      8.00980
     T- 2        .04483      7.84299
     T- 3        .04812      7.93458
     T- 4        .04859      7.93666
     T- 5        .04687      7.54278
     T- 6        .04354      6.82839
     T- 7        .03911      6.03680
     T- 8        .03402      5.28642
     T- 9        .02867      4.54786
     T-10        .02336      3.76343
     T-11        .01837      2.98210
     T-12        .01388      2.34263
     T-13        .01003      1.89237
     T-14        .00689      1.23803

             ------------ ----------

     SUM         .47122     20.58561    MEAN LAG  5.51
```

```
LAG WEIGHTS:  L2

PERIOD       WEIGHT     T-STATISTIC

T- 0        -.02506     -4.51620
T- 1        -.03772     -6.89386
T- 2        -.04533     -7.41929
T- 3        -.04885     -7.71194
T- 4        -.04918     -7.71095
T- 5        -.04710     -7.26863
T- 6        -.04331     -6.52807
T- 7        -.03845     -5.72737
T- 8        -.03302     -4.97436
T- 9        -.02747     -4.24994
T-10        -.02215     -3.51499
T-11        -.01732     -2.81970
T-12        -.01315     -2.29464
T-13        -.00972     -2.02298
T-14        -.00702     -1.48746

        ------------- -----------

SUM         -.46484    -19.79586              MEAN LAG  5.47

DW STATISTIC=  1.93469  WALLIS-DW( 4) STATISTIC=  1.85461
```

(5) Securities-Value or q Model:

```
 SAMPLE PERIOD: 194902-198204
 NUMBER OF OBSERVATIONS: 135

ORDINARY LEAST SQUARES
 POLYNOMIAL DISTRIBUTED LAG

AUTOREGRESSIVE CORRECTIONS: COCHRANE-ORCUTT TECHNIQUE

GIE=C1*IPGNP+L1*Q<D=4,L=9>+C2*L1KE

            PARAMETER      T-STATISTIC    STD ERROR

 C1)         -57.158       -2.10975        27.09212
 C2)         0.19335        7.18744          .02690

RHO( 1)=  .96434      ACCURATE TO 3 DIGITS.

VARIANCE=  .40557019E-05         DEPENDENT MEAN= .62762E-01
STANDARD ERROR=      .00201388     PERCENT ERROR=  3.2

R-SQUARE=  .9624           R-BAR-SQUARE=  .9603
F TEST(  7,127)=    460.4250

LAG WEIGHTS

PERIOD       WEIGHT     T-STATISTIC

T- 0        -.00037       -.30527
T- 1         .00439       5.33376
T- 2         .00533       6.87060
T- 3         .00432       6.60223
T- 4         .00275       4.05363
T- 5         .00153       2.25298
T- 6         .00109       1.67764
T- 7         .00139       1.82820
T- 8         .00190       2.40147
T- 9         .00161       1.36347

          ------------ ----------

SUM          .02395       8.96316    MEAN LAG  3.87

DW STATISTIC=  1.80445  WALLIS-DW( 4) STATISTIC=  2.03271
```

(6) ARIMA (2, 1, 2) -- With Seasonality as ARIMA (2, 0, 0)

SAMPLE PERIOD: 194702-198204
NUMBER OF RESIDUALS: 143

VARIANCE ESTIMATE = 5.466E-06
STD ERROR ESTIMATE = 0.00233799

AUTOCORRELATION CHECK OR RESIDUALS AUTOCORRELATIONS

TO LAG	CHI SQUARE	DF	PROB
6	0.00	0	0.000
12	4.58	5	0.469
18	12.81	11	0.306
24	14.69	17	0.618

PARAMETER	ESTIMATE	T-STATISTIC	LAG
MU	-2.7E-05	-0.15	0
MA1,1	0.97875	4.46	1
MA1,2	-0.54072	-2.89	2
AR1,1	1.24778	6.63	1
AR1,2	-0.73125	-4.54	2
AR2,1	0.02245	0.24	4
AR2,2	-0.31241	-3.47	8

FORECAST EVALUATION

FIRST: ANALYSIS OF THE ERRORS TO TEST FOR UNBIASDNESS

NUMBER (N) OF RESIDUALS	MEAN OF RESIDUALS	STANDARD DEVIATION (STD)
143	-0.000001870	0.0022881

FROM THE ABOVE INFORMATION, WE CALCULATE THE RATIO:

T_{calc} = [MEAN . $(N)^{1/2}$ / (STD)]; WHICH IS DISTRIBUTED AS T DISTRIBUTION

T_{calc} = 0.01 ⇒ REJECT THE NULL HYPOTHESES, AND CONCLUDE THAT THE ERRORS OF THE FORECAST ARE UNBIASED SINCE THE NULL HYPOTHESES THAT THE MEAN OF THE ERRORS EQUAL TO ZERO CAN NOT BE REJECTED.

SECOND: TEST FOR EFFICIENCY OF THE FORECAST

MODEL: $(\text{ACTUAL})_t = \beta\ (\text{PREDICTED})_t + \varepsilon_t$

TEST HYPOTHESES: $H_0 : \beta = 1$
$H_1 : \beta \neq 1$

TEST STATISTICS: $[(b - 1) / \sigma_b]$,

WHERE b is the estimated value for β.

THE TEST IS DISTRIBUTED AS T DISTRIBUTION

REGRESSION RESULTS

PARAMETER	ESTIMATE	STANDARD-ERROR
β	0.999407	0.002993610

$T_{calc} = 0.198 \Rightarrow$ WE DO NOT REJECT THE NULL HYPOTHESES,

AND CONCLUDE THE EFFICIENCY OF THE FORECAST.

Models for Nonresidential Structures

(1) Accelerator Model:

```
     SAMPLE PERIOD: 195001-198204
     NUMBER OF OBSERVATIONS: 132

     ORDINARY LEAST SQUARES
     POLYNOMIAL DISTRIBUTED LAG

     AUTOREGRESSIVE CORRECTIONS: COCHRANE-ORCUTT TECHNIQUE

GIS=C1*IPGNP+L1*ACC<D=3,L=11>+C2*L1KS

             PARAMETER     T-STATISTIC    STD ERROR

     C1)        8.2052        .60372       13.59112
     C2)       0.07765       6.66187         .01166

     RHO( 1)=  .95703

     VARIANCE=  .10298004E-05        DEPENDENT MEAN= .45190E-01
     STANDARD ERROR=     .00101479     PERCENT ERROR=  2.2

     R-SQUARE=  .9345           R-BAR-SQUARE=  .9314
     F TEST(  6,125)=    294.9229

     LAG WEIGHTS

     PERIOD      WEIGHT    T-STATISTIC

     T- 0       .02341      2.55972
     T- 1       .03785      4.80894
     T- 2       .04599      5.32309
     T- 3       .04892      5.23702
     T- 4       .04772      4.98205
     T- 5       .04350      4.54904
     T- 6       .03733      3.92174
     T- 7       .03030      3.20267
     T- 8       .02352      2.56073
     T- 9       .01806      2.13001
     T-10       .01501      1.94414
     T-11       .01547      1.72117

             ------------- -----------

     SUM        .38708     12.44474    MEAN LAG  4.63

     DW STATISTIC=  1.52855  WALLIS-DW( 4) STATISTIC=  1.97789
```

(2) The Accelerator-Cash Flow Model

```
SAMPLE PERIOD: 194803-198204
NUMBER OF OBSERVATIONS: 138

ORDINARY LEAST SQUARES
POLYNOMIAL DISTRIBUTED LAG

AUTOREGRESSIVE CORRECTIONS: COCHRANE-ORCUTT TECHNIQUE

GIS=C1*IPGNP+L1*ACC<D=3,L=5>+L2*(CFS<D=3,L=5>)+C2*L1KS

          PARAMETER     T-STATISTIC    STD ERROR

C1)        -11.287        -.60497       18.65657
C2)        0.08103        4.91268         .01649

RHO( 1)=  .97387     ACCURATE TO 3 DIGITS.

VARIANCE=  .10531192E-05         DEPENDENT MEAN= .45188E-01
STANDARD ERROR=      .00102622      PERCENT ERROR=  2.3

R-SQUARE=  .9331            R-BAR-SQUARE=  .9278
F TEST( 10,127)=    175.7540

LAG WEIGHTS:  L1

PERIOD       WEIGHT    T-STATISTIC

T- 0        .02300      2.35004
T- 1        .03247      3.39420
T- 2        .03751      4.12494
T- 3        .03798      4.18744
T- 4        .03372      3.60864
T- 5        .02461      2.57566
         ------------- -----------
SUM         .18929      8.21562    MEAN LAG  2.53


LAG WEIGHTS:  L2

PERIOD       WEIGHT    T-STATISTIC

T- 0       -.00240      -.11513
T- 1       -.00709      -.46575
T- 2       -.00355      -.26251
T- 3        .00619       .47659
T- 4        .02011      1.36642
T- 5        .03616      1.98794
         ------------- -----------
SUM         .04942      1.24905              MEAN LAG  5.37

DW STATISTIC=  1.47162  WALLIS-DW( 4) STATISTIC=  2.05955
```

(3) The Neoclassical Model

```
SAMPLE PERIOD: 195001-198204
NUMBER OF OBSERVATIONS: 132

ORDINARY LEAST SQUARES
POLYNOMIAL DISTRIBUTED LAG

AUTOREGRESSIVE CORRECTIONS: COCHRANE-ORCUTT TECHNIQUE

GIS=C1*IPGNP+L1*NS<D=3,L=11>+C2*L1KS

             PARAMETER     T-STATISTIC    STD ERROR

C1)           14.121        1.18937        11.87259
C2)          0.07476        7.08577          .01055

RHO( 1)=  .94840      ACCURATE TO 3 DIGITS.

VARIANCE=  .11161445E-05          DEPENDENT MEAN= .45190E-01
STANDARD ERROR=      .00105648      PERCENT ERROR=  2.3

R-SQUARE=  .9290            R-BAR-SQUARE=  .9256
F TEST(  6,125)=    270.5092

LAG WEIGHTS

PERIOD       WEIGHT     T-STATISTIC

T- 0       -.00027       -.26348
T- 1        .00186       1.93869
T- 2        .00324       2.99019
T- 3        .00399       3.37620
T- 4        .00423       3.46064
T- 5        .00409       3.31827
T- 6        .00370       2.99132
T- 7        .00319       2.58463
T- 8        .00268       2.24169
T- 9        .00231       2.09689
T-10        .00219       2.22363
T-11        .00247       2.25181

          ------------- ------------

SUM         .03368       8.56634      MEAN LAG  5.75

DW STATISTIC=  1.49438  WALLIS-DW( 4) STATISTIC=  1.89086
```

(4) Modified Neoclassical Model:

```
 SAMPLE PERIOD: 194804-198204
 NUMBER OF OBSERVATIONS: 4

 ORDINARY LEAST SQUARES
 POLYNOMIAL DISTRIBUTED LAG

 AUTOREGRESSIVE CORRECTIONS: COCHRANE-ORCUTT TECHNIQUE

GIS=C1*IPGNP+L1*MNS1<D=3,L=6>+L2*MNS2<D=3,L=5>+C2*L1KS

            PARAMETER     T-STATISTIC    STD ERROR

 C1)         -16.795      -1.61618       10.39170
 C2)         0.04209       3.57292         .01178

RHO( 1)=  .93561     ACCURATE TO 3 DIGITS.

VARIANCE=  .96957570E-06        DEPENDENT MEAN= .45174E-01
STANDARD ERROR=     .00098467     PERCENT ERROR=  2.2

R-SQUARE=  .9387           R-BAR-SQUARE=  .9338
F TEST( 10,126)=    191.4024

LAG WEIGHTS:  L1

PERIOD      WEIGHT    T-STATISTIC

T- 0       .00435      2.81295
T- 1       .00351      1.94456
T- 2       .00380      1.81274
T- 3       .00452      2.12190
T- 4       .00496      2.26466
T- 5       .00442      2.35389
T- 6       .00220      1.86718
        ------------- -----------
SUM        .02775      5.63269    MEAN LAG  2.88

LAG WEIGHTS:  L2

PERIOD      WEIGHT    T-STATISTIC

T- 0      -.00148      -.70195
T- 1      -.00280     -1.21971
T- 2      -.00341     -1.42037
T- 3      -.00371     -1.54451
T- 4      -.00409     -1.75857
T- 5      -.00498     -2.67545
        ------------- ------------
SUM       -.02047     -3.72962      MEAN LAG  3.03

DW STATISTIC=  1.54629  WALLIS-DW( 4) STATISTIC=  2.01031
```

(5) Securities-Value or q Model:

```
     SAMPLE PERIOD: 194802-198204
     NUMBER OF OBSERVATIONS: 139

     ORDINARY LEAST SQUARES
     POLYNOMIAL DISTRIBUTED LAG

     AUTOREGRESSIVE CORRECTIONS: COCHRANE-ORCUTT TECHNIQUE

GIS=C1*IPGNP+L1*Q<D=3,L=5>+C2*L1KS

            PARAMETER     T-STATISTIC    STD ERROR

     C1)       -10.814      -.56141       19.26256
     C2)       0.08848      5.97693         .01480

    RHO( 1)=  .97851     ACCURATE TO 3 DIGITS.

    VARIANCE=  .10494878E-05        DEPENDENT MEAN= .45193E-01
    STANDARD ERROR=     .00102445     PERCENT ERROR=  2.3

    R-SQUARE=  .9308           R-BAR-SQUARE=  .9277
    F TEST(  6,132)=    293.8574

    LAG WEIGHTS

    PERIOD      WEIGHT    T-STATISTIC

    T- 0      -.00072     -1.14168
    T- 1       .00076      1.67937
    T- 2       .00162      4.06863
    T- 3       .00191      4.80154
    T- 4       .00167      3.70906
    T- 5       .00094      1.48918

          ------------- -----------

    SUM        .00617      5.02406    MEAN LAG  3.41

    DW STATISTIC=  1.61759  WALLIS-DW( 4) STATISTIC=  2.19097
```

(6) ARIMA (1, 1, 0) -- With Seasonality as ARIMA (1, 0, 0)

SAMPLE PERIOD: 194702-198204
NUMBER OF RESIDUALS: 143

VARIANCE ESTIMATE = 1.139E-06
STD ERROR ESTIMATE = 0.0010671

AUTOCORRELATION CHECK OR RESIDUALS AUTOCORRELATIONS

TO LAG	CHI SQUARE	DF	PROB
6	0.91	3	0.823
12	6.49	9	0.690
18	10.76	15	0.769
24	14.05	21	0.867

PARAMETER	ESTIMATE	T-STATISTIC	LAG
MU	-2.62-05	-0.24	0
AR1,1	0.31834	3.69	1
AR2,1	-0.21780	-2.59	4

FORECAST EVALUATION

FIRST: ANALYSIS OF THE ERRORS TO TEST FOR UNBIASDNESS

NUMBER OF RESIDUALS	MEAN OF RESIDUALS	STANDARD DEVIATION
143	0.0000003000	0.0010595

FROM THE ABOVE INFORMATION, WE CALCULATE THE RATIO:

T_{calc} = [MEAN . $(N)^{1/2}$ / (STD)]; WHICH IS DISTRIBUTED AS T DISTRIBUTION

Tcalc = 0.003 ⇒ REJECT THE NULL HYPOTHESES, AND CONCLUDE THAT THE ERRORS OF THE FORECAST ARE UNBIASED SINCE THE NULL HYPOTHESES THAT THE MEAN OF THE ERRORS EQUAL TO ZERO CAN NOT BE REJECTED.

SECOND: TEST FOR EFFICIENCY OF THE FORECAST

MODEL: $(\text{ACTUAL})_t = \beta\ (\text{PREDICTED})_t + \varepsilon_t$

TEST HYPOTHESES: $H_0 : \beta = 1$
$H_1 : \beta \neq 1$

TEST STATISTICS: $[(b - 1) / \sigma_b]$,

WHERE b is the estimated value for β.

THE TEST IS DISTRIBUTED AS T DISTRIBUTION

REGRESSION RESULTS

PARAMETER	ESTIMATE	STANDARD-ERROR
β	0.999707	0.001954419

$T_{calc} = 0.150 \Rightarrow$ WE DO NOT REJECT THE NULL HYPOTHESES,

AND CONCLUDE THE EFFICIENCY OF THE FORECAST.

VITA

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Doctor of Philosophy

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Minor Field: Statistics

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