INFORMATION TO USERS

This was produced from a copy of a document sent to us for microfilming. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the material submitted.

The following explanation of techniques is provided to help you understand markings or notations which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting through an image and duplicating adjacent pages to assure you of complete continuity.

2. When an image on the film is obliterated with a round black mark it is an indication that the film inspector noticed either blurred copy because of movement during exposure, or duplicate copy. Unless we meant to delete copyrighted materials that should not have been filmed, you will find a good image of the page in the adjacent frame. If copyrighted materials were deleted you will find a target note listing the pages in the adjacent frame.

3. When a map, drawing or chart, etc., is part of the material being photographed the photographer has followed a definite method in "sectioning" the material. It is customary to begin filming at the upper left hand corner of a large sheet and to continue from left to right in equal sections with small overlaps. If necessary, sectioning is continued again—beginning below the first row and continuing on until complete.

4. For any illustrations that cannot be reproduced satisfactorily by xerography, photographic prints can be purchased at additional cost and tipped into your xerographic copy. Requests can be made to our Dissertations Customer Services Department.

5. Some pages in any document may have indistinct print. In all cases we have filmed the best available copy.
Respess, Thomas Sanford, III

THE EFFECTS OF INFLATION AND INFLATION UNCERTAINTY ON
BUSINESS INVESTMENT

Rice University

University Microfilms International 300 N. Zeeb Road, Ann Arbor, MI 48106
RICE UNIVERSITY

THE EFFECTS OF INFLATION AND INFLATION UNCERTAINTY
ON BUSINESS INVESTMENT

by

Thomas S. Respess III

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE

DOCTOR OF PHILOSOPHY

APPROVED, THESIS COMMITTEE:

[Signatures and names]

Gordon W. Smith, Professor of Economics, Chairman

George R. Zodrow, Assistant Professor of Economics

Richard J. Stoll, Assistant Professor of Political Science

HOUSTON, TEXAS

May 1982
THE EFFECTS OF INFLATION AND INFLATION UNCERTAINTY
ON BUSINESS INVESTMENT

by

Thomas S. Respess III

ABSTRACT

Previous theoretical analysis suggests that by reducing the real value of depreciation deductions based on historic-cost asset prices, inflation reduces the incentive to purchase depreciable plant and equipment. This analysis also suggests that the negative effects of inflation on investment will be greater for equipment than structures, and will vary according to different initial assumptions about real interest rates and asset purchase prices. Further, previous arguments indicate that increases in inflation uncertainty lead to reductions in business investment, brought about by increased hurdle rates, greater planning costs, and an overall slower rate of economic activity. This research is designed to supply data necessary to evaluate the importance of these factors as determinants of investment demand.

From the data provided in this dissertation, four basic conclusions are identified. First, the empirical evidence supports the hypothesis that the decline in the real value of depreciation
deductions brought about by inflation leads to a decline in real business investment. The data suggests that such effects are substantial, and that failure to account for the interaction of inflation and historic cost depreciation leads to incorrect predictions of investment demand. Second, the evidence in this dissertation supports the hypothesis that inflation leads to a much greater decline in equipment than structures investment. This result persists over a wide range of assumed economic conditions, indicating that the recent shift in the composition of business investment toward equipment is not explained by increases in inflation. Third, the data also confirm the hypothesis that the effects of inflation and historic cost depreciation on investment will vary over time. Changes in investment brought about by changes in inflation are jointly determined with real interest rates and asset purchase prices, and proper measurement of such effects is critically dependent on additional economic variables. Finally, the evidence obtained by this research confirms the hypothesis that inflation uncertainty is a significant determinant of investment demand. Although these effects are much smaller than the measured effects of inflation and historic cost depreciation on investment, they are nevertheless significant to the explanation of recent business investment behavior.
ACKNOWLEDGEMENTS

I would like to express my gratitude to the many people who willingly gave assistance during the course of this research. I am deeply grateful to Dr. Thomas McCaleb who from the outset encouraged, challenged, helped me to refine the ideas expressed in this dissertation, and gave generously of his time in reading successive drafts of this work. Special thanks are felt for Dr. George Zodrow whose insightful questions, comments, and suggestions proved essential to the completion of this research. I would also like to thank Dr. Gordon Smith and Dr. Richard Stoll for the many interesting questions and well-timed words of encouragement.

I am also grateful to Anita Poley for typing several versions of this document with such amazing speed and accuracy, and to Christine for the constant understanding during my long graduate school years and for never doubting I would finish.

Houston, Texas

May 8, 1982

Thomas S. Respess III
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter 1: INTRODUCTION</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 2: INFLATION, DEPRECIATION DEDUCTIONS, AND CAPITAL FORMATION</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Inflation and the User Cost of Capital</td>
<td>11</td>
</tr>
<tr>
<td>B. Inflation and the Net Cost of Investment</td>
<td>23</td>
</tr>
<tr>
<td>C. Ambiguity in the Net Cost Approach</td>
<td>30</td>
</tr>
<tr>
<td>D. Inflation and Effective Tax Rates</td>
<td>35</td>
</tr>
<tr>
<td>E. User Cost of Capital and Effective Tax Rates:</td>
<td></td>
</tr>
<tr>
<td>Potential Ambiguity</td>
<td>41</td>
</tr>
<tr>
<td>F. Summary</td>
<td>44</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 3: INFLATION AND CAPITAL FORMATION: EMPIRICAL EVIDENCE</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>46</td>
</tr>
<tr>
<td>A. Inflation, Depreciation Deductions, and Investment:</td>
<td></td>
</tr>
<tr>
<td>Empirical Evidence</td>
<td>47</td>
</tr>
<tr>
<td>B. Investment and Inflation Uncertainty</td>
<td>55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 4: EMPIRICAL METHODOLOGY</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Neoclassical Model of Investment Demand</td>
<td>65</td>
</tr>
<tr>
<td>B. Lags and Investment Behavior</td>
<td>72</td>
</tr>
<tr>
<td>C. Econometric Technique: Random Coefficients</td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>77</td>
</tr>
<tr>
<td>D. Real Versus Nominal After-Tax Finance Rates</td>
<td>82</td>
</tr>
</tbody>
</table>
E. Tax Depreciation ......................................... 93
F. Characteristics of the Data Sets .................... 96
G. Inflationary Expectations .............................. 100
H. Other Data Series ..................................... 101

Chapter 5: EMPIRICAL RESULTS ............................. 103
A. Tests for Aggregation Bias ............................ 104
B. Estimation Results: Random Coefficients
   Regression ............................................. 109
C. Estimates of \( \hat{\alpha} \) .................................. 111
D. Measured Effects of Inflation on Manufacturing
   Investment ............................................ 115
E. Measured Effects of Inflation Uncertainty on
   Manufacturing Investment ............................. 124
F. Summary of Empirical Results .......................... 125

Chapter 6: SUMMARY OF RESEARCH .......................... 128
Appendix A: LAG SELECTION ............................. 133
Appendix B: INDIVIDUAL EQUATION STATISTICS: RANDOM
   COEFFICIENTS REGRESSION ........................... 135
FOOTNOTES ............................................... 141
BIBLIOGRAPHY ............................................ 146
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The Relative Net Cost of Investment in Structures with Existing Historic Cost Depreciation Rules</td>
<td>27</td>
</tr>
<tr>
<td>2.</td>
<td>The Relative Net Cost of Investment in Equipment with Existing Historic Cost Depreciation Rules</td>
<td>28</td>
</tr>
<tr>
<td>3.</td>
<td>Manufacturing Industries</td>
<td>97</td>
</tr>
<tr>
<td>4.</td>
<td>Tests for Aggregation Bias</td>
<td>108</td>
</tr>
<tr>
<td>5.</td>
<td>Estimation Results: Random Coefficient Regression</td>
<td>110</td>
</tr>
<tr>
<td>6.</td>
<td>Estimated Elasticities of Output</td>
<td>112</td>
</tr>
<tr>
<td>7.</td>
<td>Exogenous Parameters: User Cost of Capital</td>
<td>117</td>
</tr>
<tr>
<td>8.</td>
<td>Estimated Impact on Manufacturing Investment of a Change in the Inflation Rate from Zero to $P^*$: Case 1</td>
<td>120</td>
</tr>
<tr>
<td>9.</td>
<td>Estimated Impact on Manufacturing Investment of a Change in the Inflation Rate from Zero to $P^*$: Case 2</td>
<td>121</td>
</tr>
<tr>
<td>10.</td>
<td>Estimated Impact on Manufacturing Investment of a Change in the Inflation Rate from Zero to $P^*$: Case 3</td>
<td>122</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------</td>
<td>------</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

One of the disturbing features of the U.S. economy in the 1970s has been the sluggish performance of productivity growth. Between 1948 and 1965, labor productivity in the non-farm business sector grew almost 3 percent per year. Between 1965 and 1973, this figure dropped to about 2 percent per year, and between 1973 and 1981, productivity growth slowed further to only 1 percent per year. In recent literature, economists have suggested that this poor performance of labor productivity is related to two trends in the formation of capital for the United States.¹

The first trend concerns the share of Gross National Product devoted to net investment. By definition, net investment is the portion of gross investment in excess of that necessary to replace worn out capital. It essentially measures the amount of investment devoted to an expansion in the aggregate capital stock. Using data from the Commerce Department, Summers (1981) finds that the share of net investment in Gross National Product was .026 for the 1975-79 period compared to .042 for 1965-69 and .031 for 1948-79. The decline in net investment is partly responsible for the reduction in the growth rate of the capital labor ratio from 3 percent for 1948-75 compared to
1¾ percent since 1975. It is precisely this decline in the growth rate of the capital-labor ratio, brought about by low levels of net investment, that prompted Clark (1978) to link the slowdown in capital formation to the poor performance of labor productivity.

The second trend in capital formation concerns the dramatic increase in the portion of aggregate investment devoted to purchases of producers' durable equipment. In 1960, for example, equipment expenditure represented 56 percent of total investment in private non-residential capital. By 1970, the portion of aggregate investment devoted to equipment had risen to 61 percent, and, by 1980, equipment expenditure represented 70 percent of total investment. The net effect of this trend in investment composition has been a significant increase in the employment of equipment capital relative to structures capital, reflected in a general decline in the average economic life of the U.S. capital stock. Feldstein (1981a) suggests that the disproportionate increase in equipment capital has lowered the marginal productivity of the aggregate capital stock and thereby contributed to the decline in productivity as well.

Hendershott and Hu (1981c, 1981e), Feldstein (1980a, 1981a), and Kopcke (1981) have argued that the recent decline in net investment behavior is related to the effect of inflation on the real opportunity cost of business investment. These authors note that under existing tax law, the depreciation of plant and equipment that firms may claim in calculating taxable income is limited to the original or "historic" purchase price of the asset. Because annual depreciation
deductions are not adjusted when the replacement cost of an asset increases, inflation lowers the real value of tax depreciation deductions by reducing their effectiveness in shielding nominal income flows from taxation. Hendershott and Hu, Feldstein, and Kopcke argue that the increase in the effective rate of taxation brought about by the combination of inflation and historic cost depreciation leads to an increase in the opportunity cost of employing depreciable plant and equipment and a decline in investment. Moreover, these authors assert that a given increase in the rate of inflation reduces the real value of depreciation deductions differently for structures than for equipment, thereby distorting the relative opportunity cost and composition of investment in equipment versus structures.

In summary, Hendershott and Hu, Feldstein, and Kopcke maintain two separate, but equally important, hypotheses regarding the effect of inflation on investment: (1) by raising the opportunity cost of investment in all classes of assets, inflation reduces the aggregate demand for capital goods relative to that which would exist in a non-inflationary environment, and (2) by distorting the relative cost of investment in different classes of assets, inflation contributes to changes in the composition of business investment.

These authors disagree, however, on the direction of the relative distortion between equipment and structures. Hendershott and Hu argue that any changes in tax depreciation incentives caused by inflation have more of an effect on equipment investment, biasing the investment decision toward structures. Similar results were
obtained by Auerbach (1979). Bradford (1981) appears to agree with this conclusion also. In contrast, Feldstein (1981a) and Kopcke (1981) assert that the interaction of inflation and historic cost depreciation leads to an increase in the share of investment devoted to equipment. The results of Feldstein and Kopcke are consistent with recent trends in investment composition, whereas Hendershott and Hu's work is not. Unfortunately, the controversy related to the effects of inflation on investment composition has not been fully resolved though the bulk of the evidence appears to substantiate the results of Hendershott and Hu.

In addition to the effects of inflation on investment brought about by historic cost depreciation rules, Malkiel (1979), Cukierman (1980), Friedman (1980), and Levi and Makin (1979) suggest that inflation uncertainty has played a significant role in discouraging real capital investment. Increases in inflation uncertainty, measured by changes in the variance of forecasts of expected inflation, reduce investment by (1) increasing the hurdle rate on investment projects, (2) increasing the time and expense required to investigate and plan uncertain ventures, and (3) reducing the general level of output. Evidence on the effects of inflation uncertainty on savings behavior, however, would seem to dispute the conclusions. For example, Wachtel (1979) finds that an increase in inflation uncertainty increases savings which should lead to an increase in investment. Although the effects of inflation uncertainty on investment have not been explicitly modeled, such uncertainty appears far from
neutral. To date, however, economists have not attempted to measure directly the effects of inflation uncertainty on investment, leaving this controversy unresolved.

The major problem in assessing the effects of inflation and inflation uncertainty on capital formation is the general absence of econometric evidence on this topic. Feldstein (1981a) and Corcoran (1979) provide some evidence that inflation and historic cost depreciation are responsible for the decline in net investment, but the econometric results in both studies suffer from methodological problems. Empirical verification of these relationships has been limited primarily to the construction of simple hypothetical examples designed to characterize the decline of depreciation deductions under alternative scenarios of inflation. Although the results of these examples are consistent with theoretical predictions, they do not provide sufficient evidence to assert that inflation and historic cost depreciation rules have affected historical patterns of investment. Unfortunately, the effect of inflation uncertainty has not received even this simple level of attention. Essentially, the hypothesis that inflation and inflation uncertainty distort the level and composition of investment has not been subjected to rigorous empirical examination.

The purpose of this research is to measure directly the effects of inflation and inflation uncertainty on the level and composition of investment demand. The methodology is based on the econometric estimation of neoclassical investment equations for the U.S.
manufacturing industries. Separate equations are estimated for equipment and structures for the period 1953-80. Explanatory variables in the models are constructed to allow for explicit treatment of inflation expectations as well as inflation uncertainty.

This research is unique in several ways. First, the work contributes to the resolution of the controversy surrounding the effects of inflation on investment composition. The hypothesis of Feldstein and Kopcke that inflation biases investment toward equipment is shown to be ambiguous in theoretical terms. This ambiguity is resolved, however, when the effects of inflation on relative costs of investment are examined within the framework of the user cost of capital as shown by Hendershott and Hu (1981c). The analysis also discusses the conditions under which the predicted composition effects of inflation could be reversed, an idea that has not been discussed in the literature.

Second, estimation of the investment equations is based on an econometric procedure specifically designed to avoid the problem of aggregation bias which has plagued previous investment analysis. This procedure, known as the Random Coefficients Regression Model, is based on a cross-section, time series approach to equation estimation, thereby facilitating construction of aggregate equations consistent with heterogeneous investment behavior across manufacturing industries. Statistical tests for aggregation bias presented in this study demonstrate that use of the Random Coefficients technique is
particularly appropriate for the analysis of manufacturing investment demand.

Third, the econometric analysis is based on a unique set of investment and capital stock data which has not been used in investment demand studies before. This data set was obtained by special request from the Commerce Department, and represents the only source of investment statistics disaggregated both by manufacturing industry, and by equipment and structures purchases. Use of this data proved essential to the estimation of aggregate investment demand equations by the Random Coefficients technique, thus avoiding the critical problem of aggregation bias.

Finally, and most importantly, the empirical results in this study represent the only econometric evidence available to measure the significance of inflation and inflation uncertainty as determinants of investment demand. The evidence provided by this research suggests that both of these factors are important elements in the recent decline in net investment and growth of the capital stock, and that failure to account for these variables leads to serious specification errors. No other study has been successful in documenting this fact and for this reason, the empirical results presented in this dissertation represent a substantial contribution to the economic analysis of capital investment.

The remainder of this dissertation is divided into seven sections. Chapter 2 presents the theoretical results which link inflation and historic cost depreciation to the level and composition of
investment. Chapter 3 discusses the limited empirical evidence on
the relation of inflation to investment and the importance of infla-
tion uncertainty in explaining investment demand. Chapter 4 provides
a detailed description of the empirical methodology used in this
research, and Chapter 5 presents the actual empirical results. A
summary of the research conclusions is provided in Chapter 6. Appen-
dix A identifies the methodology for selection of model lag structure,
and Appendix B lists summary statistics for the estimated equations.
CHAPTER 2

INFLATION, DEPRECIATION DEDUCTIONS, AND CAPITAL FORMATION

Three different methodologies have been employed to derive basic propositions regarding the link between inflation, historic-cost depreciation and capital formation. The first approach, associated with Hendershott and Hu (1981c), is based on an analysis of the user cost of capital, also known as the shadow price of real capital. Hendershott and Hu find that: (1) by reducing the present value of depreciation deductions on all classes of assets, inflation has reduced the overall demand for capital, and (2) inflation has distorted the choice of asset durability towards longer-life structures. These results are derived analytically after careful specification of the user cost to include the relevant tax variables and the distinction between replacement and historic cost depreciation.

The second approach, discussed independently by Feldstein (1981a) and Kopcke (1981), focuses on the "net cost" of investment. By calculating net costs for various assets at different inflation and interest rates, these authors agree with Hendershott and Hu's first conclusion that inflation has reduced the overall level of investment demand. However, in contrast to the second conclusion, Feldstein and Kopcke argue that inflation distorts the choice of asset durability toward equipment rather than structures.
The third approach is based on the concept of effective tax rates. Auerbach (1979, 1981) analyzes the effect of inflation on the effective tax rates for capital assets of differing durability. The results suggest that inflation reduces the demand for capital, and biases this choice toward more durable structures. Similar results using the effective tax rate methodology have been obtained by Jorgenson and Sullivan (1981) and Hulten and Wykoff (1981).

Each of these models is discussed and analyzed in this chapter. The analysis demonstrates that the "net cost of investment" approach does not represent an appropriate methodology for analyzing the effect of inflation on the composition of asset demand. Under different assumptions about inflation, real interest rates, and asset service lives, the net cost of investment approach leads to ambiguous conclusions regarding the effect of inflation on investment composition. This ambiguity arises out of improper consideration for the differential importance of depreciation deductions between equipment and structures, and may be demonstrated mathematically.

One surprising result of the analysis of these models, however, is that both the user cost and effective tax rate methodologies generate ambiguous results regarding the composition of asset demand under specific economic conditions. The effects of inflation on investment composition can vary over time as economic conditions evolve, indicating that measurement of the historical link between inflation, depreciation, and investment is primarily an empirical question. Unfortunately, however, the available econometric evidence on this
topic is not useful in measuring the effect of inflation on either
the level or composition of investment demand.

The purpose of this chapter is threefold: (1) to present
the basis of theoretical propositions concerning the relationship
between inflation and the level and composition of gross investment;
(2) to reconcile the divergent results regarding the effect of in-
flation on investment composition as obtained by Hendershott and
Feldstein; and (3) to discuss the potential ambiguity in both the
user cost and effective tax rate methodologies of determining the
effects of inflation on investment composition. A review of the
econometric evidence on this topic is found in Chapter 3.

A. Inflation and the User Cost of Capital

The concept of the user cost of capital is motivated by
the neoclassical idea that business firms value each unit of capital
input according to the opportunity cost of the funds used to acquire
the asset. The user cost is essentially the real rental rate that a
firm pays to obtain a dollar's worth of real capital. In a world
with no taxes and perfect capital markets, the user cost of capital
will equal the required rate of return paid on financial assets plus
the rate of economic depreciation. However, in a world of corporate
income taxes, investment tax credit, accelerated depreciation, and
inflation, the user cost will deviate from the no-tax world. For
this reason it is important, when discussing the opportunity cost of
acquiring capital goods, to account for all relevant tax and non-tax factors which may affect the investment decision.  

The decision to invest depends on whether the present value of the expected return from an investment, net of direct operating expenses and indirect taxes, exceeds the purchase price of the asset; on marginal investments the two values will be equal. Assume that inflation is expected to cause net revenues and the supply price of capital to rise at the rate \( p^* \), and that the productivity of the investment and thus net revenues are expected to decline at the economic depreciation rate of \( d \) per year. Equilibrium in the capital goods market requires that the asset purchase price equal the discounted present value of all capital services from the asset, where the discount factor equals the market rate of return. Assume that this rate of return is exogenous to the individual firms, and that any risk premium component of this rate of return remains constant. In a world with no taxes, the asset market equilibrium condition can be expressed as:

\[
P_k = \sum_{t=1}^{\infty} \frac{(1+p^*-d)^{t-1}}{(1+r)^t} P_y \rho
\]

(1)

where

- \( P_k \) = the market price of capital (current prices)
- \( P_y \) = the market price of output (current prices)
- \( \rho \) = the marginal product of capital
- \( d \) = the rate of economic depreciation
- \( r \) = the market nominal rate of return (weighted average
of the nominal rates of return on debt and equity finance)

\[ p^* = \text{expected inflation rate.} \]

By the infinite sum rule:

\[
\sum_{t=1}^{\infty} \frac{(1+p^*-\bar{d})^{t-1}}{(1+r)^t} = \frac{1}{r-p^*+\bar{d}}.
\]

Therefore, the condition of equilibrium in the asset market may be restated as:

\[
P_k = \frac{\rho_y}{r-p^*+\bar{d}}.
\]

According to the neoclassical theory of the firm, in equilibrium the marginal product of capital will equal the real user cost (rental rate). An expression for the user cost may therefore be derived from (5):

\[
\rho = c^* \equiv \frac{P_k}{P_y} (r-p^*+\bar{d})
\]

where \( c^* \) is the real user cost of capital.

In a world without taxes the user cost of capital will equal the sum of: (1) the real rate of return to equivalent investments of amount \( P_k/P_y \) in non-depreciable financial assets, and (2) the cost associated with the decline in productivity of the investment by physical deterioration of the capital. If the marginal product of capital exceeds the real user cost, the firm will increase
its stock of real capital. If, however, the user cost of capital increases relative to the initial marginal product of capital, firms will reduce their stock of real capital. Changes in the real user cost, therefore, give rise to net investment (disinvestment) as firms increase (decrease) the optimal stock of capital.

Equation (1) ignores the existence of income taxes, investment tax credits, accelerated depreciation schedules and the possibility that true economic depreciation may differ from tax depreciation. Assume that true economic depreciation is valued at replacement cost, and for the moment, assume that the firm is allowed to value tax depreciation at replacement rather than historic cost.

Rewriting (1) to account for these assumptions:

\[(1-\mu)P_k = \sum_{t=1}^{\infty} (1+r)^{-t} \left\{ (1+p^* - d)^{t-1} (1-Tx)pY \right. \]

\[+ d(1-p^*+d)^{t-1}TxP_k + \left[ d_{Tx}(1+p^* - d_{Tx})^{t-1} \right. \]

\[\left. - d(1+p^* - d)^{t-1}TxP_k \right\} \]

where:

\[r = (1-Tx)bi + (1-b)e \]

and:

\[d_{Tx} = \text{geometric rate of tax depreciation} \]

\[Tx = \text{corporate income tax rate} \]

\[b = \text{portion of asset that is debt financed} \]
\[ e = \text{nominal after-tax return to equity} \]
\[ \mu = \text{rate of investment tax credit} \]
\[ i = \text{nominal return on corporate debt}. \]

The second term inside the large braces of (5) represents the portion of depreciation allowances just sufficient for true economic depreciation to replace worn out capital. The third term represents the tax savings from the difference between the value of the depreciation deduction under the tax law and that consistent with true economic depreciation. Accelerated rates of tax depreciation increase the third term inside the braces of (5), thereby increasing the tax savings and cash flow to the firm. From expression (5) it is possible to solve for the user cost of capital by employing the infinite sum rule once again:

\[
\rho = c^* = \frac{P_k}{P_Y} \left[ \frac{1-\mu}{1-T_X} (r-p^*+d) - \frac{T_X d}{1-T_X} \right. \\
+ \left. \frac{T_X}{1-T_X} \left( d-(r-p^*+d) \sum_{t=1}^{\infty} \frac{d_{tX}(1+p^*-d) t^{-1}}{(1+r)^t} \right) \right].
\]

Note that for any given real supply price of capital \((P_k/P_Y)\), the user cost of capital will decline as the investment tax credit \((\mu)\) increases and as the excess of tax depreciation over economic depreciation increases (the third term inside brackets of (7)). With expression (7), it is possible to analyze the effect of inflation on the user cost of capital by focusing on the difference between economic depreciation and tax depreciation.
Define the net addition to (or reduction in) the real user cost of capital associated with the difference between economic and tax depreciation as:

\[
\text{DEPR} = \frac{p_k}{p_y} \cdot \frac{T_x}{1-T_x} \left[ d - (r-p^*+d) \sum_{t=1}^{\infty} \frac{d_{tX} (1+p^*-d_{tX})^{t-1}}{(1+r)^t} \right].
\]  (8)

If the geometric rate of tax depreciation \((d_{tX})\) established by law is exactly equal to the economic rate of depreciation \((d)\), and both depreciation values are computed at replacement cost, then by the infinite sum rule:

\[
\text{DEPR} = \frac{p_k}{p_y} \cdot \frac{T_x}{1-T_x} \left[ d - \frac{(r-p^*+d)d_{tX}}{(r-p^*+d_{tX})} \right] = 0.
\]  (9)

When the rates of depreciation are exactly the same, and when the depreciation deductions (economic and tax) are valued at replacement cost, inflation has no impact on the cost of capital.

If, however, the rate of tax depreciation exceeds that of economic depreciation, and we retain the assumption of replacement cost valuation, then:

\[
\text{DEPR} = \frac{p_k}{p_y} \cdot \frac{T_x}{1-T_x} \left[ d - \frac{(r-p^*+d)}{(r-p^*+d_{tX})} \cdot d_{tX} \right] < 0.3
\]  (10)

Acceleration of the rate of tax depreciation relative to economic depreciation will reduce the cost of capital when the depreciation is valued at replacement cost.
Under present law the service life for tax purposes is less than the economic service life, and assets may be depreciated according to an accelerated schedule that exceeds economic depreciation. Specifically, the double declining balance method may be employed to depreciate equipment, and the 150 percent declining balance method may be utilized to depreciate structures. Moreover, the permissible tax service lives for structures, on average, declined from 28 years in 1952 to 23 years by 1980. The permissible tax service life for equipment, on average, fell from 18 years in the 1950s to 11 years in the early 1970s. Recent enactment of the Economic Recovery Act of 1981 shortened these lives even further. The net effect of these tax regulations has been to raise the average geometric rate of tax deduction above the economic depreciation rate for all assets. If, in conjunction with the tax laws governing service lives and accelerated rates, firms were allowed to value assets at replacement cost, then the net effect would be a reduction in the user cost of capital. Such an incentive would be a stimulus to the formation of capital.

However, under actual law, firms are required to value depreciating capital at the "historic" or original purchase price of the asset. Under this restriction, $p^* = 0$ in the construction of the tax depreciation variable for expression (8), and the difference between economic and tax depreciation reduces to:
DEPR = \frac{p_k}{p_y} \cdot \frac{T_x}{1-Tx} \left[ d - (r-p^*d) \sum_{t=1}^{\infty} \frac{d_{Tx}(1-d_{Tx})^t}{(1+r)^t} \right] \\
= \frac{p_k}{p_y} \cdot \frac{T_x}{1-Tx} \left[ d - \frac{(r-p^*d)}{r+d_{Tx}} \cdot d_{Tx} \right] \tag{11}

which will be less than the difference between economic and tax depreciation computed in (10). By computing the difference between the cost of capital under historic cost depreciation (C^*_HIST) and the cost of capital assuming replacement cost depreciation (C^*_REP), it is possible to highlight the combined effect of inflation and historic cost depreciation on the cost of business investment:

\[ C^*_HIST - C^*_REP = -\frac{p_k}{p_y} \cdot \frac{T_x}{1-Tx} \cdot (r-p^*d) \left[ \frac{1}{r+d_{Tx}} - \frac{1}{r-p^*d_{Tx}} \right] d_{Tx} > 0. \tag{12} \]

The requirement that firms must value capital assets at historic cost results in a higher user cost of capital if the inflation rate is positive. In the expression above, the effect of inflation on the cost of capital results from an increase in the nominal rate of interest relative to the "real" rate of interest. When depreciation deductions are valued at historic cost, the present value of these deductions will decline with increases in the rate of inflation. This effect is captured in (12) by the relationship between the terms inside the brackets. At positive levels of inflation, the first term inside the brackets declines relative to the second term as the
nominal rate rises with the inflation rate. The higher the rate of inflation, the greater will be the increase in the user cost of capital under historic cost depreciation relative to replacement cost. With a zero rate of inflation, \( p^* = 0 \) and \( (C^*_{\text{HIST}} - C^*_{\text{REP}}) = 0 \).

The effect of inflation on the user cost of capital is significant for all classes of assets, given historic cost valuation of depreciating capital. Because inflation increases the user cost of capital on all classes of assets, in equilibrium the optimal stock of capital will be less than that which would exist in a non-inflationary world. As the optimal stock of capital declines, the amount of gross investment also declines.

This methodology may also be used to derive specific results regarding the effect of inflation on the relative user costs of equipment and structures capital. Referring to expression (12), assume that the rate of economic depreciation \( d \) equals the rate of tax depreciation \( d_{\text{Tx}} \). This assumption is maintained for expository purposes only and may be eliminated without affecting any of the results. When \( d = d_{\text{Tx}} \), expression (12) reduces to:

\[
C^*_{\text{HIST}} - C^*_{\text{REP}} = - \frac{P_k}{P_y} \cdot \frac{TX}{1-TX} \cdot \left[ \frac{d_{\text{Tx}}(r-p^*+d_{\text{Tx}})}{(r+d_{\text{Tx}})} - \frac{d_{\text{Tx}}(r-p^*+d_{\text{Tx}})}{(r-p^*+d_{\text{Tx}})} \right]
\]

\[
= - \frac{P_k}{P_y} \cdot \frac{TX}{1-TX} \cdot \left[ - \frac{d_{\text{Tx}}p^*}{r+d_{\text{Tx}}} \right] > 0. \tag{13}
\]
Taking the derivative of (13) with respect to \( d \), it is possible to examine the relationship of the magnitude of \( \left( C^*_{\text{HIST}} - C^*_{\text{REP}} \right) \) to the economic depreciation rate. From (13),

\[
\frac{\partial \left( C^*_{\text{HIST}} - C^*_{\text{REP}} \right)}{\partial d} = - \frac{P_k}{P_y} \cdot \frac{Tx}{1-Tx} \cdot \left[ \frac{-r\pi^*}{(r+d_{\text{TX}})^2} \right] > 0. \tag{14}
\]

The magnitude of the increase in the user cost of capital given historic cost depreciation is an increasing function of the rate of economic (tax) depreciation. Therefore, the shorter is the economic life (the higher is economic depreciation rate), the more historic cost depreciation discriminates against the investment (the higher is the user cost of capital). As the inflation and economic depreciation rates increase, the analysis suggests that the user cost of equipment capital should rise relative to the user cost of structures. With positive rates of inflation, ceteris paribus, business firms would reduce the optimal stock of equipment capital relative to that of structures capital, distorting the composition of business investment toward structures.\(^4\)

The result that inflation biases the composition of investment toward structures capital runs counter to the conclusions reached by Feldstein (1981a) and Kopcke (1981). In contrast to Hendershott and Auerbach, these authors suggest that inflation has biased the composition of investment toward assets with shorter lives, basing their analysis on an examination of the present value of tax
depreciation deductions under current allowable asset lifetimes and
depreciation methods. It is shown below that these seemingly diver-
gent conclusions regarding the effect of inflation on investment com-
position may be reconciled within the framework of the user cost of
capital. Such a discussion is facilitated by further interpretation
of the results obtained by Hendershott using a simplified expression
for the user cost of capital.

Rewriting (7),

$$
\rho = c^* = \frac{P_k}{P_y} \left[ \frac{1-\mu}{1+T_X} (r-p^*+d) \cdot \frac{T_X}{1-T_X} \cdot (r-p^*+d) \sum_{t=1}^{\infty} \frac{d_{rX} (1+p^*-d_{rX})^{t-1}}{(1+r)^t} \right] \quad (15)
$$

Therefore,

$$
\rho = c^* = \left( \frac{1}{1-T_X} \right) \left( \frac{P_k}{P_y} \right) (r-p^*+d) (1-\mu-T_X \cdot Z) \quad (16)
$$

where:

$$
Z = \sum_{t=1}^{\infty} \frac{d_{rX} (1+p^*-d_{rX})^{t-1}}{(1+r)^t} = \frac{d_{rX}}{r+d_{rX}} \quad . \quad (17)
$$

The result obtained by Hendershott summarized in expression
(16) suggests that the net effect of an increase in inflation is to
raise the user cost of capital more for equipment than for structures.
To interpret this result, consider the difference in the magnitude of
the role depreciation deductions play in the determination of the
user cost of employing equipment versus structures capital. Note
that in expression (16) any changes in the value of $Z$ are magnified
by the value of \((r-p^*_d)\). For example, if \(Z\) declines, the bracketed term \((1-u-T \cdot Z)\) increases, and the user cost of capital is increased accordingly. The absolute effect on the user cost of capital, however, is governed by the magnitude of the scalars \((1/1-Tx)\), \((P_k/P_y)\) and \((r-p^*_d)\). For any given values of the first two of these scalars, the increase in the user cost will be larger, the higher is the economic depreciation rate.

Hendershott's result is a recognition of the relative importance of depreciation in the determination of the relative costs of employing equipment versus structures capital. In real terms, tax depreciation deductions allow firms the opportunity to recover the real cost of depreciable plant and equipment "used up" in the current period production of goods and services. Because equipment depreciates at a faster rate than structures (i.e., has a shorter economic life), greater deductions must be allowed in each period for equipment capital in order for the firm to replace such capital at a faster rate. More important, however, is the fact that any changes in a firm's ability to recover the "used up" capital will be of greater importance to firms employing equipment capital simply because depreciation represents a substantially greater proportionate cost to the firm in each period than for structures capital. In other words, any changes in the real value of tax depreciation deductions \((2)\) will be of greater importance for assets which depreciate at a faster rate. In terms of notation, since \(d\) for equipment in expression \((16)\) is greater than \(d\) for structures, any change in
the value of \((1-\mu-Tx\cdot Z)\) will be magnified into greater absolute increases in the user cost for equipment relative to structures capital. It is important to recognize, however, that Hendershott and Hu do not assert that inflation reduces the present value of tax depreciation deductions \(Z\) more for equipment than for structures as the basis for their conclusion. Rather, the focus of their analysis is the net effect of changes in \(Z\) on the relative cost of employing assets with different economic depreciation lifetimes. Central to their result is a recognition of the greater sensitivity of real economic cost for equipment capital to changes in the rate at which such costs are recovered.

B. **Inflation and the Net Cost of Investment**

Instead of focusing on the net effect of inflation and historic cost depreciation on the user cost of capital, Feldstein (1981a) and Kopcke (1981) analyze the behavior of the expression \((1-\mu-Tx\cdot Z)\) subject to different depreciation methods, lifetimes, and inflation rates. It is through an analysis of this variable that they conclude separately that the effect of inflation is to bias the composition of investment in the opposite direction, i.e., toward equipment and against structures. Feldstein's results are outlined below.

Consider an asset that can be depreciated over \(N\) years. The economic life of the asset, i.e., the number of years until it is scrapped, may also be \(N\) years, but it need not be; the economic life
of the asset is irrelevant in calculating and comparing the net cost of the investment. The fraction of the initial cost of the investment that can be deducted as a depreciation expense in year $t$ under the existing historic cost method of depreciation is denoted as $\Pi_t$. If $(Tx)$ is the corporate tax rate, the reduction in other tax liabilities in year $t$ is $Tx \cdot \Pi_t$. With the straight-line method of depreciation, $\Pi_t = 1/N$ in each year. If the sum-of-year's-digits method is used, $\Pi_t = 2(N-t+1)/N(N+1)$.  

Let $R$ denote the real discount rate that firms use to calculate the present value of future tax savings resulting from allowable depreciation. In the absence of inflation, the net cost per dollar of investment may be written:

$$ C_H = 1 - \mu - Tx \cdot \sum_{t=1}^{N} \frac{\Pi_t}{(1+R)^t} $$

(18)

where $\mu$ is the investment tax credit for the particular type of investment. Note that this expression is identical to the expression $(1-\mu-Tx \cdot Z)$ shown in equation (16).

Inflation reduces the real value of the depreciation allowed in future years. If the inflation rate is constant at $i$ percent per year, the real value of the depreciation in year $t$ is $\Pi_t (1+i)^{-t}$. With positive inflation rates and historic cost depreciation rules, the net cost per dollar of investment can be calculated by discounting the resulting real depreciation at the original real discount rate:
\[ C_H = 1 - \mu - Tx \cdot \sum_{t=1}^{N} \frac{DH_t}{(1+R)^t} (1+i)^{-t} \]

\[ = 1 - \mu - Tx \cdot \sum_{t=1}^{N} \frac{DH_t}{(1+R)^t(1+i)^t} . \]  

(19)

If, however, depreciation deductions were valued at replacement cost (i.e., indexed), then the expression for net cost \( C_I \) may be written as:

\[ C_I = 1 - \mu - Tx \cdot \sum_{t=1}^{N} \frac{DH_t}{(1+R)^t} (1+i)^{-t} \]

\[ = 1 - \mu - Tx \cdot \sum_{t=1}^{N} \frac{DH_t}{(1+R)^t} . \]  

(20)

The increase in the nominal amount of allowable depreciation exactly offsets the fall in the real value of the dollar, leaving the net cost of investment independent of the rate of inflation.\(^6\)

Calculating the difference in net costs under historic versus replacement cost depreciation, the following relationship holds:

\[ C_H - C_I = \sum_{t=1}^{N} \frac{DH_t}{(1+i)^t(1+R)^t} - \sum_{t=1}^{N} \frac{DH_t}{(1+R)^t} . \]  

(21)

Inflation raises the net cost of investment when historic cost depreciation is required suggesting that investment in all asset types would decline.\(^7\) Hence, Feldstein and Hendershott and Hu (as well as Kopcke) are in agreement over the effect of inflation on the aggregate
level of investment. However, the difference in the conclusions regarding investment composition can be illustrated in terms of the numerical examples presented by Feldstein.

Table 1 and Table 2 present Feldstein's calculations of the relative net cost of equipment investment and structures with existing historic cost depreciation rules. The numbers in the tables represent ratios of the net cost of equipment investment with the specified rate of inflation divided by the net cost when there is no inflation, or:

\[
\frac{C_H(P^* > 0)}{C_H(P^* = 0)} = \frac{1 - \mu - \sum_{t=1}^{N} \frac{D_H_t}{(1+R)^t(1+i)^t}}{1 - \mu - \sum_{t=1}^{N} \frac{I_H_t}{(1+R)^t}}.
\] (22)

These relative net cost ratios are presented for different combinations of the real discount rate and allowable tax lives. The depreciation method for structures is the 150 percent declining balance, and the sum-of-year's-digits method is used for equipment. From equation (22) the ratio of net costs rises above the value of unity as the inflation rate increases from \( i = 0 \). This is due, as described earlier, to the decline in the real present value of depreciation deductions which effectively raises the net cost of investment.

Feldstein draws two primary conclusions from the sample calculations presented in Tables 1 and 2. The first conclusion concerns the effect of inflation on the aggregate level of investment.
Table 1
The Relative Net Cost of Investment in Structures
with Existing Historic Cost Depreciation Rules

<table>
<thead>
<tr>
<th>Real Discount Rate</th>
<th>Inflation Rate</th>
<th>Allowable Depreciation Life (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>0.04</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>0.08</td>
<td>1.22</td>
</tr>
<tr>
<td></td>
<td>0.12</td>
<td>1.36</td>
</tr>
<tr>
<td></td>
<td>0.16</td>
<td>1.38</td>
</tr>
<tr>
<td>0.04</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>0.04</td>
<td>1.09</td>
</tr>
<tr>
<td></td>
<td>0.08</td>
<td>1.16</td>
</tr>
<tr>
<td></td>
<td>0.12</td>
<td>1.21</td>
</tr>
<tr>
<td></td>
<td>0.16</td>
<td>1.26</td>
</tr>
<tr>
<td>0.07</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>0.04</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td>0.08</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>0.12</td>
<td>1.17</td>
</tr>
<tr>
<td></td>
<td>0.16</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Table 2

The Relative Net Cost of Investment in Equipment
with Existing Historic Cost Depreciation Rules

<table>
<thead>
<tr>
<th>Real Discount Rate</th>
<th>Inflation Rate</th>
<th>Allowable Depreciation Life (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>0.04</td>
<td>1.05</td>
<td>1.13</td>
</tr>
<tr>
<td>0.08</td>
<td>1.09</td>
<td>1.23</td>
</tr>
<tr>
<td>0.12</td>
<td>1.13</td>
<td>1.31</td>
</tr>
<tr>
<td>0.16</td>
<td>1.17</td>
<td>1.38</td>
</tr>
<tr>
<td>0.04</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>0.04</td>
<td>1.04</td>
<td>1.09</td>
</tr>
<tr>
<td>0.08</td>
<td>1.08</td>
<td>1.17</td>
</tr>
<tr>
<td>0.12</td>
<td>1.12</td>
<td>1.23</td>
</tr>
<tr>
<td>0.16</td>
<td>1.15</td>
<td>1.29</td>
</tr>
<tr>
<td>0.07</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>0.04</td>
<td>1.04</td>
<td>1.08</td>
</tr>
<tr>
<td>0.08</td>
<td>1.08</td>
<td>1.14</td>
</tr>
<tr>
<td>0.12</td>
<td>1.11</td>
<td>1.19</td>
</tr>
<tr>
<td>0.16</td>
<td>1.14</td>
<td>1.24</td>
</tr>
</tbody>
</table>

Source: Martin Feldstein, "Adjusting Depreciation in an Inflationary Environment," p. 34.
for equipment and structures. Both Table 1 and Table 2 suggest that increases in the rate of inflation, for any given real rate of interest and asset lifetime, generate an increase in the net cost of investment in all circumstances. As the inflation rate increases, therefore, investment in assets of all economic or tax lifetimes would decline.

The second conclusion concerns the effect of inflation and historic cost depreciation on the composition of investment. From the evidence presented in Tables 1 and 2 Feldstein concludes that inflation clearly raises the net cost of short-lived investments by relatively less than the increase in the net cost of long-lived assets, and therefore distorts the pattern of investment in favor of short-lived assets. The basis of this conclusion is the frequency with which increases in asset lifetimes give rise to increases in the net cost ratio for any given real interest and inflation rate. Note, however, that this particular conclusion is based primarily on frequency of pattern, rather than monotonicity of result. For example, when the real interest rate is zero, increases in asset lifetime given different inflation rates generally correspond to increases in the net cost ratios for both equipment and structures. However, when the real rate of interest is greater than zero and the inflation rate is high, increases in asset lifetimes often lead to declines in the net cost of investment. Feldstein basically concludes that over feasible ranges of inflation rates, asset lifetimes and real interest rates, the combined effect of inflation and historic cost depreciation
generates a bias in the composition of investment towards equipment.

In summary, Feldstein asserts that inflation (1) reduces the level of aggregate investment over all asset lifetimes, and (2) causes a greater decline in investment in long-lived assets. It is the second of the two conclusions which runs counter to the results obtained by Hendershott and Hu regarding investment composition. Since the sample calculations and economic model discussed by Feldstein are very similar to those found in the recent work of Kopcke, the latter results are not presented here. However, it is interesting to note that the relationship of the net cost ratios to increases in asset lifetimes are also non-monotonic in Kopcke's calculation of net cost.\footnote{11}

C. Ambiguity in Net Cost Approach

The difference in the conclusions reached by Feldstein and Hendershott and Hu is the result of the divergent methodologies used by the respective authors. On the one hand, Hendershott and Hu employ the notion of the user cost of capital, whereas Feldstein bases his analysis on the behavior of tax depreciation deductions within the simplified framework of the net cost of investment. Feldstein's results regarding the effect of inflation on investment composition, however, are found to be non-monotonic with respect to asset life. By employing expression (12) reproduced below, it is possible to
demonstrate analytically why this ambiguity occurs, and also to show that determinate results regarding the effect of inflation on asset composition may be obtained only in the context of the user cost of capital.

Recall expression (12), which quantifies the relationship between the user cost under historic versus replacement cost depreciation,

$$C_{\text{HIST}}^* - C_{\text{REP}}^* = - \frac{P_k}{P_y} \cdot \frac{T_x}{1-T_x} \cdot (r-p^*+d) \left[ \frac{d_{T_x}}{r+d_{T_x}} - \frac{d_{T_x}}{r-p^*+d_{T_x}} \right] > 0 \quad (23)$$

where:

$$\frac{3(C_{\text{HIST}}^*-C_{\text{REP}}^*)}{3d} = - \frac{P_k}{P_y} \cdot \frac{T_x}{1-T_x} \cdot \left[ \frac{-rp^*}{r+d_{T_x}} \right] > 0. \quad (24)$$

Further, recall that the difference in the net costs of investment using Feldstein's methodology can be represented as:

$$C_{H}^* - C_{R}^* = - \left[ \sum_{t=1}^{N} \frac{\Delta H_t}{(1+R)^t(1+i)^t} - \sum_{t=1}^{N} \frac{\Delta H_t}{(1+R)^t} \right] > 0. \quad (25)$$

Note the similarity in the right-hand bracketed term in (23) to that of (25). Conceptually, these two terms are identical in that they both measure the magnitude of the difference between depreciation deductions under historic and replacement cost valuation. Indeed, if one follows Hendershott and Hu and assumes that the rate of tax depreciation may be expressed as a geometric equivalent, and further that
firms engage in infinite replacement, then expression (25) will reduce to:

\[
C_H^* - C_R^* = - \left[ \frac{d_{Tx}}{r^*d_{Tx}} - \frac{d_{Tx}}{r-p^*d_{Tx}} \right] > 0 \tag{26}
\]

where:  
\( r = \) nominal rate of interest  
\( r-p^* = \) real rate of interest.

From this analysis, it is clear that the concept of net cost of investment employed by Feldstein is but one component of the change in the user cost of capital due to historic cost depreciation.

Expression (26) may be used to demonstrate that in isolation the change in the net cost of investment is ambiguous with respect to changes in the economic depreciation rate (i.e., economic service life). Further, it can also be shown that the direction of change in the relative cost of equipment versus structures investment is not ambiguous when one accounts for the differential significance of depreciation deductions in the calculation of economic cost.

First, differentiate expression (26) with respect to \( d_{Tx} \):

\[
\frac{\partial (C_H^* - C_R^*)}{\partial d_{Tx}} = - \left[ \frac{r}{(r+p^*)d_{Tx}^2} - \frac{r}{(r-p^*)d_{Tx}^2} + \frac{p^*}{(r-p^*)d_{Tx}^2} \right]
\]

\[
\gg 0 \quad (\text{ambiguous}) \tag{27}
\]

Note that the sum of the first two terms inside the brackets is
negative. Considering these two terms in isolation, the net effect of decreasing the depreciation rate (i.e., increasing the economic lifetime) would be to decrease unambiguously the net cost of investment. However, since the third term inside the brackets is a positive value, expression (27) represents the sum of offsetting positive and negative magnitudes, and the sign of the expression (27) is theoretically ambiguous. Indeed, for any given real interest rate, a positive inflation rate could result in a negative sign for expression (27), suggesting that a fall in the depreciation rate $d_{T_X}$ (i.e., an increase in economic lifetime) would result in an increase in the net cost of investment as Feldstein suggests.

This ambiguity was demonstrated in numerical terms by both Feldstein and Kopcke. Therefore, by simply examining the relationship of changes in the net cost of investment and changes in economic lifetime, the effect of inflation on asset composition cannot be determined unambiguously. The effect of inflation on the net cost of investment depends jointly on the level of real interest rates and inflation rates as well as asset lifetimes.

In economic terms, resolution of the conflict between the net cost and user cost approaches may be interpreted as follows: the decision to invest in a non-depreciable asset depends on the ability of the asset to earn a given required rate of return $r$ for the owners. This return may be thought of as the opportunity cost of capital as perceived by the investors. For depreciable assets, however, the investors must be concerned with earning not only return $r$
on the asset, but also some additional return necessary to replace the capital used up in production. The sum of these two elements represents the gross return required by investors in order for the project to be acceptable. Assets with shorter economic lifetimes require a higher gross return per period in order to replace capital that physically deteriorates at a faster rate. Because short-lived assets require a higher gross return per period, they are more sensitive to changes in any of the factors which govern the assets' ability to earn that return. Specifically, changes in the real value of depreciation deductions per dollar of real capital have a much stronger impact on short-lived assets simply because owners of the asset must be concerned with replacing the depreciated capital at a much faster pace.

The user cost of capital approach explicitly allows for the difference in gross return required for assets of different service lifetimes, thereby allowing for differential sensitivities to changes in the factors which affect the assets' ability to earn such returns. The net cost approach focusses only on changes in the value of tax incentives, not recognizing the differential importance of such changes to assets of different service lives. As the above analysis demonstrates, when the relative importance of changes in tax incentives are appropriately accounted for, the ambiguity in the effects of inflation on investment composition disappears.

Before turning to an analysis of the effective tax rate methodology, it is interesting to note that Bradford (1981) has also
identified the numerical inconsistency of the net cost approach, and further suggests that Feldstein's approach is not appropriate to the analysis of inflation and investment composition. Following Hendershott and Hu, Bradford chooses instead to base his analysis on the user cost methodology. Not surprisingly, he also concludes that inflation not only reduces the stock of real capital, but also biases the choice toward structures.12

D. Inflation and Effective Tax Rates

Employing the concept of effective tax rates, Auerbach (1979, 1981) has attempted to derive specific results regarding the effect of inflation on capital formation. His model is interesting because it employs a general equilibrium framework to derive the steady-state effect of changes in inflation on the optimal composition of the capital stock. The results of Auerbach's analysis suggest that inflation biases the choice of asset durability toward assets with longer service lives, as claimed by Hendershott and Hu (1981c).

The basic model consists of a competitive economy with one production sector composed of firms which utilize two inputs, capital and labor, subject to a constant returns production technology. The price of new capital goods at time $t$ is $P_t$, and the price of a unit of labor is $w_t$. Equity holders are assumed to discount nominally measured cash flows from the firm at a nominal interest rate $r$.13
Capital goods decay exponentially at a constant rate $\delta$, which is assumed to be variable and subject to choice by the firm. An increase in $\delta$ represents an increase in the flow of capital services per unit of time from a unit of capital, such increases being subject to diminishing returns. This flow is represented by the function $A(\delta)$ where $(A' > 0)$ and $(A'' < 0)$. Gross output is defined by:

$$Y^G = H(KS, L); \quad H_K, H_L, H_{KL} > 0$$

$$H_{KK}, H_{LL} < 0$$

(28)

where $H$ is homogeneous of degree one in its two inputs, labor (L) and capital services (KS). When $I_t$ represents nominal investment at time $t$, and $\delta_t$ is the corresponding decay rate chosen by the firm, then the net capital stock remaining from this investment at time $s > t$ is $(I_t/P_t)e^{-\delta_t(s-t)}$. Total capital services derived from this investment by time $s$ are

$$KS_s = \int_{-\infty}^{s} A(\delta_t)(I_t/P_t)e^{-\delta_t(s-t)}dt.$$  

(29)

Corporate profits are taxed at rate $\tau$ after deduction of wages and depreciation allowances. Denote $D(x, \delta)$ as the deduction permitted per dollar of initial investment for an asset of age $x$ which decays at rate $\delta$. The objective of the firm in this economy is to maximize shareholders' current wealth. The firm accomplishes this by maximizing its own present value:
\[ V = \int_{0}^{\infty} e^{-rt} [(1-\tau)(p_{t}^{G} - w_{t}L_{t}) - I_{t} + \int_{-\infty}^{t} I_{s}D(t-s,\delta)ds]dt. \] (30)

Differentiating \( V \) first with respect to \( \delta_{t} \), \( I_{t} \), and \( L_{t} \), and then differentiating the whole system of equations again with respect to \( t \), Auerbach obtains the following steady-state conditions for present value maximization:

\[ \frac{\partial c}{\partial \delta} = 0 \]

\[ H_{K}[A(\delta)K,L] = \frac{c}{p} \tag{31} \]

\[ H_{L}[A(\delta)K,L] = \frac{w}{p} \]

where:

\[ c = P(\rho+\delta)(1-\tau Z)/(1-\tau), \]

the user cost of capital

\[ \rho = r-\pi, \] the real discount rate (equity holders required return)

\[ \pi = \text{expected rate of inflation} \]

\[ Z = \int_{0}^{\infty} e^{-rs}D(s,\delta)ds, \] the present value of depreciation deductions at time \( s \) on an asset which depreciates at rate \( \delta \).

The optimal steady-state behavior of firms involves two steps. In the first step, firms minimize the implicit cost of capital services (c) by their choice of \( \delta \). Second, firms then maximize profits by
employing labor and capital until their respective marginal products equal their marginal costs.  

Auerbach examines the effect of inflation on effective tax rates for assets of different depreciation rates $\delta$ by introducing a distinction between $\rho$, the real rate of return paid to equity holders (assumed constant), and the gross rate of return which a firm must earn to pay equity holders $\rho$.  

Let $v$ equal the firm's "implicit discount rate" where

$$v = \frac{(\rho + \delta)(1-\tau Z)/(1-\tau)}{1-\tau} - \delta. \quad \text{(32)}$$

Because investors still receive a rate of return equal to $\rho$, the effective corporate tax rate equals

$$\Theta = \frac{v-\rho}{v}. \quad \text{(33)}$$

If $\tau = 0$, $r = \rho$, and the effective tax rate is zero. However, if $\tau > 0$, the magnitude of $\Theta$ depends on the depreciation scheme $(Z)$ and the chosen rate of capital decay $\delta$. The effect of inflation on effective tax rates therefore must be analyzed by observing changes in $Z$.

From a dollar of capital purchased at time $t$, the amount available at time $s$ is $(1/P_\tau)e^{-\delta(s-t)}$ after physical depreciation of the asset. Multiplying this term by $(P_s \cdot \delta)$, the remaining depreciation deductions at time $s$ valued at replacement cost is determined by:
\[ D_R(s-t, \delta) = e^{-\delta(s-t)}(P_s/P_t). \] (34)

The present value of these deductions is

\[ Z_R = \delta/(p+\delta). \] (35)

If a fraction \( e \) is expensed, the value of \( Z \) per unit of capital is

\[ Z_R = e + (1-e)\delta/(\rho+\delta). \] (36)

Substitution of \( Z \) into (32) results in

\[ v = \rho(1-\tau e)/(1-\tau). \] (37)

Therefore, the effective tax rate on corporate investment is

\[ \theta = \tau(1-e)/(1-\tau e). \] (38)

With replacement cost-depreciation, inflation does not alter the relative effective tax rates between different capital assets.

However, if depreciation deductions are valued at "historic" rather than replacement cost, the results are significantly different.

With historic cost depreciation:

\[ D_H(s-t, \delta) = \delta e^{-\delta(s-t)} \] (39)

and the present value of these deductions equals

\[ Z_H = \delta/(\rho+\pi+\delta). \] (40)
Therefore,

\[ v = \frac{\rho}{1 - \tau} + \frac{\pi \tau Z_H}{1 - \tau} \]  \hspace{1cm} (41)

and

\[ \Theta = \frac{(\tau \rho + \pi \tau Z_H)}{(\rho + \pi \tau Z_H)}. \]  \hspace{1cm} (42)

Two features of the effective tax rates are apparent in the presence of historic cost depreciation and positive rates of inflation. First, if \( \pi > 0 \), \( \Theta \) is greater than \( \tau \), i.e., effective tax rates increase relative to statutory rates. Further, because \( Z_H \) is an increasing function of \( \delta \), \( \partial \Theta / \partial \delta > 0 \), and the choice of asset durability is biased toward assets with low values of \( \delta \).

These results clearly indicate that equivalent theoretical propositions regarding the effect of inflation on the composition of investment may be derived using either the concept of user costs of capital or effective tax rates. In both cases, inflation is found to bias the choice of capital toward assets with longer service lives.

The results obtained by Auerbach and Hendershott and Hu account for the relative importance of depreciation deductions in the choice between equipment and structures. Increases in inflation which affect the present value of depreciation deductions for equipment are magnified by the fact that equipment capital depreciates at a faster pace, and hence firms must recover such costs rapidly in order to earn an after-tax return of \( \cdot v \) on its assets.
E. Inflation and the Composition of Investment Demand:

Potential Ambiguity

The user cost of capital reflects opportunity costs to the extent that it measures the cost of foregone interest payments and depreciation of physical capital. As the previous discussion indicates, changes in the structure of tax incentives (i.e., depreciation deductions) are magnified according to the level of the demand price \( \frac{P_k}{P_y} \), and real interest and depreciation rates \( r - p^* + d \). As the asset demand price and real rate of interest increase, the magnitude of the effect of changes in the user cost of capital also increases. Therefore, accurate predictions of the effect of inflation and historic cost depreciation on the level and composition of business investment cannot be determined without an understanding of other economic factors influencing the inflationary effects.

Note, however, that Hendershott and Hu's basic conclusion regarding the relationship of the user cost of capital and asset depreciation rate is also ambiguous under some conditions. Taking the derivative of expression (24) with respect to the asset demand price \( \frac{P_k}{P_y} \) yields the following result:

\[
\frac{\partial (C^*_{\text{REP}} - C^*_{\text{HIST}})}{\partial (P_k/P_y)} = -\left( \frac{T_x}{1 - T_x} \right) \cdot (r - p^* + d) \cdot \left[ \frac{d_{T_x}}{r + d_{T_x}} - \frac{d_{T_x}}{r - p^* + d_{T_x}} \right] > 0. \tag{43}
\]

The effect of inflation on the user cost of capital under historic-cost depreciation rules is an increasing function of the asset purchase
price. With higher real purchase prices, the inflationary effects are magnified reflecting the fact that the real value of depreciation deductions has increased considerably. If the initial real asset purchase price for structures was substantially greater than the price for equipment, the relative increase in the user cost of capital under replacement cost depreciation could be greater for structures. Under such conditions the effect of inflation on the optimal capital composition of the stock could well be reversed. Equation (14) earlier indicates that the effect of inflation on the user cost of capital is also an increasing function of the economic depreciation rate. Combined with expression (43), however, the net effect on the user cost of capital for equipment and structures is theoretically ambiguous, and it is impossible to assess the net effect on the optimal composition of the capital stock. This result underscores the conclusion that the effect of inflation and historic cost depreciation on investment composition can only be determined accurately when all components of cost are properly accounted for.

This same ambiguity is present in the analysis of effective tax rates discussed above. Recall from expression (31) and the definitions below (31) that Auerbach assumes that all real asset prices are constant and equal to unity. Therefore, the real asset price drops out of the calculation of effective tax rates for each asset class. If such an assumption is false (as the data suggest), then the expression for the effective tax rate must be amended.
Given: \[ \nu = \frac{P(\rho+\delta)(1-\tau Z)}{(1-\tau)} - \delta, \]

and: \[ \Theta = \frac{-\rho(1-\tau)}{P(\rho+\delta)(1-\tau Z_H)} - \delta(1-\tau) \]

where: \( P \) = real price of asset
\( Z_H = \delta/(\rho+\tau+\delta). \)

Then:
\[ \frac{d\Theta}{dP} = \frac{\rho(1-\tau)}{(P)^2(\rho+\delta)(1-\tau Z_H) - \delta(1-\tau)} > 0. \quad (44) \]

The effective tax rate is an increasing function of the real asset price. Although the effective tax rate is greater for assets with shorter lives (i.e., larger \( \delta \)), it is also dependent on the magnitude of the real asset price. As with the user cost, given equal real asset prices for equipment and structures, the bias would clearly be against equipment. However, if the real price of structures should be greater relative to the real price of equipment, the direction of the overall change in user costs or effective tax rates becomes theoretically ambiguous. For this reason, it is apparent that any attempt to measure the effect of inflation on the composition of investment must carefully account for the existing set of real asset purchase prices.
F. Summary

The analysis in this chapter indicates that by reducing the real value of depreciation deductions, inflation will lead to a decline in the real capital stock and investment. Hendershott, Feldstein, Kopcke, and Auerbach all suggest that inflation can substantially affect the real value of depreciation deductions when such deductions are governed by tax laws requiring historic cost depreciation. The above analysis also indicates that inflation can potentially affect the composition of the capital stock, biasing the choice of assets toward structures. Differing conclusions regarding the effect of inflation on investment composition are resolved when the relative importance of tax factors between assets of differing service lives are properly accounted for.

One important conclusion of this chapter is that the calculation of the effect of inflation on the level and composition of the capital stock depends explicitly on the level of real interest rates and asset purchase prices. Only by properly accounting for given economic conditions can one quantify the effects of inflation on the incentives to invest in real capital.

This last conclusion has implications for selection of the appropriate econometric methodology. It suggests that proper measurement of the relation between inflation, historic cost depreciation, and actual investment behavior requires careful specification of all the relevant economic and tax variables which determine this
relationship. For example, estimation of a simple linear relation between inflation and investment would not be meaningful because quantitative links between the two variables will change over the estimation period. In econometric terms, the coefficients estimated from such a relation would be unstable and devoid of economic significance. A more appropriate methodology would provide for joint estimation of the relation between investment and some composite variable which explicitly accounts for the critical relation between asset purchase prices, real interest rates, tax rates, and inflation.
CHAPTER 3

INFLATION AND CAPITAL FORMATION: EMPIRICAL EVIDENCE

The purpose of this chapter is to review two studies which address the empirical relation between inflation, depreciation deductions, and investment. Using the Jorgenson cost of capital model, Feldstein (1980a) finds evidence that adjustment of the investment model for the effect of inflation on depreciation yields an improvement in explanatory power. Corcoran (1979) also reports statistical evidence of the importance of depreciation deductions on capital formation and indicates that inflation affects investment by reducing such deductions as suggested by the theory. These studies, however, are found to be of very limited value in measuring the empirical link between inflation and the level and composition of investment demand. The following analysis indicates that the empirical relevance of inflation for explanations of investment behavior remain essentially unexplored.

In addition to the direct effects of inflationary expectations, this chapter also discusses recent suggestions that inflation uncertainty has played a significant role in discouraging real capital investment. Malkiel (1979), Cuckierman (1981), and Friedman (1980) have stated that changes in inflation uncertainty, measured by changes
in the variance of forecasts of expected inflation, have reduced investment by (1) increasing the hurdle rate on investment projects as a result of higher risk premiums, (2) increasing the time and expense required to investigate and plan more uncertain ventures, and (3) reducing the general level of output. Evidence on the effect of inflation uncertainty on saving behavior, however, would seem to dispute these conclusions. For example, Wachtele (1979) finds that an increase in inflation uncertainty increases saving which in effect should lead to an increase in investment. These arguments are discussed briefly in this chapter. Because no direct test of the hypothesis that inflation uncertainty has reduced investment has been attempted, such a test is proposed here.

A. Inflation, Depreciation Deductions, and Investment:

Empirical Evidence

The econometric relation employed by Feldstein may be summarized as follows:

\[ I_t^G = \beta_0 + \sum_{j=0}^{n} v_j \Delta K_t^* + dK_t + \varepsilon_t \]  \hspace{1cm} (45)

where:

- \( I_t^G \) = gross investment in period \( t \)
- \( K_t^* \) = optimal capital stock, measured as the ratio of output to the user cost of capital
- \( K_t \) = actual capital stock in period \( t \)
d = depreciation rate.¹⁷

Because the user cost of capital enters directly into the investment equation through determination of K*, inflation is an explanatory variable of the model. To provide evidence of the importance of inflation, Feldstein estimated the above equation for investment in producers durable equipment at the Non-Farm Business Sector level.

Using an expression identical to equation (16), Feldstein constructs values for the equipment user cost of capital using data on depreciation and tax rates, interest rates, and an assumed measure of inflationary expectations. Actually, two measures of equipment user cost are constructed: one measure which incorporates the effects of inflation, and a second measure which does not. For the first measure of user cost, depreciation deductions are valued at historic cost, whereas for the second measure they are valued at replacement cost.

To provide evidence that inflation affects investment, Feldstein formulates an econometric test of changes in the explanatory power of the investment model. By using the two different measures of user cost described above, he hoped to demonstrate that a failure to correct for inflationary bias in the user cost would reduce its ability to "explain" historical investment behavior. Upon estimation of two separate models of equipment investment for the Non-Farm Business Sector, Feldstein does indeed observe some gain in the fit of the model. Specifically, he notes that when the correct measure of
the user cost is employed in the estimation, (1) the adjusted coefficient of determination, $R^2$, rises from .970 to .980 and (2) the sum-of-squared residuals falls to 112.5 from 167.4. On the basis of this evidence, Feldstein states:

"It is of some importance that, even within the highly constrained assumptions of the present model, the data provide clear support for the responsiveness of investment to changes in a correctly measured cost of capital services in general and to changes caused by inflation in particular. Although the data are not rich enough to provide precise estimates of the responsiveness of investment to the individual components of the cost of capital, it is worth noting that the evidence shows that a correct accounting of the impact of inflation substantially improves the ability of the analysis to explain the variation in investment over the past 25 years." 

In summary, because the statistical results suggest that a correct representation of the user cost improves the ability of the model to explain investment, Feldstein concludes that the effects of inflation have been substantial.

The conclusions drawn by Feldstein on the basis of the above econometric evidence may be criticized on several grounds. The first, and perhaps most critical, problem with the results obtained by Feldstein is the nature of the empirical test. Essentially, he is comparing the results obtained from estimation of a model that is known to be misspecified against the results from a model that on theoretical grounds more closely approximates a "true" investment
demand equation. By comparing models on the basis of some objective criteria, Feldstein hoped to assess the difference in quality of econometric "fit". However, because the first model employs a user cost variable which is measured incorrectly, it suffers the econometric problem of errors-in-variables. Under such conditions, the estimation results are known to be biased and inconsistent, and one must view these results with suspicion. Therefore, it is inappropriate to compare the results of these two models and to attach so much importance to changes in the objective measure of fit.

The problem of errors-in-variables is worth exploring in greater detail because it has relevance to the use of previously estimated neoclassical investment models that have not properly accounted for the effects of inflation and historic cost depreciation. The bias and inconsistency of previous estimates can be demonstrated as follows:

Assume that $x_i^* = x_i + v_i$ where $x_i$ is the true value and $x_i^*$ is the observed value. The true regression model is

$$ y_i = \beta x_i + e_i \quad i = 1, \ldots, T $$

while the actual regression model estimated is

$$ y_i = \beta x_i^* + (e_i - \beta v_i) $$

$$ = \beta x_i^* + \varepsilon_i^* . $$
Even if we assume that the measurement error in $x$ is normally distributed with zero mean, has no serial correlation, and is independent of the error in the true equation, problems arise when using ordinary least squares as a regression technique. This can be most easily seen by noting that the error $e^*$ and the variable $x^*$ above are correlated. In particular,

$$\text{Cov}(e^*_i, x^*_i) = E[(e_i - \beta v_i)(x_i + v_i)] = -\beta \sigma_v^2. \quad (46)$$

Thus, least squares estimates of the regression parameters will be biased and inconsistent, the degree of bias and inconsistency being related to the variance of the measurement error. Evidence suggests that the failure to incorporate inflation and depreciation in the calculation of the user cost variable will lead to significant errors of measurement assuring the presence of bias in the coefficients on user cost variables. Employing such coefficients to measure the effect of inflation on current investment is likely, therefore, to generate erroneous results. For this reason, reestimation of such equations is warranted.

One additional problem with Feldstein's results is that they do not address the issue of the effect of inflation on the composition of investment. Feldstein's analysis is limited to the behavior of investment in producers' durable equipment. Because no reference is made to the effects of inflation on the level of investment in structures it is impossible to know whether the same methodology applied to a structures equation would yield results similar to those for
equipment. Therefore, one cannot assert that the level of aggregate gross investment would fall under inflationary conditions, or whether some adjustment in composition would result. Therefore, it is clear that any econometric test, whose purpose is to quantify the effects of inflation on both the level and composition of investment, should handle both equations using the same methodology.

Of equal importance, however, is the fact that Feldstein's aggregate investment equation will likely suffer from a high degree of aggregation bias. Jorgenson and Stephenson (1967) have shown that such aggregation bias can be substantial. Using neoclassical investment equations for each of the 2-digit S.I.C. code manufacturing industries for the 1947-1960 period, the results of their analysis showed that individual industry behavior varied greatly from that implied by a total manufacturing investment equation. Jorgenson and Stephenson were able to measure the degree of aggregation bias associated with the total investment equation, and determined that serious errors of measurement were associated with the aggregate equation.

By not properly accounting for variation in industry behavior, Feldstein's equation is likely to suffer the same problem. Although Feldstein did not publish the estimated coefficients, measurement of the effect of inflation on investment using such coefficients would likely prove inaccurate compared to the aggregation of industry behavior. This problem could prove to be a serious one when attempting to measure the effect of inflation on investment composition. Because different industries often employ radically different proportions of equipment relative to structures, the effect of
inflation is likely to vary significantly across industries. For the purpose at hand, therefore, one must reject the estimation of any aggregate investment equation which does not properly account for variation in industry behavior with respect to user cost changes.

In an attempt to test the hypothesis that inflation reduces investment, Corcoran (1979) estimated the following model:

\[
\frac{I_j}{K_j} = \beta_0(R_j) + \beta_1(\text{ITC}_j) + \beta_3(\text{DEP}_j) + \epsilon_t
\]  

where:

- \(I_j\) = Gross investment in asset type \(j\) at time \(t\)
- \(K_j\) = Capital stock for asset \(j\) at time \(t\)
- \(R_j\) = Rate of Return on investment in asset \(j\) at time \(t\)
- \(\text{ITC}_j\) = Present value of the investment tax credit available on asset \(j\) at time \(t\)
- \(\text{DEP}_j\) = Present value of a dollars worth of investment in asset \(j\) at time \(t\)

Equations were estimated using generalized least-squares for seven different asset categories. The purpose of this test was to determine the sign and statistical significance of the coefficient \(\beta_3\) in equation (47). A significant and positive coefficient on this variable was assumed to provide evidence that depreciation deductions are an important element in investment behavior.

Corcoran does indeed find this result for each of the seven equations. He argues that because inflation reduces the present
value of such deductions by raising the nominal discount rate, inflation is responsible for the decline in aggregate investment in the Non-Farm Business Sector. He further argues that because inflation reduces the present value of such deductions more for structures than for equipment, inflation has distorted investment composition toward equipment rather than structures.

Criticism of these results stems primarily from the conclusions drawn in Chapter 2 regarding the appropriateness of the net cost of investment approach for analyzing this problem. Specifically, the previous analysis demonstrates that the effect of inflation on the present value of depreciation deductions varies according to the assumptions on the level of real interest rates and inflation rates. Further, the analysis of Chapter 2 indicates that simple analysis of the present value of depreciation deductions fails to account for (1) the differential importance of depreciation deductions between equipment and structures, and (2) variations in the relative prices of equipment and structures over time. These findings suggest that the relationship between investment and simple calculations of the present value of depreciations will change as economic conditions evolve.

In econometric terms, this indicates that the estimated coefficients in Corcoran's equation are not constant over time and must be considered as unstable. Essentially, no economic significance can be attached to these coefficients and one must question whether they provide any information useful for policy analysis. It is interesting to note that Corcoran makes no attempt to interpret the
coefficients or calculate changes in investment with respect to changes in inflation. Further, it is impossible to isolate from his results the change in investment generated by changes in tax laws governing allowable depreciation methods and lifetimes rather than inflation. For these reasons, Corcoran's empirical test provides essentially no econometric evidence that inflation has substantially affected capital investment in the United States.

Based on these criticisms one must assert that the results provided by Feldstein and Corcoran do not constitute sufficient evidence to conclude that inflation and historic cost depreciation have been a primary source of the current weakness in investment demand. Further, it is apparent that no econometric evidence exists which supports the hypothesis that inflation distorts the composition of investment. In summary, no real evidence exists to conclude that inflation is a significant deterrent to investment expenditure. However, because of the significance of this issue, it is clear that further empirical research is warranted.

B. Investment and Inflation Uncertainty

The previous chapter described the manner in which inflation affects the long-run level and composition of investment directly. Note that such effects are present even if economic agents are perfect forecasters of inflation as generally assumed. Inflation reduces the ability of depreciation deductions to shield real corporate income
from taxation, and expectations of such effects will alter the level and composition of investment regardless of the expectations formation mechanism.

One aspect of the relation between inflationary expectations and investment, however, has not received much attention. This problem concerns the effect of inflation uncertainty on investment. Inflation uncertainty is defined in this instance as the degree of variance in forecasts of inflationary expectations held by market participants at different points in time. Most research on price expectations assumes that the standard deviation of "market" price forecasts is constant across time, individuals, and markets, suggesting that the second moment of such forecasts can be ignored. Recent evidence, however, indicates that this usual assumption on price expectations is not consistent with survey measures of such expectations. A review of recent literature suggests that variation in the probability distribution of inflationary expectations could have real effects on the level and composition of investment. The problem with this literature, however, is that predictions of the effects of inflation uncertainty on investment are contradictory, and primarily based on conjecture. The purpose of this section is to review basic elements in this literature and propose a simple empirical test of the hypothesis that inflation uncertainty has affected the level and composition of investment.

One avenue by which inflation uncertainty is thought to affect investment was suggested by Malkiel (1979). Describing possible
reasons for sluggish investment, Malkiel suggested that high and variable rates of inflation have increased the risk associated with investment projects which has in turn raised the hurdle rate that investment projects must surpass before they are undertaken. This risk premium is calculated as the difference between anticipated rates of return on stocks and the rate of return on riskless Treasury securities. A plot of this risk premium reveals that it fell to a low point in the early 1970s, and has been increasing steadily ever since. The author suggests that the major reason for the premium has been the risk of uncertain cash flows to investment caused by high and variable rates of inflation. An increase in the risk premium associated with uncertain inflation has raised the investment hurdle rate, increasing the likelihood that returns to risky investment projects will not exceed this rate. Inflation uncertainty, therefore, lowers investment by raising the effective discount rate of such projects.

Inflation uncertainty is also thought to affect the level of investment due to the increased cost associated with collecting additional information. Using a Bayesian error-learning model, Cukierman (1980) explores this idea by considering a risk neutral firm which picks a single investment out of many that are available. Uncertainty enters this formal model as a vector of variables containing taxes, demand for product, prices, costs, and political occurrences. The primary result of this paper is that when uncertainty increases, the firm finds it necessary to delay investment
decisions in order to collect more information. An example of such uncertainty would be the need to forecast the relative variation in firm costs and prices over the lifetime of the investment. High and variable rates of inflation create uncertainty regarding the time path of price and cost increases, and this time path can be critical in measuring the discounted present value of the investment. For a given cost of acquiring information, an increase in uncertainty makes it profitable to expend resources to analyze investment projects, especially when the cost of reversing such projects is high.

Cukierman notes that the increased expenditure on information collection does not imply necessarily a permanent decrease in investment. Firms may simply postpone rather than cancel such projects. However, Cukierman also suggests that if many potential investors perceive increased uncertainty simultaneously, such postponement may be lengthy or indefinite. In other words, a sustained increase in inflation uncertainty may result in a permanent decline in investment expenditure and appropriations.

Another example of the role of inflation uncertainty is found in tests of a hypothesis proposed by Friedman (1977). In his Nobel lecture, Friedman observed that Phillips curves fitted on recent data for a number of different countries are positively sloped. He explained this finding by citing evidence that the level of the inflation rate and the variability in the inflation rate are positively correlated. An increase in unemployment is associated with an increase in inflation due primarily to the economic problems associated with
highly variable anticipations of inflation. The major element in his argument is the idea that increased volatility in the rate of inflation complicates recognition of relative price changes since information is transmitted via absolute prices. Increases in relative price uncertainty introduce frictions in all markets with a subsequent loss in the efficiency of prices as signals for economic activity. The loss of clear market signals results in a period during which markets and institutions adjust to increased uncertainty, leading to a general decline in output and an increase in unemployment.

Empirical substantiation of the relation between inflation uncertainty and reduced output has been offered by Mullineaux (1980) and Blejer and Lieberman (1980). Using the standard deviations of Livingston survey respondent's forecasts of inflation as a measure of inflation uncertainty, Mullineaux finds a negative correlation between industrial production and such uncertainty. Blejer and Lieberman also find a negative relation between industrial production and inflation uncertainty, measured by the absolute variation in several groups of commodity prices over time.

One problem with these results, however, is that we have no indication of the specific sector in which the decline in economic activity would occur. The arguments presented by Malkiel and Cukierman suggest that inflation uncertainty is negatively related to investment activity, whereas the results presented by Mullineaux indicate that the decline in economic activity could be focused on either the consumption or investment good sectors. The negative relation between
inflation uncertainty and industrial production found by Mullineaux could actually mask a more important relationship between such uncertainty and the incentives to invest. A negative relation between inflation uncertainty and investment would certainly explain the result found by Mullineaux, and would correspond more closely with the economic dislocation described by Friedman. Clearly, more work needs to be done to identify the economic relationships between inflation uncertainty and economic activity.

Taken together, the above arguments indicate that an increase in inflation uncertainty will reduce the level of gross investment. Increased hurdle rates, increased costs of acquiring information, relative price uncertainty, and lowered aggregate output all suggest that gross investment should decline. Contradicting these ideas, however, is the empirical work of Wachtel (1977) on the relation between inflation uncertainty and aggregate saving. Wachtel measures inflation uncertainty as the standard deviation on forecasts of inflation made by respondents to Michigan Survey Research Center price surveys. Regressing the quantity of savings per household on real income per household and his measure of price uncertainty, Wachtel finds a significant positive relation between such uncertainty and saving. An increase in the variability of inflation leads to an increase in the level of real saving per household. This evidence is also supported by a similar analysis made by Juster (1975). The author interprets this finding to indicate a precautionary motive in saving behavior, suggesting that as households become uncertain about
future prices and real income, they save more. In the context of investment, this increase in saving should give rise to a concomitant increase in investment. Inflation uncertainty, therefore, may be positively associated with gross investment contradicting the hypothesis offered by Malkiel, Cuckierman, and Friedman.

The result that inflation uncertainty leads to an increase in savings would also explain the results obtained both by Levi and Makin (1979) and Bomberger and Frazer (1981). The purpose of these studies is to provide an additional empirical test of the relationship between nominal interest rates, real interest rates, and inflationary expectations. These authors demonstrate, however, that an important variable missing from all empirical tests of the Fisher hypothesis is inflation uncertainty. By regressing nominal interest rates against measures of inflationary expectations and inflation uncertainty, the authors find that increases in inflation uncertainty are negatively related to nominal interest rates. In both papers, the measure of inflation uncertainty is taken to be the standard deviation of survey respondents to the Livingston Price Surveys published regularly in the Philadelphia Enquirer. Levi and Makin suggest that the negative relation between inflation uncertainty and interest rates is indicative of an underlying negative relationship between capital investment and inflation uncertainty. This hypothesis is not tested. It is important to note, however, that the results obtained in both papers are consistent with the findings of Wachtel. An increase in inflation uncertainty leads to an increase in savings which in turn would
have a negative impact on interest rates. Such a relationship would indicate an increase in investment in response to the decline in interest rates, contrary to Makin and Levi's suggestion.

Because of the contradictory nature of these conclusions, it is reasonable to develop a simple test of the hypothesis that inflation has reduced the level of gross investment. This test would serve as additional evidence of the range of possible effects of inflation on investment. By appending a measure of inflation uncertainty to the estimating equation, it would be possible to determine the direction, magnitude, and significance of the effect of inflation uncertainty on investment.
CHAPTER 4

EMPIRICAL METHODOLOGY

The purpose of this chapter is to describe the empirical methodology used to assess the effect of inflation and inflation uncertainty on the level and composition of investment demand. Five elements of this methodology are discussed in detail: (1) derivation of the estimating equations, (2) the econometric estimation procedure, (3) construction of after-tax finance rates, (4) construction of tax depreciation variables, and (5) special characteristics of the data sets. The methodology described in this chapter represents a significant improvement in the empirical analysis of investment behavior for several reasons.

First, the econometric technique is particularly suited to the analysis of investment behavior because it simultaneously allows for: (1) variation in industry investment with respect to changes in its determinants, and (2) estimation of aggregate investment equations which avoid aggregation bias. Jorgenson and Stephenson (1967) have demonstrated that aggregate investment equations can lead to predictions of investment which are inconsistent with that implied by industry level equations. The Random Coefficients Regression Model developed by Swamy (1970) is particularly suited to solution of this
problem, and has been adopted here. This procedure has not been applied to estimation of neoclassical investment models and represents an improvement in estimation technique.

Second, estimation of the investment equations is based upon a unique set of investment and capital stock data which has not been used in the estimation of investment equations before. As noted above, the RCR technique is valuable because it facilitates estimation of aggregate equations which avoid the problem of aggregation bias commonly found in econometric work. Application of the RCR technique, however, requires cross-section data on investment and capital stock disaggregated not only by industry but also by equipment and structures. This data is not published on a regular basis by the Department of Commerce, although information is collected by the Census Bureau (Census of Manufacturers, Annual Survey of Manufacturers). The Bureau of Industrial Economics (Commerce Department) has compiled this data into consistent series at the 2-digit S.I.C. Code Level for both investment and capital stock, further disaggregated into equipment and structures. Although this data was actually published once in 1979 by the Department of Labor, the series were only available to 1974. Series updated to 1980 were obtained by special request to the Bureau of Industrial Economics. These data represent a unique disaggregation of investment and capital stock series to the industry level, and provided the necessary basis for application of the RCR technique. Use of these data in estimating investment demand equations, therefore, facilitated a significant improvement in the
econometric investigation of investment behavior.

An additional feature of this analysis is the use of direct observations on inflationary expectations found in the Livingston Forecast survey. The Livingston data is composed of semi-annual national surveys of economists and businessmen on their expectations of inflation expectations. This data is published regularly in the Philadelphia Enquirer. Rather than adopt an arbitrary statistical model of inflationary expectations, the Livingston data was employed in the calculation of real tax depreciation deductions. This data is also valuable because it is possible to calculate a measure of inflation uncertainty from the variance of respondent predictions in each period. Characteristics of the data are described in the last section of this chapter.

A. Neoclassical Model of Investment Demand

The econometric investment model adopted here is based on the work of Hall and Jorgenson (1967, 1971). This model assumes that the objective of the firm is to maximize profit, defined as the difference between current revenue and outlay minus the real rental rate (user cost) of capital services. The definition of profit may be represented in the following manner:

\[ \pi = pY - wL - cK \]  \hspace{1cm} (48)

where:
\( p = \text{real price of output} \)
\( Y = \text{real output} \)
\( w = \text{real price of labor input (wage)} \)
\( L = \text{quantity of labor input} \)
\( K = \text{quantity of capital input} \)
\( c = \text{user cost of capital} \).

Profit is maximized at each point in time subject to the constraint of given production technology:

\[
Y = \Phi(K,L) \tag{49}
\]

The necessary conditions of profit maximization require that the marginal product of each input equal the real price of that input. For capital this condition may be stated as:

\[
\frac{\partial \Phi}{\partial K} = \frac{c}{p} = c^* \tag{50}
\]

Firms employ additional units of capital until the marginal product of the last unit equals the real price of that unit of capital. The right-hand side of expression (50) is equivalent to the user cost of capital described in the previous section.

Any change in the implicit determinants of the user cost of capital, such as tax laws, the real rate of interest, or inflation will cause firms to alter the stock of capital employed at any point in time. An increase in the user cost generates a net reduction in the optimal capital stock held by firms, while a decrease in the user
cost has the opposite effect.

Investment represents the process by which firms adjust the optimal stock of capital. If the user cost of capital does not change in a given period, we would not expect firms to make any adjustment in the optimal capital stock. However, because the stock of capital deteriorates physically during production, firms attempting to maintain the current stock of capital will purchase capital goods simply to replace the capital used up during production. Gross investment in any period, therefore, is determined by the sum of replacement investment and any net additions to or subtractions from the optimal capital stock, motivated by changes in the user cost of capital. Under the assumption that replacement investment is proportional to the actual capital stock, gross investment in any period equals:

\[ I_t^G = \Delta K_t^* + dK_{t-1} \]  

(51)

where:

- \( I_t^G \) = real gross investment in period \( t \)
- \( \Delta K_t^* \) = change in optimal capital stock
- \( d \) = rate of economic depreciation
- \( K_{t-1} \) = actual capital stock in period \( t-1 \).

Empirical implementation of this model requires specific assumptions on the nature of production technology. In almost all studies of investment demand based on the neoclassical model of firm behavior, the authors have assumed a Cobb-Douglas production function:
\[ Y = \phi(K, L) = K^{\alpha}L^{\beta} \]  

(52)

where \( \alpha \) and \( \beta \) are the elasticities of output with respect to capital and labor, respectively. With this specification of production technology, the necessary conditions of profit maximization lead to the following result for capital input:

\[ \frac{\partial \phi}{\partial K} = \frac{\alpha Y}{K^\alpha} = \frac{c}{p} = \frac{c^*}{p} . \]  

(53)

This profit maximization condition is then easily manipulated to obtain an expression for the optimal capital stock for the current period:

\[ K^* = \frac{\alpha Y}{c^*} . \]  

(54)

The optimal capital stock in any period is determined by the relative magnitudes of output and the real user cost of capital \( c^* \). Essentially, this expression states that the firm will employ additional units of capital until the value of the total capital stock equals the discounted value of the output produced with this capital.

A stochastic model of investment demand may then be specified as follows:

\[ I_t^G = \beta_0 + \gamma_0 (\Delta K^*_t) + dK_{t-1} + \nu_t \]  

(55)

\[ = \beta_0 + \gamma_0 \left( \frac{\Delta Y}{c^*} \right) + dK_{t-1} + \nu_t \]

where:
$\beta_0$ = constant term in regression

$\nu_t$ = stochastic disturbance term.

The econometric specification may be further refined by incorporating lagged adjustment in investment due to the time required to order, produce, and install new capital once firms have recognized the need to change the optimal capital stock. Jorgenson and others have incorporated the notion of lagged response by specifying investment demand equations which include polynomial distributed lag functions as follows:

$$i_t^G = \beta_0 + \sum_{j=0}^{n} \gamma_j \left( \Delta \frac{G}{C} \right)_{t-j} + dK_{t-1} + \nu_t. \quad (56)$$

This econometric specification of investment demand may be interpreted as follows: actual gross investment expenditure in period $t$ is determined by the sum of replacement investment and net additions to the capital stock purchased in the current period as a result of changes in the optimal capital stock in the current and previous periods. Desired changes in the optimal capital stock are brought about by the joint effect of changes in output and the user cost of capital in the current and previous periods. Gross investment in period $t$, therefore, represents the current period response of firms to changes in the determinants of desired capital which occur over time.
The most difficult element in applying this model of investment demand involves specification and construction of the user cost of capital variable \( c^* \). To construct this variable Jorgenson and others have employed the basic definition of user cost of capital derived earlier. Their expression for the user cost of capital, including all relevant tax and non-tax factors and the requirement that depreciating capital be valued at historic cost, is:

\[
c^* = \frac{P_k}{P_y} \left[ \frac{(1 - \mu)}{(1 - T_x)} (r - p^* d) - \frac{T x d}{1 - T x} \left\{ \frac{d_t (r - p^* d)}{(1 + r)^t} \sum_{t=0}^{\infty} \frac{d_{T x}}{(1 + p^* - d_{T x})^{t-1}} \right\} \right]
\]

By collecting time series data on real interest rates, schedules of accelerated depreciation, investment tax credits, tax service lives, real asset market prices, and economic depreciation rates, it is possible to construct measures of the user cost of capital for different classes of assets. The usual approach to modelling aggregate investment behavior is to construct separate user cost variables for producers durable equipment and structures.

Analysis of the historical investment behavior of firms using this model has proven very successful. In several articles Jorgenson has demonstrated consistently that the constructed measure of the optimal capital stock, determined by the relative magnitudes of real output and real opportunity (user) cost of capital, is a significant variable in the determination of aggregate investment. Jorgenson and
others have asserted on the basis of this evidence that the basic elements of the user cost of capital such as income taxes, investment tax credits, and accelerated depreciation are important determinants of the investment behavior of firms. This empirical research has been cited extensively as evidence that fiscal and monetary policy directly affect aggregate investment in addition to the accelerator effect of output changes.

The neoclassical econometric model of investment is relevant to the problem of quantifying the effects of inflation and historic cost depreciation on investment primarily for two reasons. First, because the model is derived from conditions of profit-maximization by a neoclassical firm, changes in investment behavior can be traced to changes in cost. Therefore, it is appropriate to predict that net and gross investment will react to specific economic conditions such as inflation which determine user cost. Thus, the investment demand equation represents a consistent methodology for quantifying the effects of inflation because the mechanism by which such effects can occur is made explicit.

The second reason for adopting this model of investment demand is based on the conclusion reached in earlier analysis of the user cost. Specifically, it was shown that one cannot assess the effects of inflation on depreciation and investment without explicit recognition of other important variables in the determination of cost. Quantitative predictions of the effect of inflation on the level and composition of investment can be made with accuracy only when the
qualifying effects of the level of tax rates, tax credits, real interest rates, prices of investment goods, and inflation rates have been accounted for. In this model of investment demand, firms react to changes in one aggregate cost variable, whereas inflation was shown to affect this cost variable in different ways under different economic conditions. For econometric purposes, it is imperative that the stability of estimated coefficients not be sensitive to different levels of the specified variable. Only by containing the variable effects of inflation within a single construct is it possible to estimate an econometric equation that has meaning. The neoclassical model, therefore, satisfies an additional econometric constraint.

B. Lags and Investment Behavior

Adjustment of the actual capital stock to a new optimal level is captured by a lagged process, representing the time required to plan, initiate, and complete new investment projects. This lagged adjustment process occurs in expansionary as well as replacement investment projects, although the lengths of such lags are not always equal. A brief statement of the assumed lag adjustment process is useful prior to specification of the estimating equations. 24

Let the proportion of net investment completed in period \( t \) be \( \mu_t \). The distribution of such completions over time given a sequence of changes in the optimal capital stock may be represented by:
\[ \mu_0, \mu_1, \mu_2, \ldots \]

where

\[ \mu_t \geq 0 \quad t = 1, \ldots, N \text{ periods.} \]

Assuming the adjustment to the optimal capital stock is completed, then

\[ \sum_{t=0}^{N} \mu_t = 1. \tag{59} \]

The equation in net investment may, therefore, be defined as

\[ I^N = [I_t - dK_{t-1}] = \mu(S) [\Delta K^*] \tag{60} \]

where \( S \) represents a lag operator specifying the sequence of lagged changes in the optimal capital stock in periods \( t \), \( t_{s-1} \), \( \ldots \), etc.

Following Jorgenson (1963), the sequence of coefficients \( \mu_t \) is represented by rational polynomial lag functions. With this assumption, a distributed lag function on changes in the optimal capital stock may be written as:

\[ [I_t - dK_{t-1}] = \frac{v(s)}{w(s)} [\Delta K^*] \tag{61} \]

where \( v(s) \) and \( w(s) \) are polynomials in the lag operator of degree \( s \). Multiplying both sides of expression (61) by \( w(s) \), a specification of the net investment equation becomes:

\[ \omega(s) [I_t - dK_{t-1}] = v(s) [\Delta K^*]_t. \tag{62} \]
Expanding the lag operators $\omega(s)$ and $v(s)$,

$$[1 + \omega_1 s + \ldots + \omega_n s^n][I_t - dK_{t-1}]$$

$$= [v_0 + v_1 s + \ldots + v_m s^m][\Delta k^*]$$

or

$$[I_t - dK_{t-1}] + \omega_1[I_{t-1} - dK_{t-2}] + \ldots + \omega_n[I_{t-n} - dK_{t-n-1}]$$

$$= v_0[\Delta k^*]_t + v_1[\Delta k^*]_{t-1} + \ldots + v_m[\Delta k^*]_{t-m}. \quad (63)$$

From expression (63), the final form of the estimating equation may be derived. To this equation a stochastic error term ($\varepsilon_t$) is appended which is assumed to be independently and identically distributed over time.

$$I_t = v(s)[\Delta k^*]_t + [1 - \omega(s)][I_t - dK_{t-1}] + dK_{t-1} + \varepsilon_t$$

Remembering that $k^* = \frac{gY}{c^w}$, then

$$I_t = \alpha v(s)\left[\frac{Y_t}{c_t} - \frac{Y_{t-1}}{c_{t-1}}\right] + [1 - \omega(s)'])[I_t - dK_{t-1}] + dK_{t-1} + \varepsilon_t. \quad (64)$$

This equation states that current period gross investment is determined by completions of investment projects executed to expand and/or replace the optimal capital stock. Both net and replacement investment
are assumed to follow lagged adjustment processes, and gross investment represents the sum of current period completion of both types of investment. Note that the lagged adjustment process is not required to be the same.

The parameters \( v(s) \) and \( \omega(s) \) are unknown and must be estimated. This may be accomplished by applying ordinary least squares to expression (64) after prior selection of the lag lengths for the right-hand side variables. Following Jorgenson, minimization of the standard error of regression guides the appropriate selection of lag length.

In the neoclassical theory of investment behavior with Cobb-Douglas technology, changes in desired capital are known only up to a multiplicative constant, the elasticity of output with respect to capital input \( \alpha \). The constraint that the sum of the sequence of coefficients \( u_t \) is unity may be used to obtain an estimator of this elasticity. From the estimation results, \( \hat{\omega}_{t-m} \) becomes an estimator of \( \omega_{t-m} \) for each lagged value of \( \omega(s) \), and \( \hat{\nu}_t \) becomes an estimator of \( \nu_{t-n} \) for the sequence \( \alpha v(s) \). An estimator of \( \alpha \), say \( \hat{\alpha} \), may be obtained by solving:

\[
\hat{\alpha} = \frac{\sum_{t=0}^{m} v_t^{\alpha}}{\sum_{t=0}^{n} \hat{\omega}_t}.
\]

This estimator is consistent and efficient whenever the estimators \( \hat{\omega}_t \) and \( \hat{\nu}_t \) are consistent and efficient. 26
With the estimator for \( \hat{\alpha} \), it is possible to measure the effect of changes in the inflation rate on gross investment. To assess the effect on gross investment expenditures of any change in the rate of inflation, the following partial derivative must be evaluated:

\[
\frac{\partial I}{\partial p^*} = \frac{\partial I}{\partial K^*} \frac{\partial K^*}{\partial p^*}.
\]

If \( K^* \) increases to a higher level, and subsequently investment occurs to adjust actual \( K \) to \( K^* \), then once this is achieved replacement investment is all that is occurring, and this will be higher than before by a proportion \( d \) of the increase in \( K^* \). In other words, gross investment will simply equal the amount of replacement investment for the new optimal level of the capital stock. Therefore, in the long run

\[
\frac{\partial I^G}{\partial p^*} = d \frac{\partial K^*}{\partial p^*}.
\]

Recall that \( K^* = \alpha Y/c^* \), where \( c^* \) is a function of \( p^* \). Hence, \( \partial K^*/\partial p^* \) is given by \( \frac{\partial K^*}{\partial c^*} \frac{\partial c^*}{\partial p^*} \). Differentiating,

\[
\frac{\partial K^*}{\partial c^*} = -\frac{\alpha Y}{c^2}
\]

and

\[
\frac{\partial K^*}{\partial p^*} = \left(\frac{-\alpha Y}{c^2}\right) \frac{\partial c^*}{\partial p^*}.
\]

Because inflation enters the user cost of capital variable in such a
non-linear fashion, estimates of $\frac{\partial c^*/\partial p^*}{\partial p^*}$ will be obtained by calculating the change in $c^*$ at different levels of inflation.\(^{27}\)

In summary, the effect of inflation may be calculated on a partial equilibrium basis by evaluating:

$$\frac{\delta I}{\delta p^*} = d \frac{\delta K^*}{\delta p^*}$$

$$= -d \left( \frac{\alpha Y}{C^2} \right) \left( \frac{\partial c^*}{\partial p^*} \right).$$ \hspace{1cm} (66)

This can be calculated from an estimate of $\alpha$ and estimates of the parameters of $c^*$. Since these values vary, it is necessary to choose a time on which to base the calculation. The results discussed in Chapter 5 calculate the effect of changes in inflation on gross investment using the values which held at the end of the sample period. Calculations are carried out for both the equipment and structures equations, and from these results predictions of the effect of inflation on the level and composition of investment are made.

C. **Econometric Technique: Random Coefficients Regression**

Estimation of single aggregate equations for equipment and structures at the aggregate manufacturing level will result in substantial aggregation bias. An analysis of the results of Jorgenson and Stephenson (1967) suggests that several factors are responsible for differences in the reaction of various industries to changes in determinants of gross investment. These factors include differences
in: (1) the time pattern of the rate of adjustment (i.e., magnitude of individual coefficients of lagged estimators \( \hat{\alpha} \) and \( \hat{\beta} \)), (2) the elasticity of output with respect to capital input (\( \alpha \)), and (3) differences in the rate of depreciation of industry capital stock due to differences in proportion of equipment employed relative to structures capital.

One of the most important conclusions of the Jorgenson and Stephenson analysis is that the behavior implied by the total manufacturing equation was substantially different from that implied by the summation of individual industry equations. This represents a critical problem in the present study because it suggests that accurate measurement of the aggregate effect of inflation and historic cost depreciation on manufacturing investment must be based on a cross-section study of individual industry investment behavior. Fortunately, however, Swamy (1970) has demonstrated that consistent estimates of an aggregate equation may by obtained by employing the cross-section time series procedure known as Random Coefficients Regression (RCR). This procedure is valuable to the present analysis because it calculates the coefficients on the aggregate manufacturing investment equations while systematically allowing for variation in divergent industry investment behavior. Implementation of the RCR procedure is described below.

Let an aggregate econometric relationship be represented by

\[
A = B X + U
\]

and let the corresponding industry econometric relation be

\[
A_n = B_n X_n + U_n
\]

where \( n \) represents the cross-section industries.
In particular, the NCR specification replaces the assumption of fixed intercepts and slopes with the specification that the coefficient vectors for each industry $\beta_n$ are independently but identically distributed with:

$$E(\beta_n) = \beta$$

$$E(\beta_n - \beta)(\beta_m - \beta)' = \Delta \text{ for } n = m$$

$$= 0 \text{ for } n \neq m$$  \hspace{1cm} (67)

where $\beta$ is a fixed coefficient vector, and $\Delta$ is a $(K \times K)$ nonsingular covariance matrix. The above assumption implies that the coefficient vectors $\beta_1, \beta_2, \ldots, \beta_N$ are random drawings from a global population.

Assume that the coefficient vectors for each industry are fixed over time, and that the variance of the equation disturbances $\varepsilon_{tn}$ differs according to the specific industry. Thus the model assumes that individual heteroscedasticity in the residuals across equations. Under the assumption that residuals are not autocorrelated, ordinary least squares methods can be used to estimate the $\beta_n$ vector of coefficients for each industry.

Defining $A_n$ and $X_n$ as the $(T \times 1)$ and $(T \times K)$ observation arrays for the industry dependent and independent explanatory variables, respectively, the best linear unbiased estimator of $\beta_n$ is

$$\hat{\beta}_n = [X_n'X_n]^{-1}X_n'A_n.$$  \hspace{1cm} (68)

This estimator is distributed with mean $\beta_n$ and covariance matrix
\[ E(\hat{\beta}_n - \beta_n)(\hat{\beta}_n - \beta_n)' = \sigma_n^2[X'X_n^{-1}]^{-1} \] (69)

Since \( \beta_n \) is distributed about \( \beta \) with covariance matrix \( \Delta \),

\[ E(\hat{\beta}_n - \beta) = E([\hat{\beta}_n - \beta_n] + [\beta_n - \beta_n]) = 0 \] (70)

and

\[ E(\hat{\beta}_n - \beta)(\hat{\beta}_n - \beta)' = \Delta + \sigma_n^2(X'X_n^{-1})^{-1}. \] (71)

Of particular importance is the generalized least squares procedure for calculating the aggregate estimator \( \beta \). Swamy has shown that the \( N \) estimates of \( \beta_n \) can be pooled to form an unbiased estimate of \( \beta \). Weighting the \( N \) estimators with weights inversely proportional to the covariance matrices yields a best linear unbiased estimate of \( \beta \). Thus,

\[ \hat{\beta} = \sum_{n=1}^{N} W_n \hat{\beta}_n \] (72)

where

\[ W_n = \left\{ \frac{1}{\sum_{m=1}^{N} [\Delta + \sigma_m^2(X'_mX_m^{-1})^{-1}]^{-1}} \right\}^{-1} \left[ \Delta + \sigma_n^2(X'_nX_n^{-1})^{-1} \right]^{-1}. \] (73)

Since

\[ \sum_{n=1}^{N} W_n = I, \quad E(\hat{\beta}) = \beta. \] (74)

Equation (73) contains unknown \( \{\sigma_1^2, \ldots, \sigma_k^2\} \) and \( \Delta \). Swamy has shown that \( \sigma_n^2 \) can be estimated by
\[ s_n^2 = \frac{A_n [I - X_n (X_n' X_n)^{-1} X_n'] A_n}{T - K} \]  

(75)

and \( \Delta \) can be estimated as the difference between two matrices,

\[ \hat{\Delta} = \sum_{n=1}^{N} \hat{\beta}_n \hat{\beta}_n' - \frac{1}{N} \sum_{n=1}^{N} \hat{\beta}_n \sum_{n=1}^{N} \hat{\beta}_n' \]

\[ - \frac{1}{N} \sum_{n=1}^{N} s_n^2 (X_n' X_n)^{-1} \]  

(76)

The RCR model has been applied successfully by Feige and Swamy (1974) to the analysis of demand for liquid assets, and by Swamy (1971) to Grunfield's (1961) investment model. Further, this procedure has been applied by Rodekohr (1980) to an analysis of demand for transportation fuels in the O.E.C.D., and by Mehta and Swamy (1978) to an analysis of household demand for gasoline. For each application the RCR model proved useful in improving the significance and explanatory power of the aggregated equation. Because the various industries employ different proportions of equipment and structures in production, inflation will affect each industry differently. For this reason the random coefficient approach is considered particularly appropriate in the current research. Only by employing such a procedure will aggregate investment equations for equipment and structures be obtained which avoid the severe problem of aggregation bias.
D. Real Versus Nominal After-Tax Finance Rates

The nominal after tax financing rate used to discount cash-flows was previously specified as:

\[ r = bi(1-\tau) + (1-b)e \]  \hspace{1cm} (77)

where:  
\( b = \) portion of investment which is debt financed  
\( e = \) nominal after-tax return to equity  
\( i = \) nominal rate on corporate debt  
\( r = \) nominal after-tax weighted average cost of capital  
\( \tau = \) marginal tax rate

Previous researchers [Ando, Modigliani, Racche, and Turnovsky (1973), Clark (1979)] have calculated real after-tax finance rates by employing the Standard and Poor dividend-price ratio as a measure of the real after-tax cost of equity capital, and redefine the real cost of capital in the following way:

\[ \bar{r} = (1-\tau)b(i-p^*) + (1-\alpha)e \]  \hspace{1cm} (78)

where:  
\( \bar{r} = \) real weighted average cost of capital  
\( \bar{e} = \) real after-tax cost of equity finance  
\( p^* = \) expected inflation rate

Note, however, that expression (78) does not properly specify the tax deductibility of nominal interest payments in the calculation of taxable income. Firms do not calculate interest deductions
on the basis of real interest rates, but rather on nominal interest rates. The correct specification should be:

\[ \tilde{\tau} = b[(1-\tau)i-p^*] + (1-\alpha)\tilde{e} \]  

(79)

reflecting the fact that real cost debt of debt finance is reduced first by the deduction of nominal interest payments and then, secondly, by the decline in the real value of the outstanding debt separate from the taxation question. This interpretation is implicit in the calculation of the real after-tax weighted finance rates employed by Hendershott (1981) and Feldstein, Green, and Sheshinsky (1978). The procedure for calculation of such rates is described below, beginning with discussion of the real cost of equity finance \( \tilde{e} \).

Note that in the absence of tax credits, the real after-tax rate of return on corporate equity issued to finance the investment is:

\[ \tilde{e} = e - p \]

\[ = \frac{[(1-\tau)(Y-dP_k-iD) - \tau(d^*-d)P_k + p^*D - D]}{E} \]  

(80)

where:  
D = debt issued to finance the investment  
E = equity issued to finance the investment  
d = economic depreciation rate  
d^* = tax depreciation rate  
Y = operating income net of operating costs.

The terms inside the brackets represent real earnings after-tax
adjusted to include: (1) real income accruing to the excess of tax
depreciation deductions over economic depreciation, and (2) the real
gains accruing to shareholders from the expected erosion in the real
value of the debt issued measured by \( P^D \).

In general, the expected real earnings accruing to equity
holders from a new investment are the sum of expected after-tax
operating earnings (EAT) plus the expected erosion in the market
value of the debt (\( P^D \)). The rate of return to such equity, there-
fore, may be specified as

\[
\tilde{e} = \frac{(EAT + P^D)}{E}.
\]

Assuming that \( D = bRA \) and \( E = (1-b)RA \), where RA is investment
in real assets, then

\[
\tilde{e} = \frac{EAT}{E} + \left( \frac{b}{1-b} \right) p^*.
\]

Substituting \( \tilde{e} \) into expression (79), it is possible to solve for
the real after-tax weighted cost of finance. Thus

\[
\tilde{r} = b[(1-\tau)i-P^*] + (1-b)\left[\frac{EAT}{E} + \left( \frac{b}{1-b} \right) p^* \right]
\]

\[
= b(1-\tau)i + (1-b)\frac{EAT}{E} + bp^* - bp^*
\]

\[
= b(1-\tau)i + (1-b)\frac{EAT}{E} \quad .
\]  

(81)

The decline in the real cost of debt due to inflation,
therefore, is accounted for in the real return to equity \( (EAT/E) \).
Of importance also is the fact that calculation of the real after-tax
finance rate is independent of the proxy chosen for the expected inflation rate. Nominal discount rates used in the calculation of the present value of depreciation deductions must be constructed simply by adding the expected inflation rate to \( \tilde{r} \), or

\[
r = \tilde{r} + p^*. \tag{82}
\]

With the above theoretical derivation of the nominal discount rate, it is possible to make specific predictions of the effect of inflation on the level and composition of investment. A change in \( p^* \) results in a change in the discounted present value of tax depreciation deductions, and the user cost of capital will change accordingly. Predictions of the effect on gross investment may be calculated according to the approach described in Chapter 2.

Recent literature on the effects of inflation on corporate behavior indicates that changes in inflation may affect firms optimal mix of debt and equity finance. This issue is significant because it affects the parameter \( b \) used to calculate the real and nominal finance rates discussed above.

Using a general equilibrium monetary growth model, Feldstein, Green, and Sheshinski (1978) analyze the effect of inflation on the optimal debt-equity mix both from the standpoint of the firm and the willingness of the financial markets to absorb the financial investments. Firms are assumed to engage in financial cost-minimization, optimizing the mix of debt and equity finance given known costs of employing both instruments. Likewise, buyers of
these instruments are assumed to measure the after-tax returns to owning the debt versus equity, incorporating information on differential capital gains and personal tax rates. Given the above parameters, the authors compute the derivative of the optimal debt-equity ratio with respect to a change in the inflation rate. Unfortunately, this derivative turns out to be ambiguous in theoretical terms being dependent on assumed magnitudes for various corporate and personal tax rates. The authors, however, assert that the sign of the derivative is positive, basing their conclusion on estimates of the important tax parameters. A positive sign for this derivative indicates that firms will increase the ratio of debt to equity finance given an increase in inflation.

This ambiguity can be described in economic terms with reference both to the behavior of business firms and personal investors given the change in inflation. At the corporate level, an increase in the inflation rate leads to an increase in the nominal interest costs associated with issuance of new debt. Under the tax law, however, nominal interest payments are deductible for purposes of calculation of income tax liability. Because firms can deduct the inflationary increase in the cost of debt finance, but not the inflationary increase in equity finance, firms are encouraged to finance new projects by issuing new debt. Equity owners of the firm encourage such a move because the expected decline in the real value of new debt issue due to inflation would represent a capital gain to the stockholders. Feldstein, Green, and Sheshinski note, however, that
inflationary increases in nominal interest payments received by holders on the new debt are not deductible under personal tax laws, indicating the bondholders will suffer a real capital loss due to inflation. In total, the effect of inflation on the debt-equity ratio will depend on the relative corporate and personal (interest and capital gains) tax rates experienced by the market participants. Based on their estimates of these tax rates, the authors assert that the above derivative is positive, although precise estimation of the effect on the debt-equity ratio is impossible due to the importance of unobservable tax rates.

Auerbach (1981) obtained the same result using a similar methodology and further points out that it is critical to analyze the relative movements in real cost of debt and equity finance before one can isolate the effects of inflation on the debt-equity ratio. Gordon (1979) also finds that inflation increases the debt-equity ratio, although he further qualifies his analysis by noting that increased cost of bankruptcy associated with higher debt-equity ratios further limits the firm's ability to increase the debt proportion.

Von Furstenburg (1979) has computed an empirical measure of the debt-equity ratio for the period 1952 to 1978. His analysis indicates that the aggregate debt-equity ratio has increased from .185 in 1953 to .292 in 1978. Although the estimated change in this ratio over the period would correspond to a concurrent increase in inflation, it is impossible to isolate the cause of the increase. Clearly, however, changes in this ratio must be incorporated into the computation
of the real after-tax finance rate used in the empirical work, recognizing that inflation cannot be ruled out as a primary variable. For this reason, I have used von Furstenburg's measure of the debt-equity ratio as an appropriate proxy for $b$ in equation (80) above.

The measure of the nominal finance rate used in this study (summarized by equation (82)) assumes that the nominal rate $r$ rises precisely by the expected inflation rate $p^*$. The real cost of finance $\hat{r}$ is assumed to remain constant, regardless of the increase in inflation. Hendershott (1981), Hendershott and Hu (1981a), Feldstein (1981b), and Feldstein, Green, and Sheshinski (1978) argue, however, that the real cost of finance to the corporate sector may actually increase in response to inflation. This result is obtained after careful consideration of the difference between the real costs of finance to the firm and the real returns to owners of corporate financial assets.

These authors argue that the real returns to corporate financial assets initially decline with inflation because the increase in nominal returns to bonds and equity is not sufficient to offset increased taxation on capital gains, dividends, and nominal interest payments. Essentially, the tax rates on personal income from corporate sources drive a wedge between the real cost of finance to firms and the real returns received by owners of bond and equity assets. These authors further argue that the decline in real returns to debt and equity assets leads to a shift in private savings from corporate to non-corporate assets, with corresponding effects on the equilibrium
capital stock. As the supply of savings to the corporate sector falls, the real interest cost to firms increases, and the corporate stock of real capital declines. The decline in the stock of corporate capital results in an increase in the marginal product of the remaining capital, which acts to increase the real after-tax returns to corporate assets. The new equilibrium is characterized by: (1) larger stock of non-corporate capital, (2) a smaller stock of corporate capital, and (3) equalization of the after-tax returns to owners of both types of capital.

The effects on the real finance rate described above are not captured by the simulation analysis described in Chapter 5. Calculation of the effect of inflation on real returns to owners of corporate financial assets requires selection of tax rates on capital gains, dividends, and nominal interest payments. Hendershott (1981) has shown that the measured effects of inflation on the returns to debt and equity assets is very sensitive to the selected values of dividends and capital gains tax rates.\(^{31}\) Measurement of these tax rates, especially the capital gains rate, has proven to be a difficult problem, one which has not been resolved. Because no consensus exists on the value of these parameters, it is equally difficult to measure with accuracy the corresponding decline in real returns to debt and equity, the initial disparity in returns to corporate and non-corporate assets, and the magnitude of the resultant shift in savings among the corporate and non-corporate sectors. Under these circumstances it becomes impossible to measure the subsequent increase in real finance
costs to the firm as equilibrium is restored between the corporate and non-corporate sectors. For these reasons I assume that the real return to owners of debt and equity finance is invariant with respect to a change in investment, implying no change in the real finance cost to firms for the reasons discussed above. Note, however, that by ignoring the additional increase in finance costs from this source, the effects of inflation on investment are underestimated.

The assumption that the nominal cost of finance \( r \) rises point for point with the expected inflation rate is consistent with the assumption that the real return to debt and equity finance is invariant with respect to inflation. For the real return to owners of corporate financial assets to remain constant given an increase in inflation, nominal rates of return to these assets must rise by an amount sufficient to compensate for increased effective rates of taxation as discussed above. Hendershott (1981) suggests that an increase in the rate of inflation by one percentage point would increase the nominal rate on corporate bonds by 1.92 percentage points and the nominal return on corporate equity by 1.00 percentage points if the real returns to these assets remains constant. Based on Hendershott's calculations, the net increase in the weighted average cost of finance \( r \) from a one percentage point increase in inflation can be approximated by calculating the following derivative.
Given: \[ r = (1-Tx)b_i + (1-b)e, \]
\[ Tx = .48, \ b = .292, \ \text{and} \ \beta_b/\beta_p^* = 0, \]

Then: \[ \frac{\partial r}{\partial p^*} = (1-Tx)b \frac{\partial i}{\partial p^*} + (1-b) \frac{\partial e}{\partial p^*} \]
\[ = (1-.48)(.292)(1.92) + (1-.292)(1.00) \]
\[ = .999 \]
\[ \approx 1.000. \]

A one percentage point increase in the rate of inflation leads approximately to a one percentage point increase in the weighted-average nominal cost of finance. Note that this calculation properly accounts for the deductibility of nominal interest payments by firms which increase with the rate of inflation. However, because under the assumed neutral tax system the nominal rate of interest on bonds rises by twice the rate of inflation, the net after-tax interest cost on bond finance rises by approximately one full percentage point, and the weighted average cost of finance rises point for point with inflation. The relationship of the nominal and real cost of finance summarized by equation (82) is therefore consistent with the assumption of constant real returns to holders of debt and equity finance.

Calculation of the real and nominal discount rates requires specification of proxies for each of the variables discussed above. For \( i \), the rate on AA-rated utility and industrial bonds is employed.
The corporate tax rate is set equal to a weighted average of marginal rates on federal plus state and local taxes as computed by Hendershott and Hu (1981e). The term (EAT/E) is measured as after-tax profits of non-financial corporations plus: (1) the inventory valuation adjustment, which eliminates inventory capital gains, and (2) the capital consumption adjustment, which eliminates fictitious profits from the conversion of tax depreciation allowances to replacement cost depreciation adopted in the income statistics. The market value of stocks is obtained by dividing dividends on common stock by the Standard and Poors dividend/market value ratio for common stock. Inflationary expectations are measured by the Livingston survey data which represents direct observations from the economists on expected movement in the wholesale price indices. This data set is described in more detail below.
E. Tax Depreciation

Measurement of the user cost of capital for both equipment and structures requires specification of the present value of tax depreciation deductions $Z^E$ and $Z^S$ as input to the user cost formula:

$$c^* = \frac{P_k}{P_y} \frac{\bar{r} + d}{(1 - \tau)} (1 - \mu - \tau \cdot Z).$$

Calculations of these values in turn requires assumptions on tax depreciation method and allowable depreciation lifetimes. This section describes the methodology and assumptions employed in these calculations adopted from Hall and Jorgenson (1971).

Denoting by $Z$ the present value of the depreciation deduction on one dollar's investment,

$$Z = \int_0^\infty e^{-r_s} D(s) ds \quad (83)$$

where $r$ equals the nominal after tax discount rate. For straight-line depreciation, the deductions are the same for each period. If the lifetime for tax purposes is $T$, then the deduction in period $s$ is

$$D(s) = \begin{cases} 
\frac{1}{T} & \text{for } 0 \leq s \leq T, \\
0 & \text{otherwise}
\end{cases}.$$

The present value of the deduction is:
\[ Z = \int_0^T e^{-rs} \frac{T}{e^T} \, ds \]

\[ = \frac{1}{rT} (1 - e^{-rt}) \] \hspace{1cm} (84)

For the sum-of-years digits method, the deduction declines linearly over the lifetime for tax purposes, starting at twice the corresponding straight-line rate:

\[ D(s) = \begin{cases} \frac{2(T-s)}{T^2} & \text{for } 0 \leq s \leq T \\ 0 & \text{otherwise} \end{cases} \]

The present value of the deductions is:

\[ Z = \int_0^T e^{-rs} \frac{2(T-s)}{T^2} \, ds \]

\[ = \frac{2}{rT} \left[ 1 - \frac{1}{rT} (1 - e^{-rT}) \right] \] \hspace{1cm} (85)

Tax provisions for the declining balance depreciation are more complicated. A firm may switch to straight-line depreciation at any time. If the switchover point is denoted \( T^* \), the double declining balance depreciation formula is:
where $\Theta = 2$ for double-declining balance and $\Theta = 1.5$ for 150% declining balance.

The present value of the deduction is:

\[
Z = \frac{\Theta}{T} \int_0^{T^*} e^{-(r + (\Theta/T)s)} \, ds + \frac{1-e^{-(\Theta/T)T^*}}{T-T^*} \int_{T^*}^{T} e^{-rs} \, ds,
\]

\[
= \frac{\Theta}{T} \left[ 1-e^{-(r+(\Theta/T))T^*} \right] + \frac{1-e^{-(\Theta/T)T^*}}{r(T-T^*)} (e^{-rT^*} - e^{-rT}) .
\]

(86)

The switchover point which maximizes $Z$ is $T^* = T/2$.

Selection of the appropriate depreciation formula is conditional on the time period of estimation. For reasons discussed below the estimation period selected was 1953-1980. During this period, I assume firms employed the sum-of-years digits method for depreciation of equipment, and the 150% declining-balance method with a switchover to straight-line depreciation at $T/2$ for structures. Following Jorgenson and Hall (1971) and Hendershot and Hu (1981e), I assume that over the estimation period tax depreciation
lifetimes for equipment were 18 years in 1953, falling to 11 years by 1980. Lifetimes for structures fell from 28 years in 1953 to 23 years by 1980.

F. Characteristics of the Data Sets

Two aggregate investment equations are estimated for the U.S. manufacturing sector -- one for equipment and one for structures. Implementation of the Random Coefficients Regression procedure requires cross-section/time series data on investment, capital stock, and gross value added for each of the major manufacturing industries. Specifically, it is necessary to obtain time-series estimates of capital stock and investment disaggregated (1) by equipment and structures, and (2) by each of the 20 2-digit S.I.C. code manufacturing industries. In reality, 40 economic relationships are estimated and subsequently aggregated into consistent equations for equipment and structures. The major industry groupings used in this analysis are identified in Table 3.

The data requirements represented a major roadblock to the estimation of the investment equations due to the fact that data on investment and capital stock disaggregated both by industry and type of asset is not published regularly. Total investment by industry group is available from the Bureau of Economic Analysis (Survey of Current Business), but this data is not further subdivided into plant versus equipment expenditure. Similarly, one can obtain capital
<table>
<thead>
<tr>
<th>Industry</th>
<th>S.I.C. Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food and Kindred Products</td>
<td>20</td>
</tr>
<tr>
<td>Tobacco</td>
<td>21</td>
</tr>
<tr>
<td>Textiles</td>
<td>22</td>
</tr>
<tr>
<td>Apparel</td>
<td>23</td>
</tr>
<tr>
<td>Lumber and Wood Products</td>
<td>24</td>
</tr>
<tr>
<td>Furniture and Fixtures</td>
<td>25</td>
</tr>
<tr>
<td>Paper and Allied Products</td>
<td>26</td>
</tr>
<tr>
<td>Printing and Publishing</td>
<td>27</td>
</tr>
<tr>
<td>Chemicals and Allied Products</td>
<td>28</td>
</tr>
<tr>
<td>Petroleum and Coal Products</td>
<td>29</td>
</tr>
<tr>
<td>Rubber and Plastic Products</td>
<td>30</td>
</tr>
<tr>
<td>Leather Goods</td>
<td>31</td>
</tr>
<tr>
<td>Stone, Clay, and Glass</td>
<td>32</td>
</tr>
<tr>
<td>Primary Metals</td>
<td>33</td>
</tr>
<tr>
<td>Fabricated Metal Products</td>
<td>34</td>
</tr>
<tr>
<td>Machinery, except electrical</td>
<td>35</td>
</tr>
<tr>
<td>Electrical and Electronic Equip.</td>
<td>36</td>
</tr>
<tr>
<td>Transportation Equipment</td>
<td>37</td>
</tr>
<tr>
<td>Instruments and Related Products</td>
<td>38</td>
</tr>
<tr>
<td>Miscellaneous Manufacturing</td>
<td>39</td>
</tr>
</tbody>
</table>
stock estimates for equipment and structures at the aggregate manufacturing level, but this data is not further disaggregated to the industry level. To complicate matters further, estimates of Gross Product Originating by industry are also not published on a regular basis for each of the manufacturing industries. The latter variable is necessary in order to construct industry specific measures of the optimal capital stock critical to the estimation of neoclassical investment equations. These complications were resolved, however, by investigating the public and non-public sources of data available from the Department of Commerce.

The source of data on investment and capital stock by industry was the Bureau of Industrial Economics of the Department of Commerce. The B.I.D. compiles data obtained from the periodic Census of Manufacturers and the Annual Survey of Manufacturers, conducted by the Census Bureau. Comparison of the aggregate totals for investment and capital stock value obtained from the B.I.D. to those available from the Bureau of Economic Analysis, indicate that they are nearly identical. Both series are deflated to constant dollar values (1972 = 1.00), and both series are compiled using the same S.I.C. code system. The capital stock series are both constructed using forms of the perpetual inventory technique, designed to approximate rates of discard and changes in market value due to price changes. The major difference in the two series, however, is the classification of firms on an establishment basis, rather than company basis as used in the B.E.A. data.
An establishment is defined as an economic unit, generally at a single location, where business is conducted or where goods and services are produced. In those locations where several economic activities are performed, each activity is treated as a separate establishment. A company on the other hand consists of one or more establishments. Industry classification by company is based on the primary product or service of the entire company. In the event that a company produces a narrow line of products, the distinction between company versus establishment is negligible. However, if the company is composed of many varying establishments, then there is a misallocation of investment expenditures to the company's classified industry. In other words, the investment is overstated in the principal industry and understated in those industries in which the firm produces secondary products.

This distinction has very little bearing in the aggregate due to the close consistency of the series to the B.E.A. estimates. However, in attempting to define the relationship between factors which affect the optimal capital stock and investment on an industry basis, it is better to avoid possible distortions in industry investment data created by the "company" classification method. Because the establishment basis of classification provides a more accurate allocation of investment expenditures and capital stock to the actual purchasing industry from a functional standpoint, these series on investment and capital stock are preferable.
The data series on investment and capital stock therefore are unique for two reasons: (1) the data represents the only disaggregation of investment and capital stock into equipment and structures by industry, and (2) the data provides a more useful breakdown of assets by functional category. This data has not been used in investment studies before, and represents a unique improvement in the micro-application of the neoclassical investment model. As noted before, it also facilitates the application of the Random Coefficient Regression model which provides for econometric estimation of aggregate equations which avoid the problem of aggregation bias.

G. Inflationary Expectations

Rather than compute forecasts of inflation using an arbitrarily selected statistical process, direct survey measures of expected inflation were obtained from the Livingston surveys.³² Twice a year, Joseph Livingston of the Philadelphia Enquirer surveys fifty professional economists on their forecasts of inflation. Surveys are conducted in June and December and respondents are requested to forecast the CPI and WPI for 6-month, 12-month, and 18-month horizons. The forecasts are then compiled into an average forecast for the survey group and published in Livingston's Business Outlook column. History on the inflation forecast series is maintained by the Philadelphia Federal Reserve Bank and is available on request. The average value of the survey forecasts of inflation for the
Wholesale Price Index is the estimate of $P^*$ required to construct the nominal after-tax finance rate. In addition, the Philadelphia Fed will provide any researcher with a copy of a computer tape containing the survey responses from each survey dating back to 1974. From this tape I was able to calculate the standard deviation of the WPI inflation forecast for each 12-month horizon. This calculated value was used as the measure of inflation uncertainty employed in the equation estimations.

H. Other Data Series

Estimation of the equations requires computation of optimal capital stock measures for both equipment and structures disaggregated by industry group. As described in the previous section, calculation of this variable is based on the following formula:

$$K^* = \frac{Y}{C^*}$$ for both equipment and structures

where: $$C^*_E \text{ or } S = \frac{P_k}{P^*_k} \frac{(F+d)}{(1-\gamma)} (1-\mu-\gamma Z).$$

The real price of equipment is calculated using the ratio of the implicit price deflators for capital equipment and gross national product. A similar calculation is performed to construct the real price of structures. Calculation of the real cost of finance ($F$) and the real value of depreciation deductions ($Z$) was discussed previously. For economic depreciation rates for equipment and
structures, I employed the values used by Jorgenson (1970) and Hendershott (1981) where \( d^E = .1492 \) for equipment and \( d^S = .062 \) for structures. The investment tax credit rate \( (\mu^E) \) for equipment was set equal to the statutory rates following Hendershott and Hu (1981e), and the value for \( \mu^S \) was set equal to zero reflecting the historical ineligibility of structures for this credit. To calculate industry specific values for equipment and structures, I used real Gross Product Originating values available on request from the Bureau of Economic Analysis. In this manner I was able to construct cross-section time series values of optimal capital stock for each industry disaggregated by equipment and structures. Data disaggregated to this level of detail have also not been employed in investment studies previously.
CHAPTER 5

EMPIRICAL RESULTS

The purpose of this chapter is to provide an empirical analysis of the effects of inflation and inflation uncertainty on manufacturing investment. This analysis is designed to answer four basic questions: (1) Does the interaction of inflation and historic cost depreciation rules lead to a decline in manufacturing investment?; (2) Does inflation reduce equipment investment more than structures investment?; (3) Do the effects of inflation on investment vary over different sets of economic assumptions?; and (4) Do increases in inflation uncertainty reduce manufacturing investment?

The results presented in this chapter are based primarily on the estimated coefficients from two investment demand equations. These equations are estimated using the Random Coefficients Regression technique, applied to a unique set of cross-section/time-series data on manufacturing industries. The resulting coefficients serve as direct input to a simulation procedure designed to measure the effects of inflation and inflation uncertainty on manufacturing investment. The outcome of this empirical analysis represents the only evidence available to answer the above questions. The first part of this chapter provides a simple test for the appropriateness
of the Random Coefficients Regression technique, the second part reviews the equation estimates, and the third part describes the outcome of simulation results.

A. Tests for Aggregation Bias

The Random Coefficient Regression (RCR) technique assumes a priori that the relationship between the independent and dependent variables is heterogeneous among cross-section units. In the context of the cost-of-capital investment model, this assumption suggests that industries react differently to changes in the package of economic and tax variables which determine the optimal real stock of capital. Jorgenson and Stephenson (1967) have successfully demonstrated that investment behavior is indeed heterogeneous across the twenty major industry groupings of manufacturing, suggesting that such an assumption is reasonable.

Unfortunately, these authors also demonstrated that when such heterogeneity is present, estimation of aggregate investment equations using summations of industry data will lead to aggregation bias in the estimated coefficients. Under such circumstances, predictions of total manufacturing investment based on the aggregate equations are not likely to be consistent with predictions based on individual industry equations. This conclusion suggests that aggregate equations should not be used for policy analysis whenever the implicit assumption of homogeneous behavior (i.e., identical
equation coefficients for each cross-section equation) is rejected.

The major benefit of the RCR technique developed by Swamy (1970, 1971) is that provides for a consistent method constructing aggregate economic equations from the underlying heterogeneous industry behavior. When the response vector for each individual is viewed as a random drawing from a probability distribution with mean $\bar{\Theta}$ and covariance matrix $\Lambda$, aggregate coefficients represent a weighted sum of individual industry coefficients. The methodology behind such calculations was discussed in Chapter 4. With the Random Coefficients Regression technique, consistency between the aggregate and cross-section economic relationships is maintained, and the integrity of predictions based on aggregate equations is preserved. If, however, the hypothesis of homogeneous behavior among cross-section units is accepted, the RCR technique is inappropriate and analysis based on cross-section data is an unnecessary burden. By performing simple tests for aggregation bias, one can simultaneously test the appropriateness of the RCR technique and gauge the degree to which aggregation bias is avoided. The test described here is based on Swamy (1970).\textsuperscript{33}

The test for homogeneous behavior may be described in general notation as follows: Assume that the econometric model is defined by

$$Y_n = X_n \beta + U_n$$

where the subscript $n$ indicates a specific cross-section unit. If
we assume that the true coefficient $\beta$ is the same for all cross-
section units, Zellner (1962) has shown that a consistent and asymp-
totically efficient estimator of $\beta$ is given by

$$
\hat{\beta} = \left[ \sum_{n=1}^{N} \frac{X'X_n}{S^2_n} \right]^{-1} \left[ \sum_{n=1}^{N} \frac{X'Y_n}{S^2_n} \right]
$$

where

$$
S^2_n = \frac{Y'_n[I - X_n(X_nX_n)^{-1}X'_n]Y_n}{T-K}
$$

$K =$ number of explanatory variables

$T =$ number of observations on each variable.

These equations describe the well-known Aitken-Zellner estimators of $\beta$ and $S^2_n$ using pooled cross section data and assuming homogeneous behavior across equations.

To test the restriction of homogeneous behavior, parameter estimates of $\hat{\beta}_n = \{[X'X_n]^{-1}X'_nY_n\}$ and $S^2_n$ (obtained from OLS estimation of individual cross-section equations) can be combined with the generalized least squares estimate $\hat{\beta}$ to test the hypothesis

$$
H_0: \beta_n = \beta \text{ for } n = 1, \ldots, N.
$$

Zellner (1962) has shown that such a test is accomplished by computing

$$
H = \frac{1}{(N-1)K} \sum_{n=1}^{N} \left[ \hat{\beta}_n - \beta \right]' \frac{X'X_n}{S^2_n} \left[ \hat{\beta}_n - \beta \right]
$$

(87)
where $H$ is approximated by the $F$-distribution with $(N-1)K$ and $(T-K)N$ degrees of freedom.

This test was applied to the cross-section data sets described in Chapter 4. Separate tests were performed: one for the variables included in the equipment equation, and another for the variables included in the structures equation. Recall from Chapter 4 that the general functional specification assumed for each industry is described by:

$$I^G_{jt} = \beta_0 + \alpha_j v^*_{L_j} \Delta K^*_j + [1-\omega(L_\omega)](\text{INET}_{jt}) + \delta_{jt-1} + \sigma_t \varepsilon_t$$

where:

- $I^G_j$ = gross investment, equipment or structures, industry $j$
- $\Delta K^*_j$ = change in optimal capital stock, equipment or structures, industry $j$
- $\text{INET}_j$ = net investment, equipment or structures, industry $j$
- $K_j$ = actual capital stock, equipment or structures, industry $j$
- $v_j(L_{v})$ = lag distribution or changes in the optimal capital stock, equipment or structures, industry $j$
- $\omega_j(L_\omega)$ = lag distribution on net investment, equipment or structures, industry $j$.

For purposes of this test, $L_v = 4$ and $L_\omega = 1$. With this assumption the time-path of response by firms to changes in market conditions is identified. This model assumes that (1) current and four lagged
changes in the optimal capital stock measure $K^*$ are required to capture the rate at which firms initiate investment projects in response to changed market conditions, and (2) approximately two years are required to complete an investment project once initiated. A discussion of the procedure for lag selection is found in Appendix A. The results of the test for aggregation bias described by equation (87) are shown in Table 4.

<table>
<thead>
<tr>
<th>Equation</th>
<th>DF1</th>
<th>DF2</th>
<th>N</th>
<th>K</th>
<th>T</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>171</td>
<td>380</td>
<td>20</td>
<td>9</td>
<td>18</td>
<td>5.535</td>
</tr>
<tr>
<td>Structures</td>
<td>171</td>
<td>380</td>
<td>20</td>
<td>9</td>
<td>18</td>
<td>54.896</td>
</tr>
</tbody>
</table>

Notes: Tests performed using annual data, 1953-80.

The critical value for the F-test at 1% significance level is 1.000, given the degrees of freedom listed above. Each of the computed H-statistics clearly exceeds this critical value. On the basis of the tests shown in Table 4, I reject the hypothesis that investment behavior is homogeneous across each manufacturing industry.
This data indicates that the Random Coefficient Regression model represents an appropriate technique for estimation of aggregate investment equations, and that a major source of aggregation bias will be avoided.

B. Estimation Results: Random Coefficient Regression

The estimated coefficients for the equipment and structures investment equations are shown in Table 5. Generally, the Random Coefficients Regression technique yielded significant empirical results.

Each of the coefficients $v_0, \ldots, v_4$ is positive in sign in both equations which is consistent with theoretical expectations. These results indicate that changes in the calculated optimal capital stock $K^*$ represent significant variables in the explanation of manufacturing investment behavior. I find, however, that the coefficients $v_0$ in both equations are not significant, a finding which persisted under different assumptions of lag length for $L_\omega$ and $L_\nu$. This result suggests that firms do not react very quickly to policy or economic changes which affect determination of optimal stocks of real capital.

The coefficients on net investment and replacement investment are also significant at the 5% level and positive in sign. In theory, the estimated coefficients $d$ on the replacement investment variable $K$ should approximate the assumed values of economic depreciation for equipment and structures capital (i.e., $d_E = .14$ and $d_s = .06$). The estimates of these parameters shown in Table 5 are a
Table 5
Estimation Results: Random Coefficient Regression
U. S. Manufacturing Investment
Annual Data
1953 - 80

Estimated Coefficients<sup>34</sup>

<table>
<thead>
<tr>
<th>Equation</th>
<th>( \beta_0 )</th>
<th>( \nu_0 )</th>
<th>( \nu_1 )</th>
<th>( \nu_2 )</th>
<th>( \nu_3 )</th>
<th>( \nu_4 )</th>
<th>( \omega_1 )</th>
<th>( K_{t-1} )</th>
<th>( \beta_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>-.0528</td>
<td>.0009</td>
<td>.0073</td>
<td>.0074</td>
<td>.0036</td>
<td>.0053</td>
<td>.2964</td>
<td>.1140</td>
<td>-.0241</td>
</tr>
<tr>
<td></td>
<td>(-2.98)</td>
<td>(0.63)</td>
<td>(4.71)</td>
<td>(4.83)</td>
<td>(2.41)</td>
<td>(3.73)</td>
<td>(6.93)</td>
<td>(43.40)</td>
<td>(-3.05)</td>
</tr>
<tr>
<td>Structures</td>
<td>.2800</td>
<td>.0004</td>
<td>.0041</td>
<td>.0039</td>
<td>.0032</td>
<td>.0024</td>
<td>.0497</td>
<td>.0510</td>
<td>-.0039</td>
</tr>
<tr>
<td></td>
<td>(14.83)</td>
<td>(0.85)</td>
<td>(6.89)</td>
<td>(6.21)</td>
<td>(5.63)</td>
<td>(4.75)</td>
<td>(2.83)</td>
<td>(4.67)</td>
<td>(-1.58)</td>
</tr>
</tbody>
</table>

Goodness-of-Fit

<table>
<thead>
<tr>
<th></th>
<th>R&lt;sup&gt;2&lt;/sup&gt;</th>
<th>R&lt;sup&gt;2&lt;/sup&gt;</th>
<th>F</th>
<th>DW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>.7345</td>
<td>.7172</td>
<td>41.11</td>
<td>1.93</td>
</tr>
<tr>
<td>Structures</td>
<td>.8391</td>
<td>.8287</td>
<td>77.52</td>
<td>1.89</td>
</tr>
</tbody>
</table>

Notes: (1) Values in parentheses represent t-statistics.
little low relative to the assumed values, but the difference is not large enough to indicate an estimation problem.

Inspection of the coefficients $\beta_\sigma$ for both equations indicates that inflation uncertainty is negatively correlated with gross investment in the manufacturing sector. Note, however, that the estimated coefficient on $\beta_\sigma$ for the structures equation is not statistically significant at the 5% level. Based on t-statistics, we must reject the hypothesis that inflation uncertainty leads to a decline in structures investment. We cannot reject a similar hypothesis for the equipment equation. Based on this evidence, I conclude that inflation uncertainty leads to a reduction in manufacturing investment.

C. Estimates of $\hat{a}$

Measurement of the effects of inflation and historic cost depreciation on investment requires estimates of the parameter $\alpha$ (elasticity of output with respect to capital input) for both equipment and structures. These parameters are calculated using the estimated coefficients of $\hat{v}(L_v)$ and $\hat{\omega}(L_\omega)$ shown in Table 4. The procedure for calculating $\hat{a}$ from the sequence of lag coefficients was discussed in Chapter 4, summarized in equation (65). The resulting estimates for $\hat{a}$ are shown in Table 6.
Using annual data for manufacturing investment, Hall and Jorgenson estimate \( \hat{\alpha}_{\text{EQ}} = 0.07 \) and \( \hat{\alpha}_{\text{ST}} = 0.03 \). Jorgenson and Stephenson report values of \( \hat{\alpha} \) for total investment for each industry (sum of equipment and structures) which range from 0.01 for Foods and Beverages to 0.08 for Motor Vehicles and Equipment. Aggregating the same data set, Jorgenson and Stephenson compute a total manufacturing investment elasticity of 0.06. The elasticities shown in Table 4 lie within the range of estimates for individual industries, but consistently lower than estimates obtained from aggregated data. The estimated elasticities in this study differ from those reported by Hall and Jorgenson for two primary reasons.

First, we can say with certainty that the elasticities reported in Table 6 represent a consistent aggregation of the underlying heterogeneous industry relationships, whereas those reported by Hall and Jorgenson do not. The Random Coefficients Regression
technique is designed to construct aggregate equation coefficients using the information content of each cross-section industry. Essentially, aggregate coefficients from RCR estimation represent a weighted-summation of industry level coefficients, with the weights being determined as a product of the generalized least squares estimation. Under these conditions, predictions of aggregate investment behavior will be consistent with a summation of industry-level predictions, and a major source of aggregation bias has been removed. The same statements may not be made about the elasticities reported by Hall and Jorgenson. As Jorgenson and Stephenson successfully demonstrate, estimation of aggregate equations using the techniques of Hall and Jorgenson will result in a significant degree of aggregation bias. It is interesting to note that the elasticities reported in this study will lead to more conservative predictions of the effects of inflation on investment.

In addition to differences in econometric methodology, the estimates of \( \hat{\alpha} \) in Table 6 will differ from those obtained by Hall and Jorgenson due to differences in the measurement of the user cost-of-capital variables. The discussion in Chapter 2 demonstrates that when tax depreciation deductions are based on historic asset purchase prices, inflation increases the value of \( c^* \) relative to that calculated for zero inflation or replacement cost depreciation. Theory suggests that changes in the user cost can be significant with positive inflation rates, and that serious measurement errors can occur if such effects are ignored.
Analysis of the procedure used by Hall and Jorgenson to construct estimates of $c^*$ for equipment and structures shows that no adjustment was made in the calculations to account for the interaction of inflation and historic cost depreciation. In fact, these authors: (1) assumed that the real and nominal after-tax costs of finance to the firm are always equal, and (2) set the before-tax cost of finance equal to a constant twenty-percent. Under these conditions, changes in the value of depreciation result only from tax policy changes. Significantly, inflation rates were not very high over this period, but as the results in the next section demonstrate, even low values of inflation will significantly affect the user cost of capital and investment demand.

For these reasons, the estimated values of $\hat{\alpha}$ obtained by Hall and Jorgenson are more likely to suffer from the problem of errors-in-variables than are those used in this study. This problem was discussed in Chapter 3 with respect to the empirical work of Feldstein, and was shown to result in biased and inconsistent estimates of the equation coefficients. Because the estimated coefficients $\hat{\nu}(L_y)$ and $\hat{\omega}(L_\omega)$ are used directly in the computation of $\hat{\alpha}$, we would also expect such elasticities to be biased and inconsistent. Use of such estimates for calculating the effects of policy changes on investment will result in inaccurate predictions for the manufacturing sector.

In summary, measurement errors implicit in Hall and Jorgenson's calculation of the user cost variables are likely to be a major
reason for the different elasticities reported in this study. Because measurement of the effects of inflation on investment depends critically on the estimated value of \( \hat{\alpha} \), re-estimation of such equations is clearly warranted. The evidence presented in this study indicates use of previously estimated values of \( \hat{\alpha} \) would result in significant over-predictions of the effects of inflation on investment. Likely bias in such coefficients from the joint effects of aggregation and errors-in-variables problems prohibit their use in this study.

D. Measured Effects of Inflation on Manufacturing Investment

With the estimates of \( \hat{\alpha} \) shown in Table 6, we can pursue measurement of the effects of inflation on manufacturing investment. Recall from Chapter 4 that measurement of such effects may be accomplished by evaluating the following derivative for both equipment and structures:

\[
\frac{\partial I}{\partial P} = d \cdot \frac{\partial K^*}{\partial P} = -d \cdot \left\{ \frac{\partial Y}{c_0^*} \right\} \cdot \left\{ \frac{\partial C^*}{\partial P} \right\}
\]

(88)

where: 
- \( d \) = economic depreciation rate, equipment or structures
- \( Y \) = real gross product originating in manufacturing
- \( c_0^* \) = value of the user cost of capital prior to the change in inflation, equipment or structures
- \( \hat{\alpha} \) = elasticity of output with respect to capital input, equipment or structures
\( f^G \) = gross investment, equipment or structures.

Equation (88) provides a partial equilibrium estimate of the effect of inflation on equipment and structures investment. The long-term effect of inflation on gross investment is approximated by the calculated change in the optimal capital stock multiplied by the economic depreciation rate.

In equilibrium, gross investment equals the replacement investment necessary to maintain a constant optimal stock of real capital. Given an increase in inflation, the optimal stock of capital declines, leading to a decline in gross investment consistent with the maintenance of a smaller capital stock. The estimated change in the levels of equilibrium gross investment for equipment provides a measure of the long-term effects of a change in inflation.

This estimate is partial equilibrium in the sense that all other elements of the optimal capital stock variable are assumed to remain constant, regardless of the change in investment. Such an assumption may seem unreasonable at first, but it provides the only consistent way to compare the effects of diverse policy and economic changes in the absence of explicit adjustment paths for each alternative.

Therefore, assuming initial values for \( c_0^*, Y, \alpha, \) and \( d, \) we can evaluate the effect of inflation on investment by computing the effect of inflation on the user cost of capital. Changes in the user cost of capital are computed by resolving the depreciation
formulas of Chapter 4 using the nominal interest rate which corresponds to the assumed level of inflation. Separate calculations performed for both equipment and structures investment provide a basis for measuring the extent to which inflation affects the level and composition of real business investment.

For Y, I use the 1980 aggregate value of manufacturing gross product originating equal to $376.7 billion in constant (1972) dollars. Other parameters used to calculate the user cost of capital are shown in Table 7. All of the parameters remain constant throughout the calculations.

<table>
<thead>
<tr>
<th>Table 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exogoneous Parameters</td>
</tr>
<tr>
<td>User Cost of Capital</td>
</tr>
<tr>
<td>Assumed Value</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Equipment</th>
<th>Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment Tax Credit</td>
<td>μ</td>
<td>.085</td>
<td>.000</td>
</tr>
<tr>
<td>Marginal Tax Rate</td>
<td>Tx</td>
<td>.520</td>
<td>.520</td>
</tr>
<tr>
<td>Economic Depreciation Rate</td>
<td>d</td>
<td>.1472</td>
<td>.0625</td>
</tr>
<tr>
<td>Tax Lifetime (years)</td>
<td>N</td>
<td>11.1</td>
<td>22.8</td>
</tr>
<tr>
<td>Debt-Equity Ratio</td>
<td>b</td>
<td>.292</td>
<td>.292</td>
</tr>
</tbody>
</table>
As the analysis in Chapter 2 demonstrates, the effects of a change in inflation on investment are also critically dependent on the assumed values of real asset purchase prices and real interest rates. The effects of inflation on the user cost of capital are found to vary under different assumptions of these parameters, indicating that the sensitivity of investment to changes in inflation will not be constant. To evaluate the importance of these parameters in measuring the effects of inflation on investment, I simulate equation (88) over a wide range of real after-tax interest rates and asset purchase prices.

The steps involved in this process are as follows: I first select values of equipment and structures real asset purchase prices. Three different cases are examined. For case 1, I use the actual 1980 values of the Implicit Price Deflators for Gross National Product, Producers Durable Equipment, and Producers Plant as reported by the Commerce Department. The deflator for each investment good is divided by the deflator for Gross National Product to obtain estimates of real asset purchase prices for equipment and structures. In case 2, I arbitrarily set the real asset prices equal to unity, and in Case 3, I use the inverse of the asset price used in case 1. Each case, therefore, employs a different base assumption on asset purchase prices for use in the simulations.

For each case, I then select a value for the real after-tax finance rate $\hat{r}$ discussed in Chapter 4 and compute the corresponding value of $c_{0}^{\hat{r}}$, assuming a zero inflation rate. Holding the real
after-tax finance rate constant, the inflation rate is increased from zero to a new level, which is assumed to increase the nominal finance rate by the full amount of the change in inflation. Under the assumption of historic cost depreciation rules, the increase in the nominal finance rate leads to a decline in the real value of depreciation deductions and an increase in the user cost of capital. Using equation (88), the change in investment from the exogenous change in inflation can then be estimated. The effect of inflation on investment under alternative initial finance rates is calculated by reinitializing \( c_0^* \) based on new values of \( \bar{r} \). This procedure is repeated for each of the three scenarios for real asset prices discussed above. In this manner, I emphasize the significance of varying initial assumptions on asset purchase prices and real finance rate to measurement of the effects of inflation on investment.

Tables 8-10 show the simulated effects of inflation on investment which result from the steps described above. The entries in each of these tables represent the estimated long-run change in manufacturing equipment and structures investment brought about by an increase in inflation. All entries are measured in billions of constant (1972) dollars, and may be compared to actual manufacturing investment for 1980 of $60.0 billion ($44.8 billion for equipment and $15.2 billion for structures). The inflation rate is assumed to increase from zero to the selected levels of \( P^* \), leading to the measured change in investment for both asset types. Each experiment is repeated for different assumptions on the real interest rate
Table 8
Estimated Impact on Manufacturing Investment of a Change in the Inflation Rate from Zero to $p^*$
(Billions of 1972 Dollars)

Case 1†

<table>
<thead>
<tr>
<th>Real Finance Rates</th>
<th>Asset Type</th>
<th>2%</th>
<th>4%</th>
<th>Expected Inflation Rate</th>
<th>$p^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6%</td>
<td>8%</td>
<td>10%</td>
<td>12%</td>
</tr>
<tr>
<td>2%</td>
<td>ΔIE</td>
<td>-1.030</td>
<td>-1.948</td>
<td>-2.776</td>
<td>-3.524</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.305</td>
<td>-0.552</td>
<td>-0.755</td>
<td>-0.923</td>
</tr>
<tr>
<td>4%</td>
<td>ΔIE</td>
<td>-0.676</td>
<td>-1.311</td>
<td>-1.885</td>
<td>-2.404</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.156</td>
<td>-0.290</td>
<td>-0.400</td>
<td>-0.493</td>
</tr>
<tr>
<td>6%</td>
<td>ΔIE</td>
<td>-0.525</td>
<td>-0.987</td>
<td>-1.405</td>
<td>-1.785</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.093</td>
<td>-0.173</td>
<td>-0.240</td>
<td>-0.297</td>
</tr>
<tr>
<td>8%</td>
<td>ΔIE</td>
<td>-0.380</td>
<td>-0.723</td>
<td>-1.034</td>
<td>-1.318</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.064</td>
<td>-0.116</td>
<td>-0.160</td>
<td>-0.197</td>
</tr>
<tr>
<td>10%</td>
<td>ΔIE</td>
<td>-0.278</td>
<td>-0.539</td>
<td>-0.776</td>
<td>-0.993</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.043</td>
<td>-0.078</td>
<td>-0.108</td>
<td>-0.134</td>
</tr>
<tr>
<td>12%</td>
<td>ΔIE</td>
<td>-0.224</td>
<td>-0.427</td>
<td>-0.613</td>
<td>-0.783</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.030</td>
<td>-0.055</td>
<td>-0.076</td>
<td>-0.095</td>
</tr>
</tbody>
</table>

† Indices for real asset purchase prices for Case 1: $p_e = .96$, $p_s = 1.27$. These values were constructed using actual 1980 values of the implicit price deflators for GNP, Producers Durable Equipment, and Producers Plant. (Source: Survey of Current Business, various issues (1953-1980).
### Table 9

Estimated Impact on Manufacturing Investment of an Increase in Inflation Rate from Zero to p*  
(Billions of 1972 Dollars)  
**Case 2**

<table>
<thead>
<tr>
<th>Real Interest Rates</th>
<th>Asset Type</th>
<th>2%</th>
<th>4%</th>
<th>6%</th>
<th>8%</th>
<th>10%</th>
<th>12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2%</td>
<td>ΔIE</td>
<td>-0.997</td>
<td>-1.879</td>
<td>-2.674</td>
<td>-3.393</td>
<td>-4.044</td>
<td>-4.635</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.370</td>
<td>-0.681</td>
<td>-0.936</td>
<td>-1.148</td>
<td>-1.325</td>
<td>-1.475</td>
</tr>
<tr>
<td>4%</td>
<td>ΔIE</td>
<td>-0.673</td>
<td>-1.284</td>
<td>-1.837</td>
<td>-2.337</td>
<td>-2.792</td>
<td>-3.206</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.202</td>
<td>-0.371</td>
<td>-0.512</td>
<td>-0.629</td>
<td>-0.728</td>
<td>-0.813</td>
</tr>
<tr>
<td>6%</td>
<td>ΔIE</td>
<td>-0.486</td>
<td>-0.927</td>
<td>-1.328</td>
<td>-1.691</td>
<td>-2.022</td>
<td>-2.323</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.122</td>
<td>-0.223</td>
<td>-0.308</td>
<td>-0.380</td>
<td>-0.442</td>
<td>-0.494</td>
</tr>
<tr>
<td>8%</td>
<td>ΔIE</td>
<td>-0.364</td>
<td>-0.693</td>
<td>-0.992</td>
<td>-1.264</td>
<td>-1.512</td>
<td>-1.739</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.082</td>
<td>-0.148</td>
<td>-0.203</td>
<td>-0.251</td>
<td>-0.291</td>
<td>-0.326</td>
</tr>
<tr>
<td>10%</td>
<td>ΔIE</td>
<td>-0.277</td>
<td>-0.528</td>
<td>-0.756</td>
<td>-0.965</td>
<td>-1.155</td>
<td>-1.330</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.052</td>
<td>-0.096</td>
<td>-0.134</td>
<td>-0.167</td>
<td>-0.195</td>
<td>-0.219</td>
</tr>
<tr>
<td>12%</td>
<td>ΔIE</td>
<td>-0.210</td>
<td>-0.405</td>
<td>-0.583</td>
<td>-0.745</td>
<td>-0.895</td>
<td>-1.031</td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.037</td>
<td>-0.068</td>
<td>-0.095</td>
<td>-0.119</td>
<td>-0.139</td>
<td>-0.157</td>
</tr>
</tbody>
</table>

†Indices for real asset prices for Case 2: \( P_{KE} = P_{KS} = 1.0 \).
Table 10

Estimated Impact on Manufacturing Investment of
an Increase in Inflation Rate from Zero to P*

(Billions of 1972 Dollars)

Case 3†

<table>
<thead>
<tr>
<th>Real Interest Rate</th>
<th>Asset Type</th>
<th>2%</th>
<th>4%</th>
<th>Expected Inflation Rate</th>
<th>6%</th>
<th>8%</th>
<th>10%</th>
<th>12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2%</td>
<td>ΔIE</td>
<td>- .797</td>
<td>-1.494</td>
<td>-2.122</td>
<td>-2.690</td>
<td>-3.204</td>
<td>-3.671</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.393</td>
<td>-0.718</td>
<td>-0.985</td>
<td>-1.206</td>
<td>-1.392</td>
<td>-1.548</td>
<td></td>
</tr>
<tr>
<td>4%</td>
<td>ΔIE</td>
<td>-0.550</td>
<td>-1.034</td>
<td>-1.472</td>
<td>-1.868</td>
<td>-2.228</td>
<td>-2.556</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.203</td>
<td>-0.379</td>
<td>-0.525</td>
<td>-0.647</td>
<td>-0.750</td>
<td>-0.837</td>
<td></td>
</tr>
<tr>
<td>6%</td>
<td>ΔIE</td>
<td>-0.384</td>
<td>-0.733</td>
<td>-1.048</td>
<td>-1.335</td>
<td>-1.596</td>
<td>-1.834</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.130</td>
<td>-0.236</td>
<td>-0.325</td>
<td>-0.401</td>
<td>-0.465</td>
<td>-0.520</td>
<td></td>
</tr>
<tr>
<td>8%</td>
<td>ΔIE</td>
<td>-0.284</td>
<td>-0.544</td>
<td>-0.779</td>
<td>-0.993</td>
<td>-1.189</td>
<td>-1.368</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.082</td>
<td>-0.151</td>
<td>-0.208</td>
<td>-0.258</td>
<td>-0.300</td>
<td>-0.336</td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>ΔIE</td>
<td>-0.218</td>
<td>-0.416</td>
<td>-0.596</td>
<td>-0.760</td>
<td>-0.911</td>
<td>-1.048</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.055</td>
<td>-0.101</td>
<td>-0.140</td>
<td>-0.174</td>
<td>-0.203</td>
<td>-0.229</td>
<td></td>
</tr>
<tr>
<td>12%</td>
<td>ΔIE</td>
<td>-0.170</td>
<td>-0.324</td>
<td>-0.465</td>
<td>-0.593</td>
<td>-0.711</td>
<td>-0.819</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ΔIS</td>
<td>-0.030</td>
<td>-0.068</td>
<td>-0.096</td>
<td>-0.121</td>
<td>-0.142</td>
<td>-0.160</td>
<td></td>
</tr>
</tbody>
</table>

†Indices for real asset prices for Case 3: P*_{KH} = 1.27, P*_{KS} = .90, i.e., inverse of Case 1.
identified in the first column of each table. Finally, Tables 8-10 correspond to each of three assumed values of the asset purchase prices discussed as case 1, case 2, and case 3 above.

The data provided in these tables substantiates the theoretical prediction that inflation significantly reduces investment, and that such effects are present even at low rates of inflation. By reducing the present value of depreciation deductions based on historic cost tax rules, inflation reduces investment relative to that which would occur under zero inflation (or, alternatively, under perfectly indexed depreciation deductions). Theoretical predictions developed by Hendershott and Hu (1981), Feldstein (1981), Kopcke (1981), and Auerbach (1979) are thus borne out by these empirical results. This result is invariant with respect to different initial assumptions on real interest rates and real asset purchase prices.

These tables also substantiate the predictions of Chapter 2 that inflation has a greater negative impact on equipment investment than structures investment. By comparing the $\Delta I_E$ and $\Delta I_S$ values in Tables 8-10, we see that $\Delta I_E > \Delta I_S$ under all possible initial assumptions on real interest rates and asset purchase prices. This finding is consistent with the results of Hendershott and Hu (1981c), and the discussion presented in Chapter 2. Because inflation reduces investment in equipment more than structures, the composition of investment will be biased toward structures purchases in the aggregate.
Of equal importance is the finding that inflation will affect investment differently under various economic conditions. As the data in Tables 8-10 indicate, different assumed values of real asset purchase prices and real interest rates lead to greatly different estimates of the change in investment. For example, an increase in the inflation rate from zero to four percent in Table 6 leads to a decline in equipment investment of $1.28 billion when the real interest rate is four percent. If the real interest rate rises to six percent, however, the expected change in equipment investment is only $0.93 billion. Similarly, differences in real asset prices are found to significantly alter the predicted effect of inflation on investment given an exogenous change in inflation. These findings reinforce the idea that the relation between inflation, historic cost depreciation and investment is likely to change over time.

E. Measured Effects of Inflation Uncertainty on Investment

Using the coefficients \( \beta_0 \) from Table 5, we can approximate the effect of an increase in inflation uncertainty on manufacturing investment. Recall from Table 5 that the coefficient \( \beta_0 \) for the structures equation was not significant at the 5% level using t-statistic hypothesis tests, suggesting that inflation uncertainty only affects equipment investment. For this reason, I measure only the effects of an increase in inflation uncertainty on equipment demand.
From the Livingston Surveys data, I calculate that the standard deviation of forecasts of expected inflation rose from 2.49 for the 1980 forecast to 3.53 for the year 1981. With $\beta_c = -0.0241$ for equipment, the increase in the standard deviation by 1.04 leads to a decline in manufacturing equipment investment by $0.025$ billions of 1972 dollars. In the same Livingston forecast, the expected inflation rate rose from approximately ten percent for 1980 to twelve percent for 1981. Using Table 8, and assuming a real interest rate of six percent (calculated value for 1980), the increase in the expected inflation rate from ten to twelve percent leads to a decline in gross equipment investment by $0.346$ billions of 1972 dollars. These calculations suggest that the effects of an increase in inflation uncertainty on manufacturing are clearly significant.

F. Summary of Empirical Results

As stated in the introduction, the purpose of this empirical research is to provide the evidence necessary to answer four questions: (1) Does inflation lead to a significant decline in business investment?; (2) Is the negative impact of inflation on investment greater for equipment than for structures?; (3) Are the effects of inflation on investment constant under different economic conditions?; and (4) Does an increase in inflation uncertainty have a negative impact on business investment? The data provided by this study indicate affirmative answers to each of these questions, suggesting that both
inflation and inflation uncertainty are significant determinants of both the level and composition of investment demand.

The empirical evidence provided by this chapter supports the result of Chapter 2 that the decline in the real value of depreciation deductions brought about by inflation leads to a decline in real business investment. Such effects result from the interaction of inflation and tax depreciation rules which require historic-cost valuation of assets. Investment in both equipment and structures is affected by this distortion even at low rates of inflation as shown in Tables 8-10. In general, the evidence supports the hypothesis that inflation is partly responsible for recent weak growth in aggregate business investment.

Further, the evidence in this report also supports the hypothesis that inflation leads to a much greater decline in equipment than in structures investment. The data in Table 8-10 demonstrate that an increase in inflation leads to a much larger decline in equipment investment, both in the absolute magnitude and proportionate size of the measured decline. This result persists over a wide range of economic conditions, substantiating the predictions of Chapter 2. From this evidence, I conclude that inflation does not explain the recent increase in the share of manufacturing investment devoted to equipment purchases as suggested by Corcoran (1979), Feldstein (1981), and Kopcke (1981).

In addition, the data presented in this chapter demonstrate that the influence of inflation on investment is likely to change over
time. The sensitivity of equipment and structures investment to inflation varies substantially with changes in real interest rates and real asset purchase prices, as indicated by the data in Tables 8-10. This finding confirms the idea that proper measurement of the effects of inflation on investment is critically dependent on the assumed economic conditions of the period. Changes in investment brought about by changes in inflation are jointly determined with several additional economic factors. The discussion in Chapter 3 demonstrates that failure to account for this fact leads to improper econometric specifications and misleading empirical results.

Of equal importance is the conclusion regarding the effect of inflation uncertainty on investment. Based on the econometric results presented in this chapter, I conclude that an increase in inflation uncertainty results in a decline in manufacturing investment, although the relationship appears limited to investment demand for equipment. This finding is consistent with the assertions by Friedman (1980), Malkiel (1979), and Cukierman (1981) that increases in inflation uncertainty negatively affect economic activity, and with the empirical results of Mullineaux (1981), who finds that increases in inflation uncertainty reduce industrial output. The present study indicates, however, that Mullineaux's broad empirical results mask a more interesting relation between inflation uncertainty and a sectoral component of output, namely investment.
CHAPTER 6

SUMMARY

The purpose of this research is to measure directly the effects of inflation and inflation uncertainty on the level and composition of investment demand. The results of Chapter 2 suggest that inflation reduces business investment by reducing the real value of depreciation deductions based on historic-cost asset values. Chapter 2 also demonstrates that the effects of inflation on investment will be greater for equipment than structures, capital, and that such effects will vary according to different initial assumptions about real interest rates and asset purchase prices. In addition, the discussion in Chapter 3 suggests that increases in inflation uncertainty lead to reductions in business investment, brought about by increased hurdle rates, greater planning costs, and an overall slower rate of economic activity. The major problem in assessing the significance of these factors is the clear lack of econometric evidence regarding these topics. Essentially, the hypothesis that inflation and inflation uncertainty distort the level and composition of business investment has not been subjected to rigorous empirical examination. This research is designed to supply data necessary to evaluate the importance of these factors as determinants of investment demand.
The methodology used in this study is based on the econometric estimation of neoclassical investment equations for the U.S. manufacturing industries. Separate equations are estimated for equipment and structures purchases for the period 1953-1980. Explanatory variables in the models are constructed to allow for explicit treatment of inflation expectations and inflation uncertainty. Estimation of these equations provides direct empirical tests of the hypotheses that inflation uncertainty and the user cost of capital are significant explanatory variables for manufacturing. Coefficients from these equations are then used to simulate the effects of changes on inflation and inflation uncertainty on manufacturing investment.

From the data provided by this research, four basic conclusions are reached. First, the empirical evidence of Chapter 5 supports the hypothesis that the decline in the real value of depreciation deductions brought about by inflation leads to a decline in real business investment. The data suggests that such effects are substantial, and that failure to account for the interaction of inflation and historic cost depreciation leads to incorrect predictions of investment demand. This result also supports the contention by Hendershott and Hu (1981a), Feldstein (1981a), and Kopcke (1981) that inflation is responsible for the recent decline in net investment and the growth rate in the capital-labor ratio. Second, the evidence in this dissertation supports the hypothesis that inflation leads to a much greater decline in equipment than structures investment. This finding is consistent with Hendershott and Hu (1981c), but runs
counter to the analysis of Feldstein (1981a) and Kopcke (1981). This result persists over a wide range of economic conditions, indicating that the recent shift in the composition of business investment toward equipment is not explained by increases in inflation. Third, the data also confirm the hypothesis that the effects of inflation and historic cost depreciation on investment will vary over time. Changes in investment brought about by changes in inflation are jointly determined with real interest rates and asset purchase prices, and proper measurement of such effects is critically dependent on additional economic variables. Finally, the evidence obtained by this research confirms the hypothesis that inflation uncertainty is a significant determinant of investment demand. Increases in inflation uncertainty reduce manufacturing investment, although the real effects appear limited to equipment purchases. These effects are much smaller than the measured effects of inflation and historic cost depreciation on investment, but they are nevertheless significant.

This research is unique for several reasons. The results obtained in Chapter 2 contribute to the resolution of the controversy surrounding the effects of inflation on investment composition. The hypothesis of Feldstein and Kopcke that inflation biases investment toward equipment is shown to be ambiguous in theoretical terms. This ambiguity is resolved, however, when the effects of inflation on relative costs of investment are examined within the framework of the user cost of capital as shown by Hendershott and Hu (1981c). The analysis also discusses the conditions under which the predicted composition
effects of inflation could be reversed, an idea that has not been discussed in the literature.

In addition, estimation of the investment equations is based on an econometric procedure specifically designed to avoid the aggregation bias which has plagued previous investment analysis. This procedure, known as the Random Coefficients Regression Model, is based on a cross-section, time series approach to equation estimation, thereby facilitating construction of aggregate equations consistent with heterogeneous investment behavior across manufacturing industries. Statistical tests for aggregation bias presented in this study demonstrate that use of the Random Coefficients technique is particularly appropriate for the analysis of manufacturing investment demand.

Further, the econometric analysis is based on a unique set of investment and capital stock data which has not been used in investment demand studies before. This data set was obtained by special request from the Commerce Department, and represents the only source of investment statistics disaggregated both by manufacturing industry, and by equipment and structures purchases. Use of this data proved essential to the estimation of aggregate investment demand equations by the Random Coefficients technique, thus avoiding the critical problem of aggregation bias.

Finally, and most importantly, the empirical results in this study represent the only econometric evidence available to measure the significance of inflation and inflation uncertainty on investment
demand. The evidence provided by this research suggests that both of these factors are important elements in the recent decline in net investment and growth of the capital stock, and that failure to account for these variables leads to serious specification errors. No other study has been successful in documenting this fact and for this reason, the empirical results presented in this dissertation represent a substantial contribution to the economic analysis of capital investment.
APPENDIX A

Selection of Lag Lengths

Before discussing the estimation results, it is necessary to clarify the procedure used to select the lag lengths for the coefficients \( v(L_y) \) and \( \omega(L_{\omega}) \). Essentially, I was guided in the selection of the lags by the results and procedures discussed by Jorgenson and Stephenson and Hall and Jorgenson.

Using quarterly data, Jorgenson and Stephenson find that two lagged changes in net investment are necessary to capture the rate at which investment projects are completed. Using annual data, Hall and Jorgenson also find that one lagged value for the net investment variable is sufficient to capture the rate at which the backlog of projects is completed.

This evidence indicates that it takes approximately two years on average to complete both equipment and structures investment projects from the moment changes in the current capital stock become necessary. This finding does not state that the rate of completion for equipment and structures projects will be the same. Actual coefficients on lagged values of INET will be different in most cases and must be estimated from the data. Based on the results found in these studies (and other Jorgenson studies), I assume that \( L_{\omega} = 1 \) for identification of \( \omega(L_{\omega}) \).
Given the assumption that \( L_w = 1 \), I proceed to the selection of the appropriate lag length for \( v(L_v) \), the coefficients on lagged changes in the optimal capital stock variable \( K^* \). I again base my selection procedure on the statistical methodology employed in the studies mentioned above. The procedure requires that the investment equations be estimated several times assuming successively different values of the lag length \( L_v \). The lag which minimizes the standard error of regression for each equation is selected as the estimated value for \( L_v \).

Using quarterly data on individual manufacturing industries, Jorgenson and Stephenson selected one current and five lagged changes in \( K^* \) as the appropriate explanatory variables based on this criterion. Surprisingly, however, when Hall and Jorgenson reestimated investment equations for manufacturing investment using annual data, the authors found that \( L_w = 4 \), indicating that one current and four lagged changes in the optimal capital stock are required to explain equipment and structures investment.

Applying the same criteria to the equations estimated by the Random Coefficients technique, I conclude that estimates based on cross-section data support the Hall and Jorgenson results. The statistical evidence suggests that it takes five years for manufacturing firms to completely react to changes in factors which determine the optimal capital stock. The equation estimates which result from this procedure are shown in Table 5.
APPENDIX B

Summary Statistics for
Implicit Manufacturing Equations
Random Coefficients Regression

Tables B.1 and B.2 provide the summary statistics for each of the manufacturing industry equations implicit in the aggregate coefficients shown in Table 5.

The comparison statistics are defined as follows:

- **SSR**: Sum(R(i,j)**2) Sum of Squared Residuals
- **SEE**: Sqrt(SSR/(T-1)) Standard Error of Residuals
- **CONST**: ABAR(i)-Sum(BHAT(j)*XBAR(j)) Constant for i-th category where the Sum taken over non-constant variables
- **BIAS**: FBAR(i)-ABAR(i) Bias
- **SE**: Sqrt(Sum((R(i,j)-BIAS)**2)/T) Standard Error of the regression for the i-th category
- **MSE**: Sum(R(k,j)**2)/T Mean Square Error
- **RMSE**: Sqrt(MSE) Root Mean Square Error
- **SMMSE**: RMSE/ABAR(i) Scaled Root Mean Square Error
- **MAE**: Sum(Abs(R(i,j)))/T Mean Absolute Error
- **MASE**: 100*Sum(Abs(F(i,j)/A(k,j)-1))/T Mean Abs. Percentage Error
- **SDA**: Sqrt(Sum((A(i,j)-ABAR(i)**2)/T)) Std. dev. of actuals
\[ SDP = \sqrt{\text{Sum}((F(i,j)-\text{FBAR}(i))^2)/T} \]

Std. dev. of fitted values

\[ \text{VAR} = SE^2 \]

Variance

\[ U = \text{MSE} \times T / \text{Sum}(A(i,j)^2) \]

Theil's U statistic squared

\[ \text{COV} = \text{Sum}(A(i,j) \times F(i,j)) / T - \text{ABAR}(i) \times \text{FBAR}(i) \]

Covariance between actuals & fitted values for i-th strategy

\[ \text{CORR} = \text{COV} / (\text{SDA} \times \text{SDP}) \]

Correlation between actuals & fitted values for the i-th category

\[ \text{TSSD} = \text{Sum}((A(i,j) - \text{ABAR}(i))^2) \]

Total Sum of Squares for the Dependent variable

where \( F(i,j) \) and \( A(k,j) \) denote the fitted and actual values for the i-th category at time period \( j \), \( T \) denotes the number of observations per category, \( \text{FBAR}(i) \) and \( \text{ABAR}(i) \) denote the means of the fitted and actual values for the i-th category, and all Sum's are taken over \( j \).
<table>
<thead>
<tr>
<th>S.I.C. Code</th>
<th>SSR</th>
<th>SEE</th>
<th>CONST</th>
<th>BIAS</th>
<th>SE</th>
<th>MSE</th>
<th>RMSE</th>
<th>SRMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>'20'</td>
<td>0.1139</td>
<td>0.0720</td>
<td>0.5155</td>
<td>-0.0234</td>
<td>0.0812</td>
<td>0.0050</td>
<td>0.0704</td>
<td>0.1135</td>
</tr>
<tr>
<td>'21'</td>
<td>0.0582</td>
<td>0.0514</td>
<td>0.0147</td>
<td>0.0142</td>
<td>0.0450</td>
<td>0.0025</td>
<td>0.0503</td>
<td>2.0136</td>
</tr>
<tr>
<td>'22'</td>
<td>0.0934</td>
<td>0.0652</td>
<td>0.1312</td>
<td>0.0356</td>
<td>0.0087</td>
<td>0.0041</td>
<td>0.0637</td>
<td>0.3762</td>
</tr>
<tr>
<td>'23'</td>
<td>0.0534</td>
<td>0.0493</td>
<td>0.0535</td>
<td>0.0320</td>
<td>0.0734</td>
<td>0.0023</td>
<td>0.0482</td>
<td>0.6133</td>
</tr>
<tr>
<td>'24'</td>
<td>0.0488</td>
<td>0.0471</td>
<td>0.1348</td>
<td>0.0263</td>
<td>0.0649</td>
<td>0.0021</td>
<td>0.0461</td>
<td>0.2685</td>
</tr>
<tr>
<td>'25'</td>
<td>0.0427</td>
<td>0.0440</td>
<td>0.0625</td>
<td>0.0181</td>
<td>0.0532</td>
<td>0.0019</td>
<td>0.0431</td>
<td>0.5433</td>
</tr>
<tr>
<td>'26'</td>
<td>0.0424</td>
<td>0.0439</td>
<td>0.2077</td>
<td>0.0148</td>
<td>0.0500</td>
<td>0.0018</td>
<td>0.0430</td>
<td>0.1679</td>
</tr>
<tr>
<td>'27'</td>
<td>0.2387</td>
<td>0.0765</td>
<td>0.2610</td>
<td>0.0075</td>
<td>0.0759</td>
<td>0.0056</td>
<td>0.0748</td>
<td>0.2307</td>
</tr>
<tr>
<td>'28'</td>
<td>0.2318</td>
<td>0.1027</td>
<td>0.5912</td>
<td>-0.0287</td>
<td>0.1121</td>
<td>0.0101</td>
<td>0.1004</td>
<td>0.1417</td>
</tr>
<tr>
<td>'29'</td>
<td>2.4469</td>
<td>0.3335</td>
<td>0.5266</td>
<td>-0.2108</td>
<td>0.4896</td>
<td>0.1064</td>
<td>0.3262</td>
<td>0.4790</td>
</tr>
<tr>
<td>'30'</td>
<td>0.0589</td>
<td>0.0517</td>
<td>0.1297</td>
<td>0.0302</td>
<td>0.0728</td>
<td>0.0026</td>
<td>0.0506</td>
<td>0.3165</td>
</tr>
<tr>
<td>'31'</td>
<td>0.0572</td>
<td>0.0510</td>
<td>0.0110</td>
<td>0.0147</td>
<td>0.0560</td>
<td>0.0025</td>
<td>0.0499</td>
<td>2.6614</td>
</tr>
<tr>
<td>'32'</td>
<td>0.0284</td>
<td>0.0359</td>
<td>0.1908</td>
<td>0.0256</td>
<td>0.0566</td>
<td>0.0012</td>
<td>0.0351</td>
<td>0.1482</td>
</tr>
<tr>
<td>'33'</td>
<td>0.5107</td>
<td>0.1524</td>
<td>0.5422</td>
<td>-0.0824</td>
<td>0.2063</td>
<td>0.0222</td>
<td>0.1490</td>
<td>0.2295</td>
</tr>
<tr>
<td>'34'</td>
<td>0.0544</td>
<td>0.0497</td>
<td>0.2798</td>
<td>-0.0038</td>
<td>0.0491</td>
<td>0.0024</td>
<td>0.0486</td>
<td>0.1436</td>
</tr>
<tr>
<td>'35'</td>
<td>0.1596</td>
<td>0.0852</td>
<td>0.4204</td>
<td>-0.0255</td>
<td>0.0943</td>
<td>0.0069</td>
<td>0.0833</td>
<td>0.1643</td>
</tr>
<tr>
<td>'36'</td>
<td>0.0522</td>
<td>0.0487</td>
<td>0.2682</td>
<td>0.0047</td>
<td>0.0484</td>
<td>0.0023</td>
<td>0.0477</td>
<td>0.1331</td>
</tr>
<tr>
<td>'37'</td>
<td>0.1853</td>
<td>0.0918</td>
<td>0.3416</td>
<td>-0.0337</td>
<td>0.1070</td>
<td>0.0081</td>
<td>0.0898</td>
<td>0.1980</td>
</tr>
<tr>
<td>'38'</td>
<td>0.0486</td>
<td>0.0470</td>
<td>0.1169</td>
<td>0.0193</td>
<td>0.0568</td>
<td>0.0021</td>
<td>0.0460</td>
<td>0.3110</td>
</tr>
<tr>
<td>'39'</td>
<td>0.0412</td>
<td>0.0433</td>
<td>0.0618</td>
<td>0.0188</td>
<td>0.0534</td>
<td>0.0018</td>
<td>0.0423</td>
<td>0.5456</td>
</tr>
<tr>
<td>S. I. C. Code</td>
<td>COV</td>
<td>COVR</td>
<td>MAE</td>
<td>SDA</td>
<td>SDP</td>
<td>VAR</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>'20'</td>
<td>0.003</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'21'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'22'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'23'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'24'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'25'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'26'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'27'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'28'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'29'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'30'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'31'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'32'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'33'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'34'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'35'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'36'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'37'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'38'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>'39'</td>
<td>0.000</td>
<td>0.001</td>
<td>0.019</td>
<td>0.010</td>
<td>0.052</td>
<td>0.058</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>S.I.C. Code</td>
<td>SSR</td>
<td>SFE</td>
<td>CONST</td>
<td>BIAS</td>
<td>SE</td>
<td>MSE</td>
<td>RMSE</td>
<td>SRMSE</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>-------</td>
<td>--------</td>
<td>---------</td>
<td>-------</td>
<td>--------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>'20'</td>
<td>0.3489</td>
<td>0.1259</td>
<td>-0.0470</td>
<td>0.0202</td>
<td>0.1280</td>
<td>0.0152</td>
<td>0.1232</td>
<td>0.0755</td>
</tr>
<tr>
<td>'21'</td>
<td>0.0077</td>
<td>0.0188</td>
<td>-0.0463</td>
<td>-0.0030</td>
<td>0.0190</td>
<td>0.0003</td>
<td>0.0183</td>
<td>0.2693</td>
</tr>
<tr>
<td>'22'</td>
<td>0.2534</td>
<td>0.1073</td>
<td>-0.1804</td>
<td>0.0407</td>
<td>0.1265</td>
<td>0.0110</td>
<td>0.1050</td>
<td>0.1661</td>
</tr>
<tr>
<td>'23'</td>
<td>0.0257</td>
<td>0.0342</td>
<td>-0.0590</td>
<td>0.0031</td>
<td>0.0338</td>
<td>0.0011</td>
<td>0.0334</td>
<td>0.1732</td>
</tr>
<tr>
<td>'24'</td>
<td>0.1123</td>
<td>0.0714</td>
<td>-0.0541</td>
<td>0.0001</td>
<td>0.0699</td>
<td>0.0049</td>
<td>0.0699</td>
<td>0.1218</td>
</tr>
<tr>
<td>'25'</td>
<td>0.0207</td>
<td>0.0307</td>
<td>-0.0498</td>
<td>-0.0007</td>
<td>0.0300</td>
<td>0.0009</td>
<td>0.0300</td>
<td>0.2333</td>
</tr>
<tr>
<td>'26'</td>
<td>1.1318</td>
<td>0.2268</td>
<td>-0.1084</td>
<td>0.0139</td>
<td>0.2231</td>
<td>0.0492</td>
<td>0.2218</td>
<td>0.1611</td>
</tr>
<tr>
<td>'27'</td>
<td>0.0873</td>
<td>0.0630</td>
<td>-0.0997</td>
<td>0.0250</td>
<td>0.0753</td>
<td>0.0038</td>
<td>0.0616</td>
<td>0.0940</td>
</tr>
<tr>
<td>'28'</td>
<td>2.2407</td>
<td>0.3191</td>
<td>0.0455</td>
<td>-0.0596</td>
<td>0.3288</td>
<td>0.0974</td>
<td>0.3121</td>
<td>0.1083</td>
</tr>
<tr>
<td>'29'</td>
<td>0.2790</td>
<td>0.1126</td>
<td>0.0305</td>
<td>-0.0230</td>
<td>0.1171</td>
<td>0.0121</td>
<td>0.1101</td>
<td>0.1680</td>
</tr>
<tr>
<td>'30'</td>
<td>0.2228</td>
<td>0.1006</td>
<td>-0.0679</td>
<td>0.0089</td>
<td>0.0996</td>
<td>0.0097</td>
<td>0.0984</td>
<td>0.1508</td>
</tr>
<tr>
<td>'31'</td>
<td>0.0070</td>
<td>0.0178</td>
<td>-0.0489</td>
<td>-0.0012</td>
<td>0.0175</td>
<td>0.0003</td>
<td>0.0174</td>
<td>0.3644</td>
</tr>
<tr>
<td>'32'</td>
<td>0.2033</td>
<td>0.0961</td>
<td>-0.1156</td>
<td>0.0393</td>
<td>0.1160</td>
<td>0.0088</td>
<td>0.0940</td>
<td>0.1141</td>
</tr>
<tr>
<td>'33'</td>
<td>1.9587</td>
<td>0.2984</td>
<td>-0.3363</td>
<td>0.0660</td>
<td>0.3134</td>
<td>0.0853</td>
<td>0.2918</td>
<td>0.1327</td>
</tr>
<tr>
<td>'34'</td>
<td>23.7606</td>
<td>2.3718</td>
<td>0.2107</td>
<td>-0.5014</td>
<td>2.3777</td>
<td>5.3809</td>
<td>2.3197</td>
<td>1.5449</td>
</tr>
<tr>
<td>'35'</td>
<td>0.4621</td>
<td>0.1449</td>
<td>-0.0692</td>
<td>0.0118</td>
<td>0.1441</td>
<td>0.0201</td>
<td>0.1417</td>
<td>0.0948</td>
</tr>
<tr>
<td>'36'</td>
<td>0.3662</td>
<td>0.1290</td>
<td>-0.0570</td>
<td>0.0039</td>
<td>0.1264</td>
<td>0.0159</td>
<td>0.1262</td>
<td>0.1117</td>
</tr>
<tr>
<td>'37'</td>
<td>2.2606</td>
<td>0.3206</td>
<td>-0.1112</td>
<td>0.0526</td>
<td>0.3265</td>
<td>0.0983</td>
<td>0.3135</td>
<td>0.1978</td>
</tr>
<tr>
<td>'38'</td>
<td>0.0346</td>
<td>0.0396</td>
<td>-0.0291</td>
<td>-0.0151</td>
<td>0.0467</td>
<td>0.0015</td>
<td>0.0388</td>
<td>0.1151</td>
</tr>
<tr>
<td>'39'</td>
<td>0.0456</td>
<td>0.0455</td>
<td>-0.0212</td>
<td>-0.0193</td>
<td>0.0557</td>
<td>0.0020</td>
<td>0.0445</td>
<td>0.2438</td>
</tr>
<tr>
<td>S.I.C. Code</td>
<td>COV</td>
<td>CORR</td>
<td>TSSD</td>
<td>MAE</td>
<td>SDA</td>
<td>SDP</td>
<td>VAR</td>
<td>U</td>
</tr>
<tr>
<td>------------</td>
<td>-----</td>
<td>------</td>
<td>------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>'20'</td>
<td>0.3013</td>
<td>0.9866</td>
<td>8.1338</td>
<td>0.0948</td>
<td>0.5947</td>
<td>0.5135</td>
<td>0.0164</td>
<td>0.0050</td>
</tr>
<tr>
<td>'21'</td>
<td>0.0005</td>
<td>0.7982</td>
<td>0.0115</td>
<td>0.0129</td>
<td>0.0224</td>
<td>0.0299</td>
<td>0.0004</td>
<td>0.0655</td>
</tr>
<tr>
<td>'22'</td>
<td>0.0331</td>
<td>0.8761</td>
<td>0.8654</td>
<td>0.0811</td>
<td>0.1940</td>
<td>0.1947</td>
<td>0.0160</td>
<td>0.0252</td>
</tr>
<tr>
<td>'23'</td>
<td>0.0057</td>
<td>0.9125</td>
<td>0.1344</td>
<td>0.0270</td>
<td>0.0764</td>
<td>0.0811</td>
<td>0.0011</td>
<td>0.0259</td>
</tr>
<tr>
<td>'24'</td>
<td>0.0440</td>
<td>0.9494</td>
<td>1.2368</td>
<td>0.0574</td>
<td>0.2319</td>
<td>0.1978</td>
<td>0.0049</td>
<td>0.0128</td>
</tr>
<tr>
<td>'25'</td>
<td>0.0024</td>
<td>0.8540</td>
<td>0.0535</td>
<td>0.0217</td>
<td>0.0482</td>
<td>0.0576</td>
<td>0.0009</td>
<td>0.0477</td>
</tr>
<tr>
<td>'26'</td>
<td>0.2812</td>
<td>0.9261</td>
<td>7.8459</td>
<td>0.1580</td>
<td>0.5841</td>
<td>0.5199</td>
<td>0.0498</td>
<td>0.0220</td>
</tr>
<tr>
<td>'27'</td>
<td>0.0355</td>
<td>0.9582</td>
<td>0.8903</td>
<td>0.0513</td>
<td>0.1967</td>
<td>0.1884</td>
<td>0.0057</td>
<td>0.0081</td>
</tr>
<tr>
<td>'28'</td>
<td>2.1089</td>
<td>0.9798</td>
<td>52.4309</td>
<td>0.2447</td>
<td>1.5098</td>
<td>1.4255</td>
<td>0.1081</td>
<td>0.0092</td>
</tr>
<tr>
<td>'29'</td>
<td>0.2140</td>
<td>0.9743</td>
<td>5.2520</td>
<td>0.0902</td>
<td>0.4779</td>
<td>0.4597</td>
<td>0.0137</td>
<td>0.0184</td>
</tr>
<tr>
<td>'30'</td>
<td>0.0665</td>
<td>0.9340</td>
<td>1.5511</td>
<td>0.0589</td>
<td>0.2597</td>
<td>0.2741</td>
<td>0.0099</td>
<td>0.0196</td>
</tr>
<tr>
<td>'31'</td>
<td>0.0001</td>
<td>0.3906</td>
<td>0.0019</td>
<td>0.0121</td>
<td>0.0092</td>
<td>0.0187</td>
<td>0.0003</td>
<td>0.1280</td>
</tr>
<tr>
<td>'32'</td>
<td>0.0479</td>
<td>0.9305</td>
<td>1.2474</td>
<td>0.0768</td>
<td>0.2329</td>
<td>0.2212</td>
<td>0.0135</td>
<td>0.0120</td>
</tr>
<tr>
<td>'33'</td>
<td>0.4800</td>
<td>0.9232</td>
<td>12.4718</td>
<td>0.2343</td>
<td>0.7864</td>
<td>0.7061</td>
<td>0.0982</td>
<td>0.0158</td>
</tr>
<tr>
<td>'34'</td>
<td>0.1920</td>
<td>0.1591</td>
<td>124.3004</td>
<td>0.6715</td>
<td>2.3247</td>
<td>0.5193</td>
<td>5.6535</td>
<td>0.7026</td>
</tr>
<tr>
<td>'35'</td>
<td>0.3787</td>
<td>0.9849</td>
<td>10.2386</td>
<td>0.1238</td>
<td>0.6672</td>
<td>0.5763</td>
<td>0.0208</td>
<td>0.0075</td>
</tr>
<tr>
<td>'36'</td>
<td>0.2097</td>
<td>0.9635</td>
<td>5.0510</td>
<td>0.0933</td>
<td>0.4686</td>
<td>0.4643</td>
<td>0.0160</td>
<td>0.0106</td>
</tr>
<tr>
<td>'37'</td>
<td>0.3682</td>
<td>0.9062</td>
<td>11.6145</td>
<td>0.2323</td>
<td>0.7106</td>
<td>0.5718</td>
<td>0.1066</td>
<td>0.0326</td>
</tr>
<tr>
<td>'38'</td>
<td>0.0232</td>
<td>0.9740</td>
<td>0.5702</td>
<td>0.0294</td>
<td>0.1574</td>
<td>0.1511</td>
<td>0.0022</td>
<td>0.0109</td>
</tr>
<tr>
<td>'39'</td>
<td>0.0087</td>
<td>0.9283</td>
<td>0.2555</td>
<td>0.0314</td>
<td>0.1054</td>
<td>0.0893</td>
<td>0.0031</td>
<td>0.0445</td>
</tr>
</tbody>
</table>
FOOTNOTES

1 See Clark (1978), Malkiel (1979), Hendershott and Hu (1981e), and Feldstein (1981a).

2 The discussion of the effects of inflation on the user cost of capital provided in this chapter is based on Hendershott and Hu: (1) "The Relative Impacts of Various Proposals to Stimulate Business Investment," pp. 323-326, and (2) "Investment in Producers Durable Equipment," pp. 59-100, and pp. 117-120.

3 This result is conditional on the assumption that \( r > p^* \), an assumption maintained by Hendershott and Hu. See "The Relative Impacts of Various Proposals to Stimulate Business Investment," p. 323.

4 Hendershott, P. and Hu, Sheng-Cheng, Ibid., p. 325, fn. c.


6 Ibid., p. 33, see equation (1.3).

7 Kopcke computes identical measures of the net cost of investment, as shown by the expressions \((1-\mu-TxZ)\) in equations (19) and (20). See Kopcke, R. W., "Inflation, Corporate Income Taxation, and the Demand for Capital Assets," Journal of Political Economy, Vol. 89, #11, p. 123.

Kopcke forms the inverse of this index. See Kopcke, op. cit., p. 126, Table 2, and Note to Table 2.


Kopcke, op. cit., p. 126, Table 2.


Ibid., p. 625.

Ibid., pp. 626-627.

Ibid., pp. 627.


Ibid., p. 51.

Ibid., p. 53.


25 Equation (64) is identical to the investment equations used by Jorgenson, D. W., and Stephenson, J. A., op. cit., p. 186.

26 Ibid., p. 181.

27 For an excellent presentation of this model, see Wallis, op. cit., pp. 81-120.


30 As a basic test of the hypothesis that inflation leads to an increase in the debt-equity ratio, the following equation was estimated using ordinary least squares:

$$\text{DERATIO} = \beta_1 + \beta_2 P^* + U_t$$

where: DERATIO = debt-equity ratio used to construct the after-tax finance rates, from Von Furstenberg (1978).

$P^*$ = expected inflation rate used in this study, from Livingston Surveys.

A positive, significant $\hat{\beta}_1$ coefficient would indicate that we cannot reject the hypothesis that inflation leads to an increase in the debt-equity ratio.

After correction for second-degree auto correlation, the following results were obtained:

<table>
<thead>
<tr>
<th>$\beta_1$</th>
<th>$\beta_2$</th>
<th>$\rho_1$</th>
<th>$\rho_2$</th>
<th>$R^2$</th>
<th>D.W.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.254</td>
<td>0.002</td>
<td>1.415</td>
<td>-0.434</td>
<td>0.927</td>
<td>2.165</td>
</tr>
<tr>
<td>t-statistic</td>
<td>-1.395</td>
<td>7.180</td>
<td>-2.179</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On the basis of this simple test, we must reject the above hypothesis. The debt-equity ratio is explained only by a simple autoregressive process. Though this regression represents an oversimplified hypothesis test of the inflation/debt relation, it does indicate that the relation is not that strong.


34 All econometric work was performed using the Econometric Programming System, Data Resources, Inc.
BIBLIOGRAPHY


