This dissertation has been
microfilmed exactly as received 68-13,322

HAMBOR, John Carrol, 1939-
CAPITAL APPROPRIATIONS AND BUSINESS FIXED INVESTMENT IN MANUFACTURING: AN ECONOMETRIC ANALYSIS.

The University of Michigan, Ph.D., 1968
Economics, general

University Microfilms, Inc., Ann Arbor, Michigan

CAPITAL APPROPRIATIONS AND BUSINESS FIXED INVESTMENT IN MANUFACTURING: AN ECONOMETRIC ANALYSIS

by
John Carrol Hambor

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in the
University of Michigan
1968

Doctoral Committee:

Associate Professor W. H. Locke Anderson, Chairman
Professor Paul M. McCracken
Assistant Professor William B. Neenan
Professor Daniel B. Suits

A B S T R A C T

CAPITAL APPROPRIATIONS AND BUSINESS
FIXED INVESTMENT IN MANUFACTURING:
AN ECONOMETRIC ANALYSIS

by

John Carrol Hambor

Chairman: W. H. Locke Anderson

The purpose of this study is to examine a model of business fixed investment spending in the context of a fully specified econometric model of income determination. Investment decisions are measured by appropriations for capital spending rather than by capital expenditures themselves. Although data on appropriations are restricted to the 1,000 largest manufacturing firms, this important subset accounts for virtually all of the variation of capital spending in manufacturing and a substantial portion of the variation of all business fixed investment expenditures. The relationship between expenditures and appropriations is treated separately from the relationship between appropriations and the determinants of investment decisions.

Appropriations are assumed to be determined in an internal (to the firm) market for investment funds. This view incorporates both accelerator and internal funds theories of capital spending into the theoretical structure used to explain investment decisions. The relationship between expenditures and appropriations is treated as a simple linear distributed lag.

The resulting two equation investment system was estimated by ordinary least squares in annual first differences for total manufacturing and several constituent manufacturing industries. The results indicated fairly general support for the theoretical structure. Expansion requirements (the difference between desired and actual capital stock) and the subjective

or internal cost of funds consistently appeared as significant determinants of appropriations. The long term interest rate was not generally a significant determinant of appropriations, but did appear important in some individual industries. The results of the distributed lag estimations indicated that it takes about three years for a dollar of appropriations to be fully realized in expenditures, though well over half of each appropriation dollar is phased into expenditures within a year and a half of the formal commitment.

A set of estimated equations for total manufacturing which included the appropriations equation, the distributed lag equation and several "linking" equations was introduced into the University of Michigan Econometric Model of the U.S. Economy. The Michigan model was then used to generate ex post forecasts of important measures of economic activity for the period 1960 through 1965. The results indicated that the incorporation of the estimated investment system substantially improved the forecasting accuracy of the full system when compared with forecasts which relied solely on businessmen's anticipations of capital spending for projections of business fixed investment. Even though a measure of capital appropriations was available for only the 1,000 largest manufacturing firms, the accuracy in the prediction of capital expenditures in this important subset of firms was sufficient to improve the overall forecasts of economic activity.

ACKNOWLEDGEMENTS

I wish to thank each of my committee members for his suggestions at all stages of the project. In particular, Professor W. H. Locke Anderson spent much time correcting my mistakes and forcing me to present the material in clear and concise terms. Professor Daniel B. Suits provided most of the initial motivation which led to my interest in applied econometric methods. I also wish to express special thanks to Professor Jarvis M. Babcock for his helpful comments and advice during the very early stages of the project. Finally, I wish to express my thanks to the Ford Foundation and the National Science Foundation for providing financial support during the 1966-67 academic year, when much of the work was being completed.

CONTENTS

CHAPTER I. INTRODUCTION..... 1

CHAPTER II. THE STRUCTURE OF INVESTMENT BEHAVIOR..... 9

CHAPTER III. EMPIRICAL EVIDENCE ON THE INVESTMENT STRUCTURE.... 33

CHAPTER IV. CAPITAL APPROPRIATIONS AND A MODEL OF INCOME DETERMINATION..... 75

CHAPTER V. CONCLUDING COMMENTS..... 107

SELECTED BIBLIOGRAPHY..... 118

LIST OF TABLES

Table		Page
1.1	Capital Expenditures, Gross Capital Appropriations and Appropriations Backlog: 1000 Largest Manufacturing Firms, 1953-1965	5
3.1	Capital Output Trends, by Industry	41
3.2	Regression Coefficients for $\Delta CA_t = \delta_1 \Delta ER_t + \delta_2 \Delta F_t + \delta_3 \Delta Baa_t + \delta_4 \Delta SP_t + \delta_0$	51
3.3	Regression Coefficients for $\Delta CA_t = \delta_1 \Delta ER_t + \delta_2 \Delta F_t + \delta_3 \Delta Baa_t + \delta_0$	52
3.4	Regression Coefficients for $\Delta(\frac{CA_t}{K'_{t-1}}) = \delta'_1 \Delta(\frac{\hat{\beta}^* S_t}{K'_{t-1}}) + \delta'_2 \Delta F_t + \delta'_3 \Delta Baa_t + \delta'_4 \Delta SP_t + \delta'_0$	55
3.5	Regression Coefficients for $\Delta(\frac{CA_t}{K'_{t-1}}) = \delta'_1 \Delta(\frac{\hat{\beta}^* S_t}{K'_{t-1}}) + \delta'_2 \Delta F_t + \delta'_3 \Delta Baa_t + \delta'_0$	56
3.6	"Best" Equation, Linear Model, by Industry	59
3.7	"Best" Equation, Ratio Model, by Industry	60
3.8	Comparison of Estimated Distributed Lag Equations with Almon's Equations, by Industry $CE_t = \alpha_0 CA_t + \alpha_1 CA_{t-1} + \alpha_2 CA_{t-2}$	63
3.9	Estimates of Variable Coefficient Distributed Lag, by Industry $CE_t = \beta_0 \Delta CA_t + \beta_1 \Delta\{(B/CE)_{t-1} CA_t\} + \beta_2 CA_{t-1}$	67
3.10	Evaluation of Within Sample Predictions Based on Equations (3.10) and (3.16), by Industry, 1956-1965	73
4.1	Selected One-Year Gross National Product Multipliers Calculated from the RSQE Forecasting Model	86

4.2	Forecasts of Selected Aggregate Demand, Investment and Monetary Variables for 1960.....	91
4.3	Forecasts of Selected Aggregate Demand, Investment and Monetary Variables for 1961.....	92
4.4	Forecasts of Selected Aggregate Demand, Investment and Monetary Variables for 1962.....	93
4.5	Forecasts of Selected Aggregate Demand, Investment and Monetary Variables for 1963.....	94
4.6	Forecasts of Selected Aggregate Demand, Investment and Monetary Variables for 1964.....	95
4.7	Forecasts of Selected Aggregate Demand, Investment and Monetary Variables for 1965.....	96
4.8	Root Mean Square Error for Endogenous, Exogenous and Actual Model Forecasts, 1960-1965.....	98
4.9	Actual and Predicted Values for the Change in Stock Prices (ΔSP) and Capital Expenditures (ΔCE), 1960-1965...	104
4.10	Root Mean Square Error When Actual (ΔSP) and Estimated ($\Delta \hat{SP}$) Stock Prices Are Included in the Appropriations Equation, 1960-1965.....	105

LIST OF ILLUSTRATIONS

Figure		Page
1.1	Capital Expenditures by 1000 Largest Manufacturing and Smaller Firms, 1953-1965.....	4
1.2	Capital Appropriations and Capital Expenditures by 1000 Largest Manufacturing Firms, 1953-1965.....	6
2.1	Marginal Physical Product of Capital Schedule.....	13
2.2	Marginal Cost of Funds for Debt and Liquidity Stocks.....	22
2.3	Marginal Cost of Funds Schedule.....	24
2.4a	Almon Distributed Lag Profile.....	28
2.4b	Cumulative Almon Distributed Lag Profile.....	28
2.5	Popkin Distributed Lag Profile.....	30
3.1	Actual, Desired and Trend Estimated Capital Output Ratios for Manufacturing, 1954-1965.....	40
3.2	Actual and Predicted Values of ΔCA from Equation (3.09), 1954-1965.....	47
3.3	Actual and Predicted Values of ΔCA from Equation (3.10), 1954-1965.....	49
3.4	Expenditure Predictions from Recursive System ((3.10), (3.16)) Compared With Change in Actual Expenditures, 1956-1965.....	70
3.5	Expenditure Predictions from Recursive System ((3.09), (3.16)) Compared With Actual Change in Expenditures, 1956-1965.....	72
4.1	Scatter of Manufacturing (CCA_m) Depreciation With Total Depreciation (CCA).....	81
4.2	Scatter of Manufacturing Retained Earnings (SEC-FTC) (ΔRE) With Total Corporate Retained Earnings (ΔCRE).....	82

LIST OF APPENDICES

Appendix		Page
I.	Procedure to Inflate Appropriations Backlog.....	110
II.	Data Sources and Selected Basic Data Series.....	112

CHAPTER I

INTRODUCTION

The purpose of this study is to combine a model of Business Fixed Investment expenditures (hereafter, BFI) with an interrelated forecasting model of the U.S. economy. The first part of the study focuses on investment decisions as measured by the capital appropriations series published by the National Industrial Conference Board (hereafter, NICB)[1] rather than on capital expenditures. The second part of the study is concerned with the relationship between expenditures and appropriations. Finally the combined decision-expenditure model is integrated into a macro-economic model which takes account of the interconnections inherent in the economic system and provides a consistent forecasting procedure for application to policy questions.

Since BFI is one of the most volatile and least predictable components of aggregate economic activity, fluctuations in BFI spending have been a key determinant of business cycle movements in the post-war period. Thus, government stabilization policy has been oriented to a large extent toward counterbalancing this expenditure flow.

However, despite the importance to cyclical stability of these expenditures and the need to make intelligent predictions about the effects on BFI of particular government policies, the body of knowledge, both

---

[1]National Industrial Conference Board, "A New Survey of Capital Appropriations," The Conference Board Business Record, XIII (1956), pp. 418-34. The data are published quarterly in The Conference Board, "Quarterly Survey: Capital Appropriations," Investment Statistics, 1953-1965.

theoretical and empirical, concerned with BFI decisions has been somewhat unsatisfactory for policy making and short-run forecasting purposes. Most investment models recognize the importance of stock adjustment or accelator mechanisms on the determination of BFI. In addition, they have included interest rates, equity yields and flow-of-funds variables to account for the cost of funds to be raised for capital spending.

However, a principal difficulty encountered in past studies has been the determination of the appropriate time lag between the actual decision to add to the capital stock and the subsequent expenditure for new plant and equipment. Expenditures on a large investment, such as a new plant facility, take place over a period of twenty-four to forty-eight months, and during this period may be subject to changes in the original facility specifications and the prices of capital goods. Trying to determine the correct lag period between decisions to invest and the corresponding capital outlays is a hazardous process of empirical trial and error, with the final result usually arrived at by choosing the "best" statistical fit. The distributed lag formulations which arise in some models are beset by the presence of strong intercorrelations among the lagged variables, making accurate estimations of these formulations extremely difficult.

The approach to be employed here to eliminate much of this uncertianty about the lag structure is based on results reported by Shirley Almon.[2] Mrs. Almon has developed a method of determining the quarterly spending pattern of capital appropriations by estimating relationships which assign weights according to an inverted U pattern, relating capi-

---

[2]Shirley Almon, "The Distributed Lag Between Capital Appropriations and Expenditures," Econometrica, XXXIII, (January, 1965), pp. 178-197.

tal expenditures to appropriations made during the previous eight quarters. Thus, this approach phases appropriations into expenditures without introducing decision-expenditure lags into the behavioral relation itself. The decision process relevant for investment theory is shifted to the appropriations level. Here, the short-run cyclical movements of capital appropriations can be examined in the same manner as capital expenditures have been examined in previous studies.

The Appropriations Data

The NICB data are compiled, by survey, for only the 1000 largest manufacturing firms. This is not a real inconvenience however, since the cyclical variation in BFI is mainly due to fluctuations in the manufacturing sector.[3] Within manufacturing, the NICB coverage easily accounts for the majority of cyclical movement in BFI as illustrated in Figure 1.1. Non-NICB expenditures[4] are seen to be essentially constant during the period of the survey (1953-1965) and the variance around trend for expenditures of the 1000 largest manufacturers is almost eight times the variance of expenditures by small firms.[5] Thus, by examining in detail the fluctuations of NICB expenditures we can go a long way toward

---

[3]The variance of the deviations from a linear trend line for total manufacturing plant and equipment spending was 5.8 billion dollars versus 2.9 billion for the difference between the Commerce Department's (National Income Accounts) definition of BFI for the whole economy and total manufacturing expenditures as measured by the Office of Business Economics and the Securities and Exchange Commission (hereafter, OBE-SEC)

[4]Non-NICB spending is the difference between the OBE-SEC series on manufacturing investment and the NICB series.

[5]The variance around a linear trend for NICB spending was 4.75 and for non-NICB manufacturing investment was .61.

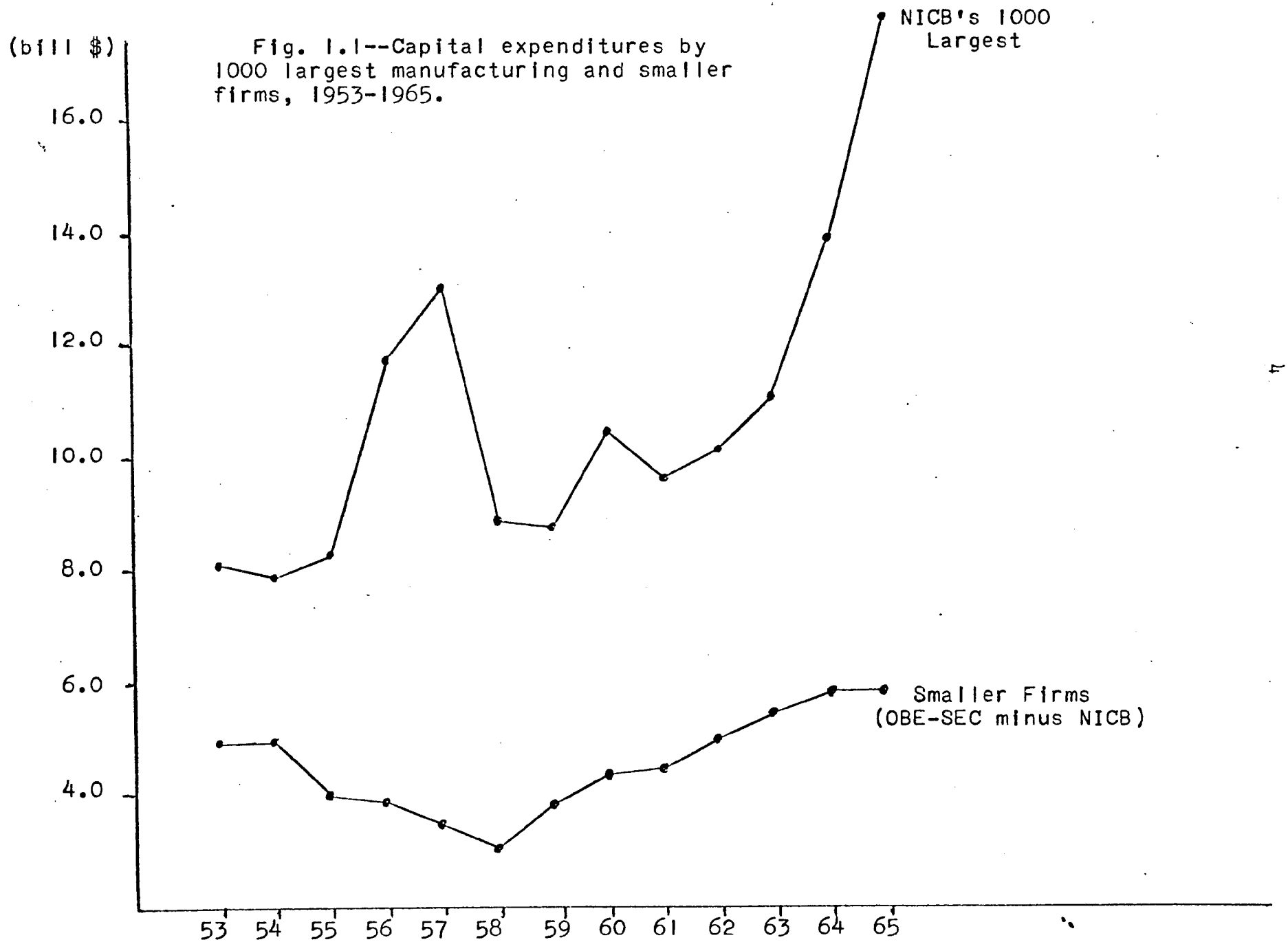


Fig. 1.1--Capital expenditures by 1000 largest manufacturing and smaller firms, 1953-1965.

explaining fluctuations in total BFI.

Appropriations data are reported quarterly along with expenditures, the appropriations backlog and cancellations of past appropriations. We are interested in annual movements and thus have added together the seasonally unadjusted quarterly data to construct annual series. Data combined in this manner are presented in Table 1.1 for expenditures, gross appropriations and the backlog of unspent appropriations. Appropriations and expenditures are plotted in Figure 1.2.

TABLE 1.1

CAPITAL EXPENDITURES, GROSS CAPITAL APPROPRIATIONS AND APPROPRIATIONS BACKLOG: 1000 LARGEST MANUFACTURING FIRMS, 1953-1965 (MILLIONS OF DOLLARS)

Year	Capital Expenditures	Gross Capital Appropriations	Backlog(EOP)[a]
1953	8,194	7,910	5,656
1954	7,937	7,688	5,276
1955	8,326	13,398	8,562
1956	11,833	14,316	9,856
1957	13,132	11,261	7,828
1958	8,873	8,113	6,078
1959	8,802	11,543	7,888
1960	10,585	10,306	7,022
1961	9,717	9,901	7,699
1962	10,187	11,688	8,407
1963	11,050	13,343	10,077
1964	13,853	17,934	13,346
1965	17,792	22,207	17,095

[a]End of Period

Source:

The Conference Board, "Quarterly Survey: Capital Appropriations," Investment Statistics, 1953-1965.

Inspection of Figure 2.1 shows clearly the anticipatory nature of appropriations relative to expenditures. The investment boom of 1956-57 is mirrored in the high levels of appropriations in 1955-56, with

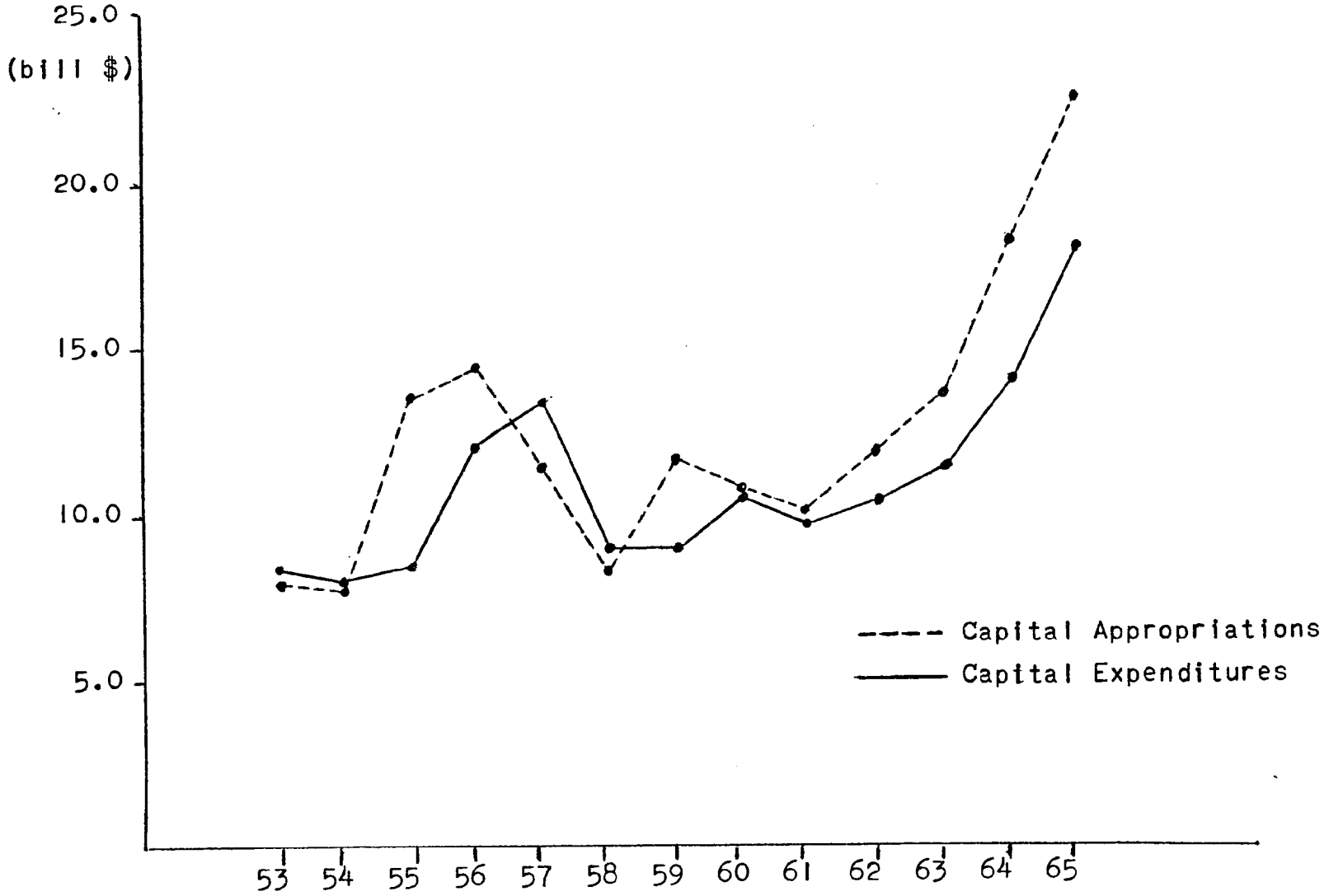


Fig. 1.2--Capital appropriations and capital expenditures by 1000 largest manufacturing firms, 1953-1965.

the sharp drop in new appropriations in 1957 precipitating the 1958 (and late 1957) expenditure decline. The climate for capital expansion is reflected by the movement of appropriations rather than expenditures, and thus emphasizing the relationship of investment determinants to appropriations is clearly a more meaningful way of studying investment behavior.

Outline of the Study

Our analysis will proceed along the following lines. In Chapter II, a short-run internal funds model similar to Duesenberry's[6] is developed to explain the nature of appropriations decisions. The gap between desired and actual capital stock, interest rates, the costs of internal funds and the share price of common stock are shown to be the relevant explanatory variables for appropriations. A linear distributed lag model is formulated as the mechanism which links appropriations decisions to capital expenditures.

Chapter III deals with the estimation and testing of the hypothesized structure for both aggregate and individual industry data. The appropriations and expenditure relationships are brought together and forecasts of expenditures are made as a further test of the applicability of the model.

Finally in Chapter IV, the capital expenditures structure is combined with the macro-econometric model used by the Research Seminar in Quantitative Economics at the University of Michigan (hereafter, RSQE Model) in order to study the impacts of investment spending on the whole

---

[6] James Duesenberry, Business Cycles and Economic Growth, (New York: Mc-Graw Hill, 1958).

economy. The forecasting record of the RSQE Model with appropriations included is shown to be better than the record of the same model when capital expenditures are determined by the OBE-SEC Capital Expenditures Survey.

CHAPTER II

THE STRUCTURE OF INVESTMENT BEHAVIOR

In this chapter we shall describe in detail the underlying determinants of investment decisions and the transmission of decisions into capital expenditures. Since we are using capital appropriations data, we can focus attention separately on decisions and expenditures, and thus divide the study into two parts.

First, the factors affecting decisions will be analyzed and combined into a behavioral framework for forecasting appropriations. The theory underlying this specification is well-known and no attempt will be made to venture into new theoretical ground. Recent writings have extensively examined the determinants of investment decisions.[1] Our model will be a synthesis of current thought on the subject and will incorporate a form of the accelerator and a financial theory of investment into the determination of appropriations.

Second, the relationship of appropriations to capital expenditures will be examined and expenditures will be explained by a distributed lag function of capital appropriations.

This dual approach will place the emphasis of investment theory where it properly belongs -- on investment decisions. The problem of

---

[1]See R. Eisner and R.H. Strotz, "The Determinants of Business Investment" in Impacts of Monetary Policy, prepared for the Commission on Money and Credit (Englewood Cliffs, N.J.: Prentice-Hall, 1963), for a thorough bibliography on investment theory.

timing, inherent in the pattern of capital spending, will be excluded from the decision model and be explained independently of the factors affecting decisions.

Determinants of Capital Appropriations

Decisions to undertake capital expansion projects are made by individual firms after an evaluation of their current situation with respect to certain economic factors and their expectations about the future. Some of the factors can be directly influenced by the firm, e.g. pricing and output policy and financial policy, while other factors, such as interest rates and prices of capital goods, are outside of the firm's control. The outside or exogenous factors vary in the aggregate as all firms in the economy (or an industry) implement their own policies but individual firms make decisions acting as if the exogenous factors were independent of their own decisions. Expectations about outside conditions affect the decision process, but the expectations are formulated internally and, of course, may be wrong. Thus, the theory of investment decisions should be formulated at the micro-economic level in order to establish a foundation which can be extended to the study of macro-economic fluctuations in investment decisions.

In this context, it is best to think of the level of appropriations during a year as being determined in an internal (within the firm) market for investment funds. The demand for funds will depend on the potential return from available investment projects, summarized in the marginal efficiency of investment schedule (hereafter, mei). The supply of funds depends on the cost of obtaining funds, represented by a marginal cost of funds schedule (hereafter, mcf). Motivated by profit max-

imization, the firm will appropriate funds for investment projects so as to equate the marginal rate of return with the marginal cost of obtaining funds.

Our main interest will center on the conditions encountered by the firm at decision time which determine the slope and position of the two schedules. The succeeding analysis will show that the mei schedule depends mainly on capacity utilization represented by a flexible accelerator mechanism and the mcf schedule depends on the firm's internal financial position and the cost of funds obtained from external sources.

The development of the theory underlying the mei schedule proceeds along the lines suggested by Duesenberry.[2] Potential expansion projects are evaluated according to the returns expected from them during their estimated useful lifetimes. Expected returns are linked to technology, capital intensiveness of production, and capacity utilization through the effects of these factors on the firm's cost and revenue structure. The basic motivation for plant expansion is the ability to lower the marginal cost curve by increasing capacity.

The decision to go ahead with an investment project can be viewed as a decision to buy a lower marginal cost curve.[3] The new cost curve will provide increased revenue net of variable cost from two sources. First, the output currently being produced by the firm can now be turned out with lower variable cost. Second, there will be increased net revenue from output expansion, the size of the increase depending on the elasticity of demand for the firm's products.

This expected increase in net revenue spread over the life of the

---

[2] Duesenberry, Business Cycles, Chapter 4.

[3] Ibid., p. 52

investment is discounted against the current cost of the project. The rate of discount needed to equate future earnings with the present value of the project is the project's rate of return.

After rates of return are computed for a series of projects, the potential investments are arrayed in the descending order of their marginal efficiencies resulting in a downward sloping mei curve. The projects offering the highest return will be exploited first and those of lowest return only if conditions allow for a high level of appropriations.[4]

Additions to a firm's capital stock are either for replacement needs or expansion needs. Some projects serve both purposes, as when a new machine with a larger productive capacity is purchased to replace an older, obsolete machine used in the past for the same function. Though replacement and expansion components cannot be explicitly separated, it is usually true that the older a firm's capital stock, the larger will be the expected return from additions to the stock.[5] Thus, the mei schedule is related positively to the age of the capital stock.

Conditions which make additions to capital profitable (whether capital deepening or capital widening) are related to the concept of a long-run desired or equilibrium capital stock. The equilibrium stock (K*)[6] is determined by the techniques of production available to the firm, the relative prices of factor inputs including capital and the level of output the firm expects to produce. If the desired stock is

---

[4] Ibid., p. 52.

[5] Ibid., p. 59.

[6] K* is used here as an expository device which conveniently summarizes a firm's motivation to enlarge capital stock. There is no reason to believe K* will ever be reached.

greater than the current stock, the firm will appropriate funds for additional capital in an effort to reduce the size of the gap. That is, lower cost curves are available which can be profitably employed by the firm.

Capital is an input to the productive process and its use is governed by traditional marginal productivity theory. If we assume as given the amount of other necessary factors, the level of expected output, and the production function, there is a relationship between capital's marginal physical product (MPPK) and the size of the capital stock based on the law of diminishing returns, i.e. MPPK falls as K increases. If, as is traditionally assumed, the "real" price of capital is invariant with respect to the size of K, the desired capital stock is determined at the point of equality between the "real" price of capital and its MPPK, as depicted in Figure 2.1.

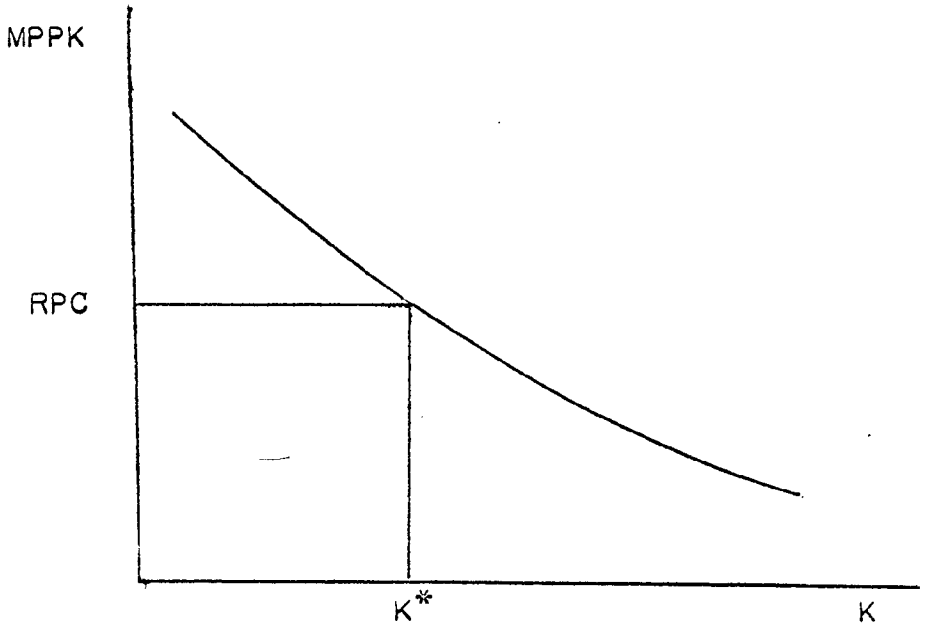


Fig. 2.1--Marginal physical product of capital schedule.

The "real" price of capital should be a measure of the current cost of the services of a unit of capital. Thus, a definition like Hickman's[7] which includes both the interest rate and depreciation rate would seem to apply. His formulation accounts for the opportunity cost of maintaining part of a firm's assets in real capital (the long-term interest rate) and the average rate of deterioration of capital (depreciation rate) both valued at the current market price of capital goods. This money price of a unit of capital services is then deflated by the price of output to get the "real" price of capital (RPC),

$$(2.01) \qquad RPC = \frac{P_k(r_1 + d)}{P_Q}$$

where P_k = market price of capital goods,

r_1 = long-term market rate of interest,

d = average depreciation rate,

P_Q = price level of output.[8]

---

[7] Bert G. Hickman, Investment Demand and U.S. Economic Growth, (Washington D.C.: The Brookings Institution, 1965), pp. 28-30.

[8] The equilibrium condition RPC = MPPK is equivalent to the condition that the marginal efficiency of capital (mec) equal the interest rate (r). The cost of a one-period investment will be equal to

$$(i) \qquad P_k = \frac{MPPK \cdot P_Q + sP_k}{(1 + r)}$$

if its rate of return equals the interest rate. The dollar value of P_k is divided between its discounted return in output ($MPPK \cdot P_Q$) and its discounted remaining service value, sP_k, where s (=(1 - d)) is the survival rate.

For a two period investment, P_k equals

$$(ii) \qquad MPPK \cdot P_Q\left\{\frac{1}{(1 + r)} + \frac{s}{(1 + r)^2}\right\} + \frac{s^2 P_k}{(1 + r)^2}$$

if the discounted output from P_k is $\frac{MPPK \cdot P_Q}{(1 + r)}$ in the first period,

Since P_k and r_1 are exogenous to the firm, while the depreciation rate varies little with respect to the size of K[9] and product prices are relatively inflexible in the oligopolistic structure of most manufacturing industries, the perfectly elastic RPC curve is probably a good approximation of capital costs for the determination of K*. However, we shall argue below that short-run considerations, which are more relevant to the determination of annual appropriation levels, introduce a vari-

---

$\frac{sMPPK \cdot P_Q}{(1+r)^2}$ in the second period, and the discounted remaining service value of P_k is $\frac{s^2 P_k}{(1+r)^2}$.

An n-period investment is valued at

$$\text{(iii)} \qquad P_k = MPPK \cdot P_Q\{\frac{1}{(1+r)} + \frac{s}{(1+r)^2} + \frac{s^2}{(1+r)^3} + \ldots + \frac{s^{n-1}}{(1+r)^n}\} + \frac{s^n}{(1+r)^n} P_k.$$

Solving for MPPK gives

$$\text{(iv)} \qquad MPPK = \frac{P_k}{P_Q}\{1 - \frac{s^n}{(1+r)^n}\} \cdot \frac{1}{\frac{1}{(1+r)} \sum_{i=1}^{n} \frac{s^{i-1}}{(1+r)^{i-1}}}.$$

Since the sum of the first n terms of a geometric series is $T_n = \frac{1 - t^k}{1 - t}$, (iv) can be written as

$$\text{(v)} \qquad MPPK = \frac{P_k}{P_Q}\{1 - \frac{s^n}{(1+r)^n}\} \cdot \frac{(1+r)\ \{1 - (\frac{s}{1+r})\}}{(1 - \frac{s^n}{(1+r)^n})}$$

which simplifies to

$$\text{(vi)} \qquad MPPK = \frac{P_k}{P_Q}(1+r)\ (\frac{1+r-s}{1+r}) = \frac{P_k}{P_Q}(r+(1-s)).$$

Since (1-s) = d, (vi) is equivalent to RPC as defined in (1).

[9] A common assumption in models of investment behavior is that the level of capital depreciation is proportional to the capital stock.

able cost of capital in the form of the marginal cost of funds schedule. To maintain the flavor of the flexible accelerator theory of investment, we shall allow capital requirements to be determined by the difference between the desired and actual capital stock, but superimpose upon it considerations about internal financial factors which affect investment decisions.

In order to introduce K* formally as a determinant of mei, we write

$$K^* = f(Y^e, RPC, W/P) \tag{2.02}$$

to represent the determinants of K*. Desired capital increases with expected output (Y^e), decreases with the RPC and rises with the real wage (W/P), (representing the cost of other factors). The functional notation, f, indicates the current technology embodied in the production function.

The mei schedule is positively related to the difference between K* and K. An increase in K* means that the rate of return on all available investment projects will rise in response to the potential net revenue gain to be obtained by increasing K. Thus, the demand for investment funds, through its dependence on (K*- K), depends on the determinants of K*.

One modification of this proposition should be mentioned since we are dealing with appropriations rather than actual additions to K. Because appropriations are not instantly transformed into physical capital, we should add to the existing physical stock the sum of past appropriations which are still unspent. This backlog of unspent appropriations (B) must be looked upon as part of the current capital stock when new appropriations are being considered. The inequality then is between K* and (K + B).

Most theories of investment, including flexible accelerator theories, focus on expected output as the primary determinant of K*, thus assuming a constant desired capital output ratio over time.[10] The final form of the model under consideration here will maintain this emphasis on capital widening as the primary motivation for investment, but will modify somewhat the assumption of a fixed capital output ratio.

If we assume constant returns to scale, (2.02) can be written as

$$K^* = \eta(RPC, W/P) \cdot Y^e, \tag{2.03}$$

and the desired capital output ratio depends on the production function, the RPC and the real wage rate. Combining (2.03) with our earlier discussion, the mei is expressed as

$$\begin{aligned} mei &= g\{(K^* - (K+B)), R, CA\} \\ &= g\{(\eta(RPC, W/P) \cdot Y^e - (K+B)), R, CA\}, \end{aligned} \tag{2.04}$$

where R = replacement demand

CA = capital appropriations

and,

$$\frac{\partial mei}{\partial RPC} < 0, \quad \frac{\partial mei}{\partial W/P} > 0, \quad \frac{\partial mei}{\partial Y^e} > 0, \quad \frac{\partial mei}{\partial (K+B)} < 0, \quad \frac{\partial mei}{\partial R} > 0, \quad \frac{\partial mei}{\partial CA} < 0. \tag{2.05}$$

We can now introduce the determinants of the supply of funds into the analysis. The relationship developed for the mei schedule (2.04) will be combined with the factors affecting the marginal cost of funds to form the complete internal supply and demand system for appropriations. The outline of the theory of investment funds presented by Duesenberry[11]

---

[10] Two classic theoretical articles on the flexible accelerator are Hollis B. Chenery, "Overcapacity and the Acceleration Principle," Econometrica, XX, (January, 1952), pp. 1-20; R.M. Goodwin, " The Non-Linear Accelerator and the Persistence of Business Cycles," Econometrica, XIX, (January 1951), pp. 1-17.

[11] Duesenberry, Business Cycles, Chap. 5.

and the more explicit version developed by Anderson[12] form the basis for the following discussion.

Business firms are faced with several alternative sources when seeking funds for capital expenditures. Each alternative source has a cost associated with it which must be compared with the return expected on the proposed investment project. The costs vary with the type of financing and are both implicit and explicit to the firm.

The major sources of funds are the expected flow of gross retained earnings (gross of depreciation allowances), the current stock of liquid assets (defined here as cash plus short-term government securities), external funds from commercial banks or the corporate bond market and the issue of new equity.

The implicit cost of investment funds is related to the relative riskiness of the firm's overall balance sheet position. If the firm is holding too much debt (in its own estimation) it feels the threat of insolvency. If it holds too little liquidity, it risks a cash shortage. This implies that the marginal cost of funds is related to the difference between the actual and desired stock of debt ($D - D^*$) and the actual and desired stock of liquid assets ($L - L^*$). It is this implicit cost, which rises as the amount of appropriated funds increases, that causes the mcf schedule to have a positive slope, even if the firm faces perfect external capital markets.

In addition to these subjective costs there are explicit costs attached to some funds in the form of market rates of interest. Converting liquid assets into capital assets involves giving up the return being

---

[12] W.H. Locke Anderson, Corporation Finance and Fixed Investment, (Cambridge, Mass.: Harvard University Press, 1964).

earned on government securities. Issuing corporate bonds or obtaining bank loans involves paying interest charges.

To solidify the general observations of the preceding few paragraphs, we shall examine in turn each of the major sources of funds and their associated costs.

Most readily available for investment financing are the funds incorporated in the flow of gross retained earnings (RED). The costs associated with using these funds are based on their potential alternative uses. Cash flow can be used to increase liquidity by buying treasury bills. By diverting gross retained earning from liquid assets into capital expenditures, the firm gives up the return on treasury bills and incurs the subjective cost attached to the loss of safety. The latter cost will be higher the closer the current stock of liquid assets is to the desired minimum. Gross retained earnings can also be used to repay outstanding debt. The cost of not repaying debt is higher the closer the actual stock of debt is to the desired maximum. Thus, the cost of using gross retained earnings depends on $(L - L^*)$, $(D - D^*)$ and the treasury bill rate.

There is another implicit cost associated with the determination of the size of the pool of retained earnings. Keeping profits in the business as opposed to paying them out in dividends involves a cost in the form of unhappy stockholders. However, secular changes in dividend policy occur slowly so that their short-run effect on potential investment funds can be ignored. We assume that the dividend pay-out rate is adjusted very slowly and that fluctuations in retained earnings are dominated by fluctuations in profits and are little affected by changes in dividend policy.[13]

---

[13]Duesenberry, Business Cycles, p. 101.

A second source of internal funds is the firm's current stock of liquid assets. The cost of reducing liquid balances to finance capital spending depends on the difference between actual and desired liquidity, and on the bill rate. A firm maintains a certain stock of cash balances and highly liquid securities in order to meet its expected cash requirements. Firms can estimate expected demands on liquidity with some degree of accuracy, since a large part of these demands are determined in advance by policy or law. Payments on tax liabilities are certainly easily predictable. Dividend policy is set by the firm and is relatively static. The desired stock (L*) consists of allowances for these components. But, since liquidity is required to carry out the normal operations of the firm, there must also be an allowance for less predictable liquidity needs. Thus, firms also hold an additional component of L* in the form of buffer stocks of liquidity to guard against unexpected drains on cash balances. Desired liquidity then depends on the level of operations,[14] tax liabilities and dividend payments. The composition of L* between governments and cash will depend on the imminence of payment.[15] Excess liquidity (L - L*) will be held in the form of government securities and is available for capital financing at the cost of the return from those securities. To the extent that liquid balances are managed closely, the opportunity cost of using them for capital expenditures will be high.

Once available internal funds have been exhausted by appropriations,

---

[14]The term "level of operations" encompasses liquidity needs for repayment of accounts payable and short-term debt.

[15]See W.J. Baumol, "The Transactions Demand for Cash: An Inventory Theoretic Approach," Quarterly Journal of Economics, LXVI, (November, 1952), pp. 545-56.

the firm has the option of turning to outside sources for funds. This will occur only if the expected return on remaining investment projects is no smaller than the cost associated with obtaining external funds. The interest rate paid for the use of these funds is part of the cost of borrowing in external markets.[16] But the cost of external funds also depends on the relationship of the actual stock of debt to the desired stock. The implicit cost of incurring more long-term liabilities to pay for physical capital is the subjective attitude of management toward increasing balance sheet risk.[17] Thus the cost of debt financing depends on $(D - D^*)$ and the long term rate of interest.

A second source of external funds is the issue of new equity shares. The cost of this type of financing, the current return being earned by outstanding shares, is usually higher than the cost of other forms of finance.[18] New shares will not be issued for investment financing unless the return on the marginal projected expenditure meets or exceeds the return currently being earned by shareholders. Since the new shares reduce average earnings per share, the proposed expansion must have an expected return at least as large as current earnings per share in order to be justified.

Before combining a formal statement of the determinants of mcf with (2.04), it will be useful to consider briefly the shape of the mcf curve.

The source (or combination of sources) the firm chooses for capital

---

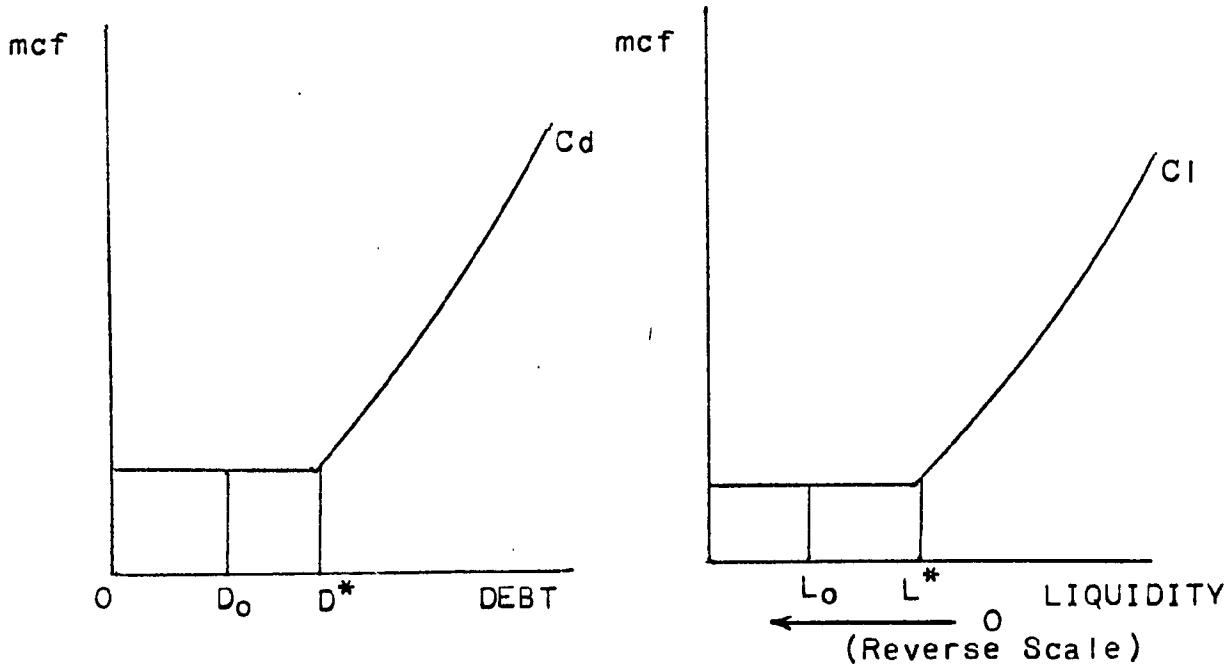
[16] Non-price rationing techniques by commercial banks may override price (interest rate) rationing in allocating funds during tight money. This effect is probably most pronounced among smaller firms who do not have the higher credit ratings of larger or more established firms.

[17] The desired stock of debt seems to depend primarily on the size of the firm. See Anderson, Fixed Investment, p. 46

[18] Duesenberry, Business Cycles, p. 95.

financing depends on the relative cost of each source at the time the funds are appropriated. Relative costs will, as we have seen, vary with the firm's balance sheet position and the level of interest rates.

Figures 2.2a and 2.2b illustrate the shape of separate mcf curves for the balance sheet funds sources -- debt and liquidity. The mcf curves are drawn for a given level of interest rates and desired stocks.



2.2a 2.2b

Fig. 2.2--Marginal cost of funds for debt and liquidity stocks.

Since the minimum cost of borrowing is the long-term interest rate (r_l), D has a constant height until D = D*.[19] A value of D to the left of D* (say D_0) represents a position of excess debt capacity (D* - D_0).

[19]The cost may actually rise before D = D*, if firms feel less safe when they anticipate reaching the safe debt limit. If that were the case we could simply define D* (and L*) to be the value of the stock at which mcf rises above the simple interest cost. The analysis of mcf will be the same in either case.

A firm in this situation can expand debt to D* at the cost of current interest rate charges. Once D* is reached, the cost of debt financing increases sharply above r_1, reflecting the firm's aversion to carrying debt above D*.

A similar argument holds for Figure 2.2b. Only here, the short-term interest rate determines the height of the curve until liquidity is reduced to L* (by moving to the right on the reverse scale). Excess liquid balances (L_0 to the left of L*) are available at a cost of r_s. When excess liquidity is exhausted, the cost of further reducing L rises rapidly.

When funding decisions are made there will be a pool of minimum cost funds (M) available from expected gross retained earnings, excess debt capacity and excess liquidity, i.e. $M = RED^e + (D^* - D) + (L - L^*)$. The size of this pool will vary with changing internal financial conditions as $(L - L^*)$ and $(D^* - D)$ fluctuate from positive to negative values and RED^e varies over the business cycle. When all of M has been appropriated and the mei is still above mcf, funds have to come from expansion of debt beyond D* or reduction of L below L* and thus subjective costs are incurred along with explicit interest charges.

Both D_0 and L_0 can be beyond the subjective limits imposed by D* and L*, i.e. $L_0 < L^*$ and $D_0 > D^*$. In either (or both) of these situations, mcf is already above the minimum cost imposed by interest rates and these changes in the stocks of debt and/or liquidity lead to large incremental changes in the cost of funds.

This suggests an mcf schedule shaped like the one in Figure 2.3. It rises slowly from r_s to r_1 as the firm uses minimum cost funds to

supply OM of appropriations.[20] At M, minimum cost funds are exhausted, and the mcf curve slopes sharply upward as funds are acquired by increasing financial risk. The slope of the segment ME will be the slope obtained by adding the Cd and Cl mcf curves of Figure 2.2 horizontally. The mcf curve will be more elastic (with respect to CA) in the ME range, the more elastic are both the curves in Figures 2.2a and 2.2b when $D > D^*$ and $L < L^*$.

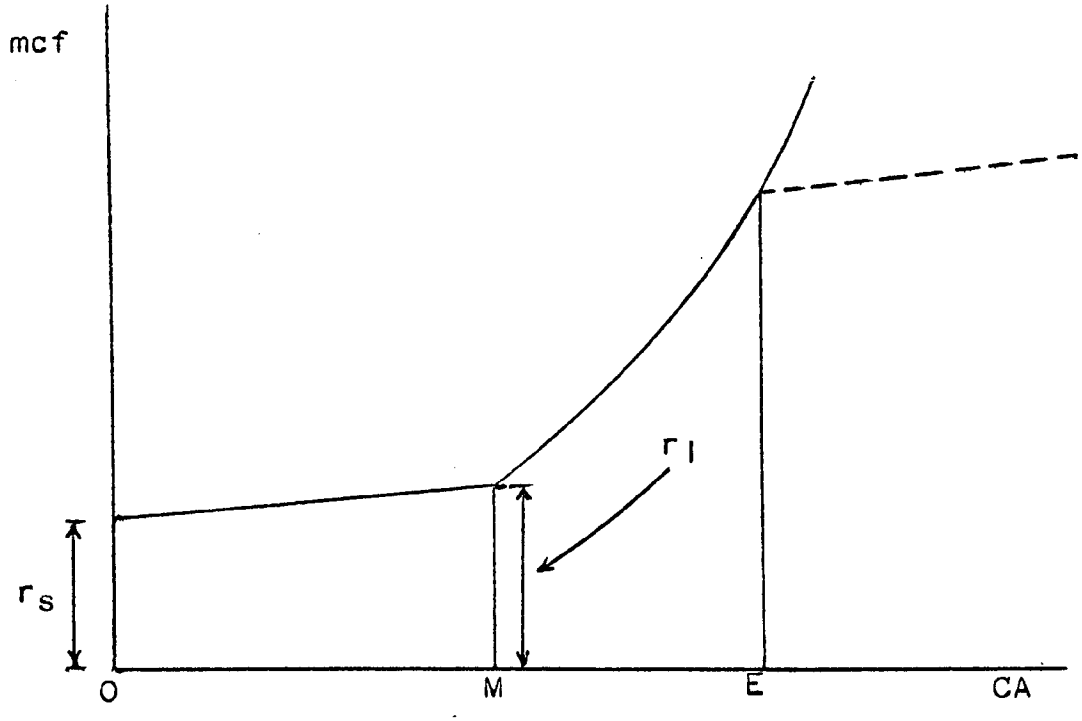


Fig. 2.3--Marginal cost of funds schedule.

At some point in the rising range of the mcf schedule, the subjective cost of funds will equal the cost of issuing new equity. This new source of funds will add a relatively inelastic range to the schedule (the dot-

[20]This assumes a yield structure with short rates below long rates. If the opposite yield structure prevails, excess debt capacity could be used at a lower cost than RED.

ted line in Figure 2.3), since some amount of new equity can be issued with little effect on the earnings-price ratio.

The above arguments lead to a supply of funds schedule which can be expressed as

(2.06) $\quad mcf = h(RED^e, (D - D^*), (L - L^*), E, r_s, r_l, CA),$

where E is the cost of issuing new equity and the other variables are as defined above. The partial derivatives of (2.06)

(2.07) $\quad \frac{\partial mcf}{\partial RED^e} < 0, \frac{\partial mcf}{\partial (D-D^*)} > 0, \frac{\partial mcf}{\partial (L-L^*)} < 0, \frac{\partial mcf}{\partial E} > 0, \frac{\partial mcf}{\partial r_s} > 0,$

$\frac{\partial mcf}{\partial r_l} > 0, \frac{\partial mcf}{\partial CA} > 0.$

Combining (2.06) with (2.04), to form the reduced form solution for the internal funds market, involves setting mei = mcf and solving the resulting equation for CA. If we let the funds market be represented by

(2.08a) $\quad mei = g(CA,D)$

(2.08b) $\quad mcf = h(CA,S)$

(2.08c) $\quad mcf = mei$

where D and S are the determinants of the position of the mei and mcf schedules respectively, then, using (2.08c), we can write

(2.08d) $\quad g(CA, D) = h(CA, S)$

and

(2.08e) $\quad CA = \phi(D, S)$

as the solution for CA.

Letting $(K^* - (K+B)) + R = CR$ (capital requirements), the solution for CA based on the preceding discussion will be

(2.09) $\quad CA = \phi(CR, RED^e, (D-D^*), (L-L^*), E, r_s, r_l).$

The form of (2.09) used to predict CA will be defined explicitly in Chapter III.

The Relationship of Capital Appropriations to Capital Expenditures

Once appropriations have been determined by (2.09), the next step is to develop a mechanism which converts appropriations into investment expenditures. Fixed investment spending during a given time period reflects appropriations approved in that time period as well as appropriations approved on earlier dates. The structure of the expenditure-appropriation relationship depends on the mix between short delivery time investments (most of producers' durable equipment) and longer delivery time investments (business construction, special order capital equipment, etc.), and the level of capacity utilization in the capital goods industry. The effect of these factors on expenditures can be approximated by a distributed lag function of capital appropriations.

Since the question of the structure or profile of the distributed lag is of prime interest here, and because this is really an empirical question, the focus of this discussion will be on recent empirical studies which have estimated this lag structure. Particular attention is placed on papers by Shirley Almon[21] and Joel Popkin,[22] both of whom have worked directly with capital appropriations data.

The general fixed coefficient distributed lag function can be written

$$(2.10) \qquad CE_t = \sum_{i=0}^{n} \alpha_i CA_{t-1} + u_t,$$

where CE_t = capital expenditures in t,

CA_{t-i} = capital appropriations in $t-i$,

α_i = ith lag coefficient,

---

[21] Almon, "Distributed Lag."

[22] Joel Popkin, "Comment on 'The Distributed Lag Between Capital Appropriations and Expenditures,'" Econometrica, XXXIV, (July, 1966), pp. 719-24.

u_t = random disturbance term.

The presence of multicollinearity in (2.10) makes direct estimation of the α_i's unreliable. In order to achieve parameter estimates which have some validity, a priori assumptions about the lag profile must be made. Almon estimates (2.10) with quarterly observations and assumes the lag profile follows an inverted U distribution.[23] Her results are quite good according to the standard statistical tests, the best fit for total manufacturing being an eight quarter lag on appropriations. The distributed lag equation she obtained was

$$(2.11) \quad CE_t = \underset{(.023)}{.068CA_t} + \underset{(.017)}{.122CA_{t-1}} + \underset{(.013)}{.156CA_{t-2}} + \underset{(.021)}{.168CA_{t-3}} + \underset{(.022)}{.157CA_{t-4}}$$
$$+ \underset{(.014)}{.127CA_{t-5}} + \underset{(.017)}{.084CA_{t-6}} + \underset{(.023)}{.037CA_{t-7}} - \underset{(48.0)}{113\ BLC}$$
$$+ \text{seasonal dummies} \qquad \bar{R} = .933.$$

The lag profile indicated by (2.11) is plotted in Figure 2.4a along with the cumulative distribution of expenditures in Figure 2.4b. In Figure 2.4a, the inverted U nature of the profile is apparent as an almost symmetric array around t-3. The distribution is slightly skewed to the right, but (as we shall see below) not nearly so much as Popkin's. Over half (51.4%) of a quarter's appropriations are realized in expenditures within four quarters of approval as shown in Figure 2.4b. By the ~~end~~ of eight quarters, 91.9% have been expended. The remaining 8% approximates the average cancellation rate over the period of Almon's estimates.

BLC in (2.11) is a dummy variable which accounts for the unusually high capacity pressure on the capital goods sector during 1956-57.[24]

---

[23] Almon's Lagrangian interpolation method is described in Almon, "Distributed Lag," pp. 179-181.

[24] Ibid., pp. 189-190.

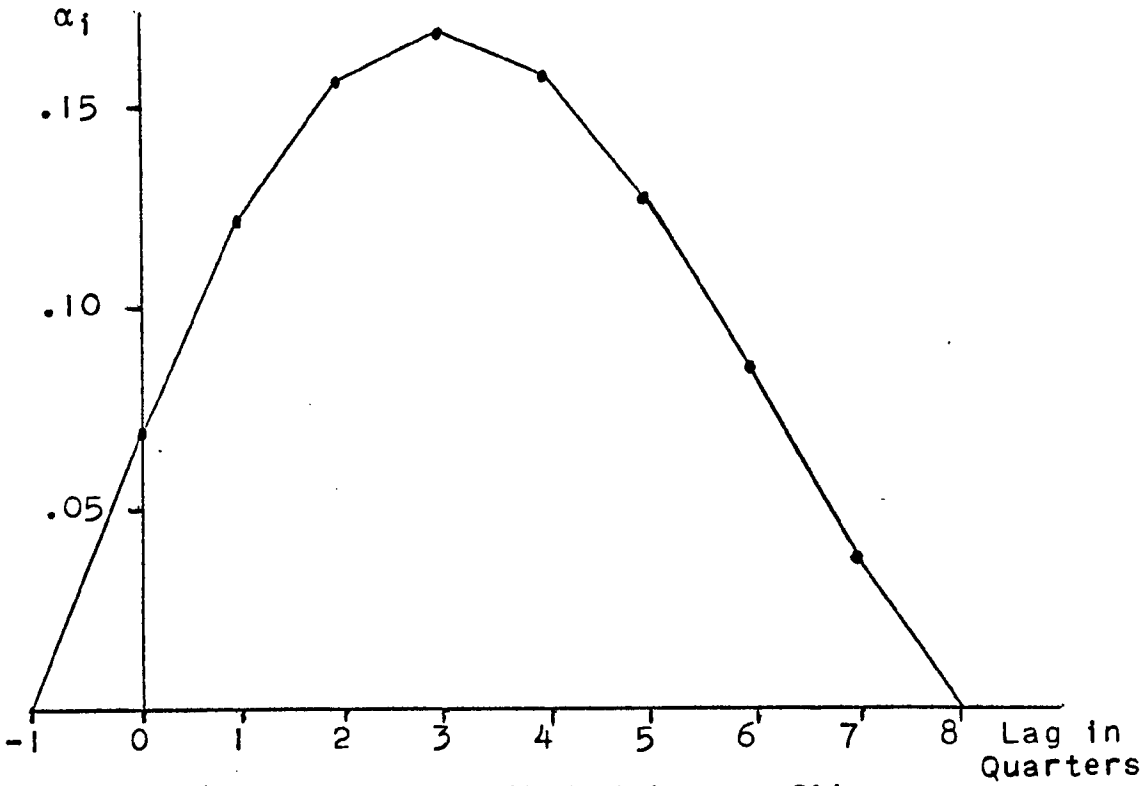


Fig. 2.4a--Almon distributed lag profile.

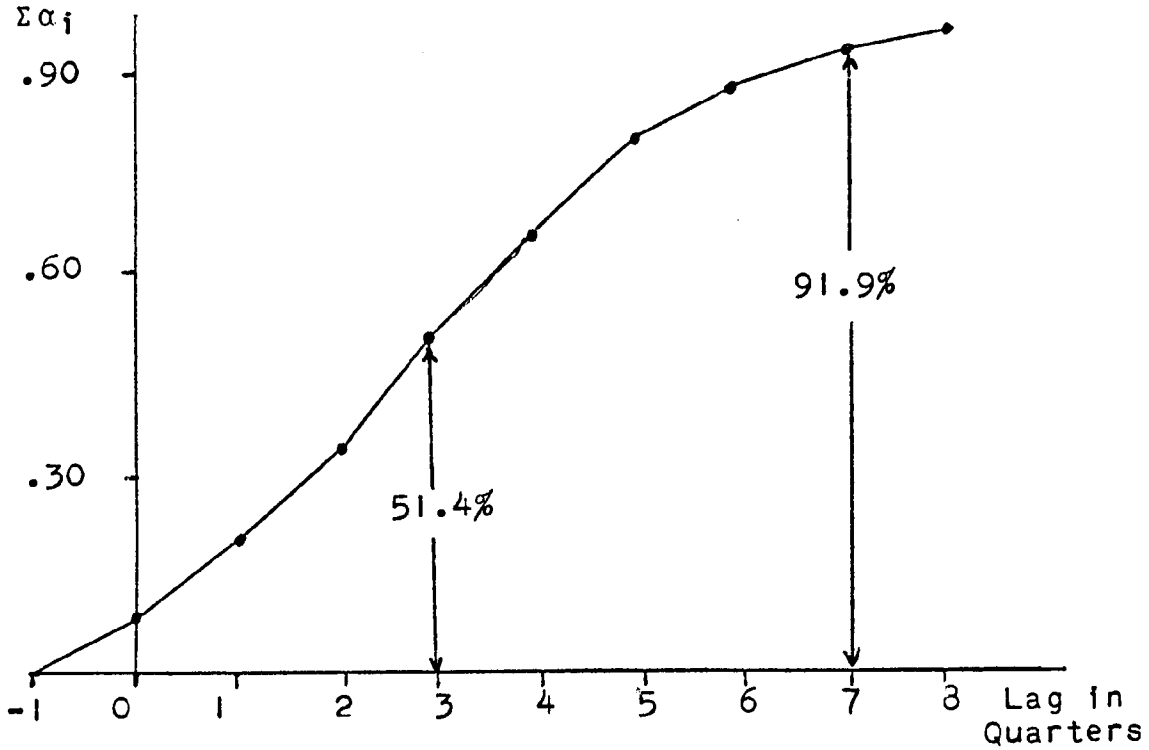


Fig. 2.4b--Cumulative Almon distributed lag profile.

This was the only attempt Almon made to explain possible changes in the lag structure during periods of capital goods shortages.

Popkin introduces variable coefficients directly into his lag structure to account for capacity pressure on delivery time. The lag structure in his model is much simplified from the more general form estimated by Almon. He explicitly introduces only two (adjacent) lagged values of appropriations into the lag function. His variable lag model is formulated as follows:

$$(2.12) \qquad CE_t = \alpha_{1,t} CA_{t-i} + \alpha_{2,t} CA_{t-i-1},$$

$$(2.13) \qquad \alpha_{1,t} = \beta_0 + \beta_1 (B/CE)_{t-1},$$

$$(2.14) \qquad \alpha_{2,t} = 1 - \alpha_{1,t-1} = 1 - \{\beta_0 + \beta_1 (B/CE)_{t-i-1}\}.$$

Substituting (2.13) and (2.14) into (2.12), results in

$$(2.15) \qquad CE_t = \beta_0 \Delta CA_{t-i} + \beta_1 \Delta\{(B/CE)_{t-i} (CA)_{t-i}\} + 1.0 CA_{t-i-1}.$$

The variable (B/CE) represents the ratio of appropriations backlog to capital expenditures, a measure of the build-up of orders for capital goods. The higher the ratio, the more strain on capacity and the longer the delivery time, so that $\beta_1 < 0$. Equation (2.14) assumes that appropriations left over from t-i will be converted into expenditures in the next time period.[25]

To estimate (2.15) Popkin assumes there is a lag between appropriations and orders of about two quarters. Thus, he fixed t-i as the midpoint between the t-2 and t-3 quarter and t-i-1 as the midpoint of the t-4 and t-5 quarter. Given these values for the lag pattern of (2.15)

---

[25] Popkin modifies this assumption by letting the coefficient on CA_{t-i-1} be determined by the regression. The resulting value (.78) becomes the constraining value for the sum $(\alpha_{1,t-1} + \alpha_{2,t})$. Popkin, "Comment," pp. 720-21.

his estimate yields the lag profile pictured in Figure 2.5. The values of α_i are calculated from (2.13) and (2.14), and the α_i's plotted in Figure 2.5 are those at the mean value of $(B/CE)_{t-i}$.

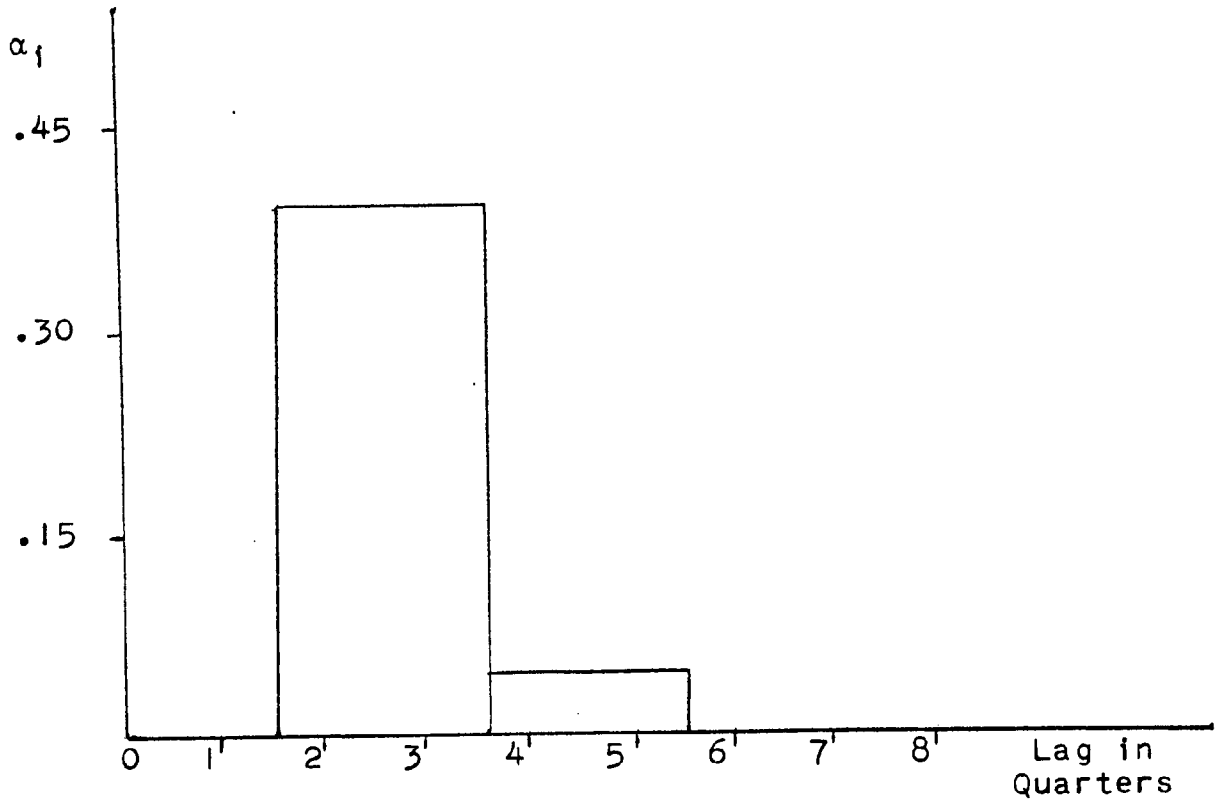


Fig. 2.5--Popkin distributed lag profile.

The lag structure in Figure 2.5 is more heavily weighted toward recent lagged values than Almon's (72% by t-3 versus 51.4% by t-3 in Almon's equation), implying a quicker response of expenditures to appropriations. Popkin considers this result justified by the large (72% from 1959 to 1964) fraction of capital expenditures accounted for by machinery and equipment (short delivery time investments).[26]

Other studies which have paid special attention to the lag properties of investment spending have found that inverted U type lag struc-

---

[26] Ibid., p. 6.

tures seem to fit better than simple Koyck lags or other possible structures. DeLeeuw,[27] Jorgenson,[28] and Griliches[29] have estimated the lag structure using only expenditure data and concluded that the lag profile with the best statistical fit has an inverted U shape. However, the skewness of the distribution and the total length of the lag vary from one study to another, depending upon the initial assumptions made about the distribution.[30]

The major point of the above discussion is that a lag structure approximated by an inverted U distribution seems to best explain the appropriation-expenditure lag. Only Popkin's simplified structure (to allow for variable lag coefficients) does not directly lead to an inverted U.

Support for the inverted U profile is based on estimations made with quarterly data. In this study we are using annual observations and thus will not be able to define the lag structure as finely as the quarterly studies. However, we will be in a position to estimate the α_i's in (2.10) with less fear of multicollinearity. Thus, rather than fixing the shape of the lag profile *a priori*, we will estimate the α_i's freely and observe whether an inverted U lag profile is the result. The details of the estimation will be discussed thoroughly in Chapter III.

---

[27]Frank DeLeeuw, "The Demand for Capital Goods by Manufacturers: A Study of Quarterly Time Series," Econometrica, XXX, (July, 1962), pp. 407-424.

[28]Dale W. Jorgenson, "Anticipations and Investment Behavior" in J.S. Duesenberry, et. al., The Brookings Quarterly Econometric Model of the U.S., (Chicago: Rand McNally, 1965), pp. 35-95.

[29]Z. Griliches and N. Wallace, "The Determinants of Investment Revisited," International Economic Review, VI, (September, 1965), pp. 311-329.

[30]See Griliches and Wallace for a striking comparison between their lag profile and one obtained from Jorgenson's results. Ibid., p. 322.

An equation based on Popkin's (2.15) will also be tested. However, it is expected that annual data will not reflect the variable lag structure as well as quarterly time series.

CHAPTER III

EMPIRICAL EVIDENCE ON THE INVESTMENT STRUCTURE

This chapter will be devoted to the statistical estimation of the model developed in Chapter II and a partial evaluation of its predictive ability. The model, summarized in equations (2.09) and (2.10), will be judged by the usual statistical criteria for goodness of fit and by the ability of the estimated structure to forecast investment expenditures. In this chapter, the forecasting test will be carried out by combining recursively estimates of (2.09) and (2.10) to predict expenditures during the sample period. A more comprehensive test of the model's predictive ability will be carried out in Chapter IV, where the equations are incorporated into a full model of income determination.

We shall divide the discussion in this chapter into three sections. The first will be concerned with the specification and estimation of the capital appropriations function, (2.09). This, of course, is the most important relationship in the structure and will accordingly receive the most attention in what follows. The second section will be a discussion of the estimates of (2.10) with special attention focused on their similarity to the lag profiles discussed at the end of Chapter II. Finally, the forecasting record of the estimated equations will be examined.

In deference to the form of the income determination model used in Chapter IV,[1] the equations will be estimated from annual observations

---

[1] Daniel B. Suits, "Forecasting and Analysis with an Econometric Model," American Economic Review, LII (March, 1962), pp. 104-132.

which have been first differenced. The constraint of an annual time period will force a considerable oversimplification to be placed on the lag structure which might be present in (2.09)[2] and is certainly present in (2.10).

The inability to examine the detail of any within-year lag response in these equations is regretable. In the case of (2.09) there is some evidence that the lag pattern is more complicated than that reflected by an annual equation.[3] Equation (2.10) is also oversimplified when formulated in annual terms and is more properly specified as a quarterly equation.[4] However, annual estimates of (2.10) may be less susceptable than quarterly estimates to multicollinearity between the lagged values of appropriations. To the extent that intercorrelation is reduced, we are presented with an opportunity to estimate a lag profile without a priori restrictions, albeit a much simplified one.

Using first differenced data to obtain parameter estimates tends to reduce the apparent statistical significance from what could be obtained if the same relationship were estimated in levels. Lower correlations are generally observed because differenced data lack common trend components. When studying short-run economic behavior, our concern is with

---

[2]This refers to the lag between the recognition of the need for more capital and the implementation of the need into a formally approved appropriation. This so-called "decision lag" precedes the expenditure lag of (2.10). Noting that DeLeeuw, "Demand for Capital Goods," finds a 12 quarter lag between recognition and expenditure and that Almon finds an 8 quarter lag between appropriations and expenditures, the decision lag (in distributed lag form) may be as long as a year.

[3]Shirley Almon, "The Determinants of Capital Appropriations in Manufacturing," (mimeo), finds that an 8 quarter inverted U lag profile on expansion requirements provides the best fit for a quarterly relation similar to (2.09).

[4]See Chapter 2 above.

fluctuations around trend values and we implicitly assume that long-run behavioral compoments remain relatively constant during the differencing interval. Thus, differences are the relevant form for short-run analysis[5] and the lower R^2s associated with differenced equations are the reward for being honest. If a comparison of correlations is to be made, the most relevant one is between the R^2 from the differenced equation and the partial R^2 after trend from the levels equation.

There are several well-known advantages to using the differencing procedure (aside from "honesty") which should be mentioned briefly here. First, as we have indicated above, differencing focuses the analysis directly on short-run reactions. Thus, we do not need to determine explicitly the correct way of introducing long-run phenomena into the relation and thus avoid further complicating the already complex problem of specification.

A second important advantage applies when the structure is to be used for forecasting. When we predict the change in a variable we add the predicted change to the last observed value of the level to predict the next period's level. Thus we can employ the information contained in knowing where we are now to forecast where we will be a year from now. Of course, this procedure is valid whether or not the equation has been estimated in first differences since equations estimated in levels can be algebraically differenced for use in forecasting.

Finally, perhaps the most often cited advantage of using first differences is that the statistical properties of this procedure introduce the likelihood of a substantial reduction in the autocorrelation of resi-

---

[5]Franklin Fisher, A Priori Information and Time-Series Analysis, (Amsterdam: North Holland, 1966), gives a formalized statement of this.

duals. Although differencing is not always the best way of reducing serial correlation, under certain (pessimistic) assumptions it is the correct transformation[6] and has become widely known as an easy method of providing more efficient estimates of equations subject to obvious first-order serial correlation.

Capital Appropriations in Manufacturing

Equation (2.09) is expressed in linear form as:

$$(3.01) \qquad CA_t = \delta_0 + \delta_1(K_t^* - (K_{t-1} + B_{t-1})) + \delta_2 r_{1t} + \delta_3 r_{st} + \delta_4 F_t + \delta_5 E_t + \delta_6 R_t,$$

where F is a composite variable (to be defined below) representing the internal financial position, and the other variables are defined as in Chapter II. The time subscripts indicate that the initial reaction of appropriations to its determinants takes place within a one-year period. Stocks are measured at the end of period so that $(K_{t-1} + B_{t-1})$ represents the "effective" stock of capital at the end of year t-1.

If we first difference (3.01) and add a stochastic term (u_t), the resulting equation

$$(3.02) \qquad \Delta CA_t = \delta_1\Delta(K_t^* - (K_{t-1} + B_{t-1})) + \delta_2\Delta r_{1t} + \delta_3\Delta r_{st} + \delta_4\Delta F_t + \delta_5\Delta E_t + \delta_6\Delta R_t + u_t,$$

is in proper form for statistical estimation. The object of the remainder of this section is to report and interpret estimates of the δ's in (3.02) for total manufacturing and eleven constituent manufacturing industries.

---

[6] J. Johnston, Econometric Methods, (New York: McGraw Hill, 1963), Chap. 7.

The Variables and Data

The data used to meaure capital appropriations are only available from 1953 to 1965[7] and thus restrict the sample size to twelve observations after differencing. Because of this acute lack of degrees of freedom, several oversimplifications and condensations were necessary so that the statistical results would retain some semblance of meaning. In the following discussion of definitions of variables and the data used to measure them, the oversimplifications will be explained and justified.

Capital Appropriations (CA). - The series used as the dependent variable is available only on a quarterly basis and, as mentioned, is unavailable for the period preceeding 1953. Quarterly totals of non-seasonally adjusted gross capital appropriations were summed to arrive at annual figures. Gross appropriations (as opposed to appropriations net of cancellations) were used since they best reflect investment decisions.[8]

Expansion Requirements ($K^*_t - (K_{t-1} + B_{t-1})$). - This variable, the gap between desired and actual capital stock, is the most complex variable appearing in the model. Initial experiments with equations like (3.02) which allowed separate regression coefficients on K^*_t and ($K_{t-1} + B_{t-1}$) were found to give consistently implausible coefficient signs because of collinearity between the two variables.[9]

---

[7] The Conference Board, "Investment Statistics."

[8] The distributed lag relation between appropriations and expenditures relates lagged values of gross appropriations to expenditures with cancellations reflected by the lag weights summing to less than unity.

[9] In the earlier estimates, K^*_t was defined as a constant proportion of expected output in t ($K^*_t = \beta Y^e_t$). The term ($K_{t-1} + B_{t-1}$) when differenced is equivalent to net capital appropriations in t-1 (NCA_{t-1}) minus

In order to try to reduce the collinearity it was decided to construct a single series for the gap between desired and actual capital stock, i.e. expansion requirements (ER). This procedure required some independent measure of the capital output ratio (β) and the capital stock.

From (2.03) we can express K_t^* as

$$K_t^* = \eta(RPC_t, (W/P)_t) \cdot Y_t^e,$$

where $\beta_t^* = \eta(RPC_t, (W/P)_t)$ is the desired or optimal capital output ratio.

We can approximate β_t^* by the expression

$$\beta_t^* = \frac{K_t^{58}}{O_t^* \cdot S_{58}}, \tag{3.03}$$

where K_t^{58} is Hickman's[10] series for capital stock in 1958 prices (EOP), O_t^* is the Federal Reserve Index of Industrial Production for December of year t divided by the McGraw Hill[11] capacity utilization index at the

---

replacement investment in $t-1(R_{t-1})$. Letting CN_t = cancellations, this can be shown as follows:

$$\Delta(K_{t-1} + B_{t-1}) = NCA_{t-1} - R_{t-1},$$

$$B_{t-1} = B_{t-2} + CA_{t-1} - CN_{t-1} - CE_{t-1}, \tag{i}$$

$$\Delta B_{t-1} = CA_{t-1} - CN_{t-1} - CE_{t-1}, \tag{ii}$$

$$K_{t-1} = K_{t-2} + CE_{t-1} - R_{t-1}, \tag{iii}$$

$$\Delta K_{t-1} = CE_{t-1} - R_{t-1}. \tag{iv}$$

Hence, $\Delta K_{t-1} + \Delta B_{t-1} = NCA_{t-1} - R_{t-1}$

Thus, this form could be estimated without having to include a measure of K in the equation and β (the capital output ratio) was contained in the regression coefficient on Y_t^e.

[10] Hickman, Investment Demand.

[11] Various issues of Business Week, Mc-Graw Hill, 1954-1965.

end of the year, and S_{58} is sales in 1958. Multiplication of O_t^* by S_{58} is merely a device to convert the denominator from a dimensionless index number to a dollar value for comparability with K^{58}. Obviously variations in $O_t^* \cdot S_{58}$ reflect only movements of O_t^*.

The time path of the optimal[12] capital output ratio (β^*) from 1954 to 1965 for total manufacturing is plotted in Figure 3.1 along with the actual ratio (β) and an estimated exponential trend ratio ($\hat{\beta}^*$). It is quite evident that the optimal capital output ratio is more closely related to an exponential trend than is the actual capital output ratio. As one would expect, the actual ratio (unadjusted for capacity utilization) is much more susceptible to cyclical fluctuations in O_t, as evidenced by the sharp peaks inβ at the end of 1954, 1957, and 1960, all recession periods. Therefore, since it appears that β^* approaches a stable trend during the sample period, it will not be a misrepresentation to approximate (3.03) as a semi-log trend.

The negatige slope of the trend equation is in accord with the general tendency in the post war period toward a net reduction of the capital-output ratio. This decline is the result of technological advances which have increased capital's productivity more than enough to offset the increased capital intensiveness of production.

Optimal capital-output ratios were computed for all industries covered by the study and semi-log trends were estimated for each industry. The resulting regressions are summarized in Table 3.1. With one exception the regression slopes are all significantly different from zero at

---

[12] Optimal is used in the sense of a desired or normal operating rate. Expression (3.03) is a representation of the capital-output ratio which would be in effect when firms are operating at desired or normal levels of capacity. The optimal capital output ratio is always below the actual ratio because it is defined as the actual ratio times the utilization rate, the latter always being less than one.

Fig. 3.1--Actual (β), desired (β^*) and trend estimated ($\hat{\beta}^*$) capital output ratios for manufacturing, 1954-1965.

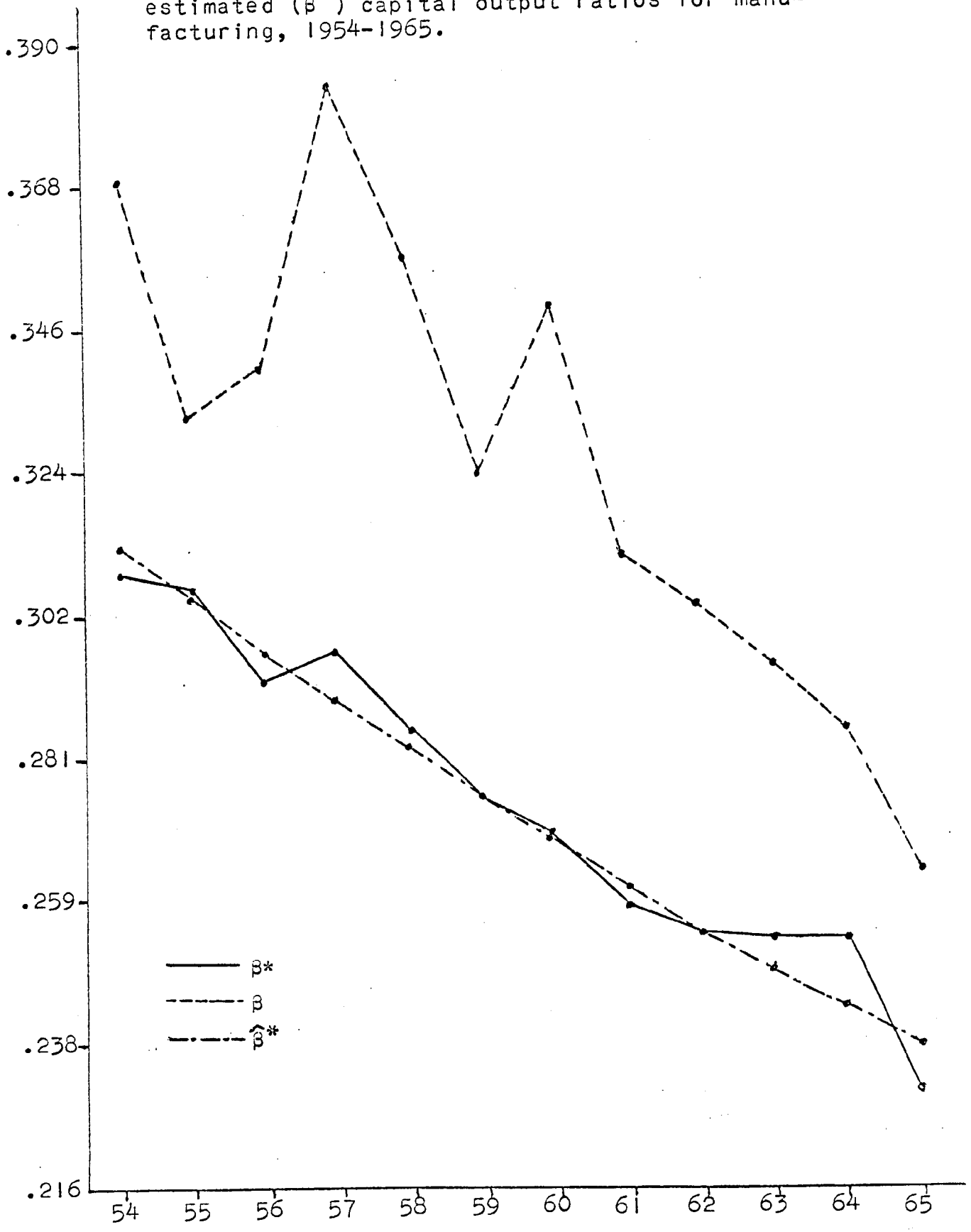


TABLE 3.1

CAPITAL OUTPUT TRENDS, BY INDUSTRY[a]

SIC Ind. No.	Industry	R^2	B[b]	A[c]
01	Total Manufacturing	.960	-.0255	.321
20	Food and Beverages	.940	-.0388	.128
22	Textiles	.929	-.0296	.447
26	Paper Products	.650	-.0123	.358
28	Chemicals	.977	-.0667	.512
29	Petroleum and Coal Products[d]	.521	-.0121	1.821
30	Rubber Products	.833	-.0374	.208
32	Stone, Clay and Glass	.843	-.0298	.395
33	Primary Metals	.449	.0094	.404
35	Non-Electrical Machinery	.168[e]	-.0058	.201
36	Electrical Machinery	.892	-.0370	.147
371	Automobiles and Parts	.783	-.0442	.340

[a] Based on the equation: $\hat{\beta}^*_t = Ae^{Bt}$.

[b] Rate of decline (%) = (B · 100)%.

[c] Value of $\hat{\beta}^*$ for t = 0, i.e. 1953.

[d] Capital stock series includes mining. See Hickman, p. 245.

[e] Non-significant at 2% level.

at least the 2% level. The exception is the non-electrical machinery industry where β^* is essentially constant over the sample period. All of the slopes are negative except for primary metals which shows a very slight (.9%) annual rise in β^*.

Given the trend determined capital-output ratio ($\hat{\beta}^*_t$), desired capital stock is computed as

$$(3.04) \qquad K^*_t = \hat{\beta}^*_t \cdot \frac{S_t}{WPI_t},$$

where S equals sales in money terms and WPI is the wholesale price index. Several efforts were made to formulate an explicit series for expected output (Y^e) based on current and lagged values of sales as well as on data from the OBE-SEC sales expectations survey.[13] However, the estimated coefficient for expansion requirements was smaller than its standard error and sometimes negative when direct attempts to measure expectations were incorporated into the regression. Thus, it was decided to use current sales as the approximation to expected output. Since changes in demand are reflected in sales before being transmitted into production, the series on manufacturer's sales is somewhat closer to expected output than a direct measure of production would be.

Effective capital stock is constructed from Hickman's capital stock series and an adjusted backlog series based on data published by the NICB. The adjustment to backlog is required because of the NICB's coverage of only the 1000 largest manufacturing firms. Since K and S represent all manufacturing firms, not just the 1000 largest, an inflation of the appropriation's backlog must be made in order to combine desired and "effective" capital stock.[14]

We can now write the expression for expansion requirements as

$$(3.05) \qquad ER_t = \{\hat{\beta}^*_t \cdot \frac{S_t}{WPI_t} - (K_{t-1} + B^T_{t-1})\}$$

---

[13] Various issues of Survey of Current Business, U.S. Department of Commerce, Office of Business Economics.

[14] See Appendix I for a detailed description of the approximation.

where B^T is the backlog adjusted to include all firms in the industry.

Cost of Internal Funds (D, D^*, L, L^*, RED^e). - In order to include all of the balance sheet variables from (2.09) in the analysis, at least three separate variables would have to be specified in (3.02). If the desired stocks of debt and liquidity are to be approximated by explicit inclusion of their major determinants, even more variables would need to be included. To save degrees of freedom, it was decided to approximate balance sheet conditions by a single composite variable incorporating debt, liquidity and expected gross retained earnings.

After experimenting with several alternatives,[15] the form

$$(3.06) \qquad F_t = \frac{D_{L,t-1}}{(G + C - T_L)_{t-1} + 1/2(RED_t + RED_{t-1})},$$

was decided upon. In this formulation, $D_{L,t-1}$ is the stock of outstanding log-term debt from banks and all other sources, G is the stock of government securities, C the stock of cash and T the cumulated corporate tax liability. Together, the last three variables form a measure of the stock of liquid assets. Tax liabilities are subtracted as an offset to the stock of governments, since corporations are known to fund their tax liabilities in government securities until cash payments are due. The simple average of gross retained earnings in the current and preceeding year is a proxy for expected gross retained earnings in year t.

Equation (3.06) can be viewed as an approximation to

$$(3.07) \qquad F_t^* = \frac{(D_{L,t-1} - D_{L,t}^*)}{(L_{t-1} - L_t^*) + RED_t^e},$$

---

[15] Two alternatives which introduced short-term liabilities and other current assets (other than cash and government securities) were tried but consistently gave poorer results than the form which was finally adopted.

where the asterisks represent desired stocks. By using F_t for F_t^*, we are assuming the effects of changes in D* and L* have neutral impacts on the variance of ΔF_t^*. This will not be too much of an oversimplification if D* and L* increase at approximately the same trend dominated rate.

Data from the Federal Trade Commission and Securities Exchange Commission's "Quarterly Financial Reports" were used to calculate F after several adjustments were made for changes in sampling procedure.[16] Both $D_{L,t-1}$ and L_{t-1} are computed as averages of stocks at the end of each quarter. This is equivalent to using a simple four-quarter moving average for seasonal adjustment of quarterly data. Since the seasonal pattern of the balance sheet items is not constant from one year to another (especially in the case of T_L), we felt the use of annual averages would tend to produce a more representative series of end of year stocks than the published fourth quarter values.

Cost of External Funds (r_l, r_s, E). - The Baa corporate bond rate and the yield on new issues of 90-day treasury bills were used as the long term and short term interest rates respectively.

Initial regression estimates of (3.02) for total manufacturing consistently resulted in positive signs on the short term interest rate coefficient whether or not the long term rate appeared in the equation. This result was also observed in several industries where it was suspected that interest rates would be an important explanatory variable. It appears that the strongly procyclical short term rate is so highly correlated with the long term rate and/or expansion requirements that

---

[16] Federal Trade Commission and Securities and Exchange Commission, Quarterly Financial Report for Manufacturing Corporations, 1952-1965. The adjustments to the Quarterly balance sheet data were similar to those in Anderson, "Corporation Finance."

it is impossible to measure its separate influence on appropriations with any reliability. Thus, r_s was dropped from the analysis.

Moody's dividend-price ratio was used to measure the cost of issuing new equity shares. Dividends were used in the numerator of the ratio rather than earnings because dividends per share are a more accurate indication of the discounted future earnings streams reflected in the market price of shares. However it became apparent after a few attempts at statistical estimation that any contribution to be made by the dividend-price ratio was primarily due to movements in price per share. Thus, only stock prices (SP) were included in the regression equations.[17]

The Regressions

If we include the changes indicated above and let the change in replacement needs (ΔR_t) be constant,[18] the appropriations equation actually estimated becomes

$$(3.08) \qquad \Delta CA_t = \delta_0 + \delta_1 \Delta ER_t + \delta_2 \Delta F_t + \delta_3 \Delta Baa_t + \delta_4 \Delta SP_t + u_t,$$

with expected coefficient signs:

$$\delta_0 > 0,\ \delta_1 > 0,\ \delta_2 < 0,\ \delta_3 < 0,\ \delta_4 > 0.$$

Equation (3.08) was estimated in current dollars[19] to be consistent

---

[17] The correlation of the first differences of Moody's series on Industrial dividend-price ratios and Moody's Industrial stock price series was .75. The stock price data is from U.S. Dept. of Commerce: Office of Business Economics, Business Statistics, (Washington, 1965), p.107.

[18] This puts depreciation into the constant or trend term (δ_0) of the differenced equation.

[19] Plant and equipment deflators from Hickman's study (Hickman, "Investment Demand") were used to reflate the components of ER. He has published deflators for all two-digit manufacturing industries using 1954 as the base year. Real sales $(S/WPI)_t$ and real capital (K^{54}_{t-1})

with the estimates of the distributed lag function which are sensible only in current dollars. Once capital expenditures have been determined from the distributed lag they can be converted into real terms if desired. The least squares regression estimate of (3.08) for the period 1953-1965 for total manufacturing was:

$$(3.09) \qquad \Delta CA_t = .910 + .1115\Delta ER_t - 1.298\Delta Baa_t - 25.454\Delta F_t + .0613\Delta SP_t$$

$$(.0461) \qquad (1.306) \qquad (6.231) \qquad (.0209)$$

$$\{-.4728\} \qquad \{-1.5679\} \qquad \{.8806\}$$

$$\bar{R}^2 = .851 \qquad (D.F. = 7)$$

The numbers in parentheses are standard errors and the numbers in brackets are elasticities computed at means of levels.[20] Actual and predicted values from (3.09) are plotted in Figure 3.2.

All of the coefficients have the expected sign and, except for the bond rate, are significant at the 5% level.

The significant contribution of stock prices may in part be an expectational effect not fully reflected in the other variables. It seems improbable that the cost of equity financing would exert such a strong influence on appropriations since new stock issues comprise a very small

---

were reflated by the concurrent value of the deflator in t. The appropriations backlog, reported in current dollars, was left unchanged. This formulation allows changes in capital goods prices, which affect appropriations by changing the money value of K_t^*, to be reflected in capital in place, but not in backlog. Thus appropriations decisions, hypothesized as being determined by real capital requirements, can be made in response to price changes in previously planned expenditures which have not yet been incorporated into the physical stock of capital.

[20] ΔCA and ΔER are measured in billions of dollars, ΔF is the change in a ratio, ΔBaa is the change in a percentage and ΔSP is the change in an index number. Because of the difficulty in interpreting the coefficients, elasticities are also given for the coefficient estimates. Elasticities are not reported for ΔER since the levels of this series take on negative values.

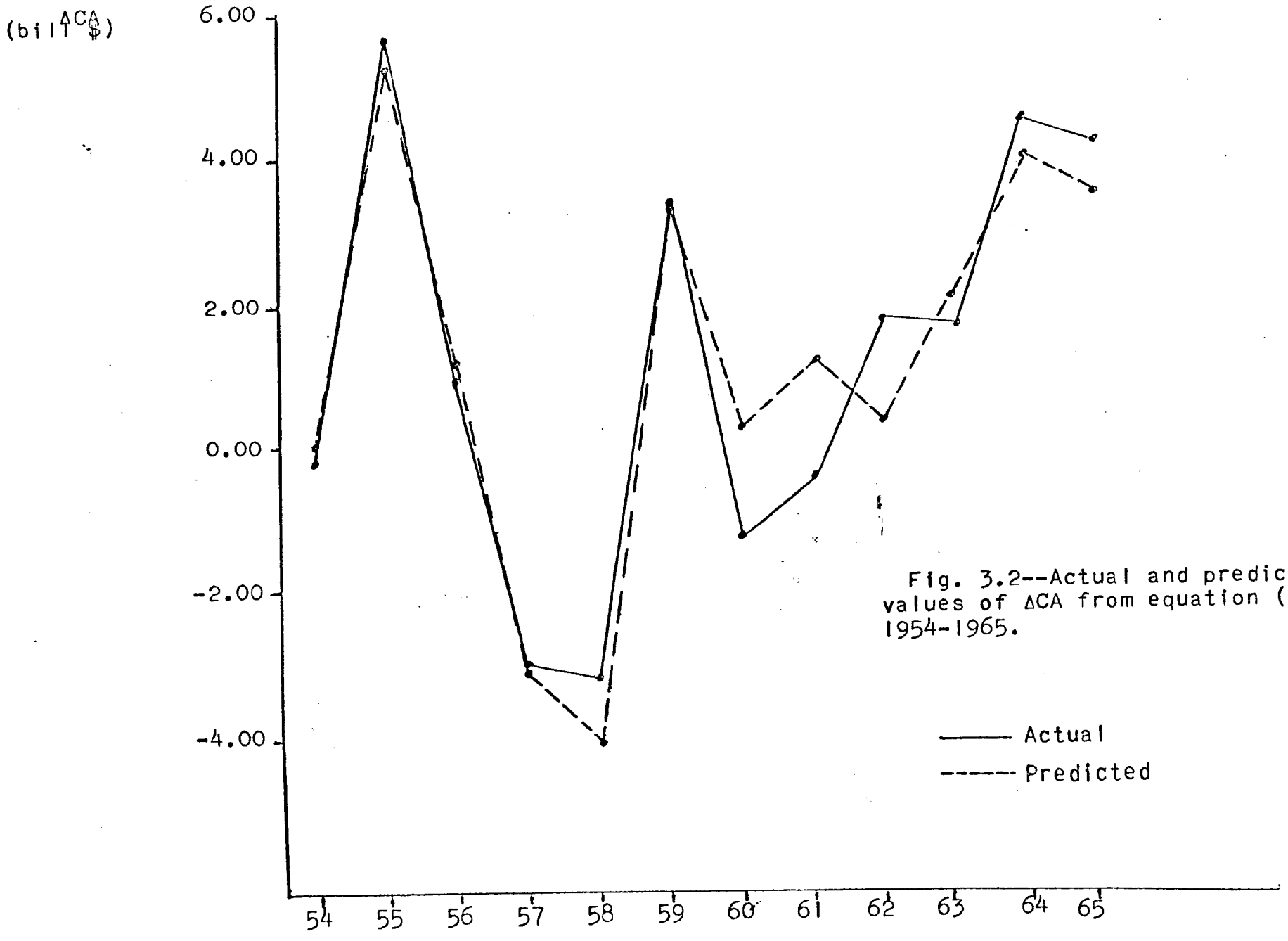


Fig. 3.2--Actual and predicted values of ΔCA from equation (3.09), 1954-1965.

share of new capital funds.[21] However, regardless of the main source of its impact, since it is specified as a concurrent determinant of appropriations, including it in the equation raises serious problems when appropriations are considered in the context of an aggregate macroeconomic forecasting model. Unless there is a good way of determining ΔSP_t from a separate equation, only forecasts conditional upon a value or range of values assigned a priori to stock prices will be possible.

Because of this complication, a second equation was estimated which did not include the stock price variable. The estimate for total manufacturing for this version was:

$$(3.10) \qquad \Delta CA_t = 2.219 + \underset{(.0633)}{.1373\Delta ER_t} - \underset{(1.739)}{\underset{\{-.9016\}}{2.475\Delta Baa_t}} - \underset{(8.427)}{\underset{\{-1.8546\}}{30.107\Delta F_t}}$$

$$\bar{R}^2 = .708 \qquad (D.F. = 8)$$

Again all coefficients have the hypothesized sign though the coefficient on ΔBaa remains smaller than twice its standard error. The reduction in $\bar{R}^2$ when stock prices are dropped indicates that it has a relatively strong independent influence on appropriations. Predicted and actual values for (3.10) are plotted in Figure 3.3 for comparison with (3.09).

To further test the applicability of the specification, both equations were estimated for the eleven two-digit manufacturing industries for which all of the necessary data series were available.[22] These

---

[21] The ratio of new stock issues by non-financial corporations to appropriations during the period 1953-1965 was .127. Since the numerator includes all new issues, not just those of the 1000 largest manufacturing firms, the computed ratio is higher than the actual ratio. The simple correlation of Δ New Issues and ΔCA was .093. Much of the variation in new issues is due to occasional large issues by single firms.

[22] The major data constraint was the availability of Hickman's capi-

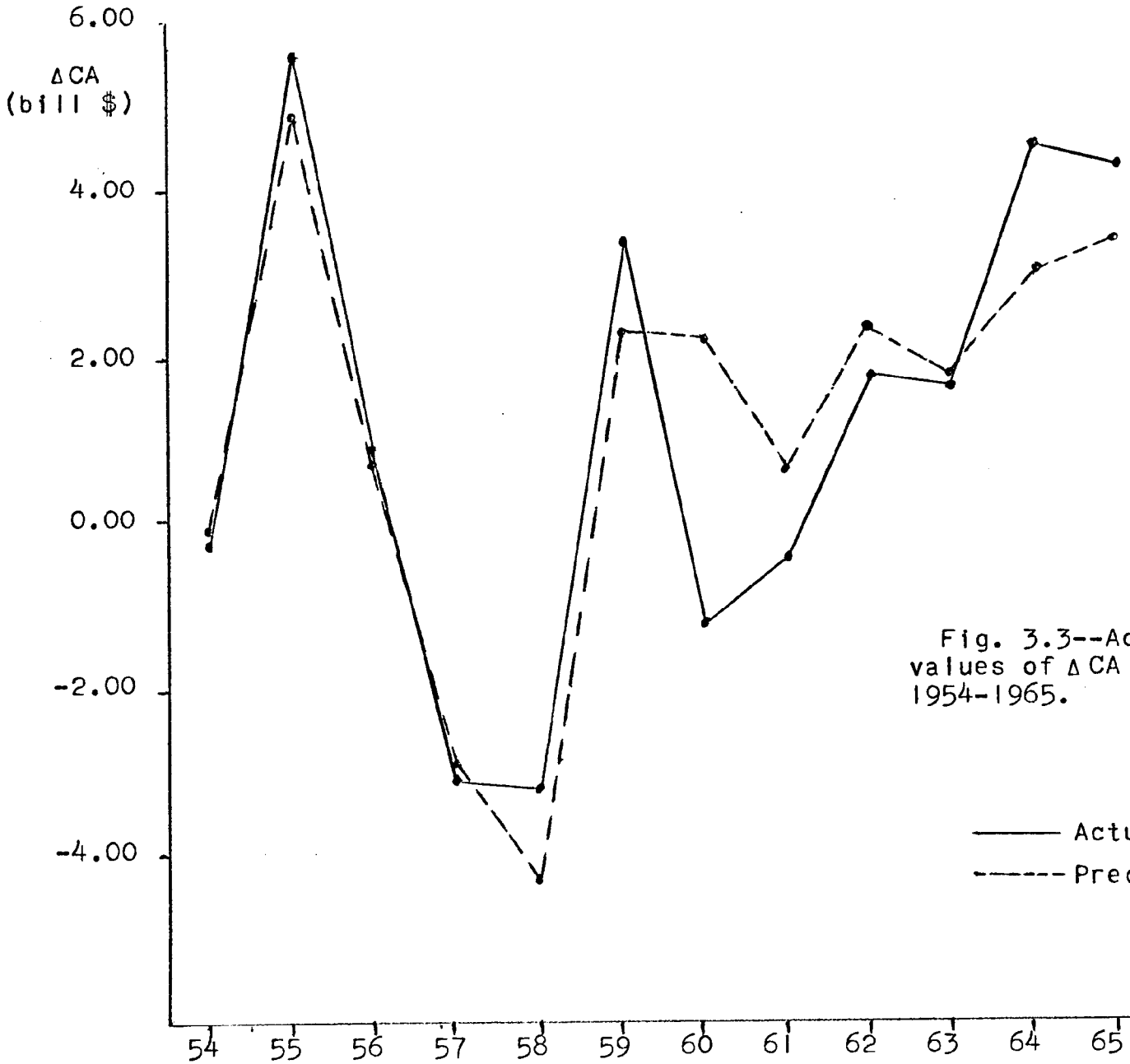


Fig. 3.3--Actual and predicted values of ΔCA from equation (3.10), 1954-1965.

equations, also estimated in current dollars, are listed along with relevant goodness of fit statistics in Table 3.2 (including ΔSP) and Table 3.3 (excluding ΔSP).

Unhappily, the results are mixed. The equations in Table 3.2 (stock prices included) have generally higher $\bar{R}^2$'s. However, it is worth noting that in some industries there is substantial correlation between stock prices and both ΔER and the cost of internal funds. This is evident from the increase from 6 to 8 in significant coefficients on the latter two variables after stock prices are removed. In all only eight of the 33 slope coefficients were of the expected sign and significantly different from zero in the equation without stock prices, while the additon of stock prices reduced the ratio to 8 of 44. The bond rate is the weakest variable in the equations, with no significant negative coefficients. This may be due in part to the fact that only deviations from trend are reflected in Δr_1. Any effect due to trend is already incorporated in the trend estimated capital output ratios.

On the positive side, 35 of 44 coefficients (including δ_0) had the anticipated sign in the equation without ΔSP, while 43 of 55 coefficients were of expected sign when ΔSP was included. Of the 24 slope coefficients with the hypothesized sign in Table 3.3, 17 were larger than their stnadard errors. In Table 3.2, 26 of 35 were greater than their standard errors.

Because the regression results of the linear model are of the borderline variety, a non-linear formulation was estimated in additon to the

---

tal stock series. Several smaller industries for which appropriations are available were not covered by Hickman and thus could not be included.

TABLE 3.2

REGRESSION COEFFICIENTS FOR

$$\Delta CA_t = \delta_1 \Delta ER_t + \delta_2 \Delta F_t + \delta_3 \Delta Baa_t + \delta_4 \Delta SP_t + \delta_0$$

Industry (SIC Number)	δ_1	δ_2	δ_3	δ_4	δ_0	$\bar{R}^2$
Food and Beverages (20)	-.3976 (.2805)	-1.2399 (.9857)	.2085 (.1487)	.0162 (.0084)	-.032	.002
Textiles (22)	-.0205 (.0270)	-.2271 .1028)	.0421 (.0290)	.0074 (.0013)	.005	.844
Paper and Allied Products (26)	.2169 (.1482)	-.9930 (.3928)	-.1168 (.1562)	.0003 (.0019)	.155	.519
Chemicals (28)	.0959 (.1785)	-2.9187 (1.6891)	.1705 (.3987)	.0322 (.0232)	.132	.340
Petroleum and Coal (29)	.1434 (.0790)	-5.0074 (2.1422)	.2681 (.3433)	.0131 (.0101)	.101	.459
Rubber Products (30)	.3018 (.1545)	-.0674 (.1239)	-.0094 (.0592)	.0010 (.0008)	.019	.509
Stone, Clay and Glass (32)	.3140 (.1191)	-.8701 (.4987)	-.1275 (.1018)	.0032 (.0058)	.110	.645
Primary Metals (33)	.2727 (.0661)	-.7383 (.8607)	-.6290 (.4457)	.0153 (.0096)	.249	.711
Non-Electrical Machinery (35)	-.0843 (.2224)	-1.3247 (1.1210)	-.0028 (.2534)	.0118 (.0089)	.062	.250
Electrical Machinery (36)	.2354 (.2668)	-.5337 (.5326)	.0965 (.2308)	.0086 (.0044)	-.024	.550
Autos (371)	.2479 (.0658)	2.6339 (2.1638)	-.6503 (.5044)	.0359 (.0153)	-.127	.716
Number of Coefficients with Hypothesized Sign	8	10	6	11	8	
$\delta_i > \sigma_{\delta i}$ (with hypothesized sign)	6	8	3	9	-	
$\delta_i > 2\sigma_{\delta i}$ (with hypothesized sign)	3	3	0	2	-	

TABLE 3.3

REGRESSION COEFFICIENTS FOR
$\Delta CA_t = \delta_1 \Delta ER_t + \delta_2 \Delta F_t + \delta_3 \Delta Baa_t + \delta_0$

Industry (SIC Number)	δ_1	δ_2	δ_3	δ_0	$\bar{R}^2$
Food and Beverages (20)	-.0404 (.2424)	-.4568 (1.0367)	.0551 (.1448)	.053	--[a]
Textiles (22)	.0494 (.0554)	-.2885 (.2338)	-.0111 (.0630)	.022	.190
Paper and Allied Products (26)	.2230 (.1345)	-1.0054 (.3613)	-.1214 (.1440)	.160	.578
Chemicals (28)	.2660 (.1373)	-3.0367 (1.7823)	.0824 (.4159)	.321	.263
Petroleum and Coal (29)	.1506 (.0821)	-5.7701 (2.1470)	.1658 (.3482)	.212	.413
Rubber Products (30)	.4076 (.1379)	-.1140 (.1229)	.0084 (.0598)	.032	.471
Stone, Clay and Glass (32)	.3503 (.0946)	-1.0332 (.3823)	-.1259 (.0972)	.124	.676
Primary Metals (33)	.2983 (.0699)	-.7711 (.9389)	-.5101 (.4794)	.294	.656
Non-Electrical Machinery (35)	-.1157 (.2313)	-1.9234 (1.0734)	.0875 (.2554)	.110	.179
Electrical Machinery (36)	.1052 (.3008)	-1.0611 (.5350)	.2078 (.2604)	.079	.402
Autos (371)	.2854 (.0800)	1.6507 (2.6571)	-1.1084 (.5823)	.230	.553
Number of Coefficients with Hypothesized Sign	9	10	5	11	
$\delta_i > \sigma_{\delta i}$ (with hypothesized sign)	7	7	3	-	
$\delta_i > 2\sigma_{\delta i}$ (with hypothesized sign)	4	4	0	-	

[a] Negative

equations reported in Tables 3.2 and 3.3.

Splitting ER into its two components $(\hat{\beta}^*S_t)$ and $(K_{t-1} + B_{t-1})$ and dividing the dependent variable and the two parts of ER by $(K_{t-1} + B_{t-1})$ results in

$$(3.11) \qquad \frac{CA_t}{(K_{t-1}+B_{t-1})} = \delta_0' + \delta_1'\frac{\hat{\beta}^*S_t}{(K_{t-1}+B_{t-1})} + \delta_2'F_t + \delta_3'Baa_t + \delta_4'SP_t.$$

Since F_t, Baa_t and SP_t are all given as percentages or index numbers, there is no need to normalize them. Equation (3.11) was estimated in first differences for the same sample period covered by the linear version.

For total manufacturing the resulting estimates were:

$$(3.12) \qquad \Delta\{\frac{CA_t}{K_{t-1} + B_{t-1}}\} = .0040 + .1698\Delta\{\frac{\hat{\beta}^*S_t}{K_{t-1} + B_{t-1}}\}$$
$$(.0504)$$
$$-.1420\Delta F_t - .0265\Delta Baa_t + .0004\Delta SP_t$$
$$(.0557) \quad (.0116) \quad (.0002)$$
$$\bar{R}^2 = .830$$

and

$$(3.13) \qquad \Delta\{\frac{CA_t}{K_{t-1} + B_{t-1}}\} = .0133 + .1917\Delta\{\frac{\hat{\beta}^*S_t}{K_{t-1} + B_{t-1}}\}$$
$$(.0628)$$
$$- .1748\Delta F_t - .0351\Delta Baa_t$$
$$(.0683) \quad (.0140)$$
$$\bar{R}^2 = .729$$

All coefficients in the two ratio equations are of expected sign and significantly different from zero at the 5 percent level, though the $\bar{R}^2$s are essentially the same as those for (3.09) and (3.10).

The fact that the specification holds up in the new formulation

lends additional support to the plausibility of the appropriations relationship. Coefficients estimated from industry data, reported in Tables 3.4 and 3.5, further support the model. Except for three noticably poor industry performances, the industry ratio estimates tend to support the linear estimates. A comparison of Tables 3.2 and 3.3 with Tables 3.4 and 3.5 shows that in general, variables which are not important in the linear version are not important in the ratio model.

The regression coefficients on expansion requirements in the linear model and on $\frac{\beta^* S_t}{(K_{t-1} + B_{t-1})}$ in the ratio model can be interpreted as "speed of adjustment" coefficients in a flexible accelerator model. Traditionally, a stock adjustment model contains a constraint on the reduction of the gap between the desired and actual stock of capital. Some proportion of the gap is assumed to be made up in any given time period. This incorporates a Koyck-type decaying weight distributed lag into the structure. The mechanism can be described by

$$CA_t = \gamma(K_t^* - (K_{t-1} + B_{t-1})), \tag{3.14}$$

where $\gamma(0 < \gamma < 1)$ is the speed of adjustment coefficient.

Since the data used for ER is complete industry data and the series for CA covers only the 1000 largest subset of manufacturing firms, the calculated adjustment coefficients are somewhat lower than they would be with consistent data series. Using the inverse of the ratio of NICB capital expenditures to OBE-SEC expenditures during the sample period (= 1.41) to adjust the coefficients, gives a γ of .196 for total manufacturing in the linear model without stock prices and .274 in the counterpart ratio model. The same calculations can be made with industry data to calculate the adjusted γ's on an individual industry basis.

The particularly poor results for both the linear and ratio models

TABLE 3.4

REGRESSION COEFFICIENTS FOR

$$\Delta\left(\frac{CA_t}{K'_{t-1}{}^a}\right) = \delta'_1\Delta\left(\frac{\hat{\beta}^*S_t}{K'_{t-1}}\right) + \delta'_2\Delta F_t + \delta'_3\Delta Baa_t + \delta'_4\Delta SP_t + \delta'_0$$

Industry (SIC Number)	δ'_1	δ'_2	δ'_3	δ'_4	δ'_0	$\bar{R}^2$
Food and Beverages (20)	-.3525 (.2549)	-.1342 (.1090)	.0243 (.0165)	.0019 (.0009)	-.0044	.081
Textiles (22)	-.0039 (.0202)	-.0400 (.0149)	.0046 (.0042)	.0009 (.0002)	.0007	.852
Paper and Allied Products (26)	.2750 (.1297)	-.1570 (.0608)	-.0282 (.0244)	.0003 (.0003)	.0183	.695
Chemicals (28)	.1918 (.1980)	-.2045 (.1420)	.0023 (.0334)	.0022 (.0020)	.0081	.400
Petroleum and Coal (29)	.1820 (.0875)	-.1605 (.0649)	.0045 (.0108)	.0002 (.0003)	-.0008	.436
Rubber Products (30)	.3403 (.1377)	-.0501 (.0763)	-.0186 (.0357)	.0008 (.0005)	.0015	.650
Stone, Clay and Glass (32)	.3895 (.0950)	-.1618 (.0793)	-.0483 (.0165)	.0008 (.0009)	.0193	.824
Primary Metals (33)	.3015 (.0616)	-.0064 (.0552)	-.0615 (.0280)	.0011 (.0006)	.0105	.777
Non-Electrical Machinery (36)	.0548 (.1387)	-.1413 (.1091)	-.0075 (.0236)	.0012 (.0008)	.0062	.562
Electrical Machinery (36)	.3162 (.2593)	-.1768 (.1473)	-.0024 (.0714)	.0018 (.0014)	-.0060	.527
Autos (371)	.3271 (.0617)	.4961 (.2859)	-.1135 (.0667)	.0036 (.0020)	-.0101	.794
Number of Coefficients with Hypothesized Sign	9	7	10	11		
$\delta_i > \sigma_{\delta i}$ (with hypothesized sign)	7	4	8	8		
$\delta_i > 2\sigma_{\delta i}$ (with hypothesized sign)	6	2	4	2		

[a] $K'_{t-1} = (K_{t-1} + B_{t-1})$

TABLE 3.5

REGRESSION COEFFICIENTS FOR

$$\Delta\left(\frac{CA_t}{K'_{t-1}{}^{a}}\right) = \delta'_1\Delta\left(\frac{\hat{\beta}^* S_t}{K'_{t-1}}\right) + \delta'_2\Delta F_t + \delta'_3\Delta Baa + \delta'_0$$

Industry (SIC Number)	δ'_1	δ'_2	δ'_3	δ'_0	$\bar{R}^2$
Food and Beverages (20)	-.0231 (.2483)	-.0404 (.1213)	.0052 (.0169)	.0044	--[b]
Textiles (22)	.0217 (.0436)	-.0586 (.0324)	-.0025 (.0088)	.0047	.271
Paper and Allied Products (26)	.2979 (.1292)	-.1703 (.0601)	-.0337 (.0241)	.0025	.689
Chemicals (28)	.3496 (.1398)	-.1977 (.1439)	-.0025 (.0336)	.0201	.381
Petroleum and Coal (29)	.1825 (.0842)	-.1717 (.0600)	.0029 (.0100)	.0008	.478
Rubber Products (30)	.4491 (.1356)	-.0849 (.0817)	-.0066 (.0390)	.0112	.567
Stone, Clay and Glass (32)	.4307 (.0796)	-.1991 (.0644)	-.0489 (.0162)	.0233	.831
Primary Metals (33)	.3290 (.0673)	-.0070 (.0624)	-.0534 (.0312)	.0136	.717
Non-Electrical Machinery (35)	.0226 (.1468)	-.2098 (.1060)	.0028 (.0242)	.0110	.497
Electrical Machinery (36)	.2497 (.2658)	-.2708 (.1347)	.0233 (.0717)	.0157	.484
Autos (371)	.3563 (.0669)	.3928 (.3148)	-.1601 (.0689)	.0261	.740
Number of Coefficients with Hypothesized Sign	10	7	10		
$\delta_i > \sigma_{\delta i}$ (with hypothesized sign)	7	4	8		
$\delta_i > 2\sigma_{\delta i}$ (with hypothesized sign)	7	2	4		

[a] $K'_{t-1} = (K_{t-1} + B_{t-1})$

[b] Negative

in food and beverages (20), textiles (22) and non-electrical machinery (35) deserve some individual rationalization.

The food and beverage industry apparently makes investment decisions upon the advice of Greek oracles. In several studies of investment which include estimates of industry equations, this industry consistently shows up with the poorest fit, as it does here.[23] If equation (3.08) is estimated in levels for industry 20 with a time trend added, it is apparent that only the trend is contributing anything to the equation's explanatory power. The addition of all four variables after the trend raises the R^2 from .794 to only .850, which of course is what the low R^2 of the differenced version of (3.08) signifies. The only systematic movement of appropriations in this industry which seems to be identifiable is the fairly strong trend component, an indication that people continue to eat.

In the case of the textile industry, a reasonably good fit was obtained when 1965 was dropped from the analysis. The coefficients on both ΔER_t and ΔF_t became significant (with stock prices excluded) and $\bar{R}^2$ rose to .716. The main source of the improvement stems from the fact that the simple correlation between ΔER and ΔCA rises from .536 to .804 when the 1965 observation is removed from the sample.

Other than a possible increase in Department of Defense orders concurrent with plans for the military build-up in Viet Nam, there is no obvious reason for the inconsistency of the 1965 observation in the textile industry.

The fit for non-electrical machinery also improves when 1965 is ex-

---

[23] See Almon, "Determinants;" Anderson, "Fixed Investment;" Robert Resek, "Investment by Manufacturing Firms: A Quarterly Time Series Analysis of Industry Data," Review of Economics and Statistics, XLVIII, (August, 1966), pp. 322-347.

cluded. The simple correlation between ΔCA and ΔER rises from .404 to .715 when the last observation is removed. However, in this instance the individual coefficients are not substantially affected by the change. The coefficient on ΔER becomes barely significant while the coefficient on ΔF remains insignificant and the coefficient on ΔBaa is virtually unaffected. The addition of ΔSP has no appreciable effect on the regression excluding 1965.

Several alternative forms of the basic equation were tried for the three industries in question, but with little success. A distributed lag on expansion requirements as well as a simple accelerator ($\Delta^2 S_t$ in differences) were estimated for both textiles and food and beverages. Non-electrical machinery was combined with electrical machinery to see if an apparent inconsistency in the NICB data[24] might account for the poor results with the two industries separated. The estimates of the modified equations in all cases showed no improvement on the results which appear in Tables 3.2 and 3.3.

A final tabulation of industry equations is summarized in Tables 3.6 and 3.7. There, we have reported only a "best" equation for each industry. The "best" equation relates appropriations only to those variables which seem to have an important impact in a particular industry and drops variables which apparently have no impact. Omitted variables in most cases have standard errors much larger than their coefficients and excluding them generally has the effect of raising $\bar{R}^2$ without appreciably affecting the coefficients on the remaining variables.

---

[24] There is evidence that the sample coverage by the NICB in electrical machinery may include firms from other industries, perhaps from non-electrical machinery. See Almon, "Determinants."

TABLE 3.6

"BEST" EQUATION, LINEAR MODEL, BY INDUSTRY

Industry (Number)	ΔER	ΔF	ΔBaa	ΔSP	δ_0	$\bar{R}^2$
Textiles (22)[a]	.0516	-.1882			.005	.746
	(.0184)	(.1773)				
	--	{-.9105}[b]				
Paper Products (26)	.270	-1.049			.154	.592
	(.121)	(.352)				
	--	{-1.972}				
Chemicals (28)	.260	-3.007			.326	.341
	(.126)	(1.678)				
	--	{-1.685}				
Petroleum and Coal (29)	.135	-5.814			.222	.463
	(.072)	(2.061)				
	--	{-1.234}				
Rubber Products (30)	.408	-.109			.033	.528
	(.130)	(.112)				
	--	{-.539}				
Stone, Clay and Glass (32)	.350	-1.033	-.126		.124	.676
	(.095)	(.382)	(.097)			
	--	{-1.332}	{-1.282}			
Primary Metals (33)	.285		-.576	.016	.232	.721
	(.063)		(.434)	(.010)		
	--		{-1.471}	{.553}		
Electrical Machinery (36)	.236	.465		.0090	-.023	.604
	(.253)	(.480)		(.0040)		
	--	{-.612}		{1.143}		
Autos (371)	.286		-1.012		.239	.584
	(.077)		(.542)			
	--		{-4.186}			

[a] Excludes 1965

[b] Elasticities computed at means of levels.

No "best" equation was selected for food and beverages (20) and non-electrical machinery (35).

TABLE 3.7

"BEST" EQUATION, RATIO MODEL BY, INDUSTRY

Industry (Number)	$\Delta(\frac{\hat{\beta}S}{K+B})$	ΔF	ΔBaa	ΔSP	δ_0'	$\bar{R}^2$
Textiles (22)[a]	.0466 (.0178)	-.0360 (.0132)			.0009	.760
Paper Products (26)	.298 (.129)	-.170 (.060)	-.0337 (.0241)		.0225	.689
Chemicals (28)	.352 (.127)	-.198 (.136)			.0199	.450
Petroleum and Coal (29)	.171 (.071)	-.172 (.057)			.0010	.511
Rubber Products (30)	.448 (.128)	-.089 (.074)			.0105	.614
Stone, Clay and Glass (32)	.431 (.080)	-.1991 (.0644)	-.0489 (.0162)		.0223	.807
Primary Metals (33)	.304 (.055)		-.0610 (.0260)	.0011 (.0006)	.0103	.805
Electrical Machinery (35)	.195 (.090)		-.0206 (.0222)	.0017 (.0008)	.0076	.524
Autos (371)	.361 (.069)		-.1373 (.0684)		.0283	.724

[a]Excluding 1965

No "best" equations for food and beverages (20) and non-electrical machinery (35).

The Distributed Lag

Two models were estimated from annual data for the distributed lag between appropriations and expenditures. The first model was the simple fixed coefficient linear lag structure of (2.10). The second was based on Popkin's variable coefficient model (2.15) modified to fit the annual specification.

The most interesting results were obtained from the fixed coefficient model. Regressions were fitted in homogeneous form for levels and first differences from 1955-1965 for a model which allowed appropriations of t, t-1 and t-2 to affect expenditures in t. The length of the lag was based on the results obtained by Almon.[25]

For total manufacturing, the estimated equations were:

$$(3.15)\qquad \Delta CE_t = \underset{(.119)}{.356}\Delta CA_t + \underset{(.107)}{.595}\Delta CA_{t-1} + \underset{(.118)}{.098}\Delta CA_{t-2} \qquad \hat{R}^2 = .891^{26}$$

$$(3.16)\qquad CE_t = \underset{(.059)}{.272}CA_t + \underset{(.094)}{.620}CA_{t-1} + \underset{(.067)}{.041}CA_{t-2} \qquad \hat{R}^2 = .925$$

where CE is capital expenditures and all variables are measured in billions of current dollars.

The regression results can be compared to Almon's equation (2.11)

---

[25] Almon, "Distributed Lag."

[26] The $\hat{R}^2$'s were computed from the formula: $\hat{R}^2 = 1 - \dfrac{SSE_H}{\Sigma_i (Y_i - \bar{Y})^2}$

The term SSE_H is error sum of squares from the homogeneous regression. Even though the equation is estimated from moments around zero, the R^2 which is of interest should of course reflect the fraction of the variance around the mean (rather than zero) explained by the independent variables.

for total manufacturing if we assume that capital appropriations are forthcoming at a constant rate in each quarter of the year. Under this assumption it is easy to convert her quarterly weights into annual weights.[27] Upon transformation, equation (2.11) becomes

$$(3.17) \qquad CE_t = .280CA_t + .538CA_{t-1} + .102CA_{t-2} \qquad \bar{R}^2 = .933$$

The inverted U form of the lag profile, apparent in the two fitted equations, is very close to the lag pattern of (3.17). Since we made no assumptions about the form of the distributed lag when estimating (3.15) and (3.16) these results support the a priori assumptions usually made about the shape of the lag structure[28] and the coefficients are encouragingly close to the values obtained from Almon's transformed quarterly estimates.[29]

Table 3.8 presents the estimates of these equations for the eleven manufacturing industries with the counterpart equations from Almon's paper included for comparison.

---

[27]The transformation involves cumulating the lag responses attributable to appropriations in year t, t-1 and t-2. For example, using the weights from (2.11), the weight for year t is computed from the following format.

Quarter					Sum
0	.068	.122	.156	.168	.514
1		.068	.122	.156	.346
2			.068	.122	.190
3				.068	.068
					1.118

$$\alpha_0 = \frac{1.118}{4} = .2795$$

[28]See Chapter II.

[29]Some of the differences in coefficients arise from the averaging effect when the quarterly Almon weights are transformed to an annual basis. Also, Almon's sample period did not include the 1962-1965 period.

TABLE 3.8

COMPARISON OF ESTIMATED DISTRIBUTED LAG EQUATIONS WITH ALMON'S EQUATIONS, BY INDUSTRY

$$CE_t = \alpha_0 CA_t + \alpha_1 CA_{t-1} + \alpha_2 CA_{t-2}$$

Industry (SIC Number)		α_0	α_1	α_2	$\Sigma\alpha_i$	$\hat{R}^2$
Food and Beverages (20)	D	.419	.388*	--	.807	.17
	L	.398*	.444	.074*	.916	.83
	A	.251	.656	.055	.962	.78[a]
Textiles (22)	D	.402	.449*	--	.851	.55
	L	.250	.727	--	.978	.90
	A	.343	.638	.017	.998	.85
Paper and Allied Products (26)	D	.188*	.559	.069*	.816	.89
	L	.175	.577	.184	.936	.94
	A	.330	.491	.151	.972	.87
Chemicals (28)	D	.244	.603	.060*	.906	.94
	L	.244	.613	.091*	.948	.97
	A	.238	.507	.205	.950	.85
Petroleum and Coal (29)	D	.615	.262*	.218*	1.095	.74
	L	.548	.285*	.036*	.869	.90
	A	.546	.326	--	.872	.88
Rubber Products (30)	D	.191*	.261	--	.452	.39
	L	.211	.612	.089*	.912	.94
	A	.298	.401	.189	.888	.82
Stone, Clay and Glass (32)	D	.423	.675	.115*	1.213	.90
	L	.289	.662	.037*	.987	.89
	A	.263	.552	.138	.952	.89
Primary Metals (33)	D	.221*	.640	.334	1.194	.77
	L	.136*	.618	.219	.973	.89
	A[b]	--	--	--	--	--
Non-Electrical Machinery (35)	D	.680	.554	--	1.234	.87
	L	.810	.127*	--	.937	.97
	A	.289	.528	.062	.879	.84
Electrical Machinery (36)	D	.318	.391	.117*	.827	.95
	L	.355	.388	.154	.897	.88
	A	.247	.428	.193	.875	.86
Automotive (371)	D	.202	.613	.121*	.936	.93
	L	.213	.621	.118	.951	.96
	A[c]	.277	.585	.102	.964	.91

[a] $\hat{R}^2$ from quarterly data.

[b] Available only on a separate basis for primary non-ferrous metals

TABLE 3.8 - Continued

and primary iron and steel.

[c]Includes non-automotive transportation equipment (37 - 371).

D = Equation estimated in first differences

L = Equation estimated in levels.

A = Almon's modified weights.

* Not significant at 5% level.

In general, the industry expenditure equations fit the data quite well with $\hat{R}^2$s larger than .70 for eight of eleven industries in differences and all coefficients of determination $\geq$ .87 in levels. Even though a two year lag on appropriations is not significant in most industries, the coefficients on CA_{t-2} (or ΔCA_{t-2}) are usually of comparable magnitude with the Almon coefficients. Only one industry, non-electrical machinery, does not conform to the lag profile implied by Almon's modified results in both levels and first differences.

The sum of the distributed lag weights for each industry is computed in the fourth column of Table 3.8. Normally these sums should be slightly less than one to account for cancellations and the small amount of expenditures which depend on appropriations outside the estimated lag structure (i.e. CA_{t-3}). The coefficient sums in Table 3.8 fit this requirement for the equations estimated in levels, but the first difference weights sum to slightly more than one in five industries (including total manufacturing) and in one case, rubber products, the sum is less than one-half.

The variable lag model of Popkin (2.15) was also tested with annual data after being modified to conform to an annual lag structure.

Using the notation of (2.12 - 2.15) with t signifying an annual rather than quarterly time period, we can write:

(2.12a) $$CE_t = \alpha_{1,t} CA_t + \alpha_{2,t} CA_{t-1},$$

with variable coefficients determined by

(2.13a) $$\alpha_{1,t} = \beta_0 + \beta_1 (B/CE)_{t-1}$$

and

(2.14a) $$\alpha_{2,t} = 1 - \alpha_{1,t-1} = 1 - \{\beta_0 + \beta_1 (B/CE)_{t-2}\},$$

where the backlog expenditure turnover ratio (B/CE) is measured at the end of year t-1. The lag structure incorporating variable coefficients, is thus

(2.15a) $$CE_t = \beta_0 \Delta CA_t + \beta_1 \Delta\{CA_t \cdot (\frac{B}{CE})_{t-1}\} + \beta_2 CA_{t-1}.$$

Because of the restriction to incremental annual lags, $(B/CE)_{t-1}$ was used as the determinant of $\alpha_{1,t}$ rather than the analogous (to Popkin's equation) $(B/CE)_t$. Placing the backlog ratio at the beginning of quarter t-3 puts the lag at the midpoint of Popkin's range of t-2 to t-5.

The structure of the variable lag model forces all appropriations postponed in time period t due to capacity pressures (reflected by a lower α_1) to be spent in t+1 so that $\alpha_{1,t} + \alpha_{2,t+1} = \beta_2$. This assumption seems more appropriate for an annual lag pattern than one based on a quarterly time period. High capacity utilization may be maintained over a period of several quarters making the requirement that all postponed expenditures (plus normal expenditures from past appropriations) be realized two quarters after the initial postponement unrealistic. The annual formulation allows the "catching up" process to occur over a more reasonable four quarter interval. Thus in Popkin's model β_2 X 100

percent of a dollar's worth of appropriations are realized in expenditures between t-2 and t-5, while in the annual version eight quarters are allowed for $\beta_2 \times 100$ percent of appropriations to be delivered.

The estimate of (2.15a) for total manufacturing was:[30]

$$(3.18) \qquad CE_t = \underset{(.086)}{.324}\Delta CA_t - \underset{(.056)}{.050}\Delta\{CA_t \cdot (\tfrac{B}{CE})_{t-1}\} + \underset{(.015)}{.930}CA_{t-1}$$

$$R^2 = .972$$

The interaction term has the expected negative sign but is smaller than its standard error. Both β_0 and β_2 are of reasonable magnitudes when compared with their counterparts in the fixed lag relations.[31]

Regressions were estimated for the eleven industries, with results similar to the one for total manufacturing. Most interaction coefficients were not significant but the estimates of β_0 and β_2 were somewhat in agreement with those of the fixed coefficient model.[32] For the record, the industry equations are reproduced in Table 3.9, but further analysis will employ only the linear coefficient model for the distributed lag.

---

[30] Equation (2.15a) was estimated only in levels since the differenced version would have required second differences of CA. This would have entailed the loss of another degree of freedom and used a relatively unstable series in the regression.

[31] As rough approximations, $\beta_2 = \Sigma\alpha_i$ and $\beta_0 = \alpha_1$ when there is no interaction term, i.e. $\beta_1 = 0$.

[32] If the distributed lag is longer than two years, i.e. (CA_{t-2}) is relevant, then we would expect $\Sigma\alpha_i \simeq \beta_2$.

TABLE 3.9

ESTIMATES OF VARIABLE COEFFICIENT DISTRIBUTED LAG, BY INDUSTRY

$$CE_t = \beta_0 \Delta CA_t + \beta_1 \Delta\{(B/CE)_{t-1} CA_t\} + \beta_2 CA_{t-1}$$

Industry (SIC Number)	β_0	β_1	β_2	R^2
Food and Beverages (20)	.480* (.161)	-.151 (.195)	.924* (.036)	.872
Textiles (22)	-.571 (.197)	.683 (.154)	1.045* (.029)	.975
Paper and Allied Products (26)	.324 (.184)	-.122 (.088)	.909* (.031)	.972
Chemicals (28)	.367* (.100)	-.082 (.058)	.934* (.017)	.972
Petroleum and Coal (29)	.503* (.231)	.043 (.200)	.863* (.020)	.908
Rubber Products (30)	.259* (.091)	-.047 (.082)	.905* (.037)	.944
Stone, Clay and Glass (32)	.461* (.162)	-.098 (.083)	.971* (.025)	.909
Primary Metals (33)	.221 (.137)	-.266 (.149)	.952* (.165)	.873
Non-Electrical Machinery (35)	.780* (.206)	.033 (.169)	.940* (.055)	.986
Electrical Machinery (36)	.648* (.106)	-.231* (.078)	.883* (.019)	.922
Automotive (371)	.355* (.067)	-.110* (.040)	.966* (.032)	.973

*Significant at the 5% level (with expected sign).

Predicted Expenditures Within the Sample Period

The structure estimated in the first sections of this chapter can be thought of as a two-equation recursive system. We can combine the equation explaining appropriations with the estimated expenditure equation to predict the change in expenditures by the 1000 largest firms during the period used for estimation. If we substitute the predicted values of the change in appropriations into the estimated expenditure equation, the resulting values of expenditures will depend on both estimates and thus be subject to errors from both sources.

Letting $\Delta\hat{C}A$ be the predicted values from the least squares appropriations regression, the predicted values of expenditures become

$$\Delta C\tilde{E}_t = \alpha_0 \Delta\hat{C}A_t + \alpha_1 \Delta CA_{t-1} + \alpha_2 \Delta CA_{t-2},$$

$$\Delta C\tilde{E}_t = \alpha_0(\Delta CA_t - u_t) + \alpha_1 \Delta CA_{t-1} + \alpha_2 \Delta CA_{t-2}, \tag{3.19}$$

where u_t is the stochastic term in the appropriations equation. Denoting expenditures predicted from the least squares estimate of the distributed lag by $\Delta\hat{C}E$ and using (3.19), we can write

$$\Delta C\tilde{E}_t = \Delta\hat{C}E_t - \alpha_0 u_t.$$

If v_t is the stochastic term in the distributed lag estimate ($v_t = \Delta CE_t - \Delta\hat{C}E_t$), then

$$w_t = \Delta CE_t - \Delta C\tilde{E}_t = \Delta CE_t - (\Delta\hat{C}E - \alpha_0 u_t) = v_t + \alpha_0 u_t \tag{3.20}$$

is the prediction error made by the combined equations.

Since v_t and u_t both have zero expected values,[33] the sum of squares

[33] In order for $E(v) = 0$, the distributed lag must truly be a homogeneous relationship. Using the estimates for total manufacturing (in levels) the F ratio of the residual variance for the homogeneous and non-homogeneous cases was 1.104, not significantly different at the 5% level.

for w_t is

$$\Sigma w^2 = \Sigma v^2 + \alpha_0^2 \Sigma u^2 + 2\alpha_0 \Sigma vu. \tag{3.21}$$

If $2\alpha_0 \Sigma vu > \alpha_0^2 \Sigma u^2$ and Σvu is negative, $\Sigma v^2 > \Sigma w^2$. Otherwise, the residuals from the distributed lag equation alone will be smaller than the residuals generated by the recursive system.

A measure of the relative explanatory power of the recursive versus the least squares estimates of expenditures can be obtained by comparing their respective coefficients of determination,

$$\tilde{R}^2 = 1 - \frac{\Sigma w^2}{\Sigma(\Delta CE - \overline{\Delta CE})^2}$$

and

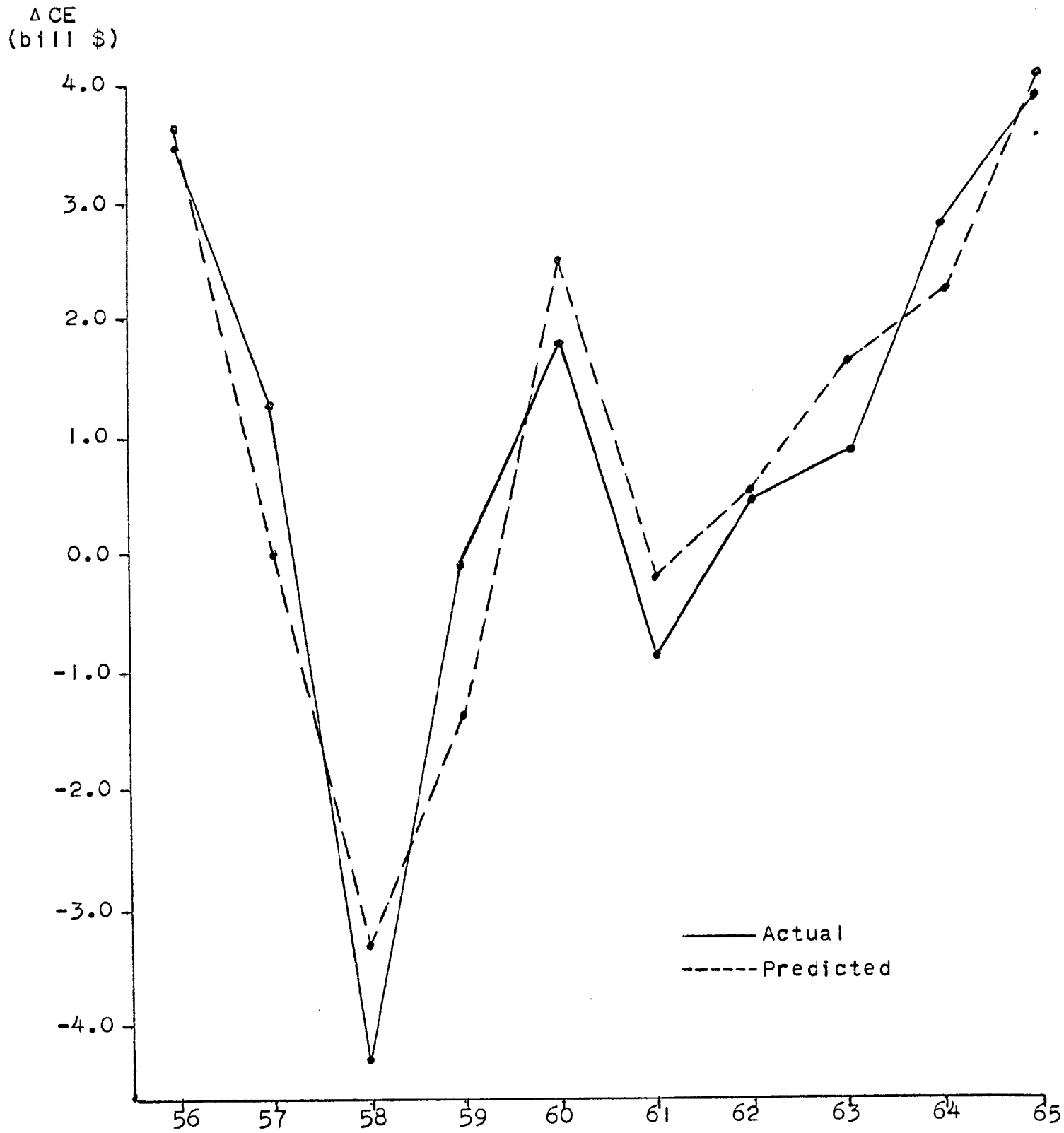
$$\hat{R}^2 = 1 - \frac{\Sigma v^2}{\Sigma(\Delta CE - \overline{\Delta CE})^2}$$

The closer $\tilde{R}^2$ is to $\hat{R}^2$ (when $\hat{R}^2 > \tilde{R}^2$), the less the influence of errors in predicting appropriations on the predicted values of expenditures. If $\hat{R}^2 < \tilde{R}^2$, the covariance term in (3.21) is negative and greater than $\alpha_0^2 \Sigma u^2$, an indication that the errors are offsetting.

$\Delta C\tilde{E}$ was computed for the period 1956-1965 using the first difference estimates of the lag coefficients (3.16) and $\Delta \hat{C}A$ from (3.10) for all of manufacturing. The calculated values are plotted along with the actual values in Figure 3.4.

The system estimates turning points correctly for both levels (indicated by ΔCE and $\Delta C\tilde{E}$ taking the same sign) and first differences. The w_t's have a mixed distribution exhibiting no systematic under or over estimation of expenditures. The root mean squared deviation (RMS) is 785 million dollars compared to the mean expenditure level of 10.64 billion. $\tilde{R}^2$ is .881.

Fig. 3.4--Expenditure predictions from recursive system (3.10 and 3.16) compared with change in actual expenditures, 1956-65.



If equation (3.09) is used for $\Delta\hat{C}A$, the same general accuracy results except for a turning point error in 1962 both in levels and first differences. The large reduction in stock market prices, apparently devoid of any economic significance, explains the 1962 error. Overall, the RMS is somewhat lower (767 million) and $\tilde{R}^2$ rises slightly to .886. Actual and predicted expenditures are plotted together in Figure 3.5 for the system including stock prices.

Industry predictions are summarized in Table 3.10 for the equations without stock prices. The figures in the U^2 column represent a third measure of the goodness of fit of the predictor equations.

The U^2 statistic, described by Theil,[34] is the ratio of the sum of the squared forecast errors to the sum of the actual values squared, i.e.

$$U^2 = \frac{\Sigma(\Delta CE - \Delta\hat{CE})^2}{\Sigma CE^2} .$$

The ratio measures the estimated model's predictive ability against a no-change naive model. Obviously $U^2 = 0$ when the prediction is perfect for all values. If the predictions do no better than the naive model, $U^2 = 1$, and values greater than one indicate a performance poorer than a simple no change estimate.[35]

U^2 is really designed to evaluate true (outside the sample) forecasts. In this case, a fairly good way of evaluating the equation estimates is contained in the comparison of $\tilde{R}^2$ and $\hat{R}^2$. However, U^2 does indicate how well the system does against a simple alternative and

---

[34]Henri Theil, Applied Economic Forecasting, (Chicago: Rand-McNally and Co, 1966), pp. 26-29.

[35]If the expected value of the change in capital expenditures was zero, i.e. $E(\Delta CE) = 0$, the U^2 could be interpreted as $1 - R^2$.

Fig. 3.5--Expenditure predictions from recursive system (3.09 and 3.16) compared with actual change in expenditures, 1956-1965.

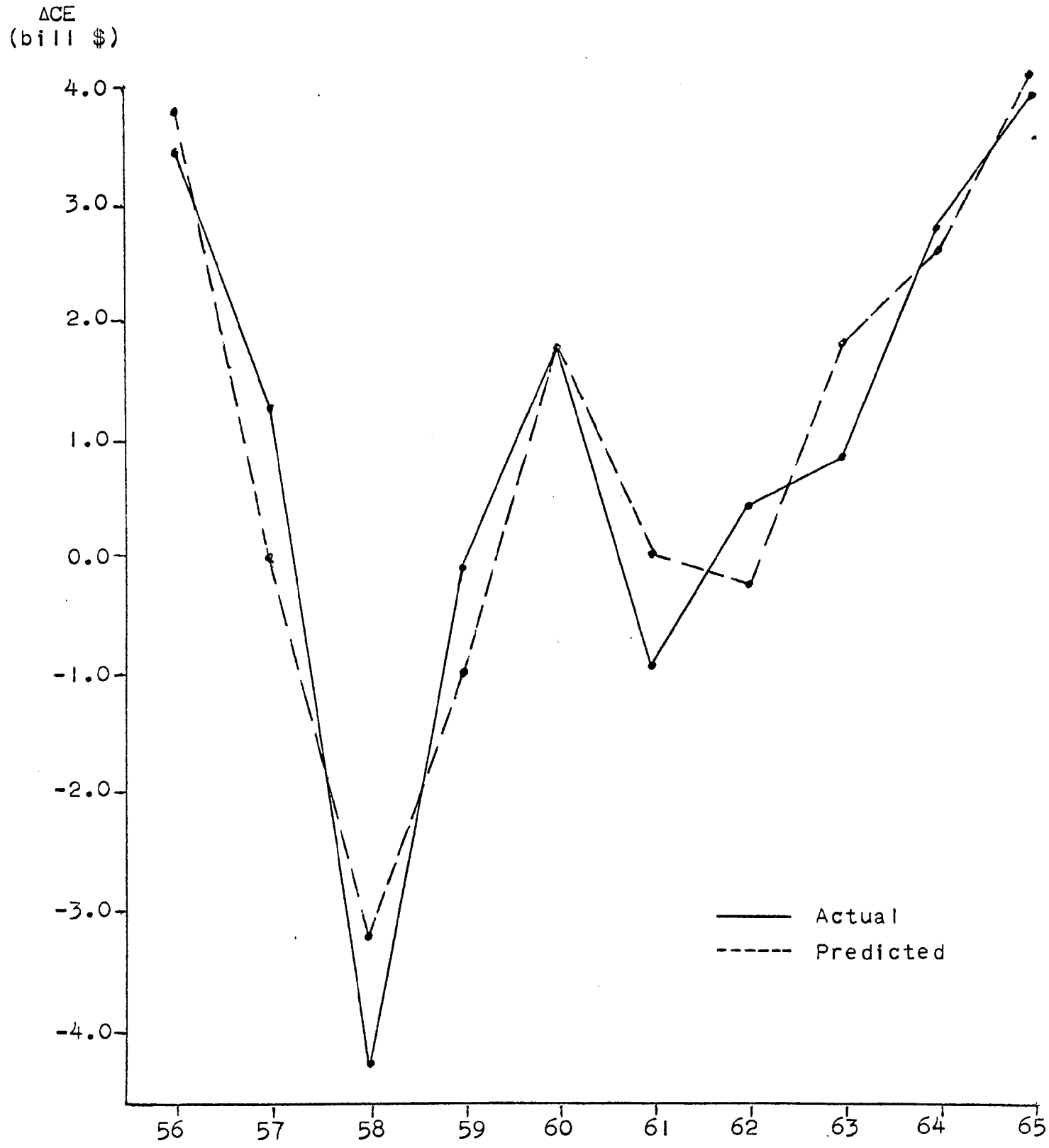


TABLE 3.10

EVALUATION OF WITHIN SAMPLE PREDICTIONS BASED ON EQUATIONS (3.10) AND (3.16), BY INDUSTRY, 1956-1965

Industry (SIC Number)	RMS[a]	$\overline{CE}$[c]	U^2	$\tilde{R}^2$	$\hat{R}^2$
Manufacturing (01)	.785	10.636	.102	.881	.89
Food and Beverages (20)	.069	.621	.792	-.238	.17
Textiles (22)	.032	.188	.379	.490	.55
Paper Products (26)	.042	.478	.100	.878	.89
Chemicals (28)	.121	1.444	.125	.863	.94
Petroleum and Coal (29)	.205	2.721	.372	.554	.74
Rubber Products (30)	.028	.217	.642	.210	.39
Stone, Clay and Glass (32)	.047	.456	.148	.858	.90
Primary Metals (33)	.272	1.638	.195	.795	.77
Non-Electrical Machinery (35)	.154	.768	.247	.652	.87
Electrical Machinery (36)	.059	.631	.187	.802	.95
Autos (371)	.153	1.018	.095	.901	.93

[a] $$RMS = \left\{\frac{\sum_{t=1}^{N}(\Delta CE_t - \Delta \hat{CE}_t)^2}{N}\right\}^{\frac{1}{2}}$$

[b] From Table 3.8, Line D.

[c] $\overline{CE} = 1/N\{\sum_{i=1955}^{1965} CE_i\}$ (billions of dollars).

thereby allows us to rank the industry predictions on a common standard. For this reason, it seemed reasonable to include U^2 along with RMS and $\hat{R}^2$ to create a more complete picture of the model's performance during the sample period. Because of the few data points available it was not possible to leave the last few observations out of the time series and then predict them from the estimates based on the included data points. The latter procedure would of course have been preferable and would have produced a more stringent forecasting test.

CHAPTER IV

CAPITAL APPROPRIATIONS AND A MODEL OF INCOME DETERMINATION

The previous analysis has developed and tested a model of fixed investment determination which starts with appropriations decisions. Our task in the final chapter is to examine the estimated model, first in isolation and then in conjunction with a complete national income determination system. The most interesting questions relate to the policy implications of the estimated parameters and the predictive ability of the structure when the interactions of the whole economy are taken into account. Thus we want to examine the "impact" multipliers[1] of the system as well as trace out the forecasting record of the macro-model with and without currently induced investment.

Single Equation Impacts

Before we examine the implications of combining appropriations with an interdependent system, it will be useful to study the impact of the determinants of appropriations on capital expenditures when the explanatory variables are treated as strictly exogenous. In particular, we shall focus on the effects of manufacturers' sales, cash flow and the corporate bond rate.

---

[1] "Impact" multiplier refers to the change in an endogenous variable with respect to the change in an exogenous variable during the period specified in the model. Since we are dealing with an annual model, the "impact" multiplier is a one-year multiplier.

Using the coefficients from equations (3.10) and (3.15)[2] we can compute the partial derivatives of capital expenditures with respect to each of the independent variables from the form:

$$(4.01) \qquad \frac{\partial CE}{\partial X_i} = \frac{\partial CA}{\partial X_i} \cdot \frac{\partial CE}{\partial CA},$$

where CA = capital appropriations,

CE = capital expenditures,

X_i = independent variables.

The partials for the three variables under consideration are

$$\frac{\partial CE_t}{\partial S_t} = \delta_1 \cdot \hat{\beta}^* \cdot \alpha_0,$$

$$\frac{\partial CE_t}{\partial RED^e_t} = \frac{-\delta_3 \cdot D_{L,t-1} \cdot \alpha_0}{(L_{t-1} + RED^e_t)^2},$$

$$(4.02) \qquad \frac{\partial CE_t}{\partial Baa_t} = \delta_2 \cdot \alpha_0,$$

or

$$\eta^3_{CE \cdot Baa} = \delta_2 \cdot \alpha_0 \cdot \left(\frac{Baa}{CE}\right),$$

where all variables and coefficients are defined as in Chapter III. The interest rate effect is also reported in its more familiar elasticity form.

Since we are measuring the "average" marginal effect of each variable on expenditures,[4] we should use the means of $\hat{\beta}^*$, $D_{L,t-1}$, L_{t-1}, RED^e_t, Baa_t

---

[2] Equations (3.10) and (3.15) were chosen because they represented the best forecasting set in Chapter III. Stock prices will be introduced in the forecasting experiments below.

[3] $\eta_{CE \cdot Baa}$ is the elasticity of expenditures with respect to the Baa rate.

[4] Since the regression coefficients are averages (of slopes) during the sample, the usual procedure is to treat the value of a variable as its mean during the same sample period.

and CE_t to obtain numerical estimates for each of the partial derivatives in (4.02). Substituting the mean values of the several variables into the equations yields:

$$\frac{\partial CE_t}{\partial S_t} = .013, \qquad \frac{\partial CE}{\partial RED_t^e} = .237 \text{ and } \eta_{CE \cdot Baa} = -.424.$$

The calculated effects appear somewhat smaller than might have been anticipated. A billion dollar increase in manufacturing sales will result in new capital expenditures of only 13 million dollars in the initial period. A one billion dollar rise in expected cash flow (a current period increase in RED of two billion dollars) will add 237 million dollars of capital expenditures. An increase of one per cent in the bond rate will generate a .42 per cent decline in expenditures.

Of course, the expenditure effects measured here are only one period impact effects and do not reflect the full effect of the distributed lag between appropriations and expenditures. If we assume that each dollar of appropriations is eventually spent, the marginal impact of each determinant on appropriations can be computed in a manner similar to that used to compute the effect on expenditures.

Calculating the partials of appropriations with respect to each determinant results in estimates of

$$\frac{\partial CA_t}{\partial S_t} = \delta_1 \cdot \hat{\beta}^* = .035$$

$$\frac{\partial CA_t}{\partial RED_t^e} = \frac{-\delta_3 \cdot D_{L,t-1}}{(L_{t-1} + RED^e)^2} = +.665$$

and

$$\eta_{CA \cdot Baa} = \delta_2 \cdot \left(\frac{Baa}{CA}\right) = -.902$$

where again all variables are measured at their means.

The marginal impacts on appropriations are of course higher, but the output and cash flow effects seem still somewhat low. The interest elasticity of investment decisions is high (almost one) but is based on the least reliable regression coefficient in the equation.

The estimated parameters imply a rather sluggish investment mechanism. Some of this sluggishness will be removed when interdependencies are accounted for, but the results at this point do seem to understate impacts on investment spending, particularly in the case of the low output effect. The marginal impact of sales on appropriations is slightly higher if the "adjusted" speed of adjustment coefficient[5] is used for δ_1. Using the "adjusted" δ_1 lets the impact on total manufacturing appropriations be proportional to the distribution of appropriations between large and small firms, thus making the impact slightly higher than the impact on appropriations by only the 1000 largest firms. The partial derivative of appropriations with respect to sales rises to .052 when this adjustment is made. However, this is still a fairly small effect[6] and the procedure of proportionate weighting leads to an overestimate if investment by small firms is less volatile than investment by large firms.

A more comprehensive reflection of the output, cash flow and interest rate impacts can be obtained by introducing these variables into an interdependent macro-ecomomic system. Sales fluctuate in response to changes in the several components of gross national product, retained earnings and depreciation are responsive to fluctuations in corporate

---

[5] See Chapter III , p. 54.

[6] Remember, however, that $\frac{dCA}{dS} = \frac{\partial CA}{\partial S} + \frac{\partial CA}{\partial RE} \cdot \frac{\partial RE}{\partial S}$ so that the total effect will be somewhat larger than the partial effect.

profits, taxes and so forth, while the interest rate responds to money market conditions. All of these factors should be taken into account before a final judgement can be made about the estimated investment structure.

A Macro-Econometric Model of the U.S. Economy

The econometric model used to study the full system impacts on appropriations and capital expenditures is modified from a recent version of the Research Seminar in Quantitative Economics (RSQE) forecasting model used at the University of Michigan.[7] The investment equations (3.10) and (3.15) were incorporated into the model for the experiments described below to explain manufacturing investment . Residual investment (the difference between the national accounts definition of business fixed investment and capital expenditures by the 1000 largest manufacturing firms) was projected on the basis of the OBE-SEC non-manufacturing investment anticipations series[8] and thus was made completely exogenous.

Since the RSQE model does not separate out the manufacturing sector, equations had to be introduced which linked manufacturers' sales and cash flow to gross national product, capital consumption allowance and total corporate retained earnings. In all three cases the best "linking" equation was found to be a simple linear relationship between each of the

---

[7] The equations in the model are published in The Economic Outlook for 1967 , (Ann Arbor: University of Michigan, 1967), and are not reproduced here.

[8] Op. cit. The March issues of the Survey of Current Business report the results of the January-February quarterly survey which includes an annual projection of investment expenditures. The reported anticipated rate of increase in non-manufacturing plant and equipment spending was applied to residual investment.

manufacturing series and the aggregate series. The relevant scatter diagrams along with two of the estimated regression lines are shown in Figures 4.1 and 4.2.

Both the sales and depreciation links fit quite closely. Inspection of Figure 4.1 shows the close relationship between manufacturing and total depreciation, close enough in fact to fit the equation by eye. However, there are several large residuals in the retained earnings equation shown in Figure 4.2. These are most likely caused by the different treatment of capital gains in the determination of corporate profits by the Commerce Department and the Federal Trade Commission. Since the fit was reasonably good it was decided to use this relationship rather than some other more complex equation with a slightly higher R^2.

When these "linking" equations are combined with the previously discussed behavioral equations, the relationships added to the RSQE model to complete the investment subsystem can be summarized by the following equations and definitions:

(3.10) $$\Delta CA_t = 2.219 + .137\Delta(\hat{\beta}^* S'_t - (K'_{t-1} + B_{t-1})) - 2.48\Delta Baa_t - 30.107\Delta F_t,$$

(3.15) $$\Delta CE_t = .356\Delta CA_t + .595\Delta CA_{t-1} + .098\Delta CA_{t-2},$$

(4.03) $$\Delta S'_t = -7.86 + 1.612\Delta G^{**}_t, \quad R^2 = .95, \quad (.117)$$

(4.04) $$\Delta RE_{m,t} = .242 + .493\Delta CRE_t, \quad R^2 = .76, \quad (.088)$$

(4.05) $$\Delta CCA_{m,t} = .250\Delta CCA_t,$$ Fitted by eye (See Figure 4.1).

(4.06) $$\Delta CE_{R,t} = CE_{R,t-1}(1 + \theta) - CE_{R,t-1},$$

(4.07) $$\Delta PE_t = \Delta CE_t + \Delta CE_{R,t},$$

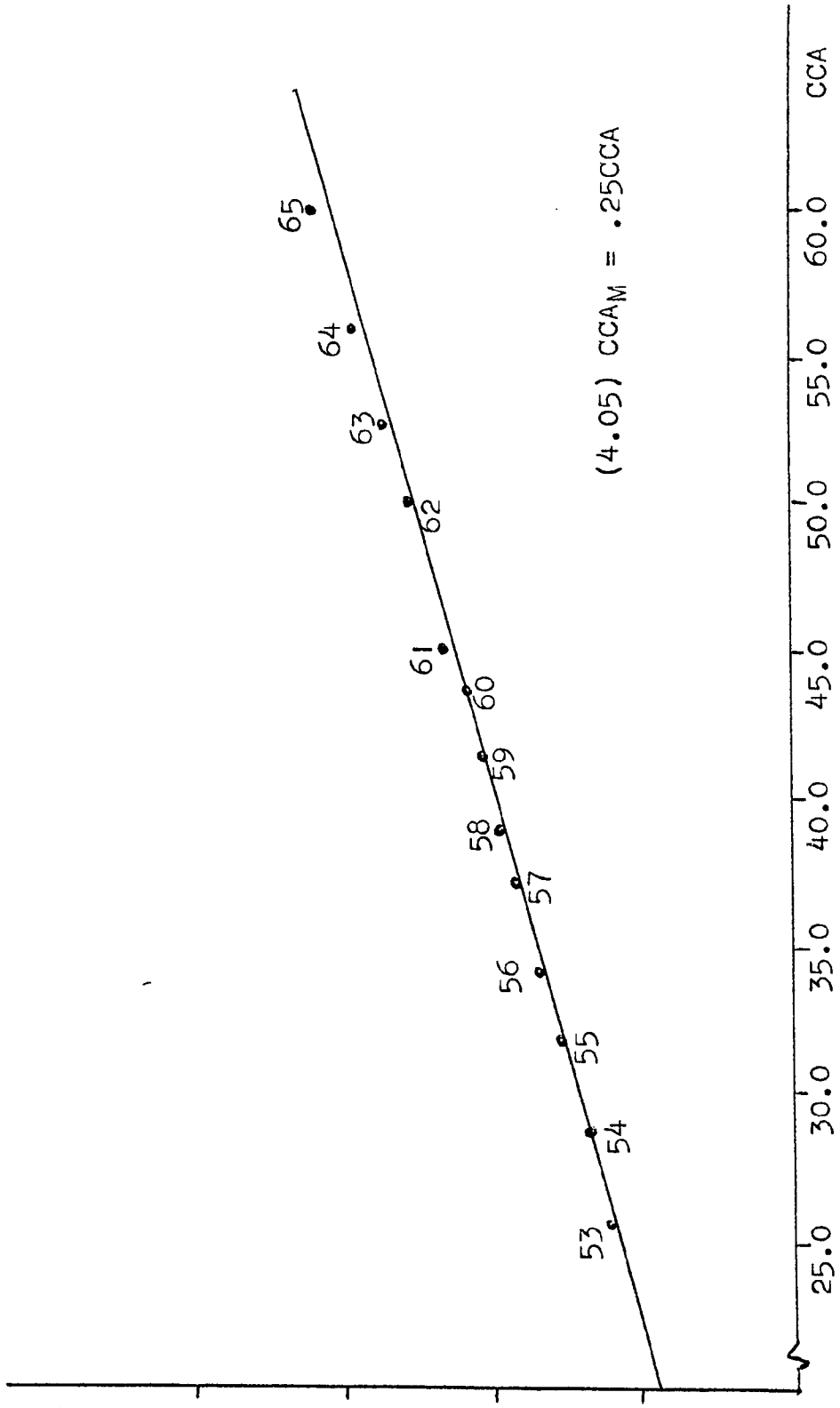
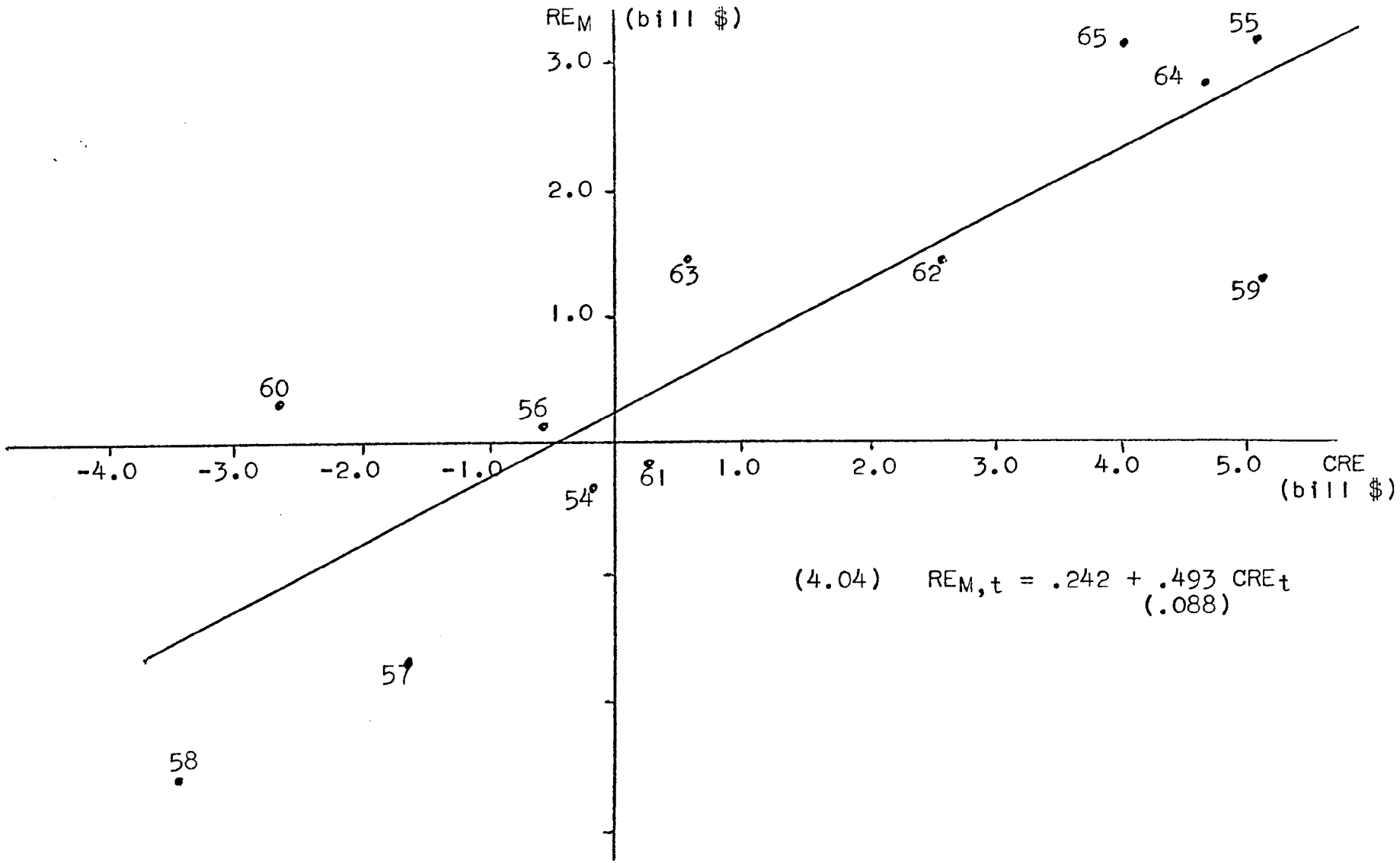


Fig. 4.1--Scatter of manufacturing depreciation (CCA_M) with total depreciation (CCA).



(4.04) $RE_{M,t} = .242 + .493\ CRE_t$
(.088)

Fig. 4.2--Scatter of manufacturing retained earnings (SEC-FTC) (RE_M) with total corporate retained earnings (CRE).

where: CA = capital appropriations of 1000 largest firms,

$\hat{\beta}^*$ = trend estimate of capital-sales ratio,

S' = manufacturers' sales divided by wholesale price index and multiplied by investment deflator,

K' = capital stock multiplied by investment deflator in t+1,

B = appropriations backlog,

Baa = corporate hond rate,

F = balance sheet and cash flow variable,

CE = capital expenditures of 1000 largest firms in current dollars,

G** = gross national product minus all service expenditures in current dollars,

RE_M = manufacturing retained earnings (SEC-FTC),

CRE = total corporate retained earnings,

CCA_M = capital consumption allowances in manufacturing sector (SEC-FTC),

CCA = capital consumption allowances for total economy,

CE_R = "residual" capital expenditures,

θ = percentage increase in non-manufacturing investment anticipated in first quarter of year t,

PE = national income accounts definition of business fixed investment expenditures in current dollars.

All price deflators were treated as exogenous variables since the version of the RSQE model used here made no explicit determination of price movements. Since the appropriations and expenditures equations were estimated with current dollar values, prices are only used to deflate money expenditures once those expenditures have been determined.

When equations (3.10), (3.16) and (4.03)-(4.07) were inserted into

the model, the resulting 97 equation system was solved by an iterative procedure.[9] Multipliers were obtained for several key variables and a series of annual forecasts for a wide range of variables was generated for a period of several years.

The Multipliers and the Structure of the RSQE Model

Perhaps the simplest method of describing the structure of the RSQE model, without specific reference to the myriad equations contained in the system, is to break down in detail the components of a familiar parameter, the government expenditure impact multiplier. The properties of this multiplier are a good indication of the nature of the model and the role played by induced investment in its structure.

Ignoring monetary effects for the moment, the government expenditure multiplier can be written in the form

$$(4.08) \qquad \frac{\Delta\overline{GNP}}{\Delta\overline{GOVT}} = \frac{1}{1 - \left(\frac{\Delta\overline{YD}}{\Delta\overline{GNP}} \cdot \frac{\Delta\overline{C}}{\Delta\overline{YD}} + \frac{\Delta\overline{PE}}{\Delta\overline{GNP}} + \frac{\Delta\overline{V}}{\Delta\overline{GNP}} - \frac{\Delta\overline{M}}{\Delta\overline{GNP}}\right)}$$

where $\overline{YD}$ = real disposable income,

$\overline{C}$ = real consumption expenditures,

$\overline{PE}$ = real fixed investment expenditures,

$\overline{V}$ = real change in stock of inventories,

$\overline{GNP}$ = real gross national product,

$\overline{GOVT}$ = real government expenditures,

$\overline{M}$ = real imports.

The estimated model parameters (marginal propensity to consume, marginal

---

[9] Barry Bosworth and Barbara Moores, "The RSQE Model Solution Program," (Ann Arbor: University of Michigan), 1967 (mimeo).

propensity to import, etc.) result in numerical estimates for the terms in the denominator of (4.06) of

$$\frac{\Delta\overline{YD}}{\Delta\overline{GNP}} = .563, \qquad \frac{\Delta\overline{C}}{\Delta\overline{YD}} = .780, \qquad \frac{\Delta\overline{PE}}{\Delta\overline{GNP}} = .025,$$

$$\frac{\Delta\overline{V}}{\Delta\overline{GNP}} = .090, \qquad \frac{\Delta\overline{M}}{\Delta\overline{GNP}} = .083.$$

The expression in parentheses, the respending coefficient, equals .471 and the multiplier is thus 1.89.

Additionally, there is a small monetary impact still unaccounted for explicitly in expression (4.06). The investment effect ($\Delta\overline{PE}/\Delta\overline{GNP}$) already includes the negative monetary effect of an increased corporate bond rate.[10] Besides the effect on investment, the only monetary feedback of increased government expenditures is on housing expenditures. This arises through the negative impact of higher interest rates and the positive impact of increased saving at commercial banks and non-bank saving institutions on the mortgage market. The net effect of a one billion dollar injection of government spending on the housing component is slightly positive and raises the multiplier to 1.92.

The primary determinant of the size of the respending coefficient is the high marginal propensity to consume in the consumption functions. Both the inventory and import respending coefficients seem reasonable, though inventories may (as seen below) be a bit high. However, the large consumption effect makes up for the small induced investment effect and results in a multiplier of reasonable magnitude.

Thus, the system can be characterized as having strong consumption

---

[10]The change in the corporate bond rate induced by a one billion dollar change in GNP (through government expenditures) was only .001 percentage points.

and inventory effects but very little investment or monetary impact. Each additional billion dollars of GNP induces 430 million dollars of consumption spending, 90 million dollars of inventory investment, 83 million dollars of imports and 25 million dollars of capital investment in the manufacturing sector.

In Table 4.1 the government multiplier is recorded along with three other important multipliers generated from the system -- exogenous or autonomous investment expenditures, the federal income tax and the treasury bill rate, a proxy for a monetary policy multiplier.

TABLE 4.1

SELECTED ONE-YEAR GROSS NATIONAL PRODUCT MULTIPLIERS CALCULATED FROM THE RSQE FORECASTING MODEL

Description	Symbol	Multiplier
Government Expenditures	$\frac{\Delta\overline{GNP}}{\Delta\overline{GOVT}}$	1.92
Exogenous Capital Investment	$\frac{\Delta\overline{GNP}}{\Delta\overline{PE}}$	2.77
Federal Income Tax	$\frac{\Delta\overline{GNP}}{\Delta T_{Fy}}$	-1.50
Treasury Bill Rate	$\frac{\Delta\overline{GNP}}{\Delta R_b}$	-1.99

The crucial role of inventory investment in the RSQE Model becomes clearer when the effect on GNP of a one billion dollar increase in non-manufacturing (exogeneous investment expenditures) is examined.

From Table 4.1, the reported multiplier is 2.77. The majority of

the increase in the multiplier is caused by the fact that producer's durable equipment is specified as an important direct determinent of durable inventory investment. With such a large direct impact on inventories, the respending coefficient for inventory change, i.e. $\Delta\overline{V}/\Delta\overline{GNP}$ shoots up to .28. The net effect on the multiplier is somewhat reduced by increased negative monetary impacts on plant and equipment and housing. These offsets arise because the corporate bond rate is strongly affected by an increased demand for capital goods. The rise in the Baa rate both reduces the investment respending coefficient ($\Delta\overline{PE}/\Delta\overline{GNP}$) and causes shifting from the mortgage market into the corporate bond market, thereby reducing the available supply of mortgage credit. The latter effect causes a reduction in the housing respending coefficient and further offsets the increased inventory respending coefficient.

The income tax multiplier and government bill rate multiplier are included in Table 4.1 to complete the picture of the system's interworkings. A one billion dollar increase in income tax liability will reduce real expenditures by one and a half billion dollars.

The bill rate multiplier indicates that a two billion decline in real gross national product would occur if a monetary policy were pursued which resulted in a one percentage point rise in the bill rate. This is obviously a very small monetary effect on GNP.

With such a small induced investment effect, the multipliers are little affected when all capital expenditures are treated exogenously. The government expenditure multiplier falls to 1.8, the monetary multiplier falls to 1.33 and the plant and equipment multiplier falls to 2.6 when all investment is made exogenous. Removal of the endogenous investment system reduces the bill rate multiplier proportionately more than

the government expenditure multiplier. This reaffirms our earlier observations on the relative size of the output and interest rate impacts on capital expenditures. It would be nice to be able to conclude that this indicates a strong interest elasticity of investment demand, but as pointed out above, the corporate bond rate is not significant in the appropriations regression and speculation about its importance on investment decisions must be modified accordingly.

When viewed in the context of the full interworkings of the economy, the investment response to output (GNP) may not be overly small. We have made manufacturing investment the only endogenous component of business fixed investment. Certainly the preponderance of induced effects occur in the manufacturing sector. To the extent that some of the "residual" catagory is induced, this formulation understates the impact of exogenous shifts in spending on plant and equipment. However, the multiplier which results from this specification is close to two. Even though the consumption and inventory impacts may be somewhat overstated, this result does not seem very far from a reasonable interpretation of the properties of the economic system.

Long Run Multipliers

An interesting extension of the preceding analysis would be the calculation of long run multipliers which measure the effects of exogenous changes in key policy variables on the system over a period of several years. In particular, our interest would focus on the two or three year impact on investment spending of a change in government spending or monetary policy. The two or three year period is of interest because of the expenditure-appropriation lag. We would like to measure the full impact

of the dynamic interworkings of the system, when the distributed lag is fully worked out.

However, the complicated formulation of the accelerator and balance sheet variables made this type of analysis impractical with the current RSQE model. The changes in four stocks, long term debt (D_L), liquid assets (L), capital stock (K), and appropriations backlog (B), must be generated from the model in order to determine the dynamic adjustment pattern of the investment component. L and D_L require detailed knowledge about the composition of assets and liabilities on the manufacturing sector's balance sheet and the change in B requires some estimate of cancellations of past appropriations. The structure of the RSQE Model makes no allowance for the determination of these flows.[11]

Full Model Forecasts

The complete model was used to make ex-post forecasts of various expenditure components of real GNP for the period from 1960 to 1965.[12] Primary interest in the forecast results, of course, centers on the forecasting performance of the investment expenditure equation when the major explanatory variables of manufacturing investment are made endogenous. However, we also want to evaluate the performance of the rest of the

---

[11] The real problem is the determination of the composition of manufacturer's assets and liabilities. Crude adjustments could be made to get cancellations by way of the distributed lag relationship of appropriations to expenditures.

[12] The limitation of the forecasting period to these six years was necessary due to the great amount of work entailed in collecting and keypunching the data necessary to satisfy the model's requirements. Some economies were achieved in this process by jointly collecting data with my colleague Wayne Vroman, who used much of the same data in his study relating to the Social Insurance Sector of the U.S. Economy.

system, since the quality of the other equations has some bearing on the forecasts of investment spending.

All forecasts were made with actual values of the predetermined and lagged endogenous variables in the system. Though this procedure is unrealistic from the point of view of practical forecasting, the alternative would have required an approximation of the projection procedure used to determine these values under realistic forecasting conditions. This procedure was not undertaken for obvious reasons. The result is a set of forecasts with errors reflecting misspecifications in the system plus random fluctuations in economic behavior, but not ex-ante errors in exogenous variables.

Two important variables were treated as completely determined in each time period. As mentioned earlier, prices were not made endogenous because the 1966 version of the model made no allowance for them.[13] Also, the monetary sector was still in experimental form and the equations determining money supply turned out to be quite unreliable. Therefore, money supply was made exogenous for these forecasts, though the money demand equation was left intact. A complete revision of the monetary sector is currently under way, but was not in a usable form for these experiments.

Tables 4.2 through 4.7 report summaries of the six annual forecasts. The demand components are reported in detail along with two relevant monetary indicators, the bill rate and the corporate bond rate, and several variables relevant to investment expenditures.

---

[13]Price equations were listed in the 1966 version of the model, but were not used to generate forecast values. See "The Economic Outlook for 1967," esp. Equas. VII A and VII B.

TABLE 4.2

FORECASTS OF SELECTED AGGREGATE DEMAND, INVESTMENT AND MONETARY VARIABLES FOR 1960 (ALL VALUES ARE FIRST DIFFERENCED UNLESS OTHERWISE NOTED)

Variable	Predicted Values			Observed Values
	"Endogenous Model"	"Exogenous Model"	"Actual Model"	
Aggregate Demand				
Automobiles (1958$)	2.6	3.0	2.0	1.0
Other Durables (1958$)	1.1	1.2	.8	.2
Non-Durables (1958$)	4.6	5.0	3.9	2.8
Services (1958$)	3.4	3.5	3.2	2.6
Change in Inventories (1958$)	.9	1.6	-1.1	-1.5
Business Fixed Investment (1958$)	4.7	5.8	3.0	3.0
Residential Construction (1958$)	-2.0	-2.1	-1.9	-2.8
Imports (1958$)	.8	1.0	.5	-.5
Gross National Product (1958$)	18.7	21.2	14.3	9.6
Investment (current $)				
Capital Appropriations	2.52	--	--	-1.24
NICB Capital Expenditures	2.63	--	--	1.79
Business Fixed Investment	5.13	6.20	3.3	3.30
Monetary				
Corporate Bond Rate (Baa)	.24	.28	.17	.14
Treasury Bill Rate*	3.38	3.42	3.31	2.93

*Levels

TABLE 4.3

FORECASTS OF SELECTED AGGREGATE DEMAND, INVESTMENT AND MONETARY VARIABLES FOR 1961 (ALL VALUES ARE FIRST DIFFERENCED UNLESS OTHERWISE NOTED)

Variable	Predicted Values			Observed Values
	"Endogenous Model"	"Exogenous Model"	"Actual Model"	
Aggregate Demand				
Automobiles (1958$)	-1.6	-1.8	-1.6	-1.6
Other Durables (1958$)	.4	.3	.4	.7
Non-Durables (1958$)	3.1	3.0	3.1	3.4
Services (1958$)	2.6	2.6	2.6	2.7
Change in Inventories (1958$)	-2.1	-2.3	-2.0	-1.4
Business Fixed Investment (1958$)	-1.6	-2.0	-1.6	-1.6
Residential Construction (1958$)	1.8	1.9	1.8	-.3
Imports (1958$)	.7	.7	.7	-.1
Gross National Product (1958$)	8.4	7.5	8.2	8.2
Investment (current $)				
Capital Appropriations	1.03	--	--	-.42
NICB Capital Expenditures	-.03	--	--	-.87
Business Fixed Investment	-1.35	-1.72	-1.40	-1.40
Monetary				
Corporate Bond Rate (Baa)	-.17	-.18	-.17	-.11
Treasury Bill Rate *	2.79	2.78	2.79	2.38

*Levels

TABLE 4.4

FORECASTS OF SELECTED AGGREGATE DEMAND, INVESTMENT AND MONETARY VARIABLES FOR 1962 (ALL VALUES ARE FIRST DIFFERENCED UNLESS OTHERWISE NOTED)

Variable	Predicted Values			Observed Values
	"Endogenous Model"	"Exogenous Model"	"Actual Model"	
Aggregate Demand				
Automobiles (1958$)	2.3	2.5	2.7	3.4
Other Durables (1958$)	1.2	1.3	1.4	1.7
Non-Durables (1958$)	3.8	4.0	4.2	5.2
Services (1958$)	2.9	2.9	3.0	3.8
Change in Inventories (1958$)	2.1	2.4	2.8	3.4
Business Fixed Investment (1958$)	2.8	3.3	4.2	4.2
Residential Construction (1958$)	1.8	1.8	1.7	2.2
Imports (1958$)	2.1	2.2	2.4	2.6
Gross National Product (1958$)	23.6	24.8	26.6	30.9
Investment (current $)				
Capital Appropriations	2.41	--	--	1.79
NICB Capital Expenditures	.48	--	--	.47
Business Fixed Investment	3.31	3.82	4.6	4.6
Monetary				
Corporate Bond Rate (Baa)	-.09	-.07	-.04	-.06
Treasury Bill Rate*	3.12	3.14	3.17	2.78

*Levels

TABLE 4.5

FORECASTS OF SELECTED AGGREGATE DEMAND, INVESTMENT AND MONETARY VARIABLES FOR 1963 (ALL VALUES ARE FIRST DIFFERENCED UNLESS OTHERWISE NOTED)

Variable	Predicted Values			Observed Values
	"Endogenous Model"	"Exogenous Model"	"Actual Model"	
Aggregate Demand				
Automobiles (1958$)	-.6	-.7	-.7	2.3
Other Durables (1958$)	1.7	1.7	1.7	2.3
Non-Durables (1958$)	3.5	3.4	3.4	4.0
Services (1958$)	3.5	3.5	3.5	3.9
Change in Inventories (1958$)	-1.7	-1.8	-2.1	-.2
Business Fixed Investment (1958$)	2.4	2.1	2.3	2.3
Residential Construction (1958$)	.4	.4	.4	1.0
Imports (1958$)	.5	.5	.5	1.1
Gross National Product (1958$)	12.6	12.0	12.3	18.8
Investment (current $)				
Capital Appropriations	.77	--	--	1.65
NICB Capital Expenditures	1.30	--	--	.86
Business Fixed Investment	2.73	2.48	2.60	2.60
Monetary				
Corporate Bond Rate (Baa)	-.04	-.05	-.05	-.16
Treasury Bill Rate *	3.32	3.31	3.32	3.16

*Levels

TABLE 4.6

FORECASTS OF SELECTED AGGREGATE DEMAND, INVESTMENT AND MONETARY VARIABLES FOR 1964 (ALL VALUES ARE FIRST DIFFERENCED UNLESS OTHERWISE NOTED)

Variable	Predicted Values			Observed Values
	"Endogenous Model"	"Exogenous Model"	"Actual Model"	
Aggregate Demand				
Automobiles (1958$)	4.6	4.4	4.8	1.5
Other Durables (1958$)	3.6	3.6	3.7	3.9
Non-Durables (1958$)	9.5	9.3	9.7	8.3
Services (1958$)	5.2	5.1	5.2	4.6
Change in Inventories (1958$)	2.2	1.9	1.5	.1
Business Fixed Investment (1958$)	5.0	4.6	5.5	5.5
Residential Construction (1958$)	.9	1.0	.9	-.2
Imports (1958$)	2.0	1.9	2.1	1.4
Gross National Product (1958$)	34.0	32.9	35.1	26.8
Investment (current $)				
Capital Appropriations	3.41	--	--	4.59
NICB Capital Expenditures	2.37	--	--	2.80
Business Fixed Investment	5.93	5.50	6.40	6.40
Monetary				
Corporate Bond Rate (Baa)	-.06	-.07	-.04	-.03
Treasury Bill Rate*	3.81	3.79	3.82	3.55

*Levels

TABLE 4.7

FORECASTS OF SELECTED AGGREGATE DEMAND, INVESTMENT AND MONETARY VARIABLES FOR 1965 (ALL VALUES ARE FIRST DIFFERENCED UNLESS OTHERWISE NOTED)

Variable	Predicted Values			Observed Values
	"Endogenous Model"	"Exogenous Model"	"Actual Model"	
Aggregate Demand				
Automobiles (1958$)	1.5	1.2	1.9	4.4
Other Durables (1958$)	2.7	2.6	2.8	2.9
Non-Durables (1958$)	6.7	6.4	7.1	7.7
Services (1958$)	4.9	4.8	5.0	5.0
Change in Inventories (1958$)	2.3	1.7	4.8	2.7
Business Fixed Investment (1958$)	6.5	5.8	7.5	7.5
Residential Construction (1958$)	-1.1	-1.0	-1.4	-.5
Imports (1958$)	1.6	1.4	1.8	3.0
Gross National Product (1958$)	27.4	25.4	29.7	31.9
Investment (current $)				
Capital Appropriations	2.57	--	--	4.28
NICB Capital Expenditures	3.81	--	--	3.94
Business Fixed Investment	7.94	7.13	9.00	9.00
Monetary				
Corporate Bond Rate (Baa)	.11	.08	.23	.04
Treasury Bill Rate *	3.95	3.92	4.28	3.95

*Levels

Three sets of forecasts are presented for each year, one with manufacturing investment endogenous (Endogenous Model), one with all investment determined by the OBE-SEC anticipations survey (Exogenous Model),[14] and a third which used the actual value of investment expenditures for ΔPE (Actual Model). A fourth set of forecasts which make use of the appropriations relationship including stock prices as a determinant is reported later.

The evaluation of a series of forecast values can be treated as a very mechanical process of computing standard errors of forecast or it can be a quite subjective interpretation of each forecast in conjunction with the unique circumstances in the particular year being predicted. The procedure here will try to incorporate the best features of each type of evaluation. We shall compute standard errors of forecast as a short cut way of focusing on the overall effectiveness of the forecasts. But where possible, we shall try to include in our evaluation unusual circumstances which may have contributed to particularly poor predictions.

In Table 4.8, the root mean square forecast error is shown for each demand component and the three key investment variables in the Endogenous Model. Both capital appropriations and capital expenditures are of course excluded from the Exogenous Model and the estimates of investment spending have no error in the Actual Model.[15]

---

[14]The expected annual increase in investment expenditures reported in the first quarter of the year was applied to total business fixed investment (PE) as defined in the National Accounts. The use of this late figure (as opposed to say the Mc-Graw fall survey figure) is consistent with the ex-post nature of the forecasts. It would not be fair to take the fall survey results for comparison with a behavioral equation which has the advantage of knowing the correct values of exogenous variables. Op. cit., Survey of Current Business, March issues for 1960-1965.

[15]The Actual Model is included as a convenient device which indicates the extent of forecast error due to imperfect forecasts of investment

TABLE 4.8

ROOT MEAN SQUARE ERROR[a] FOR ENDOGENOUS, EXOGENOUS AND ACTUAL MODEL FORECASTS, 1960-1965

Expenditure Variables[b] (1958$)	Endogenous Model	Exogenous Model	Actual Model
Automobile Expenditures	2.24	2.33	2.13
Other Consumption Expenditures	2.11	2.69	1.66
Business Fixed Investment	1.01	1.44	0
Inventory Investment	1.57	1.74	1.35
Residential Construction	1.09	1.12	1.14
Imports	.93	1.02	.81
Gross National Product	6.41	7.05	5.11
Investment Variables (current $)			
Capital Appropriations	1.90	--	--
Capital Expenditures (1000 Largest Manufacturers)	.55	--	--
Business Fixed Investment	1.03	1.45	0

[a] $$RMS = \{1/6 \sum_{i=1960}^{1965} (P_i - A_i)^2\}^{\frac{1}{2}}$$

[b] Standard errors of forecast for the monetary variables (Baa, Rb) were not included because of the tenuousness of the monetary sector.

---

spending. A detailed discussion of its forecasting ability is not included in the body of the text because any remarks made about its performance are obvious -- gross national product and its components can be forecast more accurately if actual investment spending is known beforehand. However, it does give some insight into the ability of the RSQE Model to forecast expenditure catagories other than investment spending. For example, the fact that the RMS error for automobile spending in the Actual Model is roughly the same as the forecast error for that catagory in the other two models emphasizes the poor quality of the equation used to explain automobile demand in the RSQE model.

Three things can be noticed from an inspection of Table 4.8. First, the forecasts of GNP were not unreasonable. Assuming that forecast errors are normally distributed around the true value of ΔGNP and that the variance of forecast error is the same in each year, two-thirds of the forecasts would be within 6.41 billion dollars (in the Endogenous Model) of the actual change and 95 percent of the forecasts would be within thirteen billion dollars of the true value.[16] Considering that we are making truly ex-post forecasts, this may seem a large error, but the fact that we have only six forecast observations tends to inflate the computed standard errors of estimate. None of the forecasts produced an error exceeding the two standard error interval, though three forecast errors fell outside the one standard error limits. It should also be pointed out that several equations outside of the investment subsystem performed badly during the forecast period. Due to time limitations, no attempt was made to adjust these equations in order to improve their performances

---

[16]The efficiency of the model forecasts as compared with naive no change alternative forecast can be measured by the U^2 coefficient of Theil. Theil, "Economic Forecasting." The computed value of U^2 was .08 indicating the model does much better than a no change forecast for GNP. However, a no change forecast is a little ridiculous, especially during the 1960's when the economy was growing relatively rapidly. Perhaps a better alternative is to compare the model forecast with the average change (21.0 billion dollars) in GNP during the period. This at least allows some recognition of the presence of economic growth in the economy. The ratio $\frac{\Sigma(\Delta\hat{GNP} - \Delta GNP)^2}{\Sigma(\Delta GNP - \Delta\overline{GNP})^2}$ was .45 (in the Endogenous version) for the six year period. The interpretation of this ratio is similar to the interpretation of Thiel's U^2. A value of zero indicates perfect forecasts in each year and a value of 1 indicates forecasts only as good as those using mean values for predictors. As in the case of U^2, the ratio has no upper bound.

A second conclusion apparent from Table 4.8, is that the Endogenous Model does a better job of forecasting than the Exogenous Model which projects investment on the basis of the OBE-SEC anticipations series exclusively. All the components of Gross National Product have lower standard errors with the appropriations system included in the model. Even more t· the point, the standard error of estimate for current dollar fixed investment in the Endogenous Model (PE) is almost half a billion dollars lower than the anticipations estimate. The standard error of estimate for the endogenous component of fixed investment alone (capital expenditures of the 1000 largest manufacturers) (CE) is only 550 million dollars. Since the errors in CE are in the same direction as the gross national product error in four out of six years, a tightening up of the rest of the system would most likely reduce the stnadard error of estimate of total plant and equipment spending even more.

Finally, the main culprit in the system appears to be the automobile equation.[17] The standard error of estimate of two and a quarter billion

---

[17]The equation used in the model was:

$$\overline{\Delta A} = .265\Delta(\overline{YD} - \overline{TR})_g - 3.790(NR - SC)_{-1} - 29.54\Delta P_a + 5.42, \quad R^2 = .75,$$

where: $\overline{A}$ = real consumption expenditures on automobiles,

$\overline{YD}$ = real disposable income,

$\overline{TR}_g$ = real government transfer payments,

$NR - SC$ = new registrations minus scrappage,

P_a = automobile expenditure deflator divied by total consumption expenditure deflator.

Several variants on this theme including distributed lags on $\overline{YD}$ and allowance for credit conditions are currently being tested by members of the RSQE.

dollars in this important consumption catagory is certainly a major contributor to the overall forecasting error of the model.

A closer examination of the individual forecasts reveals more detail about the nature of the model's forecasting errors. Since the best predictions came from the Endogenous Model, the following individual forecast analysis focuses primarily on this model. Where relevant, comparison with the Exogenous Model is incorporated into the discussion.

In 1960 an overestimate of almost two billion dollars in PE plus a 2.4 billion dollar overestimate of inventory change caused most of the overestimate in GNP. The large error in the appropriations equation plus the 2.9 billion dollar error in investment anticipations in the Exogenous Model suggests that optimistic expectations based on a strong recovery year in 1959 may have been the primary cause of the overall overestimate in 1960.

The model closely follows the 1961 recession, correctly predicting the decline in fixed investment spending. A large error in housing expenditures was largely offset by slight underestimates in the consumption and inventory components.

The 1962 recovery was slightly underestimated with the bulk of the error centered in PE and inventories. An anticipations forecast slightly closer to the actual value than the endogenous prediction caused the Exogenous Model to come closer to the actual size of the recovery. This was the only year in which anticipations did better than appropriations in explaining capital spending.

The error in 1963 can be attributed almost solely to the underprediction of automobile demand. However, despite the large error in autos and an overprediction of that year's inventory decumulation, the model

did catch the slowdown in growth and was able to forecast the concurrent slowdown in investment spending.

Again in 1964, the error in the automobile equation is the most noticable in the forecast. Along with the generally poor performance of this equation in 1964, an additional error was introduced by the slowdown in auto spending caused by the October automobile workers' strike. Since no allowance could be made a priori for such an occurrence,[18] further error was introduced into the 1964 forecast. The Exogenous Model appears to predict GNP better in 1964 than the counterpart Endogenous Model because it under predicts PE by more than the endogenous PE system does. The larger investment forecast error led to a more bearish (and thus more accurate) GNP forecast than did the Endogenous Model, despite the latter's better investment prediction.

Finally, in 1965 autos and PE are underestimated leading to a low overall forecast. Some of the automobile error may have been caused by a shift of sales from the strike year into calendar 1965.

The main impression of the model's forecasting preformances is that all of capital investment is forecast quite accurately (at least more accurately than by the anticipations survey) when only part of total expenditures -- the manufacturing sector -- are made endogenous. Only once (in 1962) does the absolute deviation of predicted PE from actual PE exceed the absolute value of the forecast error of endogenous PE. However, the automobile equation appears to present a definite forecasting problem for the whole model, though improvements in that equation (and other

---

[18] A "dummy" variable which accounted for strikes was not present in the equation. Though it would have been a simple procedure to add a "dummy," it was decided that the major problems with the equation far outweighed the absense of a strike allowance variable and so the equation was left intact rather than spend time on a complete overhaul.

problem equations) are beyond the scope of this study. Thus, despite weak spots in the performance of the RSQE model, it is heartening to find that the endogenous PE system does forecast well and that improvements in the whole model would most likely result in even better investment forecasts.

Addition of Stock Prices

A third set of forecasts made use of the appropriations equation in which stock prices were included as an explanatory variable (equation (3.09) replaced equation (3.10) in the system). Stock prices should be treated as an endogenous variable in the full system, since they do react to economic stimuli in the current year, but finding a predictor equation seemed to be a rather large order for the purposes of this study.[19]

Instead, it was assumed that the most one could do about stock market movements was to project a time trend of the level of Moody's series[20] based on the range of years covered in the prediction period. The initial observation for the trend line was chosen to be 1953 since the data used to obtain coefficient estimates of the behavioral equations started with that year. To predict 1960-65, an initial linear trend equation was fitted to the years 1953-59. This equation was used to forecast SP in 1960 and the predicted value ($\hat{SP}_t$) minus the observed value in 1959 (SP_{t-1}) was taken as the estimate of ΔSP_t. For succeeding years, the previous year's observation for SP was added to the data period and a new trend equation was estimated to predict that year's market. Thus,

---

[19] An equation relating stock prices to the corporate bond rate and lagged stock prices was tried, but proved completely unsuccessful.

[20] Department of Commerce, "Business Statistics."

$$SP_t = f(t \text{ from } 1953 \text{ to } t\text{-}1).$$

This simple procedure resulted in the estimates listed in Table 4.9 below.

TABLE 4.9

ACTUAL AND PREDICTED VALUES FOR THE CHANGE IN STOCK PRICES (ΔSP) AND CAPITAL EXPENDITURES (ΔCE), 1960-1965

Year	$\Delta\hat{SP}$	ΔSP	$\Delta\hat{CE}$	ΔCE^{ν}	ΔCE
1960	11.3	-13.1	2.46	1.90	1.79
1961	28.3	26.7	.15	.11	-.87
1962	15.0	-9.9	.30	-.27	.47
1963	28.9	28.2	1.54	1.53	.86
1964	13.1	40.4	2.09	2.72	2.80
1965	-5.6	25.7	3.17	3.89	3.94

$\hat{}$ = based on trend estimated stock prices

ν = based on actual stock prices

The trend estimates of ΔSP lead to poorer estimates of ΔCE in all cases, when compared with estimates of ΔCE based on actual stock prices. The estimate of ΔSP is close to the acutal change in stock prices in only two years, 1961 and 1963. Thus, this rather primitive estimating technique leads to very poor forecasts of the stock market.

Table 4.10 reports the root mean square (RMS) errors of forecasts when both actual (ΔSP) predicted ($\Delta\hat{SP}$) stock prices are used in the appropriations equation (3.09). The addition of stock prices improves the forecast of appropriations when actual ΔSP is used during the fore-

casting period.[21] However, both gross national product and capital expenditures have virtually the same forecast error as they do in the Endogenous Model, which does not include the stock market variable. When the trend estimates are used in the forecasts the RMS error is larger for both appropriations and capital expenditures, due to the large prediction errors in $\Delta\hat{S}P$.

TABLE 4.10

ROOT MEAN SQUARE ERROR WHEN ACTUAL (ΔSP) AND ESTIMATED ($\Delta\hat{S}P$) STOCK PRICES ARE INCLUDED IN THE APPROPRIATIONS EQUATION, 1960-1965

Variable	$\Delta\hat{S}P$ Model	ΔSP Model
Gross National Product (1958$)	6.49	6.54
Capital Expenditures (1000 Largest Manufacturers) (current $)	.72	.57
Capital Appropriations (current $)	2.26	1.35

$\Delta\hat{S}P$ Model = trend prediction of ΔSP.

ΔSP Model = actual values of ΔSP.

Thus, the forecasting power of the appropriations equation is somewhat improved (at least in the 1960-65 period) if actual stock prices are known. However, it would take a substantially better stock price predictor than the trend method used here to generate forecasts good enough to match those of the Endogenous Model. When the root mean square errors of

[21] This is consistent with the higher $\bar{R}^2$ for equation (3.09) of .85 when compared with equation (3.10) which has an $\bar{R}^2$ of .71. The errors in Table 4.10 are based on full model forecasts.

gross national product and capital expenditures in the actual stock price model are compared with the errors in the same catagories of the Endogenous Model, it is evident that the improvement in the appropriations forecasts would not lead to improved forecasts in those two crucial catagories.[22] Thus, the lack of a good method of predicting stock market movements does not rule out a structure which would lead to better forecasts than those generated by the Endogenous Model.

---

[22] In fact the RMS error for ΔCE is slightly larger when appropriations equation (3.09) is used instead of (3.10). The difference is small (.57 versus .55) and not significant. However, the fact that the RMS error for ΔCE does not fall at least slightly when compared with the Endogenous Model, emphasizes the fact that fairly large appropriations errors can average out to fairly small expenditure errors because of the nature of the lag between expenditures and appropriations.

CHAPTER V

CONCLUDING COMMENTS

The preceeding analysis has demonstrated that a reasonably good explanation of manufacturing fixed investment spending is feasible when capital appropriations are explicitly introduced as the dependent variable in a behavioral model of investment spending. Even though appropriations data is only available for large manufacturing firms, most of the variation in total investment spending arises in that particular segment of the economy. Thus, the analysis is relevant to a discussion of all manufacturing investment fluctuations.

The specification tested here, though much simplified, captures the flavor of an integrated output and funds theory of investment spending. Evidence supporting the general applicability of such a theory was obtained from individual industry as well as aggregate manufacturing estimations. In addition, the appropriations approach produced full-economy investment forecasts in a macro-econometric model which were better than a straight application of the Commerce Department's survey of investment spending intentions.

The fact that the statistical estimation of the structure resulted in reasonable parameter estimates and that the structure was able to predict well goes a long way toward justifying the model as a workable approximation to reality. Certainly it introduces further evidence in favor of the compatability (really complementarity) of accelerator and cost

of funds theories of investment spending behavior.

Several comments are in order regarding some of the more obvious shortcomings of the analysis. First, the self-imposed constraint of formulating the structure in an annual format eliminated the possibility of a detailed examination of the lag relationships in both the appropriations and expenditures equations. Though the annual specification gives useful results, it seems clear that a more thorough study of the form of the distributed lag response in both relationships would lead to a higher degree of accuracy in estimation and prediction. The annual specification was chosen strictly to accomodate the annual time period in the RSQE Model.

Second, the explanation of the role played by common stock prices in the determination of appropriations is unsatisfactory. This variable appears to be a significant contributor to the explanation of appropriations. However, the ad hoc argument for "expectations" is a weak one. This is primarily the result of the annual specifications. If there is an explanation for the relationship between appropriations and stock prices, its nature if certainly obscured when one looks at annual data. A shorter time period would allow the introduction of recent lagged values of the stock market variable and thereby clarify the causal ordering of the two variables.

Finally, the somewhat tenuous nature of the version of the RSQE Model used for the national income forecasts caused additional error in the predictions. Improvements in the basic model structure would result in better overall forecasts (including investment) than those actually calculated in this study. Also, it would have been useful to forecast for several periods outside the sample period used to estimate the model's

equations. This, of course, was precluded by data limitations.

The thrust of the several preceeding points is that further research should concentrate on shortening the response interval. Quarterly estimation of the structure would allow a more specific lag pattern to be introduced into the appropriations equation. While Almon[1] has already estimated the fixed coefficient distributed lag for the expenditures equation with quarterly data, further work leading to a more flexible variable coefficient lag model than Popkin's[2] should be pursued. Ultimately such a quarterly structure could be incorporated into a quarterly econometric forecasting model and experiments similar to those reported here could be performed.

In conclusion, the statistical estimates presented here represent a first step toward incorporating appropriations decisions into a macroeconomic investment structure. Despite, the limitations of this initial effort, the results indicate that this is promising framework for the empirical study of investment fluctuations.

---

[1] Almon, "Distributed Lag."

[2] Popkin, "Comment."

APPENDIX I

PROCEDURE TO INFLATE APPROPRIATIONS BACKLOG

The appropriations backlog for the 1000 largest firms is inflated to approximate a backlog figure for all firms in the industry by the following method.

Let B^T = backlog for all firms,

B^{1000} = backlog of 1000 largest firms,

B^o = backlog of smallest firms,

CE^T = capital expenditures by all firms from OBE-SEC series,

CE^{1000} = capital expenditures by 1000 largest firms from NICB,

CE^o = capital expenditures of smallest firms.

The two identities

$$(1) \qquad B^T = B^{1000} + B^o$$

$$(2) \qquad CE^T = CE^{1000} + CE^o$$

follow directly from the definition of the variables.

On the assumption that smaller firms phase appropriations into expenditures according to the same pattern as the 1000 largest and that total backlog (B^T) is proportional to the expenditures ratio (CE^T/CE^{1000}), it seemed reasonable to let the Δ in B^o in any year $\underline{t}$ be

$$(3) \qquad \Delta B_t^o = \Delta B_t^{1000}(CE_t^o/CE_t^{1000}).$$

That is, the change in B^o was made proportional to the change in B^{1000}, with the proportion determined by the relative size of the smallest and largest manufacturers as measured by expenditures.

A beginning stock was determined by letting B^T for 1953 be set by

$$(4) \qquad B^T_{1953} = B^{1000}_{1953}\left(\frac{\sum_{i=1}^{1965} CE_i^T}{\sum_{i=1}^{1965} CE_i^{1000}}\right).$$

Then for any year t, the total backlog was calculated from

$$(5) \qquad B^T_t = B^T_{1953} + \sum_{i=1954}^{t} \Delta B_i^{1000} + \sum_{i=1954}^{t} \Delta B_i^{o}.$$

APPENDIX II

DATA SOURCES AND SELECTED BASIC DATA SERIES

Capital Appropriations and Expenditures

Table II.1 and II.2 list the annual series for capital appropriations and expenditures by individual manufacturing industries. The data are compiled only for those industries used in this study. Source: National Industrial Conference Board, "A Quarterly Survey of Capital Appropriations," Investment Statistics.

Independent Variables

The following series were used as the raw material to construct the independent variables for the total manufacturing and separate industry equations. Only the data series for total manufacturing are presented in Table II.3.

(1) S = manufacturers' shipments (current $). Source: Business Statistics, 1965, (U.S. Dept. of Commerce, Washington, D.C.), pp. 25-26, for 1953-1964; for 1965, Survey of Current Business, June, 1966.

(2) K = net capital stock (1954$). Source: Bert G. Hickman, Investment Demand and U.S. Growth, (Brookings Institution, Washington, D.C., 1965), p. 231, for 1953-1962. The figures for 1963-65 were calculated from Hickman's method as described in Investment Demand, Appendix B.

(3) O = Federal Reserve Index of Industrial Production in December, seasonally adjusted. Source: Business Statistics, pp. 17, 210, for 1954-1964; for 1965, Survey of Current Business, June, 1966.

(4) WPI = wholesale price index (1957-59 = 100) for various industries. Source: Business Statistics, pp. 43-47 for 1953-1964; for 1965, Survey of Current Business, June, 1966.

(5) P_{PE} = index of price of new plant and equipment. Source: Investment Demand, p. 237 for 1953-1962; for 1963-1965 based on extrapolation of Hickman's method as described in Investment Demand, Appendix B.

(6) U = capacity utilization rate. Source: U.S. Congress, Joint Economic Committee, Measures of Production Capacity, Hearings, before the Subcommittee on Economic Statistics, pursuant to Sec. 5(a) of Public Law 304, 79th Congress, 2nd Session, 1962, p.12, for 1954-1961; for 1962-1965, various issues of Business Week (McGraw-Hill).

(7) Baa = corporate bond rate (Moody's Baa). Source: Business Statistics, p. 105 for 1953-64; for 1965, Survey of Current Business, June, 1966.

(8) SP = price per share of common stock (Moody's Industrials). Source: Business Statistics, p. 107 for 1953-1964; for 1965, Survey of Current Business, June, 1966. Individual industry data from Standard and Poor's, Trade and Securities Statistics: Security Price Index Record, 1966.

(9) D_L = corporate manufacturing long term debt outstanding from commercial banks and all other sources.

(10) L = corporate manufacturing cash on hand plus government securities minus federal income taxes accrued.

(11) RED = corporate manufacturing retained earnings plus depreciation expense. Source (For (9), (10), (11)): Federal Trade Commission and Securities and Exchange Commission, Quarterly Financial Report for Manufacturing Corporations, 1953-1965. All series have been adjusted individually for the 1956 and 1958 changes in sample composition.

(12) B^T = capital appropriations backlog of 1000 largest manufacturers inflated as described in Appendix I.

TABLE II.1

CAPITAL APPROPRIATIONS OF 1000 LARGEST MANUFACTURING FIRMS, BY INDUSTRY, 1953-1965, (MILLIONS OF DOLLARS)

Industry	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Manufacturing	7,910	7,688	13,398	14,316	11,261	8,113	11,543	10,316	9,901	11,688	13,343	17,934	22,207
Food and Beverages	485	524	515	517	632	529	647	621	797	696	847	857	1,128
Textiles	125	108	153	157	113	118	203	196	183	214	234	304	508
Paper and Allied Products	207	255	572	666	377	271	461	416	315	487	750	900	1,222
Chemicals	790	752	1,143	1,973	1,513	898	1,408	1,397	1,503	1,602	1,662	2,511	2,921
Petroleum and Coal	2,365	2,823	3,078	3,230	3,340	2,575	2,834	3,047	2,908	2,853	3,016	3,975	4,153
Rubber Products	131	117	214	226	193	123	269	228	251	238	282	450	422
Stone, Clay, and Glass	188	325	596	621	381	304	533	342	391	415	458	592	752
Primary Metals	872	732	2,486	2,568	1,780	1,152	1,963	1,152	877	1,688	1,814	2,383	3,042
Non-Electrical Machinery	350	346	464	775	715	517	607	538	597	837	941	1,372	2,097
Electrical Machinery	595	443	656	1,092	656	468	802	764	527	606	546	835	1,371
Autos	1,188	707	2,562	1,269	593	291	688	586	551	715	1,234	2,154	2,007

TABLE II.2

CAPITAL EXPENDITURES OF 1000 LARGEST MANUFACTURING FIRMS, BY INDUSTRY, 1953-1965, (MILLIONS OF DOLLARS)

Industry	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Manufacturing	8,194	7,937	8,326	11,833	13,132	8,843	8,802	10,585	9,717	10,187	11,050	13,853	17,792
Food and Beverages	477	457	430	527	633	537	560	594	587	639	661	780	883
Textiles	161	111	129	174	144	100	163	211	162	216	193	244	332
Paper and Allied Products	209	251	320	514	574	372	353	456	358	384	452	644	828
Chemicals	1,150	938	761	1,179	1,662	1,267	1,006	1,369	1,505	1,448	1,494	1,840	2,353
Petroleum and Coal	2,303	2,384	2,624	2,842	3,034	2,301	2,439	2,495	2,571	2,528	2,601	2,951	3,543
Rubber Products	144	121	141	187	200	129	150	205	221	234	252	261	410
Stone, Clay, and Glass	203	228	365	612	538	312	370	449	411	408	468	479	599
Primary Metals	1,413	855	992	1,814	2,603	1,539	1,238	1,786	1,214	1,136	1,328	1,994	2,371
Non-Electrical Machinery	374	368	384	487	717	487	519	521	502	803	865	1,180	1,986
Electrical Machinery	544	504	493	674	699	552	545	693	665	562	551	600	909
Autos	665	1,161	993	1,914	1,275	451	505	709	578	676	901	1,390	1,808

TABLE II.3

BASIC DATA FOR TOTAL MANUFACTURING (INDEPENDENT VARIABLES), 1953-1965

Year	(1) S (bill $)	(2) K* (bill 54 $)	(3) O (1957-59= 100, Dec. of t)	(4) WPI (1957-59= 100)	(5) P_{PE} (1954= 100)	(6) U (%)	(7) Baa (%)	(8) SP ($ per share)	(9) D_L* (bill $)	(10) L* (bill $)	(11) RED (bill $)	(12) B^T* (bill $)
1953	298.1	87.6	--	90.7	98.5	--	3.74	76.1	18.2	14.2	12.2	7.8
1954	280.3	90.7	89.4	91.4	100.0	84	3.51	95.8	19.0	16.4	12.4	6.7
1955	317.8	92.7	100.7	92.4	103.6	92	3.53	130.7	20.6	18.3	16.4	14.4
1956	332.9	96.4	102.6	96.0	110.7	86	3.88	149.4	23.0	16.1	17.4	16.9
1957	344.8	99.8	94.5	99.0	116.2	78	4.71	143.7	25.7	15.4	17.3	13.2
1958	327.5	98.8	100.2	100.1	118.9	80	4.73	149.8	27.7	17.3	15.1	10.4
1959	362.6	98.2	109.9	100.9	121.8	85	5.05	186.3	29.0	18.7	16.8	13.7
1960	369.6	99.3	103.0	101.0	123.4	77	5.19	173.2	30.4	17.4	17.8	12.2
1961	370.6	99.5	115.9	100.7	124.5	83	5.08	199.9	32.7	17.7	18.4	12.6
1962	400.0	100.4	119.7	100.8	125.9	83	5.02	190.0	35.3	16.9	21.0	13.6
1963	417.3	101.7	124.9	100.6	129.1	85	4.86	218.2	37.3	17.6	23.2	16.9
1964	445.6	104.8	132.9	101.1	131.4	88	4.83	258.6	39.2	19.1	26.8	22.5
1965	483.3	109.7	150.6	102.8	134.5	87	4.87	284.3	44.3	16.9	31.3	28.5

*All stocks are measured at end of period.

SELECTED BIBLIOGRAPHY

Almon, Shirley. "The Determinants of Capital Appropriations in Manufacturing." (Mimeographed)

_____. "The Distributed Lag Between Capital Appropriations and Expenditures." Econometrica, XXXIII, (January, 1965), pp. 178-197.

Anderson, W.H. Locke. Corporation Finance and Fixed Investment. Cambridge, Mass.: Harvard University Press, 1964.

Baumol, W.J. "The Transactions Demand for Cash: An Inventory Theoretic Approach." Quarterly Journal of Economics, LXVI, (November, 1952), pp. 545-56.

Chenery, Hollis B. "Overcapacity and the Acceleration Principle." Econometrica, XX, (January, 1952), pp. 1-20.

Cohen, Morris. "The National Industrial Conference Board Survey of Capital Appropriations." The Quality and Economic Significance of Anticipations Data. Princeton: Princeton University Press, 1960.

Conference on the Economic Outlook. The Economic Outlook for 1967. Ann Arbor: University of Michigan, 1967.

DeLeeuw, Frank. "The Demand for Capital Goods by Manufacturers: A Study of Quarterly Time Series." Econometrica, XX, (July, 1962), pp. 407-424.

Duesenberry, James. Business Cycles and Economic Growth. New York: McGraw-Hill, 1958.

Eisner, R. and Strotz, R.H. "The Determinants of Business Investment." Impacts of Monetary Policy, prepared for the Commission on Money and Credit. Englewood Cliffs, N.J.: Prentice-Hall, 1963.

Federal Trade Commission and Securities and Exchange Commission. Quarterly Financial Report for Manufacturing Corporations, (1952-1965).

Fisher, Franklin. A Priori Information and Time-Series Analysis. Amsterdam: North Holland, 1966.

Goodwin, R.M. "The Non-Linear Accelerator and the Persistence of Business Cycles." Econometrica, XIX, (January, 1951), pp. 1-17.

Griliches, Z. and Wallace, N. "The Determinants of Investment Revisited." International Economic Review, VI, (September, 1965), pp. 311-329.

Hickman, Bert G. Investment Demand and U.S. Economic Growth. Washington, D.C.: The Brookings Institution, 1965.

Johnston, J. Econometric Methods. New York: McGraw-Hill, 1963.

Jorgenson, Dale W. "Anticipations and Investment Behavior." The Brookings Quarterly Econometric Model of the U.S. Edited by J.S. Duesenberry, et. al.,Chicago: Rand McNally, 1965.

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

Lerner, Abba P. Economics of Control. New York: McMillan Co., 1944.

National Industrial Conference Board. "A New Survey of Capital Appropriations." The Conference Board Business Record, XIII, (1956), pp. 418-34.

_____. "Quarterly Survey: Capital Appropriations." Investment Statistics, (1953-1965).

Popkin, Joel. "Comment on 'The Distributed Lag Between Capital Appropriations and Expenditures.'" Econometrica, XXXIV, (July, 1966), pp. 719-24.

Resek, Robert. "Investment by Manufacturing Firms: A Quarterly Time Series Analysis of Industry Data." Review of Economics and Statistics, XLVIII, (August, 1966), pp. 322-347.

Suits, Daniel B. "Forecasting and Analysis With an Econometric Model." American Economic Review, LII (March, 1962), pp. 104-32.

Theil, Henri. Applied Economic Forecasting. Chicago: Rand-McNally and Co., 1966.

U.S. Congress. Joint Economic Committee. Measures of Production Capacity. Hearings before the Subcommittee on Economic Statistics, pursuant to Sec. 5(a) of Public Law 304, 79th Congress, 2nd sess., 1962.

U.S. Dept. of Commerce. Office of Business Economics. Business Statistics. Washington, D.C.: Government Printing Office, 1965.

_____. Survey of Current Business, (1953-1965).