REPLACEMENT INVESTMENT: A NEW VIEW

by

Kenneth Matziorinis

Department of Economics
McGill University
March, 1988

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy

REPLACEMENT INVESTMENT: A NEW VIEW

REPLACEMENT INVESTMENT: A NEW VIEW

ABSTRACT

The conventional approach in the theory and econometrics of investment is the partition of gross capital investment in two components: expansion (or net) investment and replacement investment. This thesis examines the latter component. A critical assessment of the literature and the empirical evidence reveal that the prevailing view of replacement known as the "proportional replacement hypothesis" is incorrectly specified and unsatisfactory.

This thesis examines a variety of data brought together under the same focus for the first time and comes up with two important findings. First, firms maintain the operating capacity of their equipment not by replacing the whole of the machine but by replacing worn out or defective parts. The cost of new parts along with that of labour and materials incurred in restoring the operating efficiency of machines are known as "repair expenditures". Data on these expenditures have been collected by Statistics Canada in its investment survey since 1947. Although in effect replacement expenditures, these data are not capitalized by firms and hence do not appear in our conventional investment statistics. Although they account for a significant proportion of capital expenditures they are completely ignored in the theory and econometrics of replacement. Second, expansion and maintenance of production capacity are not the only purposes for which firms invest funds. They also invest for a variety of other purposes, such as modernization, upgrading, retooling, revamping and pollution abatement, for example. These activities lower unit costs of production and enhance the profitability of the firm by initiating or responding to changes in the structure of demand, technology, the prices of factor inputs or the market structure. Such capital expenditures entail changes in capital-output and capital-input specificity. As the real world is characterized by capital and output heterogeneity, structural change therefore implies structural investment.

Important policy implications arise from the above findings. Tax incentives may be more effectively utilized when targeted toward firms undertaking structural investment rather than either expansion or replacement. Since repair expenditures are not included in standard investment statistics, the level of investment spending is significantly higher than conventionally thought. Also our capital stock data, particularly net capital figures, may be more deficient than previously presumed.

RESUME

Aussi bien dans la théorie économique que dans la pratique économétrique, l'approche conventionnelle consiste à diviser l'investissement brut en capital en deux composantes: l'investissement à des fins d'expansion et l'investissement à des fins de remplacement. Le propos de cette thèse est d'étudier en détail ce dernier type d'investissement. La théorie actuelle du remplacement, connue sous le nom de "l'hypothèse du remplacement proportionnel" ne résiste pas à l'évaluation critique de la littérature économique et des preuves empiriques.

Cette thèse étudie un ensemble de données réunies ici sous un même angle, pour la première fois. Deux résultats importants sont mis à jour. Le premier est que les entreprises parviennent à maintenir la capacité de production de leurs équipements, non pas en remplaçant chaque machine en entier, mais plutôt en remplaçant les pièces usées ou défectueuses. Les coûts des nouvelles pièces ainsi que les dépenses en main-d'oeuvre et en matériel nécessitées par leur installation, sont communément placés sous la rubrique des "dépenses de réparation". Statistique Canada rassemble depuis 1947, les données relatives à ces dépenses. Elles n'appairaissent pas dans les statistiques conventionnelles relatives aux investissements, bien qu'elles constituent des coûts de remplacement d'équipements. En outre, bien qu'elles représentent un pourcentage important des dépenses en immobilisations, elles sont totalement ignorées par la théorie économique et par la pratique économétrique du remplacement. Le second résultat de cette étude est de démontrer que les dépenses visant à l'expansion ou au maintien de la capacité de production ne sont pas les seules possibles. Les entreprises investissent pour une multitude d'autres raisons, telles la modernisation, l'amélioration, la modification des équipements, la dépollution de l'environnement et l'amélioration des conditions du milieu de travail. Il résulte de ces investissements une diminution des coûts unitaires de production et un acroissement de la rentabilité de l'entreprise. Les entreprises répondent ainsi à certains changements structurels de la demande, de la technologie, des coûts des facteurs de production ou de la structure des marchés. Parfois, elles sont à l'origine de tels changements. Par ailleurs, ces investissements en capital modifient les rapports spécifiques qui existent entre le capital et les produits ainsi qu'entre le capital et les facteurs de production. Le monde réel étant caractérisé par l'hétérogénéité des capitaux et des produits, tout changement structurel implique un investissement structurel.

Il résulte de ces recherches d'importantes implications quant à la politique économique. Les encouragements fiscaux peuvent être utilisés plus efficacement, quand ils visent des compagnies qui entreprennent des investissements de structure plutôt que d'expansion ou de remplacement. Etant donné que les dépenses de remplacement ne sont pas incluses dans les statistiques relatives aux investissements, le niveau des investissements est bien plus élevé qu'on ne le pense.

ACKNOWLEDGEMENTS

Writing a Ph.D. thesis is a full-time preoccupation. The real world, however, does not always afford you this luxury. When you have to share research and writing with full-time teaching, part-time consulting, a family life and personal growth it becomes an almost impossible task. Time and human capital need to be supplemented with additional variables in the production function of a thesis. Commitment to the goal and a lot of perseverance acquire an instrumental role. I never lacked the commitment and fortunately I was well endowed with perseverance. Ultimately, it was the latter, combined with the understanding and patience of my thesis director and wife that ensured the completion of this work.

My thanks go first and foremost to my thesis director, Professor J.C.R. Rowley. His assistance, in many fronts, has been invaluable. An expert in the theory and econometrics of investment, he has provided me with extensive technical support and constructive criticism throughout. Second he read and re-read my drafts very carefully and came up with countless suggestions which have made the final version a more readable and professional product. Finally, his patience, encouragement and faith in my ability to complete it have been most important. I would like to express my deep gratitude for everything he has done. I wish that every graduate student has the fortune to work under a person such as him.

I would also like to thank Professor Christopher Green, the second member of my thesis committee, and Thierry Neubert for their comments and many valuable suggestions on earlier drafts of this thesis, as well as for their moral support.

A number of thanks must also go to many individuals who assisted my research by supplying me with information. I would like to offer special thanks to Nancy Chinfen of the Department of Regional Industrial Expansion (DRIE) in Ottawa and George Spiers of the Economic Department of McGraw-Hill in New York, who supplied me with data and advice on a number of occasions. In addition, I would like to thank Roger Boucher of Alcan Aluminum Ltd., Peter Koumanakos of Statistics Canada, Paul Kovacks of the Canadian Manufacturers' Association, Brian O'Reilly of the Bank of Canada, Robert Redelmeier of Shell Canada Ltd. and David Wilson of the Canadian Pulp and Paper Association. In addition, many thanks to all of you who supplied me with data, notably the various divisions of Statistics Canada, the Bureau of Economic Analysis of the Department of Commerce in Washington, D.C., Coopers and Lybrand of Montreal, the Canadian Industrial Renewal Board, the American Iron and Steel Institute, the Motor Vehicle

Manufacturers' Association of the U.S.A. and Word's Automotive Publishing. Special thanks are also in order to my typist, Anna Brenes for the highly efficient and professional work she has done in typing and processing this thesis on her computer.

A last but certainly not insignificant set of thanks go to my wife Catherine. As one of my long-time friends says, she has never known me in the "P.T." sense (i.e. post-thesis). Thank you Nina for your understanding, patience and devotion to me over the past few difficult years. Finally, I would like to thank my brother Nicholas, my parents, my Department colleagues at John Abbott College, my former teachers at McGill University and all my friends for their encouragement and moral support.

Of course, no one is responsible for any errors or flaws in this thesis but myself.

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX TO CHAPTER FOUR

CHAPTER FIVE

LIST OF FIGURES

CHAPTER TWO

CHAPTER FOUR

APPENDIX TO CHAPTER FOUR

CHAPTER FIVE

CHAPTER ONE

INTRODUCTION

The conventional theory and econometrics of investment partition gross fixed capital formation into two components: expansion (or net) investment and replacement investment. Expansion investment is induced endogenously by changes in economic variables such as permanent changes in the level of real output (the accelerator principle) or changes in the prices of the output or inputs, such as wages, the rental cost of capital, interest rates and tax factors (the enhanced neoclassical theory of optimal capital accumulation). The bulk of theoretical and econometric work on investment has been devoted to this component of gross investment.

The nature and determinants of replacement investment, however, have received far less attention. The conventional approach, as found widely in mainstream textbooks of economics, is the view that replacement investment is intended purely to maintain the operating capacity of capital stock intact in the face of depreciation, defined as the decline in the asset's efficiency to supply capital services, the result of wear and tear in the course of production. Jorgenson (1965, 1974) has enunciated the view that the rate of replacement investment is an exogenously given constant and proportional to some measure of the economy's capital stock, and therefore equal to the rate of depreciation.

This view, known as the "proportional replacement hypothesis" (PRH) came under heavy attack almost as soon as it was proposed. Feldstein and Foot (1971), Feldstein (1974), Feldstein and Rothschild (1974), Eisner (1972, 1978), Nickell (1975, 1978), Helliwell (1976) and Rowley and Trivedi (1975) have all objected to this myopic and mechanistic treatment of replacement. Besides, Jorgenson who advanced this view has completely ignored previous and important work in this area, principally by Einarsen (1938 a,b; 1946), Bain (1939), Terborgh (1949, 1954) and Dean (1951), all of whom emphasized the importance of economic variables and dynamic considerations found widely in practice. For example, they all stress the role of technical change and obsolescence as imposing a limit to the economic service life of an asset, well before physical wear and tear set in. All of them view replacement as a variable whose value is determined endogenously by the firm and subject to the influence of other economic factors.

Our approach to replacement has not merely consisted of re-shuffling the existing evidence. We have brought together additional data in order to enlarge our insight on the subject. Examination of the quantitative and qualitative information has enabled us to inductively reconstruct an alternative perspective on replacement, one that sheds more light on the subject and allows us to escape the myopic confines of the conventional approach. Our findings are significant and open the door to new paths of productive research.

Our first finding is that replacement occurs in a different way than had been assumed until now. Firms rarely replace the <u>whole</u> of a machine by an exact replica of the old machine. Why should they do so when a machine is only a <u>composite of parts</u> which wear out at different rates, and when machine parts are interchangeable? We found that in practice, firms replace worn or damaged parts by new or rebuilt parts. The cost of the parts plus that of the materials and labour incurred in the restoration of the machine, however, are not capitalized for accounting purposes as we would have expected for replacement. Instead, firms charge the cost of parts and labour on their operating accounts. The result is that in reality the bulk of replacements occur at the sub-machine level, and by not being recorded in capital accounts, they are omitted entirely from our official statistics on capital investment expenditures. The significance of this finding is staggering, since non-capitalized replacement expenditures account for as much as 50% of capital expenditures in the Canadian manufacturing sector in 1984, for example! The implications of this omission are wide-ranging. First, the magnitude of investment activity has been considerably understated in our official accounts. Second, the level of capital stock may in fact be higher than so far presumed. Third, we have nothing to account for the "other half" of gross capital investment!

It is interesting that Statistics Canada, following a pragmatic approach has, in fact, collected data on these expenditures continuously since 1947 in its Private and Public Investment Survey. They are called "repair expenditures" and are defined as expenditures incurred "to maintain the operating efficiency of the existing stock of durable physical assets", which is the same sense in which Jorgenson has defined replacement. These repair expenditures are added alongside capital expenditures in order to derive a broader measure of "total" investment activity in Canada.

So far, economists have been unable to find direct measurable data on replacement. Their approach has consisted of imputing replacement estimates from gross capital investment figures using theoretical assumptions. At last we have before us a body of directly measured data which can be used by economic investigators in the theory and econometrics of replacement.

Our second finding concerns the "other half" of gross capital investment. If replacement expenditures are not capitalized and only a portion of capital investment is devoted to expansion, what purpose do the rest of the capital expenditures serve? For years firms have indicated in surveys of capital spending that only a fraction of their capital expenditures are committed for expansion. In 1985, for example, U.S. manufacturing firms responding to the McGraw-Hill survey reported that only 27% of the $153.1 billion spent on fixed capital investment projects was devoted to expansion. Canadian manufacturing firms responding to the DRIE survey reported that only 25% of capital spending was devoted to expansion that year. Clearly, if replacement expenditures are not capitalized, what purpose do the remainder of these capital expenditures serve?

Expansion and maintenance of production capacity are not the only purposes for which firms invest funds. Firms invest for a variety of other purposes, principally to reduce unit costs of production and enhance profitability in the context of an ever changing economic environment. We must accept that in the real world our economy undergoes continual change, not only in the values of the endogenous variables but also in the values of the exogenous variables themselves. For example, technological change and innovation (both product and process innovations) are an on-going feature of economic reality which we cannot afford to ignore. In addition, one observes change in the structure of consumer tastes and preferences and the composition of final demand, change in the prices of factor inputs, change in the structure of markets and industry competition as well as change in the regulatory and institutional environment (pollution abatement and occupational health and safety standards). Seeking to maintain their profitability and secure their long-term viability, firms both initiate and respond to this change. This structural transformation is an important aspect of the economic environment of firms. Omitting it from our analysis leaves out many of the explanatory variables which are necessary to understand the process of capital investment.

Economic reality, unlike the standard assumptions employed in the theory and econometrics of investments, is not characterized by capital and output homogeneity. We must also accept that capital and output are generic concepts defining heterogeneous entities. The vast majority of capital goods are built to perform specific functions in production, a notion which we call functional specificity of capital. Different types of products require different types of capital goods in their production, a notion which we call capital-output specificity. It follows that change in the composition of demand necessitates change in the composition of capital stock, and this in turn implies fixed capital investment. Thus some investment activity differs considerably from expansion investment in that it is the outcome of the change in the composition or structure of demand (total demand remaining constant) rather than the change in the level of total demand for output. Moreover, capital-output and capital-input specificities are changed, whereas they remain constant in expansion investment. The flow of fixed capital investment that accompanies these changes should therefore be differentiated from the traditional categorizations of expansion and replacement investment. We propose a new term, that of structural investment.

In practice, one finds many examples of such structural investment expenditures. They appear under a variety of labels such as "modernization", "upgrading", "automation", "refitting", "retooling" and "revamping". Conversion of an old newspaper mill into a fine paper mill, refitting a car assembly plant with robots, upgrading an oil refinery to produce a different mix of refined products, retooling a car assembly plant to produce a different car model and investing in the reduction of air, water and noise pollution are just a few examples. Here the purpose of the capital investment program is to restructure production.

That this is common in the real world of economics, no industry practitioner or close observer disputes. Trade and business journals and the press are full of accounts of such activity. The problem is that the mainstream of the economic profession has yet to acknowledge the nature and significance of it. Textbooks continue to portray the capital investment process in terms of expansion and replacement halfs. By ignoring the equally important issues regarding the structure of capital and output and their functional specificity, we have neglected to learn about the role that structural change exerts on investment as well as the role that capital investment plays in conditioning economic change and adaptation.

One of the crucial issues facing corporate executives and economic policy makers today is how to profitably maintain production in a mature industrial economy characterized by slow growth and intense international competition. How well we understand this process of change and the potential that structural investment holds as a strategy for industrial renewal and economic adaptation may determine how well we fare in our transition to a post-industrial society.

In this thesis we start our analysis by critically reviewing the existing literature on replacement. Chapter 2 examines two theories which treat replacement as a variable mechanistically determined by exogenous factors. They are Einarsen's (1938) hypothesis of generated reinvestment cycles, including the so-called "echo effect", and Jorgenson's (1965, 1974) "proportional replacement hypothesis". In Chapter 3 we examine other hypotheses which have been proposed to explain replacement. These theories share in varying degrees the underlying view that replacement is an economic decision and conditioned by economic forces. Present throughout this literature is the distinction between "like-for-like replacement", the static or narrow definition of replacement, and "obsolescence replacement" or "re-investment", the dynamic or broad definition. Although the same term has been used for both it is apparent that "replacement" in the broad sense has little in common with the more conventional definition of replacement in the "like-for-like" sense.

In Chapter 4 and its Appendix, we bring under the same focus a variety of data that provides us with a unique perspective on the nature of replacement. We report data which indicate that firms do not replace a machine by another machine of the same kind; that a machine is in fact a composite of parts which wear out at different rates; and that in practice, firms replace parts of the machines and by continuously replacing these parts they maintain the physical capacity of the machines intact forever. We examine the pattern of these "repair expenditures" and we add them to capital expenditures in order to obtain a more accurate picture of investment activity in Canada. We also examine data on the composition of capital in Canada, the assumptions underlying the construction of capital stock estimates and their weaknesses, and the purposes for which firms invest.

In Chapter 5, we explain the nature and determinants of all those expenditures which are devoted neither for replacement nor for expansion purposes. We introduce the notion of functional specificity of capital and capital-input and capital-output specificity and examine Canadian data which supports our assertion that output and capital are in fact heterogeneous and undergo structural change through time. The carriers of this change are the concepts of the product-life-cycle (PLC) and S-shaped secular industry growth patterns, which contribute to the economic transformation taking place. We find that structural change in our economy is the rule rather than the exception and that such change is both a determinant and a consequence of capital investment spending.

In Chapter 6, we summarize our findings and briefly discuss their policy implications. The foremost implication for public policy is that there is much that the government can do to assist the economy's adaptation to changing economic realities by targeting fiscal incentives towards firms undertaking restructuring of their capital. The foremost implication for business policy is that structural investment is a potent strategy for attaining competitiveness and enhancing profitability.

CHAPTER TWO

MECHANISTIC VIEWS OF REPLACEMENT INVESTMENT: A CRITICAL REVIEW OF THE LITERATURE

1. Introduction

Production units rely in varying degrees on man-made aids to production such as tools, machinery and equipment, engineering structures and buildings, to produce the goods and services we consume. Such capital goods do not have an infinite lifespan. Their useful life in production can be maintained and extended through maintenance and periodic repair and overhaul interventions but changes in technology, consumer tastes and competitive interactions among firms will render them economically obsolete within finite spans of time. Firms are faced with the on-going problem of replacing older by newer capital goods so as to maintain productive capacity, minimize costs of production and meet competition.

Replacement investment is not a trivial issue. At least half of all business fixed capital investment may be devoted to replacement. Relative to its quantitative importance however, replacement investment has received a disproportionately small share of the attention it deserves. This may be due to the scarcity of data on actual amounts that firms spend for replacement[1]. On the other hand, the emphasis on expansion investment

---

[1] Data are reported only for gross capital investment expenditures, which include replacement and expansion investment. Conceptually the distinction between replacement and expansion investment is easy to make, but, in practice, differentiating between the two types of expenditure is more difficult. In an environment of continual technological progress, older capital goods are replaced by more efficient and productive newer capital goods. Often, this type of replacement entails an expansion in the productive capacity of the firm as well. How to allocate the expenditure between expansion and replacement is an important problem. Another problem is that, often, expansion is accompanied with a change in product line. Here the introduction of a new product supersedes and replaces an older product and the firm may consider the expenditure as expansion rather than replacement.

may reflect the economic profession's preoccupation with issues of economic growth. Today, with growth rates well below those of the 1960s and with a more mature and aged industrial structure, issues of replacement and modernization investment have acquired greater importance[2].

The purpose of this chapter is to take stock of where we stand in our formal understanding of the processes and interrelationships which condition the replacement investment process. Previous work on replacement investment has so far been dominated by the view that replacement investment is more or less a mechanistic process that is primarily conditioned by technological parameters. For example, Jorgenson (1965, 1974) showed that under certain specified conditions replacement investment becomes a constant proportion of the economy's capital stock. This result permitted him to provide a unifying and comprehensive theoretical framework for the treatment of both expansion and replacement investment in the context of the neoclassical theory of optimal capital accumulation. Since no alternative integrated formulation of the investment process--both expansion and replacement--that lends itself to easy empirical applications seems to exist, Jorgenson's view of the replacement process has dominated theoretical and empirical work in this area.

An alternative view of the replacement process, however with antecedents to Marx (1893), Robertson (1915) and Schonheyder (1927), is elaborated by Einarsen (1938a,b; 1946). In a comprehensive empirical study

[2] Witness, for example, increased references to "industrial renewal", "de-industrialization", "new industrial policy", "industrial transformation" which have dominated headlines in major financial and economic periodicals as well as government policy in Canada.

of the Norwegian shipping industry, Einarsen found a recurrent reinvestment cycle whereby Norwegian shipowners concentrated their replacements every 19 years. At such intervals there was a surge in replacements followed by long periods of low activity. At that time economists were not preoccupied with growth but rather with the business cycle. Among the hypotheses proposed to explain the periodic ups and downs in the level of economic activity was that of a "pure" reinvestment cycle, whereby firms under pure technical necessity to replace their worn-out and depreciated machinery and equipment would periodically generate a boom in investment activity. Once initiated, an investment boom was capable, on its own, of generating re-investment cycles of replacement investment periodically over time. Replacement was an outcome of technical necessity but it did not tend towards some constant value for proportionality over time but rather exhibited periodic surges, the so-called "echo effect".

The view that reinvestment cycles were alone responsible for the business cycle were challenged early on by Tugan-Baranowsky (1901), Spiethoff (1902), Aftalion (1908), J.M. Clark (1923) and, Akerman (1928). According to these investigators the reinvestment cycle was the consequence, rather than the cause of business cycles and thus replacement investment was conditioned by economic factors rather than mechanistic ones. The most complete enunciation of the view that replacement investment was conditioned by economic factors was given by Bain (1939). He anticipated many of the arguments later advanced by Feldstein and his associates to account for fluctuations in the level of replacement investment[3].

Recent years have seen a weakening of support for Jorgenson's mechanistic-proportionality view of replacement. Eisner (1968, 1972), Feldstein and Foot (1971), Feldstein and Rothschild (1974), Nickell (1975), Bitros and Kelejian (1974), Cowing and Smith (1977), Lioukas (1980, 1982) and others produced theoretical arguments and empirical evidence which suggest that replacement investment is variable and sensitive to, among other factors, liquidity of the firm, the state of the business cycle, level of expansion investment, capacity utilization and replacement backlogs. Unfortunately, although increasing evidence has been accumulating with respect to the role of such economic factors in conditioning the level of replacements in the short-run, no comprehensive and unifying theory of replacement investment has yet emerged from this source.

Wider views of the replacement process which complement rather than compete with the views stated above are advanced by Terborgh (1949, 1954) and Dean (1951). According to Terborgh, capital goods are not necessarily scrapped and replaced by newer ones but rather displaced to a lower function, e.g., a standby or ancillary function, a process he calls "functional degradation". Replacement in this view is not equated with retirement (or scrapping) of old assets. Existing assets are merely re-assigned functions or re-deployed to other areas while making room for the utilization of newer assets. Dean (1951) distinguishes among different

---

[3] It is unfortunate that neither Jorgenson nor Feldstein and their associates refer to Bain's work in this area.

types of investment such as expansion, replacement, product and strategic investments. In particular, he differentiates between aggressive investments and defensive ones. He does not view firms merely as passive agents replacing equipment periodically whenever economic conditions are propitious. Instead he considers strategic aspects that arise from dynamic interactions among firms in an industry. For example, firms often feel compelled to replace or to modernize their equipment before they would have otherwise done, because other firms in the industry have introduced more advanced, productive machinery. These he calls defensive replacement investments. On the other hand, the firm may undertake to replace its equipment sooner by more modern equipment in order to forestall developments by its competitors and enhance its position in the industry (aggressive investments). Both Terborgh and Dean introduce dynamic elements--widely found in practice--but which have not been captured in any of our formal models of replacement investment. It is interesting to note that, at last, concepts such as "strategic entry-deterance" are generating much interest in the newer literature on industrial organization. These non-mechanistic views of the replacement process are presented in Chapter 3 below.

A considerable body of the literature on replacement is also devoted to the issue of optimal replacement. Here the focus is on developing guidelines or decision rules for the optimal timing of the replacement by firms. Important in its own right, this issue is an applied matter but falls primarily outside the scope of our present investigation. However, a brief mention is in order. The treatment of optimal replacement began with

Taylor (1923), Hotelling (1925) and continued later with Preinreich (1938, 1939, 1940). According to Taylor (1923), optimization of the replacement requires the minimization of the machine's unit cost including interest. Thus optimal timing occurs when the unit cost plus interest of the old machine exceeds the minimum cost plus interest of the new addition. Hotelling (1925) on the other hand, argued that optimization requires the maximization of the value of output minus the operating costs of the machine. Clearly, these two formulations are equivalent in a static economy but may differ in dynamic contexts. Preinreich (1938, 1939, 1940) took a longer view. He introduced the concept of the infinite chain of revenues and costs for the new and old machines and suggested the maximization of the present value of the firm's future net profits. His formulation was thus more suitable for analysis in a steadily growing hypothetical economy than those of his predecessors. Assimilation of these three perspectives resulted in rather abstract and mathematical exercises which ignored obsolescence and required the firm to have more precise information than was realistic. They were later extended by Dean (1951), Terborgh (1949, 1954), Jorgenson, McCall and Radner (1967), Vorlander and Raymond (1932), Wicksell (1934), Moonitz (1943), Alchian (1952) and Smith (1961)[4].

[4] For a more extensive review of early contributions to this literature see Grosse and Berman (1957).

2. Replacement (Reinvestment) Cycles: The "Echo Effect"

In many ways, Einarsen (1938a,b;1946) was the first economist to explicitly and systematically examine replacement investment. His purpose was to assess an hypothesis that had been advanced earlier by Marx (1893), Robertson (1915), Schonheyder (1927) and others, whereby replacement investment cycles were primarily responsible for the periodic ups and downs in the level of business activity (that is, for the business cycle). Einarsen refined and elaborated the hypothesis. According to him, bunching of investment expenditures in previous periods result in bunching of their replacements in subsequent periods, so the length of the lagged adjustment is equal to the average lifetime of assets composing the capital stock. For example, if machines last ten years on average and there has been an investment boom five years ago, then five years from now there will be a surge in the level of replacement investments. All other variables remaining constant, the same surge in replacement spending will re-occur in every subsequent ten year period. These periodic surges in the level of replacement expenditures he calls <u>pure or generating reinvestment cycles</u> with corresponding "echo effects". Figure 2-1 illustrates the reinvestment cycles, where N is the average lifetime. Assuming a steady state situation whereby gross investment equals replacement investment and capital stock remains constant through time, a one-time increase in expansion investment (EI) will cause a contemporaneous one-time increase in the level of capital stock (K). This will generate a sequence of future surges in replacement (RI) every Nth period, which are known as replacement cycles or the "echo-effect".

The necessary conditions for the existence of reinvestment cycles were spelled out by Einarsen (1938) and later by Howrey (1965). They are (a) an uneven concentration of investment activity over time or investment bunching; (b) a stable length of life for individual assets; (c) a stable composition of assets in the capital stock; and (d) a constant proportional replacement of previously acquired assets. To the extent that firms decide not to replace previously acquired assets this will affect the amplitude of

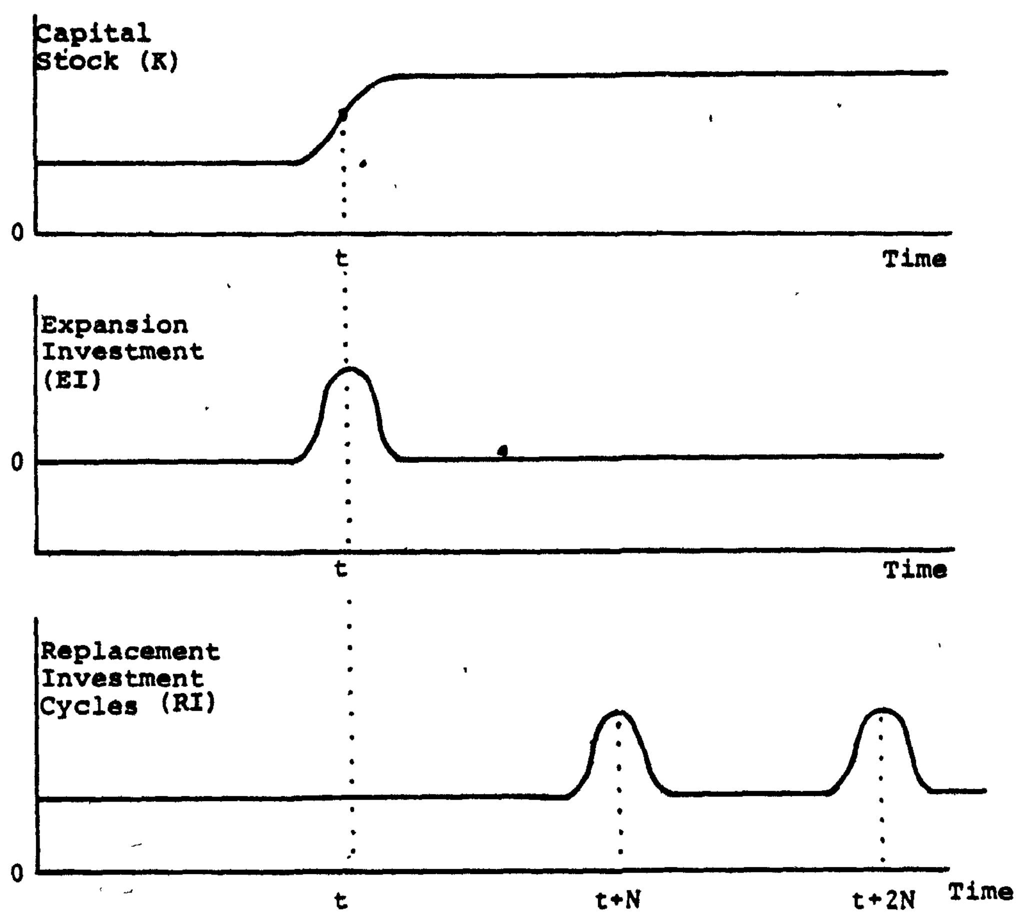


FIGURE 2-1

Generation of Reinvestment Cycles Over Time subsequent reinvestment cycles. As firms generally replace less of their assets when they reach the end of their productive lifetime, the cycles will become more and more damped.

To test whether there were indeed such cycles, Einarsen (1938a) undertook a well-controlled empirical study of the Norwegian shipping industry, using quarterly time-series data for the long period extending from 1883 to 1932. His results confirmed the existence of the reinvestment cycle. He found heavy concentrations of ship replacements every 9 years and 19 years, with the latter being most pronounced. His study of a single industry provided powerful evidence for the existence of such cycles. He did not, however, reproduce the same type of study for other industries, nor did he attempt to correlate it with business cycles. Since conditions are not the same in different industries, any extension of these results to other industries should be done with caution. Nonetheless, it is significant that the periodicity of the cycle remained stable in spite of the fact that this was a period of radical technological change for the shipping industry, one that saw the transition from sailing ships to steam ships.

Another significant--though overlooked--empirical result of his study was his finding that the bulk of the replaced ships were not scrapped by their owners. Instead they were sold to other owners who continued them in service. Clearly, at the industry level the replacement process is not tied directly to the retirement process of any individual firm.

> "Rather far-reaching consequences arise from the fact that the capital instruments in many cases do not pass directly from the first owner to the scrap heap, because there will be no direct connection between the

breaking up of old ships and the construction of new ones. ... Consequently, we cannot measure the replacement activity by comparing the magnitude of new constructions with that of those broken up, concluding that the difference is replacement. The breaking up does not cause any direct demand for new constructions and the constructions do not automatically lead to breaking up of old ships." (Einarsen, 1938a, pp. 49-50).

This phenomenon led him to introduce the distinction between "replacement", which implies the simultaneous retirement of the replaced assets and "reinvestment", which implies replacement of an asset without an accompanying retirement of the old asset. Hence his preference for the term "reinvestment cycle" as opposed to "replacement cycle". Einarsen also found that shipowners replaced only about half of their older ships. The retirement of a ship by an owner (whether sold to another ship-owner, scrapped or wrecked) was not followed by a replacement with a newer one half of the time.

These findings are significant for the theory of replacement. They imply that reinvestment cycles are damped and tend to become less visible over time. Further, they imply there is no duality between replacement investment and depreciation (or retirement). Clearly, Einarsen's study indicates that there may be contextual and dynamic considerations involved in the replacement process to which we shall turn later.

3. The Neo-Classical Theory of Replacement: Jorgenson's Proportional Replacement Hypothesis (PRH)

Most empirical studies of investment since the early 1960s have been based on variants of the neoclassical theory of capital accumulation, which Jorgenson (1963-1974) explored by building on earlier work by Lutz (1951), Hirschleifer (1958), Haavelmo (1960) and Koyck (1954). According to this theory, gross investment (GI) can be partitioned into two distinct components: expansion or net investment (EI) and replacement investment (RI). Expansion investment is viewed as a lagged adjustment by the firm to deviations between its desired and actual stock of capital (K*-K) through time or to changes in the former. Desired capital stock in turn, is a function of output and the user cost of capital services. Replacement investment (RI) is viewed to respond to an entirely different mechanism. It is treated as a constant function of the firm's (and at the macro-economic level, the economy's) stock of capital, lagged one period:

$$RI_t = \delta K_{t-1}$$

where δ is a constant and stands for the rate of economic depreciation. The theoretical basis for this treatment is provided by Jorgenson (1965; 1971; 1974) and by Jorgenson and Stephenson (1967). It is summarized in the proportional replacement hypothesis (PRH).

According to Jorgenson, fixed assets deteriorate at a constant exponential (geometric) rate. The deterioration takes the form of "output decay" where the physical productivity (efficiency) of the machine declines constantly as a result of wear and tear until at some point its productivity drops to zero. In other words the productivity of the machine decays like radioactive isotopes. The exponential rate of deterioration of the firm's capital stock is accompanied by an equivalent decline in the monetary value of the machine. Jorgenson assumes no technical change, no obsolescence, no uncertainty, and neither installation nor adjustment costs. Since firms must continually maintain intact their productive capacity, they are seen as constantly replacing the depreciated capacity by new capacity. This is accomplished by a continual positive flow of replacement investment, which Jorgenson treats as the dual of depreciation (D). By explaining the rate of decline in the efficiency (E) of assets over time (by say a mortality distribution or output decay) he can provide an "economic" explanation of the rate of replacement. Implicit in this construction is the hypothesis that there is no time lag between the time the firm's assets decay and their replacement. Thus, if output decay leads to an increase in desired (potential) replacement investment, the gap is immediately filled. In other words, while distributed time lags are present in the firm's expansion investment there are evidently no such lags in its replacement investment. Jorgenson justifies this specification as being essentially appropriate for a "recurrent event".

Based on this framework, Jorgenson showed that the rate of replacement investment will approach a constant fraction of capital stock (δ) as long as capital decays or grows at a constant rate in a probabilistic sense. This result can hold for constant, growing or declining capital stock and is independent of any particular age distribution of capital stock.

Crucial to this result is the form of output decay or depreciation.

As long as capital depreciates at an exponential rate, replacement investment will tend to become a constant proportion of capital stock. However, if capital does not decay at an exponential rate but rather at some non-exponential rate (such as the "one-hoss-shay" pattern, for example) then the age structure of the economy's capital stock will matter. Still as long as (i) the age structure remains unchanged or (ii) gross investment grows at a constant rate replacement investment will tend to become a constant fraction of capital stock.

A cursory look at the rate of investment spending in any economy is sufficient to show that the condition that gross investment and hence capital, grows at a constant rate has never been observed. Feldstein and Rothschild (1974) have shown that actual variations in the rate of growth of investment in the U.S.A. are sufficient to generate significant cycles in the rate of replacement investment. Jorgenson, however, never relied too much on this condition to prove his point.

His justification for using the PRH in his own work on investment has rested on two key grounds. First, that there is no direct evidence of changes in the age structure of capital stock. He has made much of the "indirect" evidence furnished by Meyer and Kuh (1957) who found no "echo effects"; implying that the age structure was found to have no impact on the rate of investment[5]. Second, he suggested most empirical evidence on the decline in the resale values of used capital equipment (primarily vehicles and trucks) supports his assumptions that capital goods depreciate

5 A direct implication of this result is that capital goods follow a geometric (exponential) mortality distribution.

at a geometric (exponential) rate. Both of these supplemental sources of evidence need to be clarified.

Meyer and Kuh (1957, pp. 91-100) as part of their extensive study of the determinants of investment, tested Einarsen's hypothesis of reinvestment cycles and the associated "echo effect" for 15 2-digit SIC manufacturing industries in the U.S.A. during the period 1946-1950. They assumed that bunching of investments and subsequently of replacements would be associated with a variation in the average age of physical assets. The older the existing capital stock of an industry, the greater will be the corresponding levels of replacement investment. In the context of both a profit model and a sales model, they regressed the rate of gross investment to gross fixed assets as the dependent variable on accumulated depreciation reserves divided by gross fixed assets as the independent variable. Since there are no direct data on the age of assets, they assumed that accumulated depreciation reserves should adequately reflect the relative age of assets.

If indeed there are "echo effects", they reasoned that there should be a direct, positive relationship between gross investment and age. Again since there are no direct data on replacement investment itself they assumed that surges in replacement should show themselves in surges in overall gross investment. Implicit here is the assumption that expansion and replacement investment are essentially independent of each other. Their basic hypothesis was that gross investment is positively related to the age of equipment.

This hypothesis was rejected because, with the exception of textiles and machine tool industries, all other industries showed significant negative partial correlations between age and gross investment. Meyer and Kuh (1957) explained their negative cross-sectional results by invoking the "senility effect" according to which less dynamic firms have lower rates of investment and hence higher average age of equipment while more dynamic (and growing) firms which have higher rates of investment will show a lower average age of equipment. These supplemental hypotheses are far from Jorgenson's mechanistic notions.

Meyer and Kuh were careful to defend their findings against possible criticism. They were aware that the use of gross investment as the dependent variable was not the most appropriate, because what they were really testing for is replacement investment. Also, the use of accumulated depreciation reserves as a proxy for age may be inadequate and "perhaps the variance of the age distribution of a firm's equipment should have been included as an additional independent variable." They are also aware that in principle, a better test would be based on time-series analysis rather than cross-sectional analysis, which they used. Nonetheless, they conclude that "echo effect" theories of investment "have been decisively rejected by our statistical findings."

That the amount of replacement investment and the average age of capital stock are negatively correlated however, holds <u>no</u> direct implication for the presence or absence of "echo-effects." As Nickell (1978, p. 122), for example, clearly demonstrates, there is no basis for the belief that "echo effects" and the age structure of capital stock should be related in the first place.

"For example, it may be imagined that potential replacement would increase with the average age of the capital stock on the simple argument that the older the capital stock, the more needs replacing. Unfortunately, the existence of echo effects provides no such implication and consequently their existence is neither confirmed nor denied by the discovery that there is no systematic relationship between the average age of capital stock and the amount of potential replacement (or actual replacement for that matter)."

All that Meyer and Kuh's results may indicate is simply the fact that a positive gross investment program in an industry leads to a shortening of the average age of the stock of capital. One may ask why Meyer and Kuh (1957) did not take their own advice and rely on time-series data for confirmation of the "echo-effect":

"a complete test of the echo effect should be based on time series in addition to cross-section analysis. It might turn out, for example, that while different firms within a cross section are habituated to given investment rates and equipment ages, an increase through time in the age of a given firm's capital stock would cause an increase in that firm's investment rates."

We should also note that if net and replacement investment are not independent, then higher rates of expansion investment may be associated with lower rates of replacement, and vice versa. Such connections may be, for example, due to financial, capacity and adjustment constraints, whereby firms may be unable to maintain concurrently high rates of both expansion and replacement investment. In fact, firms may alternate the two types of investment spending which leads to a smoothening over time in their rate of gross investment. To the extent this is true, the dependent variable (gross investment) employed by them will fail to pick up variations in replacement investment.

We must conclude from these considerations that Meyer and Kuh (1957) failed to detect the absence of the"echo effect." This holds important implications for Jorgenson's view that the replacement investment is a mechanical constant of capital stock. Furthermore, as Rowley and Trivedi (1975, p. 17) observe (a) Meyer and Kuh's finding of the "senility effect" is contrary to a mechanistic interpretation of replacement; and (b) in their subsequent work, both Meyer and Kuh have separately treated gross investment spending as if there is no adequate empirical foundation for explicitly partitioning them. In this context, one is hard pressed to understand why Jorgenson has made so much of Meyer and Kuh's results and why he has completely ignored the most comprehensive study on "echo effects", namely that of Einarsen (1938a,b; 1946).

4. Capital Depreciation Patterns: Discussion of Findings

Evidence on used equipment prices is relevant because in principle, it reflects the pattern of deterioration of capital goods. Since data on actual patterns of deterioration of capital goods--with the exception of Winfrey (1935)--are non-existent, the pattern of decline in the price of capital goods becomes essential in the argument. Jorgenson has justified his assumption of constant exponential decay on a number of studies of used moveable assets namely, those by Griliches (1970) on used farm trucks, Cagan (1971) and Wykoff (1970) on used automobiles and Hall (1971) on used half-ton pick-up trucks. These studies suggest that after the first year, prices of used equipment *tend* to decline at an exponential rate. However, the pattern of deterioration is not sufficiently exact to allow for a decisive acceptance of the hypothesis and the data lead to alternative interpretations. For example, Griliches (1970, p. 198) examining prices of used farm tractors for the period 1937-1958 concludes that "the data *point* to a declining balance depreciation model, with a rate somewhat higher in the 1930s than in the 1950s." Cagan (1971, pp. 225-6) finds that exponential decay provides a "satisfactory approximation" to used car prices but on the other hand observes that the average rate of depreciation tends to change slightly from one model year to another. Wykoff (1970, pp. 171-72), also for automobiles, finds that "after the first year cars do appear to decay exponentially" but he goes on to say that "first-year depreciation is almost twice the rate in succeeding years" and concludes that "depreciation rates for automobiles are not exponential". He states further, that "the assumptions economists have been making in studies of ... capital equipment are very strong, and in some cases probably sufficiently far from the mark as to render the results questionable." Hall (1971, pp. 240-71) is more sanguine in examining the prices of Ford and Chevrolet half-ton pick-up trucks for the period 1961-67 when he employs a more comprehensive design, taking into account (in addition to age) the prices of new models and technical change. He concludes that "... the geometric function is probably a reasonable approximation for many purposes. Certainly, there are no grounds for believing that any very serious error has been committed by using a geometric deterioration function in calculating capital stock."

Feldstein and Rothschild (1974), major critics of the Jorgenson position, have examined analytically all the conditions that need to be met if Jorgenson's hypothesis is to hold at the aggregate level. They find that replacement investment will be a constant fraction of capital stock if either A1) all pieces of capital stock deteriorate at the same constant exponential rate or if A2) the entire capital stock (and therefore net and gross investment) grow at a constant exponential rate. To the extent that all pieces of capital stock do not deteriorate at the same rate, the PRH will still hold provided that A1) each machine deteriorates at a constant exponential rate and A2) the composition of capital stock by type of durability remains constant.

They begin by showing that capital goods in the economy exhibit different deterioration patterns:

> "It seems hardly necessary to argue that there are differences in the deterioration patterns of capital goods. Everyone knows that computers become obsolescent more quickly than typewriters, that Volkswagens depreciate less quickly than Corvairs, that light fixtures outlast the lightbulbs in them." (Feldstein and Rothschild, 1974, p. 400).

Any engineer or accountant will agree that different types of capital goods have different lifetimes. Winfrey's (1935) study, the only direct and comprehensive study of lifetimes and patterns of depreciation of durable fixed assets ever undertaken, analyzed 176 different groups of assets. He found that assets are characterized by 18 distinct mortality distributions. The United States Treasury Department's Bulletin F indicates a wide variety of average lives for different assets. Clearly machines or equipment do not last as long as the structures and plant in which they are housed.

Table 2-1 shows the service life assumptions used by Business Economic Analysis (BEA), U.S.A. Department of Commerce, for the estimation of capital stock. Surely if all types of capital goods depreciated at the same rate it would not have been necessary for the Department of the Treasury and thousands of business corporation executives and accountants to devote so much time and resources to establishing such service life guidelines.

TABLE 2-1

SERVICE LIFE FIGURES EMPLOYED BY THE U.S.A. DEPARTMENT OF COMMERCE BUREAU OF ECONOMIC ANALYSIS (BEA) FOR CALCULATION OF CAPITAL STOCK DATA

Type of Asset	Life (Years)
Fixed nonresidential business capital	
Furniture and fixtures	15
Fabricated metal products	18
Engines and turbines	21
Tractors	8
Agricultural machinery (except tractors)	17
Construction machinery (except tractors)	9
Mining and oil field machinery	10
Metal working machinery	16
Special-industry machinery, n.e.c.	16
General industrial, including materials handling, equipment	14
Office, computing, and accounting machinery	8
Service-industry machines	10
Electrical machinery	14
Trucks, buses, and truck trailers	9
Autos	10
Aircraft	9
Ships and boats	22
Railroad equipment	25

Type of Asset	Life (Years)
Instruments	11
Other equipment	11
Industrial buildings	27
Commercial buildings	36
Religious buildings	48
Educational buildings	48
Hospital and institutional buildings	48
Other nonfarm nonresidential buildings	31
Railroad structures	51
Telephone and telegraph structures	27
Electric light and power structures	30
Gas structures	30
Other public utility structures	26
Farm nonresidential buildings	38
Petroleum, gas, and other mineral construction and exploration	16
All other private nonresidential structures	31
Residential capital	
1-to-4 unit structures	
New	80
Additions and alterations	40
5-or-more unit structures	
New	65
Additions and alterations	32
Mobile homes	16
Nonhousekeeping	40
Equipment	11
Consumer durables	
Furniture, including mattresses and bedsprings	14
Kitchen and other household appliances	11
China, glassware, tableware, and utensils	10
Other durable house furnishings	10
Radio and television receivers, records, and musical instruments	9
Jewelry and watches	11
Ophtalmic products and orthopedic appliances	6
Books and maps	10
Wheel goods, durable toys, sports equipment, boats, and pleasure aircraft	10
Trucks, trailers, and recreational vehicles, and parts and accessories	8
Autos	10

Type of Asset	Life (Years)
Fixed nonresidential government-owned capital	
Equipment	15
Industrial buildings	27
Educational buildings	50
Hospital buildings	50
Other nonresidential buildings	50
Highway and streets	60
Conservation and development structures	60
Sewer structures	60
Water structures	50
Other nonresidential structures	50

Feldstein and Rothschild (1974) further observe that deterioration patterns are not the same even for the same class of assets. They quote Griliches (1970), Cagan (1971), Wykoff (1970) and Ramm (1971), all of whom find variations in the average rate of depreciation of cars--across both makes of cars and time. For example Wykoff (1970, p. 172) found that U.S. models depreciate faster than imports; that small U.S. cars depreciate faster than large U.S. cars. Clearly, capital goods exhibit different patterns of deterioration. If this is true, the only way that capital stock will exhibit exponential decay at the aggregate level and therefore lead to a rate of replacement investment which is a constant fraction of capital stock is when both conditions (A1) and (A2) are met.

A2 requires that the composition of capital stock remains constant. Unfortunately there are no direct data on the age composition of capital stock. However the available proxy data (based on certain assumptions and undertaken at a considerable level of aggregation) do show changes in the age composition of capital stock. The U.S.A. Department of Commerce (1971, p. 109) shows that the age distribution of capital stock has changed markedly. In 1925, 34.4% of the gross capital stock was less than 9 years old while the comparable figures were 23.1% in 1938, 52.5% in 1958, 50.7% in 1963 and 54.5% in 1968. In another study, the U.S.A. Department of Commerce (1969) shows that the mean age of non-farm gross capital stock changed from 14.7 years in 1925 to 17.7 in 1945 and to 10.2 in 1968. Table 2-2 summarizes these data for equipment and structures.

TABLE 2-2

MEAN AGE OF U.S.A. NON-FARM GROSS CAPITAL STOCK
(in years)

	Equipment	Structures	Equipment and Structures
1925	9.0	17.3	14.7
1935	10.8	19.1	16.7
1945	9.1	21.7	17.7
1955	6.5	17.9	12.9
1965	6.7	14.8	10.9
1968	6.2	14.2	10.2

Source: USA Department of Commerce (1969) "Fixed Business Capital in the USA, 1925-68" *Survey of Current Business*, February, pp. 20-27.

To the extent that the assumptions underlying these calculations of mean age distributions are correct they provide indirect proof of a change in the age composition of capital goods. Changes in the rate of capital investment also affect the mean age of assets. For example, mean ages rose during the 1930s and 1940s when the rate of investment was low and fell during the 1950s and 1960s when it was high. Although Grosse, Rottenberg and Wasson (1966, p. 35) seem to suggest that changes in the age composition are entirely due to changes in the asset composition of gross capital stock, we can take a more restrained view that changes in the mean age of capital stock are due to both the changing rate of capital formation and the changing composition of capital stock. Decomposing the two effects is difficult, perhaps impossible. Further evidence that the asset composition has been changing has been supplied by Aaron, Russek and Singer (1972a;b). They found that revisions in U.S.A. tax laws (Tax Reform Act of 1969 and the Revenue Act of 1971) encouraged equipment investment relative to investment in housing and plant in recent years. Furthermore, the recent spending boom for computers and automated office-and-data-processing equipment is definitely affecting the age composition of assets as can be seen in Johnson (1981) and Schnorbus (1985) for example.

Most studies of second-hand prices show a sharp drop in the value of assets, reflecting a depreciation rate at least twice as high in the first year as compared to later years. Jorgenson (1974) dismisses this fact by arguing that "prices of new equipment are 'list' prices paid by relatively few purchasers", although it is unclear where this argument leaves measures of gross investment. What the sharp drop in the resale value of an asset after one year of service may reveal is the apprehension of second-hand buyers regarding the quality of the asset. As Eisner (1978) for example points out, it is in the nature of "moral hazard". If the buyer suspects that the reason the first owner is getting rid of the asset so soon is because it is a "lemon"--in the context of imperfect information and foresight--he will demand a premium for the perceived risk he is undertaking. If this is true, it suggests that there are other factors--in addition to output decay--which influence depreciation patterns. Accepting this, however, undermines the validity of using the pattern of decline of used equipment prices as a proxy for the pattern of decline in the efficiency of these assets.

Even if tractors, automobiles and pick-up trucks decay exponentially, one should not generalize the results for all types of assets in the economy. To begin with these are standardized moveable assets with well-organized second-hand markets. What about assets which are difficult to move or custom-built like engineering structures, plants and many types of machinery and equipment, or other moveable but more specialized assets which lack organized second-hand markets? Clearly, installation, transportation and other types of adjustment costs will exercise a significant impact on the resale price of these assets. It is of no surprise that the studies which Jorgenson quotes are limited to vehicles only. Generalizing these results to all types of assets in the economy certainly involves a very heroic assumption.

Feldstein and Rothschild make the useful analytical distinction between "output decay" and "input decay". In the former, the drop in the productivity of the machine is the result of a decline in the output that the machine can give--maintenance, repair and operating expenses remaining constant. In other words, the capital services rendered by the machine decline as a result of use. In input decay, the drop in the productivity of the machine is not the result of a drop in the amount of service it yields. It is due to an increase in the operating and maintenance expense of keeping the machine in proper working order. Depreciation reflects the combined effect of output decay and input decay. To the extent that the drop in resale values of assets reflect an exponential depreciation pattern, it reflects the combined effect of both types of decay. One must not, as Jorgenson does, attribute all of the decline in value to output decay. Furthermore, Feldstein and Rothschild rightly point out that the capital services yielded by a machine also depend on the quality of inputs (and also quality of maintenance, care, etc.) which depend on economic considerations. Thus, "automobiles last much longer and travel many more miles in Israel (where labor is relatively cheap and new cars are taxed heavily) than in the United States. Depreciation patterns, output decay patterns, and, more importantly, the relation between the two, depend on relative prices."

Another realistic account of why the pattern of decline in the resale value of an asset may not reflect the pattern of decay in the asset's productivity is given by Dean (1951, p. 163). An asset's earning power is much more valuable to the owner than is its value based on market selling prices, because (a) many assets are custom made or specially designed for a firm's purposes; (b) the firm knows more about the mechanical condition and performance of its assets than prospective buyers and (c) transfer costs of selling in imperfect markets reduce the market value of the asset.

It also seems sensible to consider alternatives to the PRH. For example, suppose machines, once put in place yield a constant flow of services until some point in the future when the machine comes to the end of its useful life and then breaks down, which is often termed the "one-hoss-shay" assumption. Here there has been no output decay throughout the useful life of the asset, but there probably was input decay. Maintenance and operating costs may have been rising over time, perhaps even exponentially, in which case the depreciation pattern of the asset will reflect exponential decay--even though its physical deterioration pattern is that of a one-hoss-shay (i.e., zero output decay). The fact that the physical productivity of the asset in terms of the output services it yields remained intact throughout its life implies that the owners of the machine did not have to undertake any replacement investment. Feldstein and Rothschild (1974), and more directly Rowley and Trivedi (1975, p. 17) and Nickell (1978, pp. 116-121), show that if the assumption of exponential output decay is replaced by the one-hoss-shay, replacement requirements will not be a constant fraction of capital stock.. Instead one will get fluctuations in replacements similar to Einarsen's pure replacement cycles. Moreover, Nickell (1978) has shown that the same result will occur for any non-exponential decay function unless the age structure of the capital stock remains constant.

In a study of 21 2-digit SIC manufacturing industries for plant and equipment, Coen (1975) found that the services provided by about 50% of plant and 12% of equipment in manufacturing resemble those of the one-hoss-shay. The services of another 28% of plant and 44% of equipment decline linearly to zero over the service life. At least 78% of plant and 56% of equipment in the U.S. manufacturing sector exhibit non-exponential decay. Clearly then, for assets with non-stochastic lives the above results point to the rejection of the exponential decay hypothesis and of course its dual, the PRH.

Finally, we must remember that service lives of assets are averages. Similar assets will not all collapse at the same time. Some will collapse before the average life, others after. Underlying the mean service life of a given asset or group of assets is a distribution of retirements. If this distribution is exponential, i.e., if the probability that a piece of equipment will be replaced after a given length of service exhibits an exponential pattern it does not matter if individual assets exhibit a one-hoss-shay pattern of decay, because as a group, their exponential retirement distribution will lead to an exponential pattern of replacement. Winfrey's (1935) empirical study based on surveys of 176 different groups of assets rejects this possibility. Only one of Winfrey's 176 retirement distribution looks remotely like an exponential distribution. What this summary of evidence and research reveals is a simple fact. There is neither strong theoretical nor empirical grounds to support the proposition that capital decays exponentially and that replacement investment approaches a constant fraction of capital stock.

5. Some Further Criticism of Jorgenson's View of the Replacement Process

There are other major aspects beyond those cited in this survey of evidence and research. These should be noted: (1) the assumed equality between replacement investment spending and desired replacement; (2) the assumed equality between desired replacement investment and economic depreciation; (3) the effect of tax factors on economic depreciation and consequently replacement investment.

Implicit in Jorgenson's formulation of the replacement process is its specification that there is no lag between the time that the need for replacement arises and the time it is filled. He assumes that firms can forecast with perfect foresight so actual replacements coincide with requirements. Thus, desired replacements are equal to actual replacements. A priori, there are many reasons why this may not be the case. First, there are adjustment costs involved. Studies by Eisner and Strotz (1963), Gould (1968), Rothschild (1971) and Treadway (1969), among others, have all shown that firms plan and carry out their investment programs in such a way so as to take into account adjustment factors and their attendent adjustment costs. Second, firms may lack the liquidity to carry out replacement. For example, Coen (1971) has provided empirical evidence which shows that lack of liquidity tends to delay the execution of investment programs whereas availability of liquidity tends to accelerate their execution. Third, as Helliwell (1976) points out, firms may not feel compelled to replace aging capital goods when there is a decline in output demand and they operate with excess productive capacity. The PRH implies that firms will always carry out a positive level of replacement investment even during years of declining demand. Fourth, machines do not just die once they reach a given age. In fact machines are often replaced for economic reasons long before they break-down for mechanical reasons. On the other hand, through a continuous maintenance policy any machine can be kept in service permanently, the only question is at what price! Replacement is clearly postponable too! Such flexibility has been known to economic theorists as far back as Aftalion (1908) Akerman (1928), Einarsen (1938) and Bain (1939). During recessions when demand for capital services is low, firms may postpone their replacements until the period of recovery and expansion. A list of reasons why actual replacements may not match desired replacements would include tax factors, interest rates, fluctuations in the level of business confidence, competitive interactions, and technological change.

Another assumption implicit in his formulation of replacement is that desired replacements (and actual replacements) are equal to economic depreciation. Depreciation is used in the economic literature at least in three senses. The first of these is <u>accounting depreciation</u>, used for accounting and tax purposes. It consists of generally accepted or legislated methods of allocating the cost of physical durable assets over time, in order to enable the firm to recover financially its investment costs for book or tax purposes. Depreciation in this sense is a convenient way of spreading cost and is not directly tied, nor is it a direct reflection of wear and tear or obsolescence[6]. The second sense in which the term is used is in a physical sense, and is equivalent to the concept of depletion. We shall call it <u>physical depreciation</u>. It refers to the decline in a machine's physical capacity to render capital services. It

[6] For a fuller discussion of depreciation for accounting and tax purposes see Matziorinis (1979).

occurs as a direct result of use in production which leads to wear and tear, and as a result of the toll over time of physical factors such as weather, rust and accidents. This definition is akin to the engineer's conception of depreciation and is equivalent to what Feldstein and Rothschild (1974) mean by the term <u>output decay</u>. It is in this sense that Jorgenson uses the term in all his work. For example:

> "At each point of time durable goods decline in efficiency, giving rise to needs for replacement in order to maintain productive capacity. For any given durable good the price of acquisition declines, reflecting the current decline in efficiency and the present value of future declines in efficiency; the decline in price is <u>depreciation</u> of the durable good." (Jorgenson 1974, pp. 189-190).

The third sense in which depreciation is used is what we may call <u>economic depreciation</u>. Economic depreciation is the decline in the value of a machine as a result of <u>all</u> factors combined. It certainly reflects the decline in the physical productivity of the machine as a result of wear and tear through use. However, it also reflects the decline in value as a result of increasing operating and maintenance costs. As the machine is used, its physical capacity to produce may remain intact, but it may require increasing amounts of maintenance and repair costs, consume an increasing quantity of materials including labour and therefore require an increasing operating cost. This is what Feldstein and Rothschild (1974) call <u>input decay</u>. Although input decay does not affect the physical efficiency of the machine, it affects its economic efficiency, because its continued use involves higher costs. The value of a machine will fall with the reduction in the level of quasi-rents that it yields. If the demand price of the machine on the resale market is the present value of such future quasi-rents this will result in a decline in price.

Economic depreciation will be affected by obsolescence which stems from two separate processes: (1) technical change which affects the relative economic efficiency of new machines and (2) market change which affects the composition of output demand and the selling price of the firm's output. Technical change can lead to the introduction of "better" machines, where "better" implies they are more efficient from an engineering standpoint or require fewer operating and maintenance expenses than the older ones. It may also lead to the introduction of "better" products, where "better" now implies they are more efficient in satisfying the needs of consumers. In either situation, change will lead to the obsolescence of the firm's existing machines. They cost more to operate, produce less than newer alternatives, or the market is willing to pay a smaller price for their use now that better products are on the market. In the second process of obsolescence, market change affects the selling price of the firm's output and thus the revenue productivity of its equipment. Such change could involve changes in consumer tastes, changes in market structure or competitive conditions. Even though the physical productivity of a firm's equipment remains intact, the revenue from this equipment may fall.

There is also a significant spatial aspect of change. What American multinationals like RCA, Zenith, Litton, General Electric, Honeywell and Apple have been doing throughout the last two decades is replacing their older capacity in the U.S.A. by newer capacity in Singapore, Taiwan and South Korea. From the American economy's point of view this amounts to non-replacement.

6. Final Comment

Two prevalent "mechanistic" views of the replacement process are represented by Einarsen's (1938) hypothesis of "reinvestment cycles" and Jorgenson's (1965, 1974) proportional replacement hypothesis (PRH). As we have seen the two views compete for they provide different explanations of replacement investment. In Einarsen's view, replacement investment expenditures exhibit a periodic cyclical pattern known as "echo effects". These echos or reinvestment cycles arise because the average length of life of assets is a technologically-determined constant. If for any reason there has been a heavy concentration of investment in any period, it will give rise to a perpetual stream of replacement cycles, where the average interval between any two successive cycles is equal to the technologically determined average useful life of assets. Implicit in Einarsen's formulation is that assets exhibit the "one-hoss-shay" pattern of depreciation, that is, they yield the same level of capital services during their life when suddenly, at the end of their life such services drop to zero.

In Jorgenson's view, replacement investment expenditures can be approximated by a constant fraction of capital stock. As long as the capital stock is constant, rising or falling at a constant rate, there will be no fluctuation in the level of replacements from one time period to the next. This pattern arises because the process of depreciation and/or deterioration of fixed assets is technologically given. Fixed assets are assumed to have a constant average life and to depreciate at a constant exponential rate like radioactive isotopes.

Although these two models give rise to different conclusions, they share the same underlying foundation which is a hypothesis in itself, namely, that the depreciation process of capital equipment is mechanically driven and is, therefore, exogenous to any other economic variables. Such models imply that the average length of life and the rate of depreciation of capital goods are constants and invariant to economic variables such as interest rates, prices, demand for output, capacity utilization, rate of technological change, obsolescence, tastes, competitive conditions, liquidity, tax variables, expectations and business confidence.

We have shown that the available theoretical, empirical and statistical evidence does not support their assumptions nor their results. Results were discussed which clearly show that depreciation and replacement are economic variables and respond to changes in the values of other economic variables. In the next chapter, we discuss this richer perspective.

CHAPTER THREE

NON-MECHANISTIC VIEWS OF REPLACEMENT INVESTMENT: A CRITICAL REVIEW OF THE LITERATURE

1. Introduction

In this chapter we turn to the examination of economic explanations of replacement and discuss pertinent empirical findings. All the available evidence suggests that replacement investment (far from being a mechanistically-determined constant) is, in fact, a variable, endogenous to the economic process and responsive to certain economic factors. The notion of replacement is examined from both the "narrow" and "dynamic" perspectives adopted in the literature and a reconciliation between the two approaches is suggested.

2. Early Discussion

Three distinct lines of development are apparent in early economic literature. We can illustrate these by looking again at Einarsen (1938) before assessing some views of Bain (1939) and, finally the more formal maximization criteria. Although Einarsen (1938) developed the reinvestment cycle hypothesis to its logical extreme, he also provides a comprehensive account of the possible role of economic variables in the replacement process. He was aware that (a) retirements did not necessarily lead to replacements, (b) only a fraction of capital stock is replaced by firms and (c) the length of life of assets was not constant for firms could postpone or accelerate their replacements within certain limits. As a result of these intervening factors, successive reinvestment cycles will tend to become more and more damped which would imply that in the long-run, echo effects tend to disappear. Thus Einarsen looked for factors which would offset the tendency toward dampening, and would maintain the amplitude and consequently the longevity of the reinvestment cycles. His vision of dynamic behaviour was eclectic as the following quotations reveal:

1. "'Secondary Reinvestment Cycles'... come into existence because the reinvestment during the business cycle will be concentrated during revival and prosperity. The secondary waves are due to ... the fact that the actual doing of the replacement may be moved forward or backward in relation to the normal reinvestment time. ... Further we have assumed that the firms come to their resolutions concerning replacement independently of each other. In reality, however, we have to consider the general optimistic state of mind of the firm's management during revival and prosperity and the pessimistic state of mind prevailing during depressions. We must also consider the possibility of mass psychology."

2. "Postponement of the Reinvestment. ... The replacement of machines, which during a depression reach their normal replacement age, is to a large extent neglected, as the machines are either kept in use longer than usually or they go out of use without being replaced. ... The replacement age depends on whether it is profitable any longer to keep the machine in use owing to the rising age expenses. There will then always be a physical possibility to keep machines in work some time beyond their normal replacement age. ... Economically this possibility for postponement is expressed in the fact that the replacement expenses are "postponable costs". In bad years firms will reduce the replacement budget. The postponing of the replacement may be motivated by lack of capital; firms need all resources to cover their current expenses. But even if capital may be provided, it may happen that firms prefer to postpone replacement because the market is glutted with goods, so that there is not full employment for the machine. Besides, postponing of the replacement may naturally be motivated by the general pessimism during a depression. One is inclined to view the future prospects of the branch so pessimistically that one does not only omit to start new enterprises, but even neglects the maintenance of the old machinery."

3. "Shortening of the Reinvestment Period. ... Some capital instruments will be replaced before they normally should be ripe for replacement. A factor which is involved here is the technical and economic progress. Usually, new machinery will be larger and technically more perfect than the replaced one. It will have greater capacity and work cheaper. When, therefore, during a revival a whole series of firms within a branch of industry is replacing their machinery by larger and better machinery, other firms within the same

branch will have to replace as well, even if the normal replacement age of their machines is not still reached." (Einarsen, pp. 62-65).

As Akerman (1928) pointed out, this more complex picture weakened the concept of pure echo effects:

"When the elasticity of the reinvestment demand is taken into account, the importance of the theory is much reduced as the present business cycle will then dominate over the influence that previous cycles may have on the development of the reinvestment group." (p. 161)

Thus, reference to the "secondary" reinvestment cycle is not only at variance with Einarsen's initial model of pure reinvestment cycles, but rather provides an alternative to this theory. What is more, the three quotations reveal key components of a "cyclical theory of replacement", one based not on exogenously given mechanical parameters but on endogenously determined economic variables.

Bain (1939), in the second line of development, also argues that the average life of a capital good is determined by economic factors well before technical necessity becomes present. He states that:

"the economic life of equipment is analytically a variable ... If little or nothing is spent in maintaining a machine, the period during which it will render service may be extremely short. If a sufficient amount is spent on maintenance and repair, it can conceivably be made to serve forever. The reason that equipment is replaced at some particular time cannot rationally be that it has ended its "physical life", but that it is no longer as economical to the firm as a replacement would be." (Bain, p. 80)

His simple theoretical model assumes that the firm will engage in a replacement policy consistent with the maximization of the value of the enterprise. He shows that the firm will continue using existing equipment as long as, ex ante, it is cheaper to operate equipment in use than to purchase and operate replacement equipment. His analysis serves to illustrate that the economic life of equipment is a variable, the final value of which is determined through cost and profit calculations. He also identifies the type of variables necessary for this calculation and shows that in a world of imperfect foresight it is the values which firms expect variables to assume which counts, and in this context the timing of the replacement has a large potential range of values. Expected output, interest rates, the level of capital goods prices and the rate of technological obsolescence are identified as being crucial determinants of the timing of replacement, whereas the role of interest rates may be marginal and overshadowed by obsolescence. While pro-cyclical fluctuations in the price of capital goods are likely to lead to a counter-cyclical rate of replacements, other variables are not constant. In fact since the fluctuations in capital goods prices are minor compared to fluctuations in expected output demand, the latter influence may overshadow the influence of capital-good prices. Bain also argues that, in a world of imperfect foresight, the profit maximizing firm will be induced to postpone replacements until after the recovery begins.

> "With the emergence of the recovery phase--i.e., after the turning point is passed--the shift in expectations of output and the reduction of risk factors, coupled with lagging capital-goods' prices and interest rates, may result in the abrupt termination of many economic lives. This pattern emphasizes clearly the fact that the life of equipment, a function of ex ante data, is potentially very sensitive to movements in the business cycle, and that a hypothetical average durability of capital may not carelessly be adduced as a cause for turning points in the cycle. The cycle in investment should instead potentially be regarded as a generated rather than a generating phenomenon." (Bain, p. 87)

In his treatment, Bain anticipates later views of Feldstein and Rothschild (1974) by treating the useful life of fixed assets as economically-determined so that replacement investment will be a phenomenon endogenously generated by the fluctuations in economic activity and is not independent of them. Here replacement investment is likely to be greatest just after the up-turn of the business cycle. Tugan-Baranowsky (1901), Spiethoff (1902), Aftalion (1908), Clark (1923) and Akerman (1928) argued along similar lines. They differ as to their explanations of the channel through which replacement is determined, but share the same view that replacement investment will be related to the business cycle, rising during expansions and falling during recessions[1].

The third line of development was elaborated by Taylor (1923), Hotelling (1925), Wicksell (1934), Preinreich (1938, 1939, 1940) and Terborgh (1949). They approach replacement independently of the business cycle but keep the view that replacement is an economic decision whose timing and value depends on profit-maximizing economic criteria. Their theoretical results show that under steady state conditions with static expectations, the "optimal" life of equipment will be a function of three variables: (a) the rate of interest, (b) the rate of technical progress and (c) the rate of change of capital goods prices. In particular, the rate of replacement investment is found to be negatively related to interest rates, positively related to the rate of technical progress (obsolescence) and negatively related to the rate of change of capital goods prices. Such

[1] See Einarsen (1938) for a complete account of their views.

results suggest some of the key variables involved under static conditions for the individual firm but for replacement at an aggregate level under dynamic conditions, they fall short of an adequate explanation of the replacement process[2].

3. Replacement as an Endogenous Economic Process

Since the early 1970s a number of studies have been conducted to explain the observed fluctuations in the level of replacement investment. As mentioned earlier, no direct data on replacement expenditures by firms exist. However, there are aggregate data on anticipated and actual replacement outlays, which have been collected by McGraw-Hill in the U.S.A. continuously since 1950, and in Canada by the Department of Regional Industrial Expansion since 1977[3]. Tables 3-1 and 3-2 show the proportion of capital investment expenditures intended for "replacement and modernization" in the manufacturing sectors of the United States and Canada. In the U.S.A. during the period 1950-1987, replacement and modernization expenditures account for about 58% of total capital expenditures in the manufacturing sector. In Canada, during the period 1977-1985, "upgrading and replacement" expenditures have accounted for 36.1% of total spending as compared to 42.5% for expansion. These data also show a considerable variation in these shares. Replacement and

---

[2] See Grosse and Berman (1957) for a discussion along these lines.

[3] McGraw-Hill (1986) and Department of Regional Industrial Expansion, Reports of the DRIE Capital Investment Intentions Survey, 1979-1986.

TABLE 3-1

REPLACEMENT & MODERNIZATION SHARE OF MANUFACTURING BUSINESS

CAPITAL INVESTMENT: U.S.A., 1950-1985

Years	% Share	Years	% Share
1950	57	1970	50
1951	47	1971	53
1952	51	1972	53
1953	52	1973	50
1954	57	1974	50
1955	53	1975	53
1956	N/A	1976	51
1957	48	1977	52
1958	56	1978	52
1959	63	1979	52
1960	69	1980	61
1961	68	1981	62
1962	70	1982	67
1963	68	1983	61
1964	64	1984	65
1965	55	1985	73
1966	52	1986*	74
1967	53	1987*	78
1968	50		
1969	50		

*Anticipated shares.

SOURCE: McGraw-Hill Economics (1986) Historical Capital Spending and Related Data, McGraw-Hill, New York.

McGraw-Hill Economics (1986) 39th Annual McGraw-Hill Spring Survey of Business Plans for New Plants and Equipment, 1986-88, McGraw-Hill, New York.

TABLE 3-2

CAPITAL EXPENDITURE SHARES, BY PURPOSE,

CANADA: 1977-1986

(Percentages)

Years	Expansion Share			Replacement & Upgrading Share	Share, Other*
	Existing Sites	New Sites	Total		
1977	33.1	21.8	54.9	27.4	17.7
1978	32.0	17.6	49.6	31.0	19.4
1979	33.1	12.9	46.0	36.3	17.7
1980	33.9	18.1	52.0	31.4	16.6
1981	36.3	14.1	50.4	33.5	16.1
1982	26.7	15.3	42.0	36.7	21.3
1983	24.9	6.3	31.2	38.8	30.0
1984	26.6	5.4	32.0	46.2	21.8
1985	19.8	5.0	24.8	43.7	31.5

* Includes spending on retooling, conversions, pollution abatement, working environment, among others.

SOURCE: Department of Regional Industrial Expansion, Business Capital Investment Intentions Surveys, April 1977 to April 1985.

modernization has fluctuated between 47% and 78% of total manufacturing capital formation in the U.S.A., and between 27.4% and 46.2% in Canada, for the corresponding period.

Feldstein and Rothschild (1974) and Nickell (1975) have furnished theoretical results while Feldstein and Foot (1971), Eisner (1972), Bitros and Kelejian (1974), Cowing and Smith (1977) and Lioukas (1980, 1982) have all furnished empirical results which seem to show that replacement investment is variable and conditioned by a number of economic variables. Some of these are (a) the level of liquidity within the firm, (b) the level of expansion investment activity undertaken by the firm, (c) adjustment costs, (d) the level of capacity utilization of the firm, (e) the level of gross investment activity, (f) the user cost of capital, (g) the level of maintenance and repair expenditures, (h) the level of interest rates, (i) the rate of obsolescence and (j) the level of anticipated capacity margin requirements. We shall examine analytically these results in the next three sub-sections.

3(i). The Role of the Liquidity Variable

Consistent with Coen's (1971) findings, Feldstein and Foot (1971), Eisner (1972) and Lioukas (1980) provide evidence to the effect that a higher level of cash-flow (i.e., net earnings plus depreciation allowances) is associated with a higher level of replacement outlays. Nickell (1974) provides supporting theoretical evidence. For example, Feldstein and Foot find that each one dollar increase in internal funds is associated with a $0.25 to $0.39 increase in replacement spending while Eisner, using cross-section analysis, finds that it is associated with a $0.15 increase in replacements. Since liquidity is highly correlated with the level of demand for output and the business cycle, it is not certain to what extent it is a causal variable directly responsible for inducing replacement, or a confounding variable picking up the influence of higher demand for output or more favourable expectations on the part of firms. Why funds play this role is not adequately explained.

3(ii). The Role of Expansion Investment

Feldstein and Foot (1971) and Eisner (1972) provide evidence which show that the level of expansion investment is positively associated with the level of replacement spending. The former find a positive correlation ranging between +0.27 to +0.47 while the latter finds a correlation of +0.48. To the extent that this evidence is accepted it implies that many of the variables responsible for expansion investment are also partly responsible for replacement. This provides support for the hypothesis that the two components of investment are not sufficiently different to warrant separate treatment in the literature. Yet oddly enough, Eisner (1972) was not able to find any relation between replacement investment and sales--a crucial determinant of expansion investment in his models. This may be due to the specification of his equation: for example expansion investment may pick up all of the influence of the sales variable or the adjustment lag may have not been properly specified. Further when positive sales expectations emerge, a firm with excess productive capacity may feel more certain about replacing and modernizing existing capacity than about adding to existing capacity.

Other evidence by Bitros and Kelejian (1974) and Lioukas (1980) on capital investments is interesting. They find that the level of gross investment is positively related to the level of retirements (scrappage). To the extent that replacements are associated with retirements, the level of gross investment will be associated with replacements. It should be mentioned here that in the model of Bitros and Kelejian gross investment is a proxy for the rate of technical change and therefore obsolescence. Since technical change is embodied in capital goods they argue that the rate of gross investment will reflect the rate of technical change. This is a reasonable assumption a priori; however, they fail to provide any evidence to support this assumption.

Although a simple positive correlation between replacement and expansion investment as well as between the former and gross investment has been established, Feldstein and Foot (1971) and Lioukas (1980) also provide empirical evidence of a negative partial correlation between the two components. Nickell (1975) provides supporting theoretical support. Feldstein and Foot find that, ceteris paribus, expansion and replacement are substitutes to a certain degree, where each one dollar change in the level of expansion investment is associated with a negative $0.33 change in the level of replacement. This is an interesting result which Eisner (1972) using separate data and a different model was unable to confirm. Clearly, Feldstein and Foot's results are sensitive to the data used. However, to the extent that such a relationship exists, it reveals that while both expansion and replacement respond to many of the same variables, and therefore may often move up and down together, there is still a partial negative correlation between the two.

Two factors dominate explanations of why this relationship may occur: the budget constraint and adjustment costs. First, firms never possess sufficient liquidity to undertake all of their investment projects at the same time. In the context of limited funds, the firm must decide which projects should receive priority in their execution. Evidently, expansion projects are higher in their priority list because if the firm does not expand in time to meet new demand, it will lose market share to other firms. On the other hand, replacement is postponable. The firm can still use its existing capacity to meet current demand, albeit it at a higher cost, and postpone replacements until a later date when the necessity for expansion will have been mitigated. Moreover as Eisner and Strotz (1963), Gould (1968) and Treadway (1969) have shown, adjustment costs are significant in determining the time-path of investment spending. Undertaking replacement or expansion programs involves the firm in considerable executive, administrative, resource and operational outlays. There are limitations to the extent that a firm can manage and operationally undertake many such projects at the same time without excessive dislocation. Therefore it is only natural that firms may want to smooth out over time their investment activities. Since replacement and modernization projects are of the postponable type it is sensible that the firm may give priority to expansion projects and stretch out its replacement and modernization activities.

3(iii). The Role of Capacity Utilization

The role of capacity utilization is less clear. Feldstein and Foot (1971) report empirical findings, supported by theoretical findings by Nickell (1975) that the level of capacity utilization and replacement investment are positively related. Feldstein and Foot find that each 10% point increase in capacity utilization is associated with a 1% increase in the replacement to capital stock ratio. On the other hand, neither Eisner (1972) nor Bitros and Kelejian (1974) were able to replicate this result. The empirical inconclusiveness of these results is in part due to the different roles that capacity utilization is assumed to play by the different investigators.

Feldstein and Foot view capacity utilization in terms of its impact on the firm's production costs. As the level of capacity utilization rises, the firm is induced to bring older and less efficient machinery into operation which increases the production costs (marginal cost). As a result pressure is built up in the firm to replace the less efficient machines by newer, more technically advanced and cost efficient equipment. Hence the rate of replacement investment tends to rise during periods of high capacity utilization. On the other hand, when the firm operates at a lower capacity utilization, it does not use the less efficient machines and feels no urgency to replace them. Even though firms possess higher cost equipment, as long as they are not being used the firm may not bother to replace them. This is clearly, a reasonable proposition.

Bitros and Kelejian (1974) argue that the rate of replacement investment, to the extent that it is related to scrappage, will be positively related to the level of utilization of capital stock and negatively related to the level of maintenance expenditures. They cite Marx (1887) and Keynes (1936) as supporting the view that the length of life of assets will depend on the rate of utilization of equipment along with theoretical evidence to that effect by Taubman and Wilkinson (1970). Similar empirical evidence has also been given by Marris (1964). This too is a reasonable proposition for long-term development as is also the fact that better maintained equipment will last longer and require less replacement. With higher utilization rates, a firm's plant will need more frequent replacement. On the other hand, fluctuations in short-term capacity utilization--which Feldstein and Foot deal with--is a different matter. Bitros and Kelejian (1974) suggest that in the short-run, high capacity utilization rates will discourage firms from undertaking replacements because replacements are accompanied with retirements and retirement of machines is unacceptable to the firm during periods of high capacity utilization. Therefore, their argument implies that firms will be motivated to shift retirements and replacements to periods of lower capacity utilization. Hence they argue that capacity utilization will be both positively and negatively correlated with replacement and this is how they explain their lack of conclusive findings regarding the role of capacity utilization.

This explanation can be criticized on a number of fronts. First, they should either purport to explain the short-run relationship between utilization and replacement or the long-run relationship--but not both. Since their model is a short-run model, reference to the positive long-run effect is out of place. Second, their model estimates the relationship between retirements and capacity utilization. The relationship between retirements and replacements is an assumed one. To the extent that replacements and retirements are not contemporaneously correlated, their findings have nothing to say regarding the connection between capacity and replacements. In other words, it is still possible during periods of high capacity utilization for firms to engage in replacement investment without a simultaneous retirement of the "replaced" capacity. In Einarsen's terminology <u>firms will engage in reinvestment without replacement</u>. To the extent that this is so, one can reconcile the view that replacements and high capacity utilization are positively correlated while retirements and capacity utilization are negatively correlated. Another factor which obscures the role of capacity utilization is that it is inter-correlated with output demand and liquidity. Decomposing the various effects and attributing causal roles is very difficult in this context.

4. Further Discussion of Replacement Models

This section takes a retrospective look at the various hypotheses which have been proposed to explain replacement investment. The objective is to examine the various models "from a distance" so to speak, in order to identify important areas where deficiencies or omissions have occurred. In this context, a number of significant observations may be made.

4(i). The Definition of the Dependent Variable

As has been mentioned above, there is no direct set of data on replacement investment. Nor is there any complete description of the replacement process to be found in published material. We have an incomplete conception of what we are investigating and few observations to clarify what this conception entails. Replacement investment is often conceived in the sense of "like-for-like" replacement which maintains intact the productive capacity of a firm or the aggregate economy. Most investigators are aware that in the real world, such "like-for-like" replacement is rare and that newer capital goods are generally "superior" to the ones being replaced due to technical progress. Since modelling technological change and its concomitant obsolescence is difficult, investigators have fallen back on the more restricted but simpler "like-for like" definition. In over one hundred annual reports of Canadian and U.S. corporations that we examined, the term "replacement" is rarely used! Rather the relevant terms used by business are "up-grading", "modernization" or a combination of the two, "up-grading and modernization".

The view of replacement implied in the professional literature in contrast to its business analogue has five elements. These are: (a) all of the capital stock requires replacement sooner or later, (b) replacement is always accompanied by retirements, (c) replacement occurs purely to maintain intact the productive capacity of capital stock, (d) replacement and expansion activities are entirely independent of each other and thus require independent decisions by the firm, (e) replacement is more or less a routine function, a matter of technical necessity.

When this view is juxtaposed to the evidence observed in practice, one is led to question it in a number of areas. First of all, firms do not replace all of their capital goods as Einarsen (1938) observed. In fact, there are a number of obvious reasons why a firm will not be compelled to replace old assets by new ones. For example, a firm might decide to reinvest its funds in a new line of business or might decide to pull out of production of a given product line altogether. Furthermore, a firm may decide to alter the structure of production and opt to transfer existing facilities, or build new facilities overseas. Technological change and market competition continuously force firms to make adjustments to their structure of production out of a need to maintain their profitability and long-term survival. A number of examples come to mind here: many U.S. firms in the 1960s and 1970s found it necessary to transfer production to countries with lower production costs, such as Singapore, Taiwan, South Korea, Thailand, Mexico, Ireland and Spain, while other U.S. firms, notably in the steel industry have found it necessary to permanently scrap much of their production capacity. Clearly, there is nothing to ensure that firms will always replace existing capacity and in fact they frequently do not. To assume otherwise results is a misleading view of reality.

Second, replacement should not be equated with retirement of assets. Not only Einarsen (1938) but also Lioukas (1980, 1982) and Bitros and Kelejian (1974) found evidence to this effect in the British and U.S.A. electric utility industries. Decisions to "replace" older capacity were not tied to the simultaneous retirement of the older capacity. Among the reasons they cite is uncertainty regarding future growth of demand and the need to maintain sufficient capacity margins to supply peak-load demand. Additional evidence is provided by Terborgh (1949) who suggests that rather than scrap the older capacity firms can still use older capacity, by relegating it to a stand-by function or re-assigning it different functions. In January 1988, Hydro Ontario confirmed its wisdom in "mothballing" and un-mothballing a non-nuclear power station in Kingston. The decision to put the unit in a standby category was obviously a sensible economic decision in line with intertemporal objectives of the public utilities in the province.

Third, replacement is rarely of the "like-for-like" variety. The newer equipment tend to be more productive, so replacement expenditures not only maintain the firm's productive capacity intact but add to it. In this case replacement reduces the extent to which the firm needs to undertake separate expansion.

Finally, if the distinction between expansion and replacement is to have any operational significance, it must differentiate between two separate behavioural functions with different conditioning variables, perhaps by pointing to <u>ex-ante</u> intentions. Otherwise there is no meaning in the distinction and both expansion and replacement should be seen as common ingredients in one behavioural process of gross investment. We face important empirical questions. To what extent are expansion and replacement separate processes? Do firms view replacement and expansion as two distinct areas of activity requiring separate decision functions? There is a different perspective that deserves more attention. Suppose that the relevant decision variables are <u>gross investment</u> and <u>retirements</u>

rather than expansion investment and replacement. Clearly, gross investment brings about an expansion in capacity while retirements bring about a diminution in capacity. There is some evidence to suggest that investment and retirement are not jointly determined in the same decision process. For example, Lioukas (1980), based on findings from the U.K. electric utility industry suggests:

> "Plant decommissioning programmes in the CEGB are constructed from bottom-up proposals submitted by its five regions. The decentralized nature of the process reflects the fact that knowledge of plant behavior and of local constraints is dispersed. On the other hand, new plant investment decisions are reached through a basically centralized process, at Corporate Headquarters." (p. 242)

If retirement and gross investment are the only variables the firm looks at and if retirement and gross investment engage separate decision processes, then replacement investment may lack any behavioural meaning.

Clearly, we know very little about what replacement entails, how replacement decisions are made and why they are made. Few attempts with rare exceptions such as that of Smith (1961), have been made to integrate replacement theory with production theory. Also few attempts have been made to integrate it with market-structure theory.

4(ii). The Role of Expectations and Uncertainty

With the exception of Bain (1939) and Dean (1951), no major attempt has been made to incorporate expectations and uncertainty into the theory of replacement. The implicit assumptions that have been adopted are those of static expectations and perfect foresight. Yet replacement may still respond to such changes as un-anticipated changes in interest rates, liquidity, prices of capital goods, and the user cost of capital variable. Expectations of the future paths of such economic variables may matter. In addition, one must also take into account expectations of technological change. Firms may defer replacements until such time as they expect that the best possible equipment have been put on the market and no further major improvements are to be made within a definite horizon. Alternatively, the success of more technologically advanced firms may prompt other firms to respond defensively by accelerating their replacement programs in their desire to remain competitive.

Another aspect concerns uncertainty. Since future demand for output is never certain, a firm may desire flexibility in the planning of its capacity requirements. This case has been clearly stated by Hart (1940, pp. 110-18). Empirical evidence to this effect has also been supplied by Lioukas (1980, 1982). He shows that the British electrical utility industry takes into account future expected demand in its decommissioning programs and ensures that it maintains a comfortable margin of capacity in case of un-anticipated increases in the demand for electricity. It is only reasonable to expect that the same may apply to firms in other industries. The penalty of not meeting unforseen demand for a firm's output may be an irreversible drop in its market share as consumers object to unfilled orders and redirect their activities. Here, one may view retirements as a variable to adjust for errors in sales expectations. One way for correcting errors in sales expectations is by maintaining a margin of excess capacity, and this can be achieved by manipulating the timing of retirements. Clearly, the firm may accelerate retirements if it has over-built capacity or delay retirements if it did not build sufficient capacity. Since the cost of old capacity is a foregone cost, the primary economic consideration is the carrying cost which, in most cases, is likely to be low.

Bain (1939) emphasized the role of cyclical shifts in the expectations of firms and concluded that replacement investment is likely to be affected by shifts from moods of pessimism to moods of optimism. Thus replacement would vary procyclically which seems to be consistent with the findings of Feldstein and Foot (1971) and Eisner (1972), who found a positive correlation between expansion and replacement. Dean (1951, pp. 146-60) discusses the relative advantages and disadvantages of investing in replacement during cyclical down-turns. Other things being equal, the cost of capital goods is lower while time-lags in the production and installation of capital goods are shorter during down-turns. He finds, however, that on balance, the disadvantages such as the cost of carrying the new capacity until the next up-turn, uncertainty and the pressure on liquidity outweigh the advantages and concludes that firms are likely to postpone replacements until at least the earliest part of the up-turn. One must keep in mind that replacement decisions may involve considerably less uncertainty than expansion decisions. This should render the former decisions less susceptible to swings in the level of confidence and is consistent with the empirical findings of Eisner (1972) that replacement investment is less volatile than expansion investment.

4(iii). Level of Aggregation and Time-Horizons

A common weakness is a failure to specify clearly the level of aggregation to which theories are supposed to apply or to specify the time horizon (short-run vs. long-run). This criticism applies the most to the work of Jorgenson and his associates. Feldstein and Foot (1972) treat Jorgenson's formulation as possibly applying in the long-run, but with the important short-run effects significantly determined by economic variables. On the other hand, Bitros and Kelejian (1974) treat replacement as responding to both short-run factors (gross investment) and long-run factors (the level of maintenance expenditures). Any reasonable formulation of replacement processes should make a clear distinction between short-run factors and long-run factors and the specification of their equations should reflect this.

The level of aggregation is equally important. When models are at the level of the plant, firm, industry or the economy, this character should by analytically incorporated in the experimental design. Replacement at the plant level takes a different form from that at the firm level. A firm may mothball (scrap) one plant while modernizing another. Replacement need not occur equally in all of the firm's plants. Replacement may occur in one set of firms within an industry but not in others. Firms, rather than replacing or modernizing their own plants, might purchase used plants from their competitors through either mergers or corporate acquisitions. To the extent that an industry is declining, one might observe a process of restructuring and rationalization whereby the surviving firms use their competitors' newer capacity and scrap--rather than modernizing--their own older capacity. Finally, at the level of the national economy, there will occur both expanding and contracting industries. To the extent that the expanding industries bring new products to the market (e.g., computers, electronics, robots, VCRs) while the declining industries (e.g., textiles, shoes, clothing, machine tools) leave the market to foreign producers, replacements are bound to diminish. Correct specifications of replacement models therefore should take the different levels of aggregation into account. Moreover, separate studies should be conducted for each level of aggregation.

None of the studies that we have cited have taken account of the morphological characteristics of different industries. The degree of corporate concentration differs among industries and different industries employ different production processes. A typical categorization of production processes distinguishes among (a) rigid-mass production (line production); (b) flexible-mass production (batch production); (c) continuous-process production (flow production) and (d) unique-product production. Surely, different production processes may entail different needs and requirements which modify replacement processes. In the June 1983 Survey of Capital Investment Intentions of the Canadian Department of Regional Industrial Expansion, it was reported that while only 12% of non-manufacturing investment was intended for up-grading and replacement, the comparable figure for manufacturing was 40%. Clearly, there are inter-industry differences that need to be taken into account.

4(iv). Capital-Output Specificity

Most capital goods are designed to perform specific tasks. An ensemble of machinery and equipment is designed and assembled in order to produce given products with pre-set specifications. In many cases, it is the nature and specifications of the output which determine the nature and specifications of the capital goods used to produce that output. A glaring example of this is the automobile industry. The predominant majority of capital expenditures in this industry are devoted toward "retooling", which is re-fitting production lines with the type of machines and equipment necessary to turn out an output of given design. The level and timing of these expenditures are a function of model design. Obviously, the rate of model change has an impact on the length of life of these capital assets. Clearly, we cannot talk about replacement in the automobile industry without explicit recognition and incorporation of the role of new models of cars. In other words we have to take into account capital-output specificity.

An examination of certain world production and trade flows over the past few decades serves to demonstrate the potential significance of such specificity. In the early 1950s, the U.S.A. produced the vast majority of its textiles, clothing, shoes, toys, consumer products, ships, automobiles, steel and basic electronic products like radios and TVs. By the late 1960s and early 1970s, much of the production of these goods shifted to countries in Europe and Japan as illustrated in Table 3-3. Today, production of much of textiles, clothing, consumer products, basic steel and ship-building is shifting out of Europe and Japan to newly industrializing countries (NICs) such as South Korea, Taiwan, Singapore and Spain. As these countries are expanding their production of these lines of products, the U.S.A. and Japan are now shifting to a different output mix composed of such advanced products as specialty steel, precision castings, robotics, special chemicals, process control devices, luxury automobiles, integrated circuits, aero-space engines and components, lasers, fiber-optics, telecommunications equipment, as described for example by Reich (1983). While the "smoke-stack" industries are still here, their share of gross output is giving place to the newer products. As the production of the newer products requires new expansion investments and little replacement and up-grading investments, the aggregate ratio of replacements to gross investment is bound to decline. This implies that as a result of the "organic" change in the "output mix" of the economy which is taking place, the ratio of aggregate replacement to gross capital stock is bound to fall, and the ratio of replacement to capital stock is likel to be much higher in established (smoke-stack) industries than it is in new expanding industries. <u>To ignore the capital-output specificity in the context of an economy undergoing pronounced changes in its output mix is to leave many of the relevant explanatory variables outside our realm of understanding</u>.

TABLE 3-3

IMPORT SHARES OF UNITED STATES MARKET*

(Percentages)

	1970	1979	1981	1984	1985
Steel (1)(2)	13.8	15.0	18.9	26.0	28.2
Telephone Equipment (1)(2)		7.0	11.7	21.0	40.0
TVs & Radios (1)		43.0		60.0	
TVs & Video Cameras (2)			61.6		72.0
Shoes (1)		51.0	51.0	71.0	77.0
Apparel (2)			25.6		36.8
Wearing Apparel (1)		12.0		21.0	
Costume Jewelry (1)		16.0		29.0	
Luggage (1)		25.0		44.0	
Fans & Blowers (1)		10.0		31.0	
Stuffed Toys (1)		50.0		79.0	
Bicycles (1)		17.0		45.0	
Copper (2)			17.7		29.4
Automobiles (2)			34.5		44.3
Machine Tools (2)			21.8		37.0
Cutting Machines (1)		22.0		39.0	
Car Stereos (2)			22.7		45.0
Semiconductors (2)			41.7		42.2
Micro-Wave Ovens (1)		20.0		48.0	
Farm Machinery	8.0		19.0		
Construction Equipment	2.6		9.2		

* Imports as a percentage of apparent U.S. consumption, based on U.S. Department of Commerce data.

SOURCES: (1) Time, October 7, 1985.
(2) Newsweek, September 9, 1985.

5. Dynamic Views of the Replacement Process

5(i). George Terborgh: Asset Displacement and Functional Degradation

George Terborgh (1945, 1949, 1954) has conducted extensive studies on the subject of replacement, depreciation and re-equipment for the Machinery and Allied Products Institute of America. For many years, he has been the recognized authority on the subject in America. Terborgh accomplished an integration of the theoretical and practical aspects of the problem in a way unequaled by other investigators. For Terborgh (1949), replacement investment is a much more intricate and dynamic process than has been perceived by the mainstream segment of the professional literature. His critique of standard views of replacement and his more dynamic approach on the issue can best be appreciated by quoting him directly, extensive as the quoted passages may be:

> "There is a widespread tendency to think of replacement as the filling of a vacuum left by the physical collapse or deterioration of existing capital goods, and hence to underemphasize the dynamic effect of external technological and economic changes. Physical deterioration is still an important factor in limiting service life--varying widely in significance from case to case--but in the modern world external change must be given even greater weight. With the heightened tempo of scientific and technical progress, capital goods are increasingly pushed out of service, or displaced, rather than merely replaced after they expire from physical decay." (1949, pp. 2-3).

> "Capital formation is not a polite game in which replacements meekly and decorously await, like dutiful heirs, the natural death of existing assets. It is a ruthless and cut-throat struggle in which new capital goods rob the function of the old. It is 'murder by degrees. We may add ... that this displacement of function is frequently due to the competition of new goods quite different in character from the old. The function of the horse and buggy was appropriated by the automobile, which dispossessed likewise the

electric interurban railway. The airplane displaces the ocean liner. Facilities for manufacturing nylon supersede the silkworm. Not only do the new capital goods differ from those displaced; it is obvious that they have different owners. An investment by one company may in effect replace the facilities of a competitor by reducing or eliminating their function." (1945, p. 107).

"Once we grasp the dynamic character of this process of mechanical displacement and transformation, the term "replacement" seems inadequate. It is too weak, too passive, too suggestive of the notion ... that new facilities merely fill a preexisting vacuum left by the demise of their predecessors. For this reason we have considered the possibility of avoiding the word entirely, employing instead such expressions as "displacement", "reequipment" or "remechanization". The term has the advantage of common usage, however, a consideration by no means negligible. Moreover, its suggestion of vacuum filling is not wholly in error, since most reequipment decisions turn in part on the physical deterioration of the incumbent asset, as well as on its obsolescence. We have decided, therefore, to continue to speak of replacement, with notice to the reader that we use the word as a synonym for mechanization in general, hence with no implication of replacement in kind. It applies equally whether the new facility is radically different from the incumbent or an exact replica thereof. It applies whether or not the function it performs is precisely the same." (1949, p. 3).

The dynamic and "Darwinian" process in which the production functions of the existing stock of machinery and equipment are gradually dislodged by the newer and hence "superior" generations of capital equipment was termed "functional degradation" by Terborgh. To use his own words, functional degradation "is a kind of progressive larceny, by which the ever-changing but ever-present competitors of an existing machine rob it of its function, forcing it bit by bit into lower grade and less valuable types of service until there remains at last nothing it can do to justify further existence", (1949, p. 16). The following passages from Terborgh describe the process in more detail:

"Consider, for a moment, the case of the 'wonderful one-hoss shay'. This remarkable vehicle ran for a hundred years, as good as new, until it suddenly collapsed, catastrophically, in a pile of junk. Assuming--since the narrative is silent on the point--that the quantity as well as the quality of its services was unimpaired to the end, it is clear that the shay was not replaced functionally until after its collapse. Its demise left a functional vacuum which the successor vehicle filled.

Consider now, by contrast, the life history of a freight locomotive of the vintage, say, of 1890. It began in heavy main-line service. After a few years, the improvement in the new locomotives available and the development of the art of railroading made the unit obsolete for that service, which was taken over by more modern power. It was thereupon relegated to branch-line duty where the trains were shorter, the speeds lower, and the annual mileage greatly reduced. For some years it served in that capacity, but better power was continually being displaced from main-line duty and 'kicked downstairs' onto the branch lines, and eventually our locomotive was forced out at the bottom, to become a switcher in one of the tanktown yards along the line. But the march of progress was relentless, and in the end, thanks to the combination of obsolescence and physical deterioration, it wound up on the inactive list. For some years more it lay around, idle most of the time, but pressed into service during seasonal traffic peaks and special emergencies. Finally, at long last, the bell tolled and it passed off the scene to the scrap heap.

While the passing of the one-hoss shay left a functional vacuum to be filled by its successor, the retirement of the locomotive was merely a belated recognition of the fact that it was already dead from a functional standpoint. Its departure created not so much as a ripple in the operation of the railroad. Unlike the shay, which maintained the full integrity of its original service to the end, and which was functionally replaced, therefore, after retirement, the locomotive was replaced while it was still in service. Its final retirement was merely an aftermath of replacement.

Now most capital goods fall somewhere between these two extremes. They suffer a partial displacement of function during their life, with the remainder displaced at retirement. Typically they undergo during their active careers an irregular down grading of function that reflects this partial displacement. New houses are built for the most part in new neighbourhoods and for occupancy by people of above-average income, but as they age, stylistic and technical obsolescence and neighbourhood deterioration commonly shake them down into lower and lower classes of occupancy. Automobiles ordinarily pass through two or more hands on their way to the scrap heap, not only rendering a progressively deteriorating quality of service but running fewer and fewer miles per year. Production equipment is frequently resold in used condition, occasionally several times, going generally into lower grade uses requiring less precision and reliability and less continuous service. Even when it is held until

> final retirement by the first buyer, it tends to gravitate with increasing age into low-precision operations and discontinuous service, winding up frequently in a merely protective, or stand-by, capacity.
>
> The debasement of function over the life of a capital good may be either quantitative or qualitative. That is to say, there may be a decrease in the amount of service rendered as the unit ages or a deterioration in the quality of the service, or both. A combination of the two forms of degradation is characteristic of most kinds of movable productive equipment, whereas for buildings and other structures qualitative degeneration is predominant." (1949, pp. 17-18).

Two major points emerge from the above passages. The first of these is the notion that replacement is not only a consequence of physical wear and tear and obsolescence, but also a consequence of the development of new products and competitive interactions among firms. As new products appear on the market and supersede (take-over, displace or replace) the older products so does the new capacity installed to produce the new products supersede (take-over, displace or replace) the existing capacity used to produce the older products. To the extent that the newer products are introduced by the same firm, the newer capacity will gradually displace the older capacity within the same firm. In this case "replacement" will take the form of re-investment with gradual retirement of the older capacity. To the extent, however, that the newer products are introduced by different firms from those producing the older products, "replacement" will take the form of "expansion investment" by the challenger firms with gradual retirement of the older capacity by the existing laggard firms. The latter possibility is far more probable than the former because firms are rarely prepared to risk the sudden obsolescence of their own existing capacity. Hence, most often, it is newly emerging firms or "challenger" firms that take the first step. The existing firms either respond to the challenge by undertaking defensive reinvestments in the new capacity or ignore the challenge, in which case they risk their eventual extinction from the marketplace. Replacement then is likely to be just as much a consequence of competitive interaction among firms, propelled by product development (further differentiation of existing products and introduction of brand new products) as a consequence of simple wear and tear.

The second major point is the view that replacement and retirement are not mutually inclusive processes whereby the former necessitates the latter. Rather, in the short-run, new capacity is added alongside the older capacity with both being kept in existence by the firm. It will be after a considerable lapse of time that the displaced older capacity will be completely retired. Thus replacement and retirement are independent processes in the short-run, but in the long-run, retirement is the consequence of replacement or reinvestment in earlier periods. The displaced equipment, although stripped from their principal functions, nonetheless are maintained in action by the same firm or, through transfer, by other firms in second, third or fourth-line duty, or as standby, peak-load or emergency capacity.

Terborgh (1949, p. 23) adopts a broader definition of replacement, as "the displacement of capital goods from their function or service". Regarding the prevailing views, he states:

> "According to one common view, each capital good is replaced but once, at the time of its final abandonment or scrappage. By another view it is replaced whenever it is retired from ownership, regardless of whether it is scrapped or put into use by the purchaser. In our opinion both views fail to get to the heart of the matter. The final

abandonment of an asset may be simply an aftermath of a process of functional erosion extending over many years, hence an event in itself of no particular consequence. As for identifying replacement with transfers of ownership, this is equally unsatisfactory. Whether functionally displaced assets find an alternative service in the same organization or are transferred in the second hand market to some other user is irrelevant. Both of these popular concepts turn on what happens to an asset after replacement but fail to define replacement itself... In our view a capital good is replaced as often as its current job or work assignment is taken over by a successor. If, like the 'wonderful one-hoss shay', the asset defends itself against functional displacement to the very end of its career--and there are some types of capital goods, like railroad crossties, for example, of which this is characteristic--replacement occurs only once. If, on the other hand, the asset undergoes in service a course of functional degradation, it may be replaced any number of times, depending on how we define separate jobs or work assignments." (1945, pp. 23-24)

Terborgh argues, as we have seen in the above passages, that an important channel through which replacement takes place is that of competition among firms, whereby the facilities in one firm may have their function appropriated, or displaced, through the competition by facilities of another firm. This process is quite important in itself and will be developed in Chapter 5.

5(ii). Joel Dean: Classification of Investments and Strategic Factors

Dean (1951) examines the nature of investment decisions from a functional point of view. He finds that investments are undertaken for a variety of purposes such as cost reduction, expansion in production of existing product, introduction of new product, quality improvement, production flexibility or risk reduction. The source of profitability enhancement is different in each case. Furthermore, the benefits that arise from investments are not always quantifiable nor are they always segregatable to any particular product segment or division of the firm. As a result, the same decision rules cannot be applied indiscriminately to all types of investments. Since capital investments possess too many facets to be adequately described by any one of them, Dean (1951) has proposed the following useful four-fold classification of investments: (a) replacement investments, (b) expansion investments, (c) product investments and (d) strategic investments.

Replacement investment is expenditure on new equipment that will perform the same task as the old equipment. In replacement decisions, the source of profitability enhancement is almost entirely reduction in costs of production. He draws a distinction between like-for-like replacements and obsolescence replacements. The latter type of replacement differs from the first only in that the new equipment's cost superiority stems from technical change whereas for the former it stems from sheer aging and wear and tear. Had the innovation not occurred, like-for-like replacement would not have shown an increase in profitability. In replacement investments, the underlying assumption is that the firm is committed to the continuance of the same line of activity. Dean, however, argues that other variables being equal, replacement investments are and should be forced to compete for funds with alternative investment opportunities on the basis of their prospective rate of return.

Maximization of the value of the firm not only involves the application of the capital budgeting criterion to new assets but also to the entire base of existing assets, which brings into consideration the related issue of disposal of assets. There are two ways of augmenting the profitability of a firm: (a) by directing new funds to projects which promise the highest yield and (b) by the systematic disposal of existing assets which no longer yield sufficient returns and the redeployment of attendant funds to assets of higher prospective profitability.

In line with Terborgh, Dean (1951) maintains that the decision to replace an asset does not stipulate disposal of the displaced asset. The replaced equipment may be retained in progressively degraded service. Dean states that in practice, the volume of disposals is likely to be much smaller than the volume of replacements because assets already owned are generally more valuable in terms of earning power to the firm than in market salvage value. Market value is likely to be lower because (a) some assets are custom built for the firm's purposes, (b) the firm knows more about the mechanical condition and performance of its equipment than others and (c) there are transfer costs of selling in imperfect markets. In addition, management is reluctant to recognize and realize capital losses through the disposal of less productive assets preferring rather to spread the loss arising from a 'bad' investment on an asset over future periods and treating it as an operating expense. Consequently, there is a strong tendency for assets to be kept in the firm until such time as aging, technical change or changes in demand destroy their economic value for anything but scrap.

Expansion investment is expenditure on new assets which will augment the existing base and expand the volume and range of production. Here, the source of profitability enhancement is not reduction in costs, but expansion in the volume of activity. Whereas the decision in replacement investments is based on a comparison of alternative ways of doing a job, it is based on whether or not to do the job in expansion investments. Estimating the cost of doing a job by different means or estimating the cost of building a larger (or smaller) facility is more reliable than the estimation of the additional sales and profits which are to arise from the expansion. The estimation of sales is subject to higher risk since it is affected by the response of competitors and future economic trends. Consequently, expansion investment entails a higher risk than replacement.

Expansion investments seldom occur in a pure form. Additions to capacity generally embody more advanced technology which lowers costs of production and may improve product quality. For example, a new lithographic printing press may not only add to capacity but may also improve the quality of existing products, add new products on the product line and reduce costs through lower maintenance costs and reduced labour requirements. The new capacity may demote existing higher-cost capacity to secondary or stand-by status and thereby increasing capacity margins.

Product investments are expenditures on new products and improvement of old products. They combine features of both replacement and expansion investments. The basic intention in adding new products is to take advantage of economies of scope, that is to eliminate excess capacity somewhere in the organization and make better use of production facilities or to complete the product line. Forecasting of both revenues and costs is more difficult here than in both replacement and expansion investment. Forecasting sales of a new product entails more risk than forecasting sales of an existing product. Moreover, forecasting costs can be more difficult because often new products make inroads into the markets of the existing products of the firm either intentionally or inadvertently. Yet there always remains a question as of whether or not old products would indeed have not been displaced by new products of competitors.

Another aspect of product investments is that they are steeped in strategic benefits for other parts of the product line, intangible and indivisible benefits that are often as important as the measurable profit estimates in the decision to invest. Dean (1951) distinguishes between two types of product investments; namely, mature product investments (improvements of existing products) and new product investments (additions to the product line).

Investments for improving the quality of existing products may take the form of research and development, engineering design, retooling of equipment, promotional activity or even better quality control. Here, competitive interactions with rival firms is important. Dean distinguishes between "defensive improvements"--those required to bring the product in line to the standards of the competitor--and "aggressive improvements" --those which raise standards above those of the competition. The dividing line in practice is usually difficult to delineate because competing products are better in some respects and worse in others. However the distinction is useful.

The risks associated with new product investments are even greater than those for product improvements because there is no base for forecasting the sales as well as costs of new products. Here, strategic considerations tend to dominate. New product investments may serve several kinds of strategic ends besides adding to profit. They may be defensive as in the addition of products to meet full-line competition or aggressive, as in staking out a claim in new areas such as video-cassette recorders or laser beam turn-tables.

Strategic investments are expenditures which have indirect benefits to other parts of the firm. Even if they show no promise of profitability in themselves, they shore up the rate of return in other products or markets or contribute to the general strength of the firm. Since the benefits exhibit strong externality effects across the activities of the entire firm and in effect are akin to "public goods", it is impractical to apply standard capital budgeting criteria in their decision. In addition, the competitive orientation is important. Most investments are either aggressive or defensive, depending on whether they lead to competitive reactions or are themselves reactions to competitors' moves. Dean (1951) identifies risk-reducing investments in vertical or horizontal integration, investments in research and development, product development and welfare investments as being of strategic orientation. Advertising expenditures of an investment character may also be considered even though they are treated as operating expenses. Clearly, the acknowledgement of these strategic elements yields a profoundly different perspective on replacement.

6. Summary

In this chapter we have examined non-machanistic or economic theories of replacement and have indicated some empirical evidence suggesting that replacement investment is a variable responsive to economic factors. The empirical evidence suggests that replacement investment is positively correlated with the level of cash flow within the firm as well as with both the levels of expansion and gross investment outlays. Partial negative coefficients between expansion and replacement investment were reported but this substitution effect seems to be dominated by liquidity and output considerations (the income effect). On the role of capacity utilization the empirical results are inconclusive.

The consensus is aptly anticipated and summarized by Bain (1939) when he says that "the economic life of equipment is analytically a variable .. The reason that equipment is replaced at some particular time cannot rationally be that it has ended its 'physical life', but that it is no longer as economical to the firm as a replacement would be", and by Dean (1951) who argues that other things being equal, replacement investments are and should be forced to compete for funds with alternative investment opportunities on the basis of their prospective rate of return.

A number of methodological issues surrounding the definition of replacement investment are discussed. There is no clear definition in the literature as to what precisely constitutes "replacement investment". This issue has been raised by Einarsen, Dean and particularly Terborgh. All three seem to agree that strictly defined, "replacement investment" entails

(a) like-for-like replacement arising from (b) physical deterioration of capital assets due to wear and tear (output and input decay) which (c) leads to the simultaneous retirement of the replaced asset by the firm whose purpose in replacing the asset is (d) the maintenance of the production capacity of its capital stock and not its expansion and (e) the continuance of the same line of activity (that is, unchanged capital-output specificity). However when replacement investment is defined in a more dynamic sense, it loses any semblance to the narrow meaning of the term replacement.

For example, Einarsen (1938) found little connection between replacements and retirements of the replaced assets and secondly found that only 50% of owners replaced their assets. As pointed out in the preceeding chapter, he opted for the term "reinvestment" which did not impose a constraint on retirement. Dean (1951) decomposed replacement investment into two components: like-for-like replacement and obsolescence replacement. Unlike the first kind, obsolescence replacement does not imply the continuance of the same line of activity by the firm and is generally associated with increase in capacity and change in the quality and composition of output. Furthermore Dean does not see any direct connection between replacement--of either kind--and retirements. The older asset may be retained in progressively degraded service because the economic value to the firm, though inferior to the new asset, is still superior to the market salvage value. Since most fixed assets are specialized in function, custom-built and bolted to the ground, transfer costs are very high. Moreover the market is unlikely to value highly an asset it does not know--even if organized second-hand markets exist for all types of capital goods. Terborgh (1945, 1949) argues that technical change and change in market tastes and preferences predominate over phyical wear and tear. Assets are continually displaced by challenger assets of superior technological vintage. Instead of finding their way to the scrap heap, firms retain capital assets in progressively degraded service until their economic value is nothing better than scrap. Terborgh (1949), like Einarsen (1938), prefers alternative terms such as "displacement", "reequipment" or "remechanization" because they describe more accurately the nature of replacement activity in the real world. Since the term "replacement" has the advantage of common usage Terborgh (1949) decides to adopt it, but with a different meaning: "we use the word as a synonym for mechanization in general, hence with no implication of replacement in kind. It applies equally whether the new facility is radically different from the incumbent or an exact replica thereof. It applies whether or not the function it performs is precisely the same."

Thus, the term replacement is used in two separate though related senses in the literature: a) like-for-like replacement in the sense defined above and b) "dynamic" replacement, or reinvestment or mechanization, where one or more of the conditions specified above does not apply. Doing so, however, leaves the door open to some important ambiguities. First, suppose a firm invests in the conversion of say a newsprint mill to a fine paper mill. Here the old plant is modified, some machines are scrapped, others are modified, others are added. The line of activity being pursued in the plant (output-specificity) has changed. To what extent does this investment represent replacement investment? Viewed from the point of view of the production capacity it may be classified as replacement. But if it is now producing a different product to what extent is it valid to speak of replacement? Should investment in any product new to the economy classify as replacement by virtue of the fact that it represents renewal of production capacity? I do not think anyone would go that far. By the same token, how can one conceivably think of an investment to produce a new product as replacement investment. On the other hand, this investment to convert the plant may also be viewed as an expansion investment because, from the point of view of the firm, it represents expansion in a new line of activity. Second, suppose a pulp and paper producer decides to modernize a plant and in the process finds that, as a by-product of the upgrading and modernization, he can expand capacity by 50%. Here, by replacing the older by more modern and up-to-date equipment the producer not only maintains production capacity but adds to it. What proportion of this investment represents replacement and what proportion represents expansion? If the outcome of the investment is to raise capacity, to what extent can we then speak of replacement? Third, suppose a firm adds new equipment in a plant while relegating the older equipment to secondary status. Here it retains the older equipment to meet excess demand or as spare capacity in the event of equipment breakdown or major repairs. To what extent are the new machines replacement investment when the older machines have not been retired from service? Fourth, suppose a firm decides to install new more automated equipment in order to lower costs of production and improve its profitability in the face of stiff competition.

If the older, less sophisticated equipment are still in excellent working order and have not reached the end of their useful lives, to what extent can one speak of replacement investment when the primary motivation of the firm in investing in new equipment is profitability and long-term survival rather than maintenance of capacity? This issue becomes more complicated when the firm introducing the new equipment is a different firm. If a new challenger firm--by virtue of superior capital equipment--drives out of the market the established firm with the older equipment, is the new firm's investment to be considered replacement too? What if this firm is a foreign producer? Looked at from the perspective of the domestic economy, there will be massive retirement of real capital with no accompanying investment flows.

Clearly then, applying the term replacement in both the traditional "like-for-like" replacement sense and the less conventional "dynamic" sense serves only to confuse the matter and to re-direct the reader's attention away from the more dynamic aspects of investment activity. A more meaningful approach may be to use separate terms for each type of investment activity. For example, one may retain the term replacement for the "like-for-like" cases, but substitute the term <u>structural investment</u> for all other cases where the intention of the firm is neither purely the expansion nor the maintenance of its production capacity. Where the firm's underlying production technology or product line composition remains basically the same one can speak of expansion and replacement investment. <u>When the firm's underlying production technology itself undergoes structural change or when the firm's composition of output undergoes</u>

significant change, then it is no longer meaningful to continue to use the terms expansion or replacement. Here it is more a case of structural transformation in either capital input or output or both and therefore a different term, such as structural investment, may be warranted.

Chapter Four and its Appendix further examine the nature of capital spending and fixed capital stock but from an empirical rather than theoretical point of view. Chapter Five develops the concept of structural investment and shows that most types of "dynamic replacements" can be better understood and explained in the context of structural investment rather than the more restrictive context of replacement investment.

CHAPTER FOUR

REPAIR EXPENDITURES AND MORPHOLOGY OF BUSINESS INVESTMENT IN CANADA

1. Introduction

In the last two chapters we have conducted a critical review of the literature pertaining to replacement investment. This review provides only a limited perspective. Nowhere does it rely on directly measured data on replacement capital expenditures. The few empirical studies we have examined use replacement data which have been constructed from gross capital investment series using various theoretical frameworks. Unfortunately, the validity of the replacement estimates is contingent on the validity of the theoretical model and the assumptions used in their construction. To gain a more accurate and reliable understanding of replacement one must rely on directly measured data. In this chapter we review and analyze all of the available data for investment and capital stock that are supplied by statistical agencies in Canada. Our approach here is inductive rather than deductive. We see what we can learn about replacement itself and about the context in which it takes place, directly from the data and without being constrained by many theoretical presuppositions.

Our most significant discovery is the existence of a body of data on non-capital repair expenditures which corresponds quite closely to "like-for-like" replacement. To our knowledge, these data have never been used in any study of replacement, and they provide us with a unique opportunity to study directly both replacement investment and the factors which condition it. There are also under-utilized data on the purpose of capital investment spending which provide us with a deeper understanding of the motivation of firms in undertaking capital outlays for replacement purposes. Combining these two sources of information with other data to examine the patterns of capital spending and the structure of capital stock in Canada, new insights are generated regarding the context and factors which condition replacements--of both static "like-for-like" and dynamic "unlike-for-like" kinds.

The investment data analyzed in this chapter come from two sources: Statistics Canada's semi-annual survey of Private and Public Investment: Intentions and Mid-Year Review (PPI) and the Department of Regional Industrial Expansion's Survey of Capital Investment Intentions and Outlays (DRIE). The PPI survey is a non-voluntary survey conducted since 1947 and spans all sectors of the economy. It collects data on planned, preliminary-actual and actual investment expenditures for both capital and non-capital repair purposes. The data collected in this survey are used as inputs in the national income accounts for the calculation of gross domestic expenditure, and in the estimation of gross capital stock using the "perpetual inventory" method. The DRIE survey is a voluntary survey of about 250 large Canadian corporations whose capital expenditures account for about 50% of total capital spending in Canada. The investment data compiled here closely track those of the PPI survey and therefore are a reliable source of information. In effect since 1969, both the scope and magnitude of this survey have been greatly enlarged in 1977 in order to provide additional information on the purpose of capital expenditures and the motivation underlying them.

The capital stock data analyzed in this chapter are those supplied by

Statistics Canada in the Fixed Capital Flows and Stocks. Unlike the investment data described above, capital stock data in Canada, like most nations in the world, are not derived from any annual survey or inventory of fixed durable assets. Rather, they represent estimates calculated from gross capital investment data using the "perpetual inventory" method, and are limited by the methodology and the assumptions used in their construction. The Appendix to Chapter Four has been included in order to describe the nature of this methodology and assumptions and to warn the reader that these estimates are quite sensitive to the underlying assumptions. This fact is so widely acknowledged among the statisticians responsible for their construction that in Canada an inter-departmental task force has been set up to examine the feasibility of a quinquennial capital stock survey as a replacement to the present method. Unfortunately, not all economists seem to be aware that capital stock data, far from representing actual figures, are merely estimates, and imperfect ones as well. Empirical studies which use capital stock data to derive replacement investment demand functions, such as those of Jorgenson (1965, 1971), should be regarded with scepticism. The same applies to studies which use this approach to partition gross investment into expansion and replacement components. On our part, we regard this approach as so speculative as to avoid it all together. Instead, we make a more cautious use of the available capital stock data, and then only for suggestive purposes.

We examine the structure of capital in terms of its composition (buildings vs. engineering structures vs. machinery and equipment) and in terms of its relationship with output and labour (capital-output and capital-labour ratios). This approach is used to generate a few insights which augment our understanding of replacement investment.

Section 2 of this chapter provides a broad overview of capital investment in Canada during the post-war period. Sections 3 and 4 examine and analyze our findings regarding repair investment outlays in Canada. Section 5 examines the distribution of plant vs. equipment expenditures in Canada. Section 6 and the Appendix to Chapter Four examine the structure of capital in Canada. Finally Section 7 examines and analyzes the data on the purpose of capital spending.

2. Overview of Capital Investment Spending in Canada: 1947-1983

Gross fixed-capital formation (GFCF) is defined as any expenditure incurred on the construction, acquisition and installation of new capital goods. A capital or producer-durable good is any man-made good used for the production of other goods and services which has a durable life, generally of one year or more. It is considered "capital" because it will provide a stream of services over a period of time.

GFCF is divided into private and public investment. Also, it is divided into business capital investment (BCI), residential housing capital investment (HCI) and public (government) capital investment (PCI). Here we are only interested in business capital investment (BCI). Statistics Canada breaks down capital investment in three categories: machinery and equipment (M&E), building construction and engineering construction. The two latter components are termed non-residential construction (NRC) and usually appear under a single heading in statistical publications. Appendix A provides the definitions given by Statistics Canada to these categories.

Nominal capital investment data can be obtained for the period 1947-1983 and converted to real 1971 dollars using separate price deflators for machinery and equipment and non-residential construction. These price deflators are given in Appendix B. To provide a sectoral perspective of investment activity, the data were grouped into four major business sectors: primary industries, mining and construction (PMC); manufacturing (MFG); utilities, communications and transportation (UCT) and trade, finance, commercial and personal services (TFS). The data were subjected to various manipulations in order to reveal basic patterns in the structure of investment activity in the post-war period in Canada.

Figures 4-1 to 4-6 provide an overview of business investment activity in Canada over the long period 1947-1983. Figures 4-1 to 4-3 show the three principal components of GFCF, namely business investment (BCI), investment in residential housing (HCI) and public investment (PCI). Business capital expenditures have accounted for approximately 63% of total capital spending, while residential housing and public investment have accounted for about 20% and 17% respectively. As a proportion of GNP, GFCF amounted to approximately 22.5% of gross national expenditure while the business component of GFCF has accounted for about 14% of the total.

FIGURE 4-1
REAL GROSS FIXED CAPITAL FORMATION IN CANADA: 1947-1983

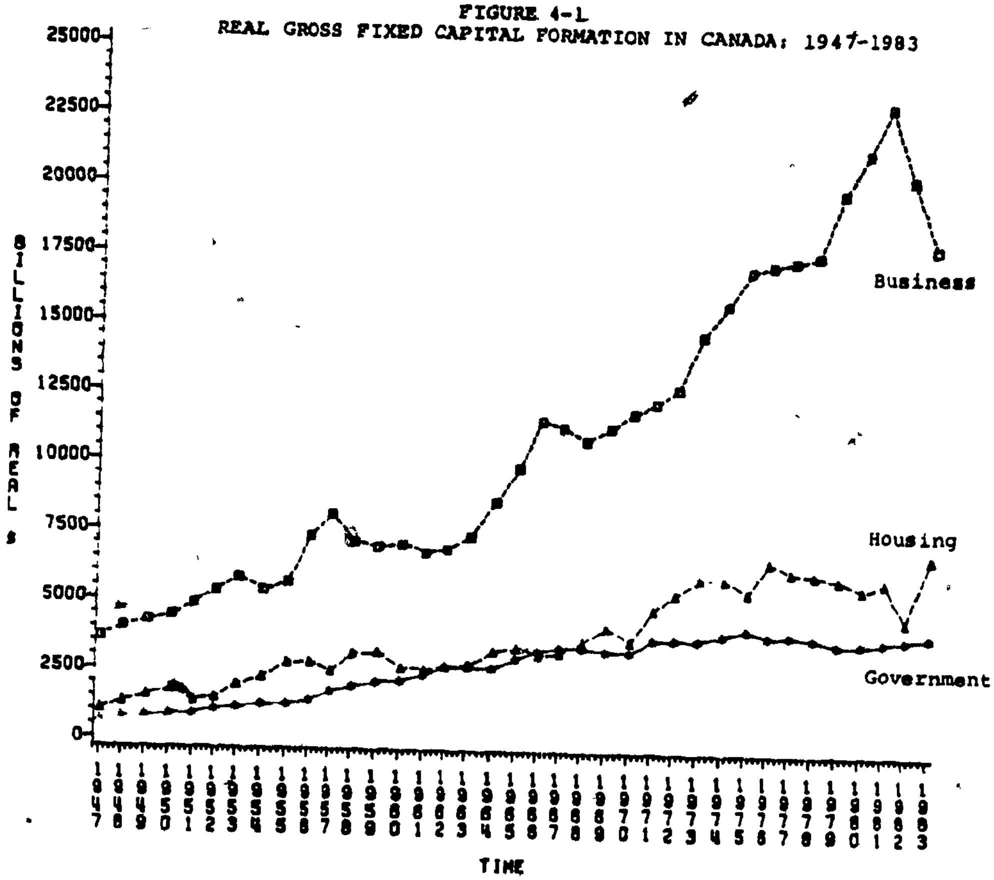
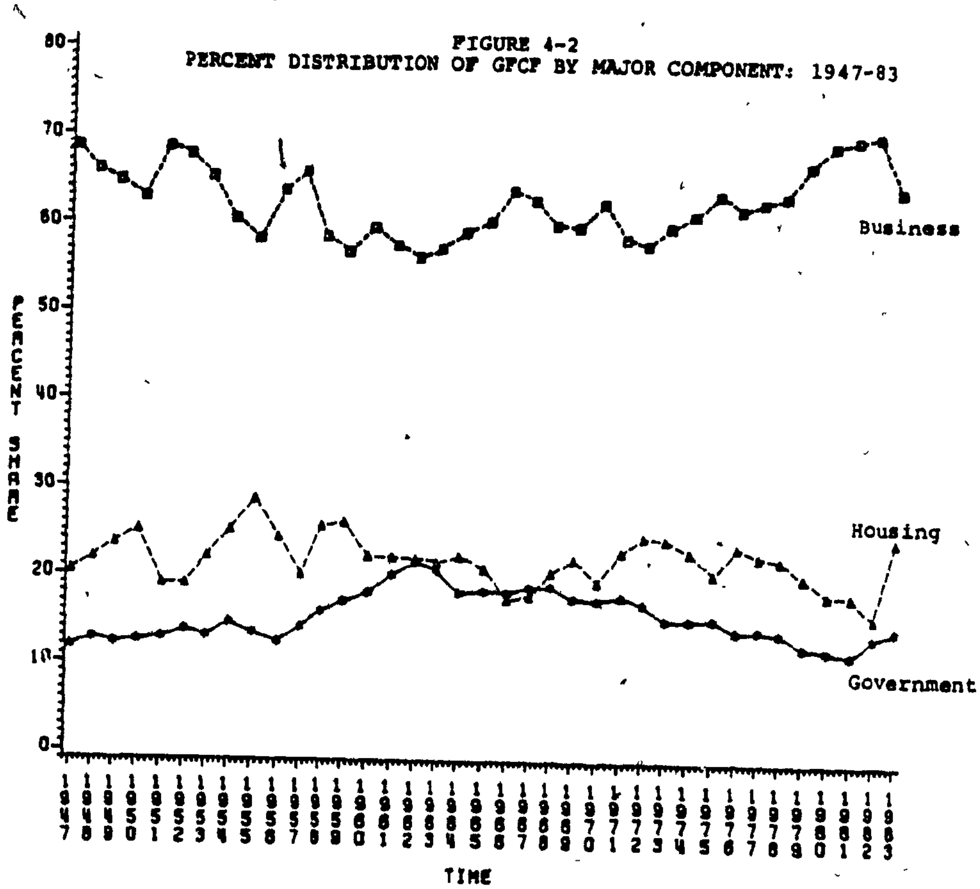


FIGURE 4-2
PERCENT DISTRIBUTION OF GFCF BY MAJOR COMPONENT: 1947-83



While GFCF exhibited considerable short-run cyclical variation in relation to GNP--fluctuating between a quarter and a fifth of GNP--no long-term trend can be discerned in Figure 4-3. Both GFCF and business capital investment, as shares of GNP, have remained remarkably stable during this 37-year period.

There have been four major investment booms during this period and are clearly depicted in Figure 4-3. The four major booms occurred in 1955-57, 1964-66, 1973-75 and 1979-81, and they were primarily responsible for the cyclical fluctuations in the share of GFCF out of GNP. Business investment has been the most volatile component of the three components, while public investment has been the most stable.

Figure 4-4 compares the annual rate of change in GFCF with that in GNP during the period. A positive correlation can be observed between the two rates of change. As one would expect, GFCF exhibited significantly more variability than GNP. A close inspection of the graph also reveals that changes in GFCF lag behind those in the GNP by about nine months.

Figures 4-5 and 4-6 depict the sectoral characteristics of business capital investment activity in Canada in the four major business sectors. Two sectors, UCT and TFS, are generally classified as services while the other sectors, PMC and MFG are classified as non-manufactured goods and manufactured goods sectors, respectively. Figure 4-5 exhibits the pattern of change for each sector during the post-war period while Figure 4-6 exhibits their relative contribution (shares) to business capital investment activity. These shares reveal important patterns of change taking place during the period. First, although capital investment in

FIGURE 4-3
GFCF AND BUSINESS GFCF AS A SHARE OF GROSS NATIONAL PRODUCT: 1947-1983

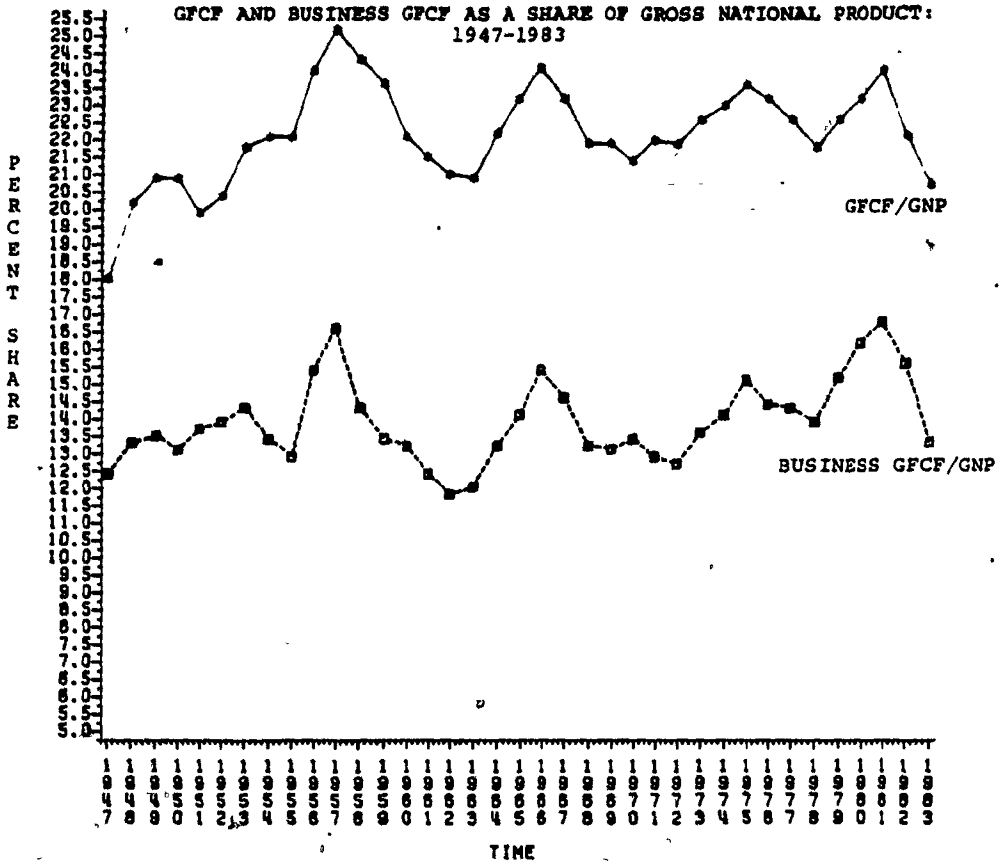


FIGURE 4-4
ANNUAL PERCENT CHANGE IN REAL GNP AND BUSINESS GFCF: 1948-83

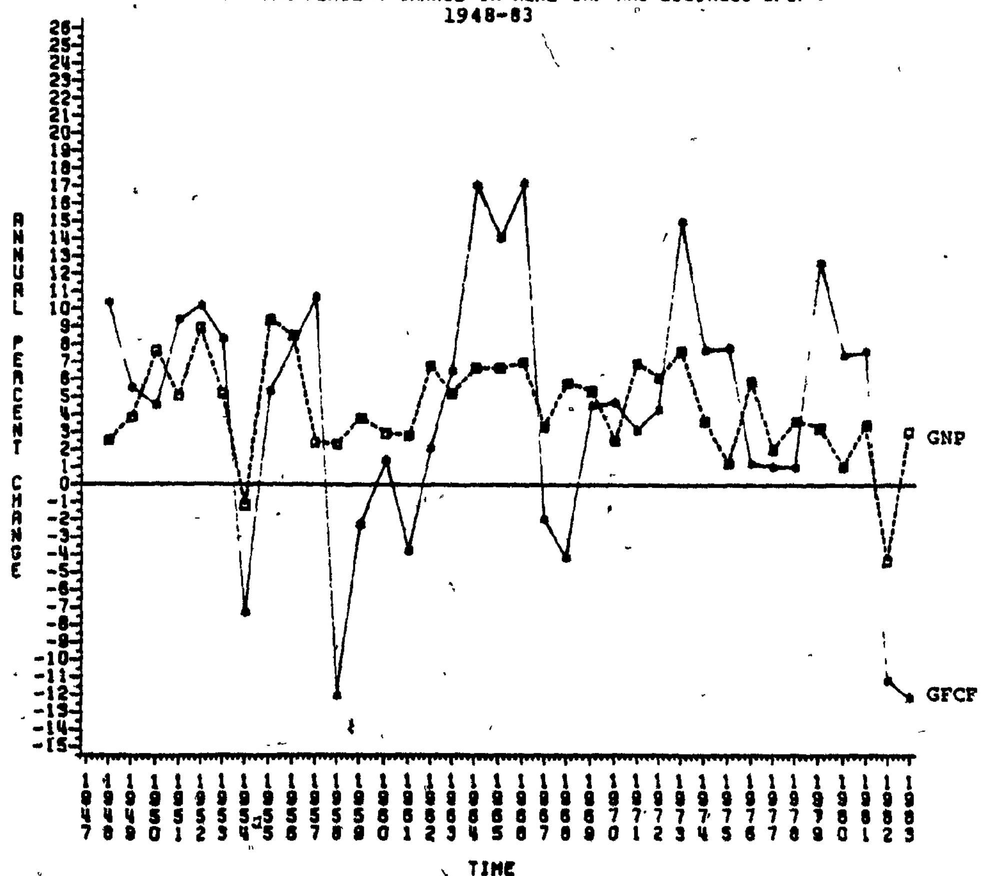


FIGURE 4-5
REAL BUSINESS GFCF BY MAJOR SECTOR: 1947-83

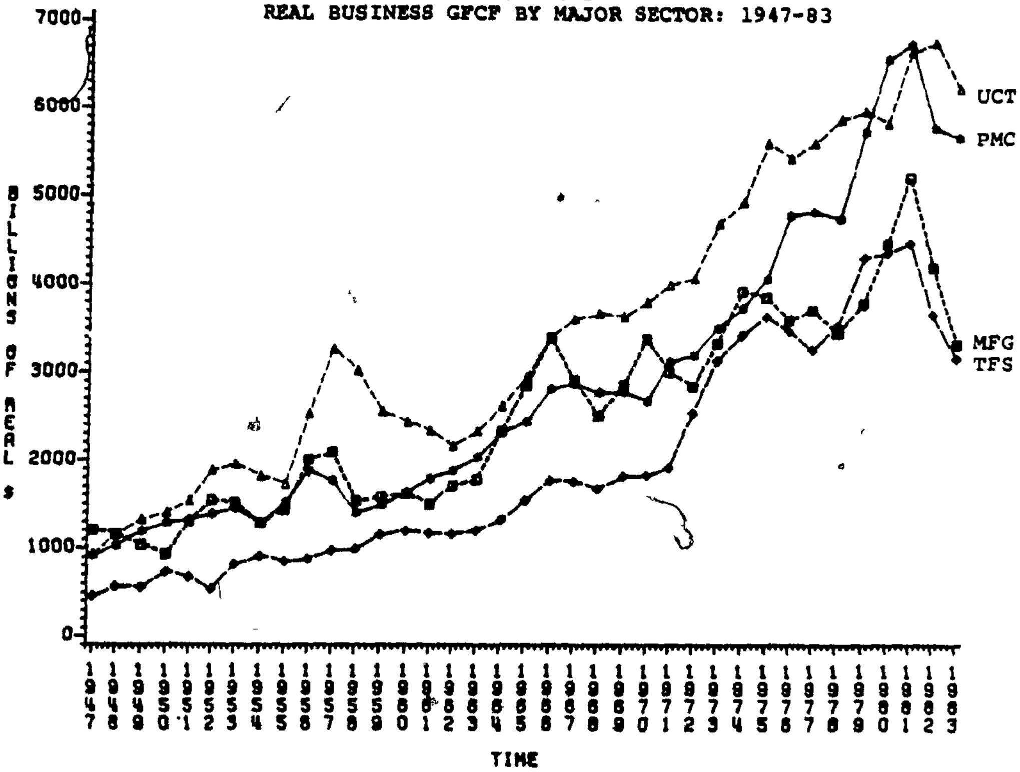
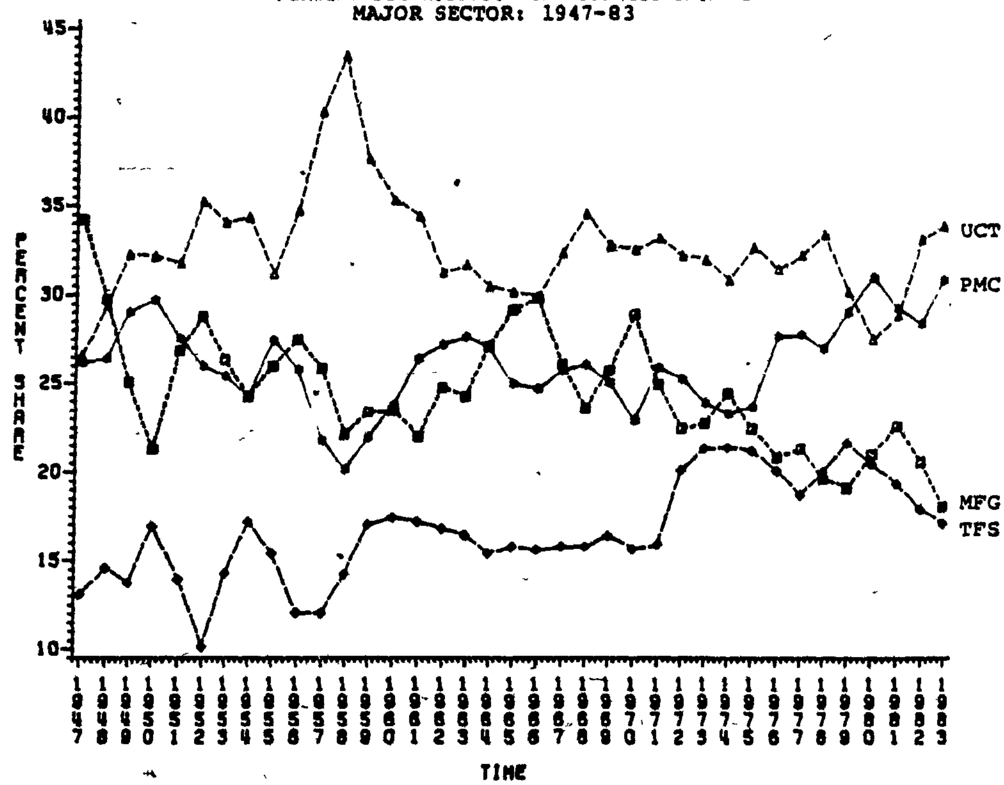


FIGURE 4-6
PERCENT DISTRIBUTION OF BUSINESS GFCF BY
MAJOR SECTOR: 1947-83



manufacturing (MFG) rose in absolute terms, it has been exhibiting a strong downward trend as a share of business capital investment. From about a third of capital spending, it has dropped to a little over a fifth of the total. The shift, is most pronounced since 1966. Second, capital investment in the trade, finance and services (TFS) sector has risen in both absolute and relative terms. The increase has been most pronounced since 1971. Third, capital investment in the utilities, communications and transportation sector (UCT) has been rising in absolute terms but remained constant in relative terms at about a third of business capital investment. Capital investment in the non-manufactured goods sector (PMC) has been rising in absolute terms throughout the surveyed period but it exhibits a mixed trend as a share of business capital investment. Although it declined in relative terms until 1975, it has been accounting for an increasing share of total investment activity since then. This development can be explained by the increase in capital spending of the energy sector which took place since the 1973 OPEC-induced increase in the world price of oil. The mining and construction industries were major beneficiaries of energy-related investment activities (oil and gas exploration, production and pipeline construction).

3. Repair Expenditures and Replacement Investment in Canada: Some Fundamental Clarifications

In addition to capital expenditures, Statistic Canada has been collecting and publishing data on non-capital "repair expenditures" in its

Private and Public Investment survey. These data which have been collected continuously since 1947 form an integral part of the investment survey. In fact, repair expenditures are collected in the same format and same degree of detail as capital expenditures, and are then added to capital expenditures to produce a "total" picture of investment activity in Canada. Appendix C illustrates the format and the magnitude of repair expenditures as they have appeared in the publication Economic Review.

Repair expenditures are defined by Statistics Canada as "non-capitalized outlays made to maintain the operating efficiency of the existing stock of durable physical assets. These repair and maintenance expenditures exclude however, the routine care of assets such as oiling and cleaning of machinery. Where the repair costs are large enough to materially lengthen the expected serviceable life of assets, increase its capacity or otherwise raise its productivity, they are treated as capital expenditures on new construction or new machinery and equipment"[1]. As a reason for their inclusion, Statistics Canada cites the following: "by including these outlays, a more complete picture is provided of all demands likely to be made on labour and materials in accomplishing the investment program." These repair expenditures do not represent a trivial sum and should not be ignored in the investment literature, especially when it concerns replacement investment. Repair expenditures represent a staggering amount, accounting for 60% of capital investment expenditures in the Canadian manufacturing sector and over 37% of business capital

[1] See the "Introduction" and "Statistical Notes" of PPI Survey, Statistics Canada, Catalogue 61-205, for any year.

investment in Canada, in 1984 for example.

What then are these "repair expenditures" and do they represent replacement investment as it is conceived in the economic literature? If we examine the definition itself, they are expenditures whose purpose is to maintain the operating efficiency of capital stock intact. This definition is exactly the same as that given for replacement investment in the literature! Consider for example:

> "At each point of time durable goods decline in efficiency, giving rise to needs for replacement in order to maintain productive capacity." (Jorgenson, 1974, p. 190).

and

> "Potential replacement investment is defined to be that quantity of investment currently required to maintain capital stock." (Nickell, 1978, p. 116).

From the definition alone then, it is clear that repair expenditures are in fact replacement investment.

To confirm the above, we sought expert opinion from industry practitioners themselves. Those responsible for collecting the information at Statistics Canada were asked as well as officers responsible for supplying the information from the reporting firms themselves. Officials at Alcan Aluminum Ltd., Domtar Inc., Shell Canada Inc., the Canadian Pulp and Paper Association and the chartered accounting firm Coopers and Lybrand were contacted. The consultations confirmed our theoretical expectation and served to clarify why these expenditures which are in essence replacement are called "repair expenditures" and charged to operating accounts as opposed to being capitalized.

Unlike what many economists would have us expect, assets are not made of a single component but of a multitude of different components which wear out at different rates. If a single component wears out, the asset is rarely scrapped unless all other, particularly the major components have also worn out! In order to maintain the operating efficiency of the entire asset, the firm will replace the worn or damaged component by a new one, and charge the expense of the component plus the cost of labour and materials necessary for its restoration as a "repair expenditure" to an operating account. Whether the expense is charged to a capital account or not does not alter the nature of the activity. Thus, whether a particular expenditure will be classified as a "repair expenditure" and charged to an operating account or as a "capital expenditure" depends on how one defines the asset. To quote from one authoritative accounting textbook:

> "The replacement of specific parts, however, is a function of the unit or composite selected for depreciation, and the distinction between replacements and maintenance is dependent upon the amount of the aggregation and the selected composite life." (Hendriksen, 1982, p. 384).

Hendriksen uses an airplane to illustrate his point. An airplane can be regarded as a single asset or, alternatively, it can be decomposed into three separate assets: the airframe, the engines and the interior fittings. In the first case, periodic replacements of engines or interior fittings will be classified as "repair expenditures." In the second case, such replacements will be classified as capital expenditures. In either case however, they are replacement expenditures which maintain the operating efficiency of the existing asset intact and contribute towards the attainment of the originally expected service life of the asset.

Defining some related notions will further help clarify the issues involved here. Following Hendriksen, the term maintenance generally refers to the normal upkeep of property in an efficient operating condition and includes normal recurring repairs such as cleaning, oiling, adjusting and replacement of minor parts. Such routine maintenance expenditures should not be confused with "repair expenditures" discussed above. They are excluded from Statistics Canada's definition of "repair expenditures"[2].

The term repair refers to the restoration, after damage by accident or prolonged use or disuse, of a fixed asset to its full productive capacity without increasing the previously estimated service life or capacity of the asset. Repairs are generally of two types: (a) the adjustment of an asset or working parts and the labour necessary to restore a damaged or worn component to its original condition, and (b) the replacement of one or more parts of an asset with new parts without replacing the entire asset.

The terms additions, improvement and betterments and major replacements refer to expenditures which result in (a) an increase in the life of an asset--that is, an increase in the number of years over which services will be obtained from an existing asset, (b) an increase in the quantity of services to be obtained in each year during the remaining life of an asset, and (c) an increase in the quality of service to be obtained in each year during the remaining life of the asset. In such cases,

---

[2] They are collected as part of a separate survey and appear as "maintenance and repairs" in the publication Corporation Financial Statistics (Annual Catalogue 61-207, Table 2B, line 14). They generally account for 30% of non-capital repair expenditures.

accounting standards demand that they be capitalized. In practice, however, classifying an expenditure as a repair or an improvement and betterment may not always be clear-cut. An expenditure program may combine elements of repair, betterment and additions. Consider the following examples:

> "Improvements and betterments are more difficult to define than additions... If the result is an increase in quantity of service provided by the assets, it may, in fact, be difficult to distinguish improvements from additions. A truck may be improved by adding overload springs and a larger bed, thus permitting heavier payloads. The result may be little different from the acquisition of a trailer, which would be considered an addition. On the other hand, many improvements may result in an increase in the quality of the service provided by the asset."

> "Major replacements are the most difficult to define and treat properly because the effect is similar to that of minor replacements and normal repairs. If an asset is made up of a single unit, a replacement involves the entire asset; in this case, the solution is simple--the old asset is retired and the replacement asset is recorded as a new asset. But in most cases, plant and equipment items are made up of several units that wear out at different rates. Recurring replacements of parts of the asset can be charged to operations in the years in which they occur because they are necessary to obtain the expected service life of the composite asset. ... Major replacements that occur infrequently, however, need to be capitalized so that all periods will be charged with a portion of the replacement costs." (Hendriksen, pp. 354-55).

Therefore, it is evident from the above that "repair expenditures" which have been collected in Canada for over 40 years are in fact replacement expenditures. This is an important finding, because as far as we know <u>these figures represent the only body of data we have on actual replacement expenditures</u>. In addition, it contains significant implications on how we view gross investment and replacement investment in particular. Let us list some of these implications. First, unlike what many economists expect , not all replacements are capitalized. Judging from the magnitude of "repair expenditures" in relation to capital expenditures, it would seem that in fact the bulk of replacements do not occur at the composite asset level, but at the component level and are therefore expensed and not capitalized. Second, to the extent that one chooses to define replacement in the strict sense of "like-for-like" replacement, "repair expenditures" by and large represent "like-for-like" replacement as it is conceived and defined in the literature. Third, to the extent that replacement investment is actually charged to operating accounts, then capital investment figures ignore replacement investment and in fact seriously understate the actual volume of investment spending in the economy. It suggests that (a) the actual level of investment as defined by economists (that is, net plus replacement investment) has been significantly higher than the one indicated by capital figures alone and (b) that both "net" and "replacement" components must be much greater than hereto believed. Fourth, it suggests that theoretical or econometric approaches which use capital stock data to impute replacement investment demand and then subtract it from gross capital spending to derive expansion demand have been completely off the mark and therefore their results may be completely erroneous! A review of the pattern of "repair expenditures" in Canada and their relation to "capital expenditures" done in the next section will further serve to augment the plausibility of this assessment.

4. Repair Expenditures and Replacement Investment in Canada: 1947-1983

In this section "repair expenditures" are treated as replacement investment and have been added to "capital expenditures" to obtain a more complete view of investment activity in Canada. Repair expenditures are added to capital expenditures for the business sector of the economy to derive a measure of "total business investment" (TBI).

Figures 4-7 to 4-10 provide a rare perspective on the patterns of repair expenditures (replacement investment) and capital investment expenditures in Canada, for the period 1947-1983. Figures 4-11 and 4-12 provide a similar picture but for the manufacturing sector, and then only for the period for which detailed information is available, 1960-1984. For a more detailed picture the reader is refered to Figures 1 to 20 in Appendix D which provides similar information at the 2-digit S.I.C. level of the Canadian manufacturing sector.

Examination of Figures 4-7 to 4-12 reveals the following features: (1) The level of repair expenditures has been very stable in relation to capital expenditures, rising gradually from 2.25 billion (1971) dollars in 1947 to a little over $6.0 billion in 1983. Over the same period, capital expenditures have risen at a much higher rate, rising from about $3.5 billion in 1947 to $23 billion in 1981, before settling to $18 billion in 1983 (see Figures 4-7 and 4-11). (2) The variability of repair expenditures has been substantially lower than that of capital expenditures (see Figures 4-8 and 4-12). Yet, in and of itself, repair spending has fluctuated considerably, but generally not exceeding the range of +10% of

FIGURE 4-7
REAL BUSINESS CAPITAL INVESTMENT VS REAL BUSINESS REPAIR INVESTMENT: 1947-1983

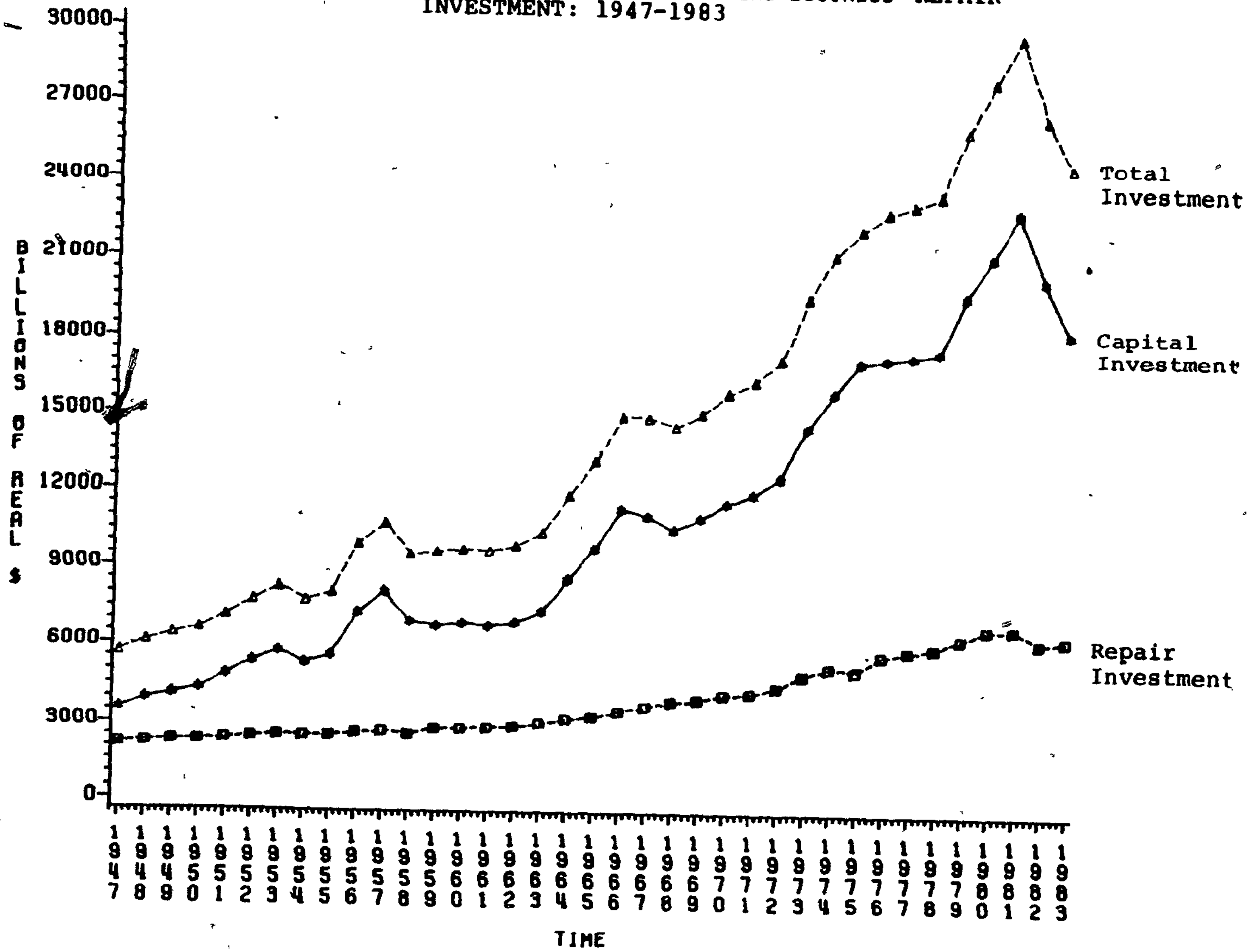


FIGURE 4-8

ANNUAL PERCENTAGE CHANGE IN REAL BUSINESS CAPITAL VS.
REAL REPAIR INVESTMENT: 1948-83

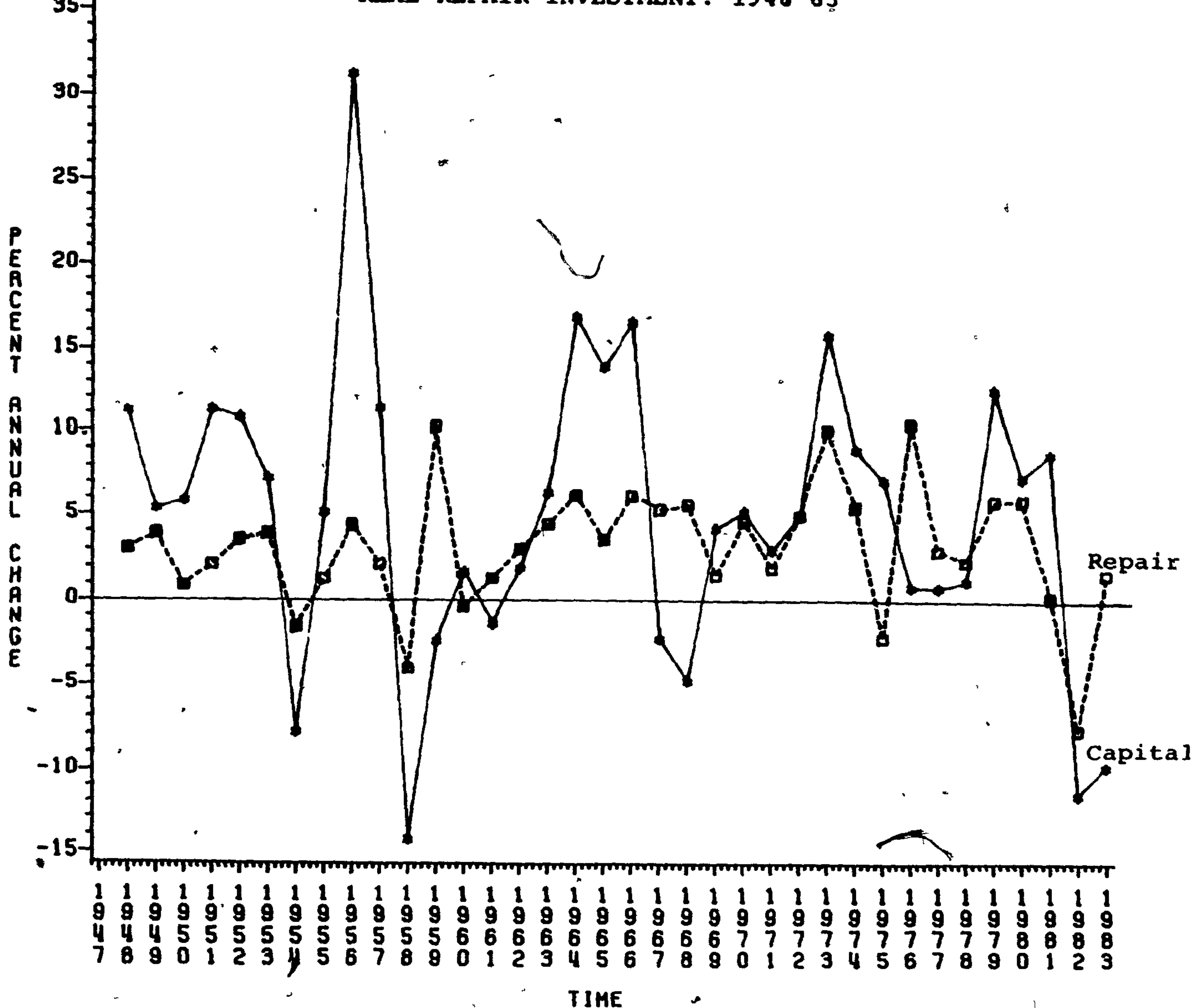
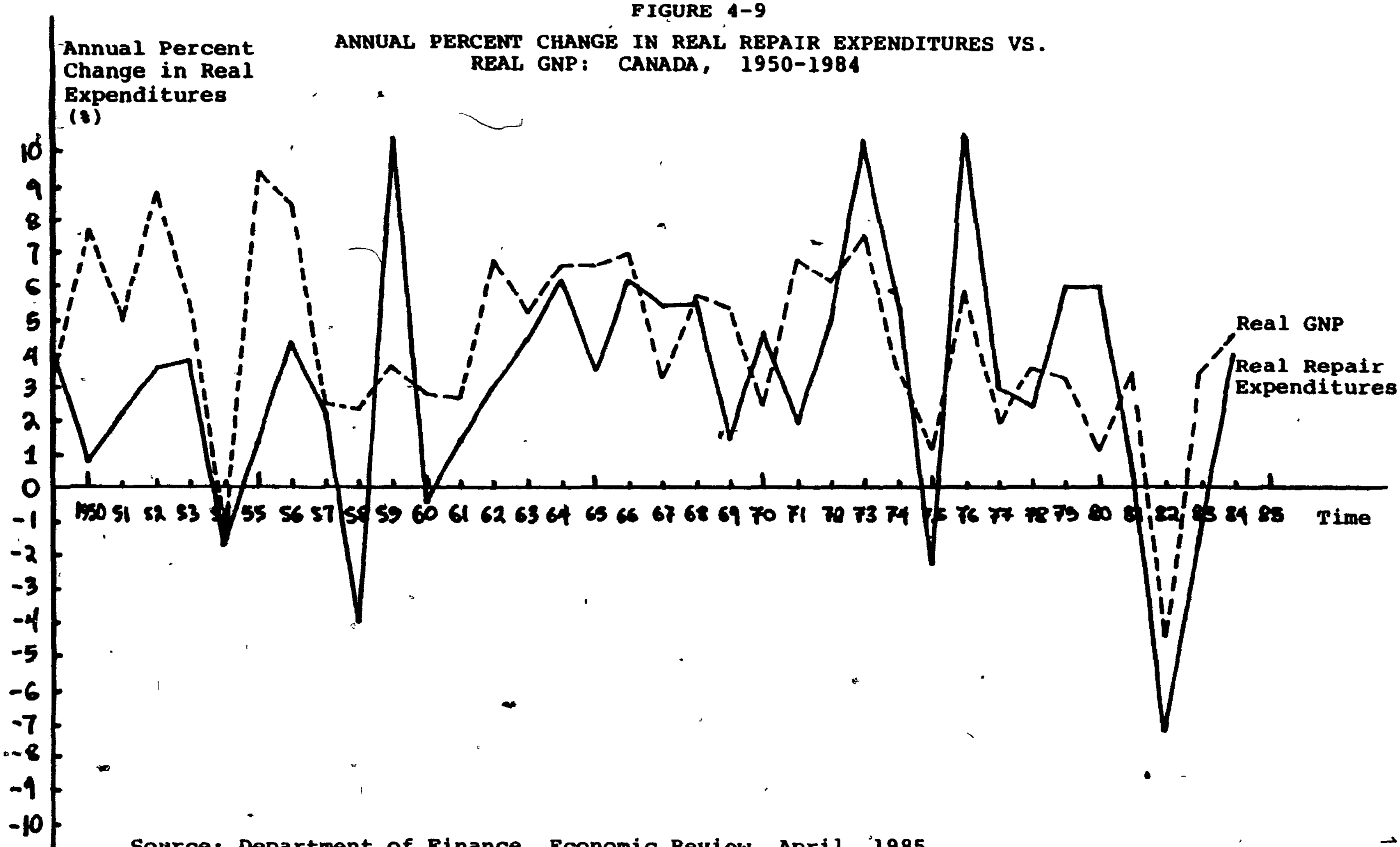


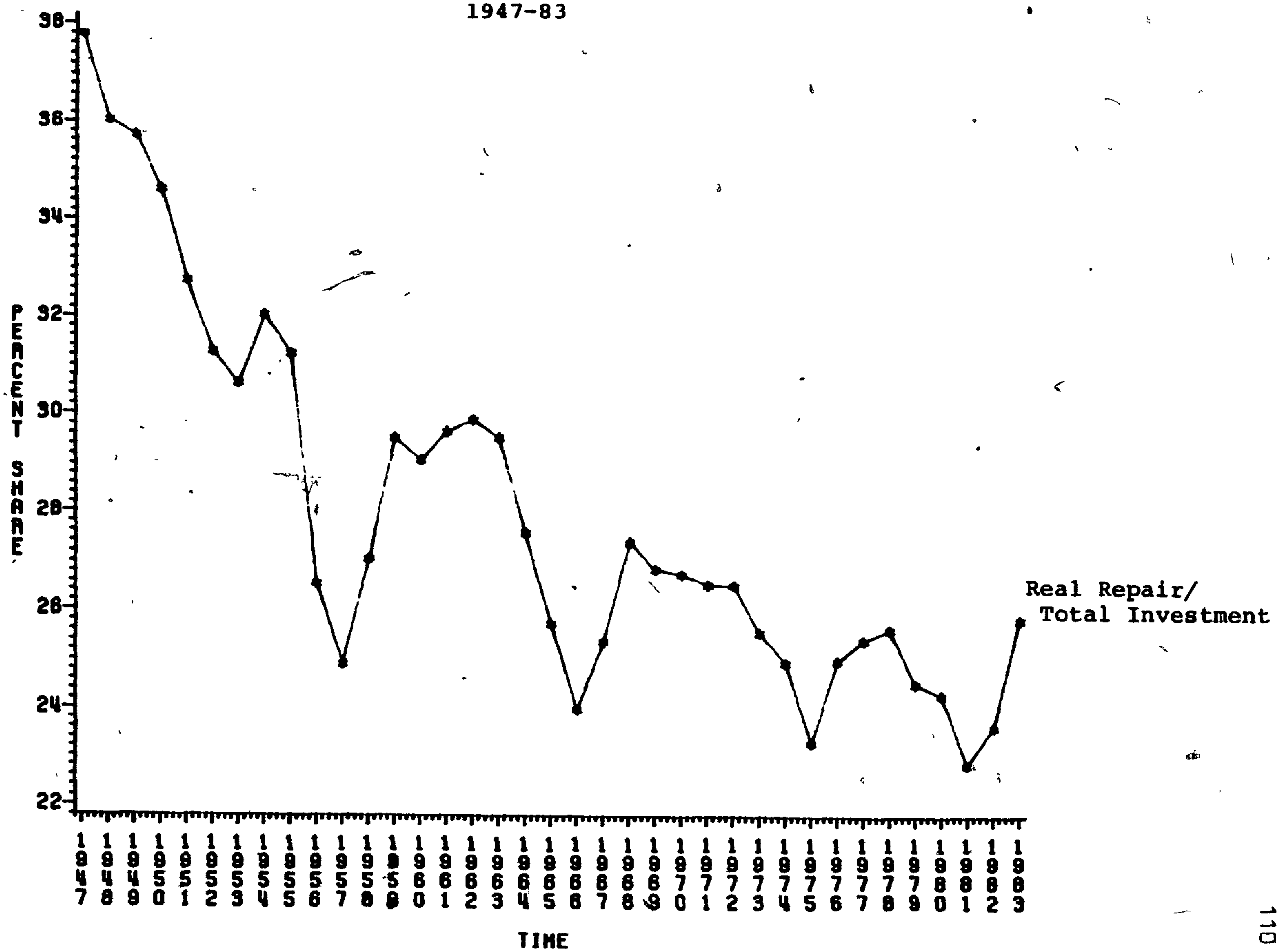
FIGURE 4-9

ANNUAL PERCENT CHANGE IN REAL REPAIR EXPENDITURES VS. REAL GNP: CANADA, 1950-1984



Source: Department of Finance, Economic Review, April, 1985

FIGURE 4-10
PERCENT SHARE OF REPAIR INVESTMENT:
1947-83



previous year's level. (3) The annual rate of change in repair expenditure is positively correlated to both the rate of change in capital spending and GNP (see Figures 4-8 and 4-9). (4) Repair expenditure, as a share of total business investment, has exhibited a secular decline over the period, falling from over one-third in the late 1940s to just above one-fourth in the early 1980s (see Figure 4-10). The cyclical troughs in the share of repair expenditures shown in Figure 4-10 are due to cyclical expansions in the levels of capital spending, and correspond to the previously cited four major investment booms of the post-war period.

These findings are all consistent with what a reasonable theory of replacement investment would predict. While repair expenditure seems to be associated with past investment outlays (that is, with capital stock), in the short-run it seems to respond to the same kind of economic factors which affect capital investment. The decline in the share of repair out of total investment may very well be due to the fact that, with high positive rates of capital spending, the average age of the economy's capital stock is decreasing and therefore there is less need for repair expenditures.

If we treat Jorgenson's (1965) proportional replacement hypothesis (PRH) as a long-run theory of replacement and allow the timing of repair expenditures to vary in the short run in response to short-term economic influences as the empirical findings of Eisner (1972) and Feldstein and his associates (1971, 1974) suggest, the data on repair expenditures contained in these figures is quite consistent with this eclectic view.

Figures 4-13 and 4-14 provide another sectoral perspective on repair expenditures. The first of these displays the levels of repair

FIGURE 4-11

REAL MANUFACTURING CAPITAL vs. REAL REPAIR INVESTMENT: 1960-1984

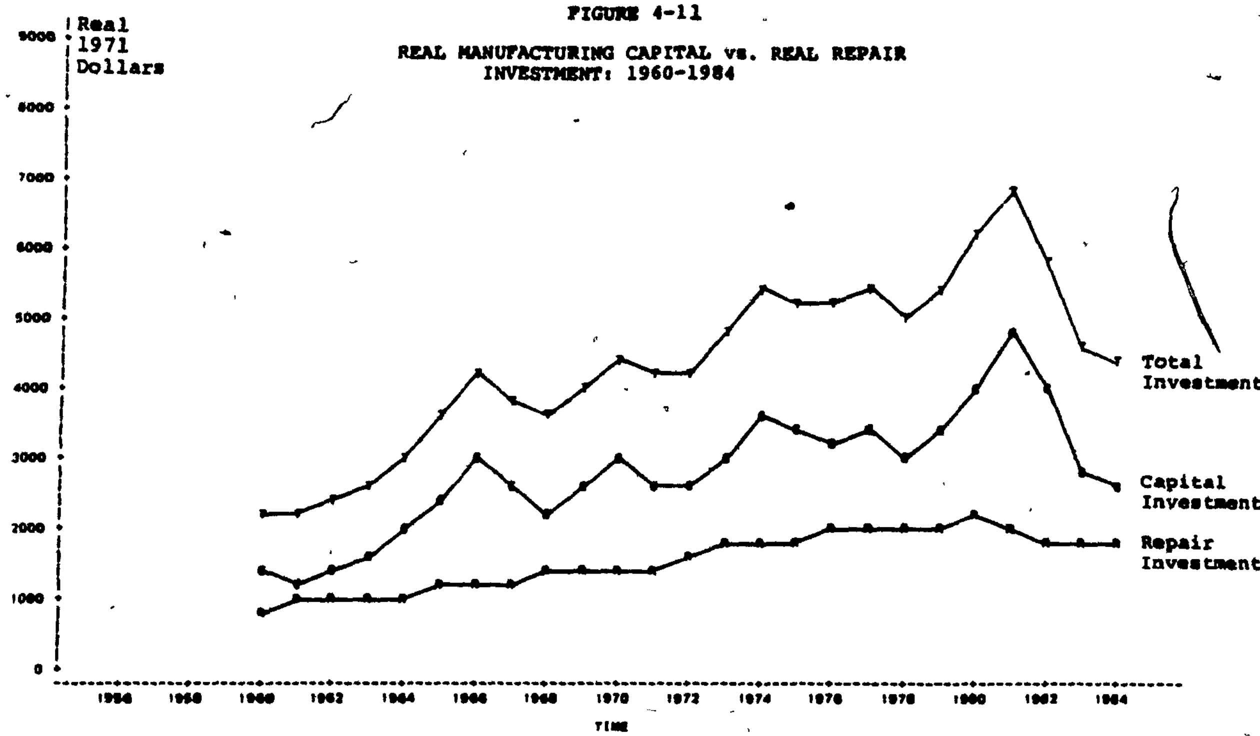
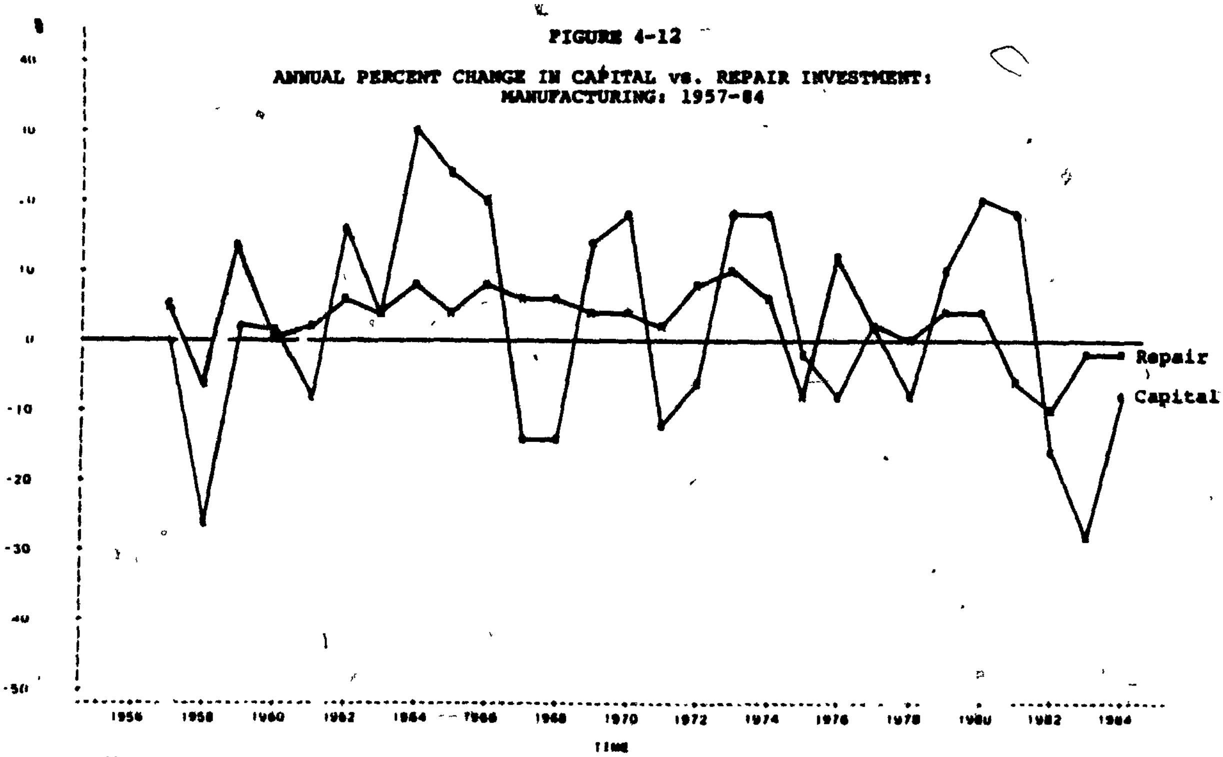


FIGURE 4-12

ANNUAL PERCENT CHANGE IN CAPITAL vs. REPAIR INVESTMENT: MANUFACTURING: 1957-84



expenditures while the second presents a disaggregated version of Figure 4-10, and thus shows the share of each sector's repair investment out of total business investment.

Examination of these figures reveals that the repair share of total investment differs both among sectors and over time for each sector. The share of repair expenditures is highest for manufacturing (MFG) averaging about 33% of total business investment[3], and it is lowest for trade, finance and services (TFS) averaging about 13% of the total in the 1970s. The other two sectors' repair shares have been alternating during the period and stand at about a quarter of total business expenditures. This shows that the morphological characteristics of capital stock are different among sectors at this considerable level of aggregation. In addition the repair share of total investment in manufacturing has remained relatively constant over this 33-year span at 33%, while the respective shares of the other sectors have exhibited varying degrees of secular decline.

The decline in the share of repair out of total business investment thus seems to be due to developments outside the manufacturing sector. The relative constancy in this particular sector reflects a lack of buoyancy in investment as compared to that occurring in other sectors.

---

[3] See also Figure 4-11.

FIGURE 4-13
REAL BUSINESS REPAIR EXPEDITURES BY
MAJOR SECTOR: 1947-1983

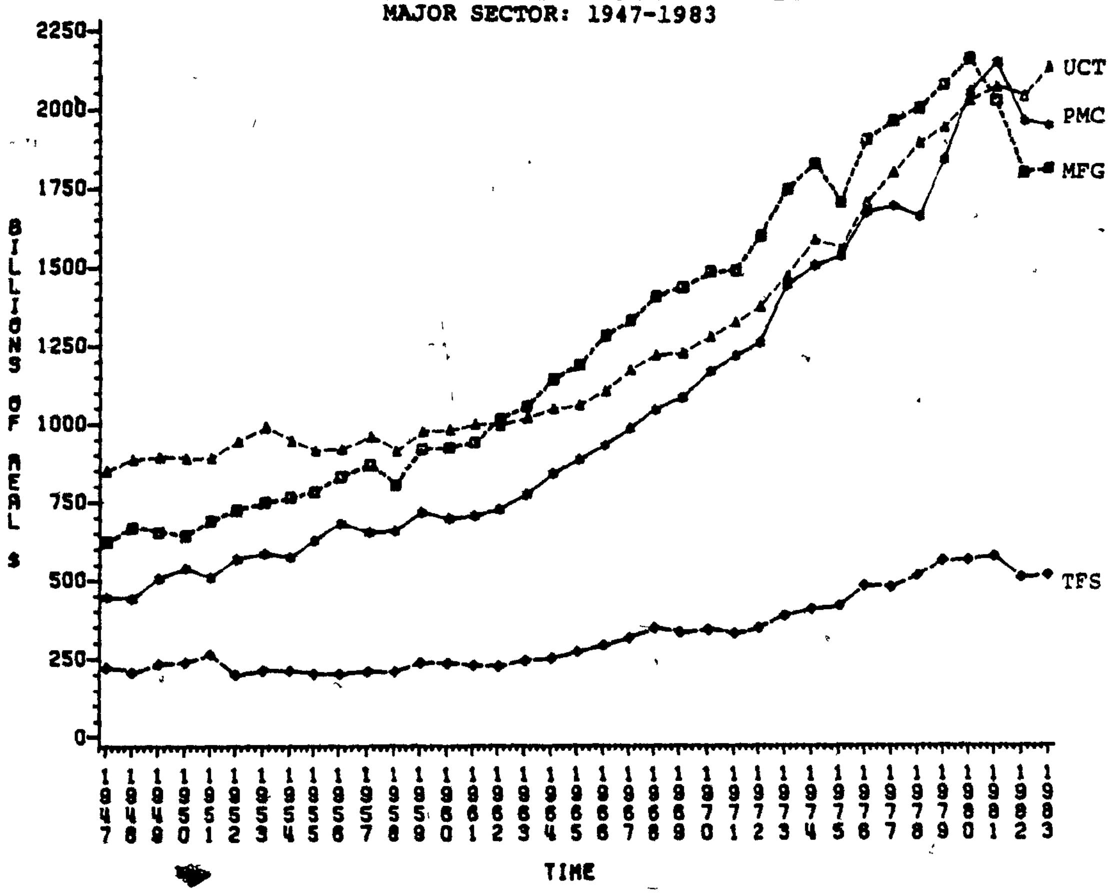
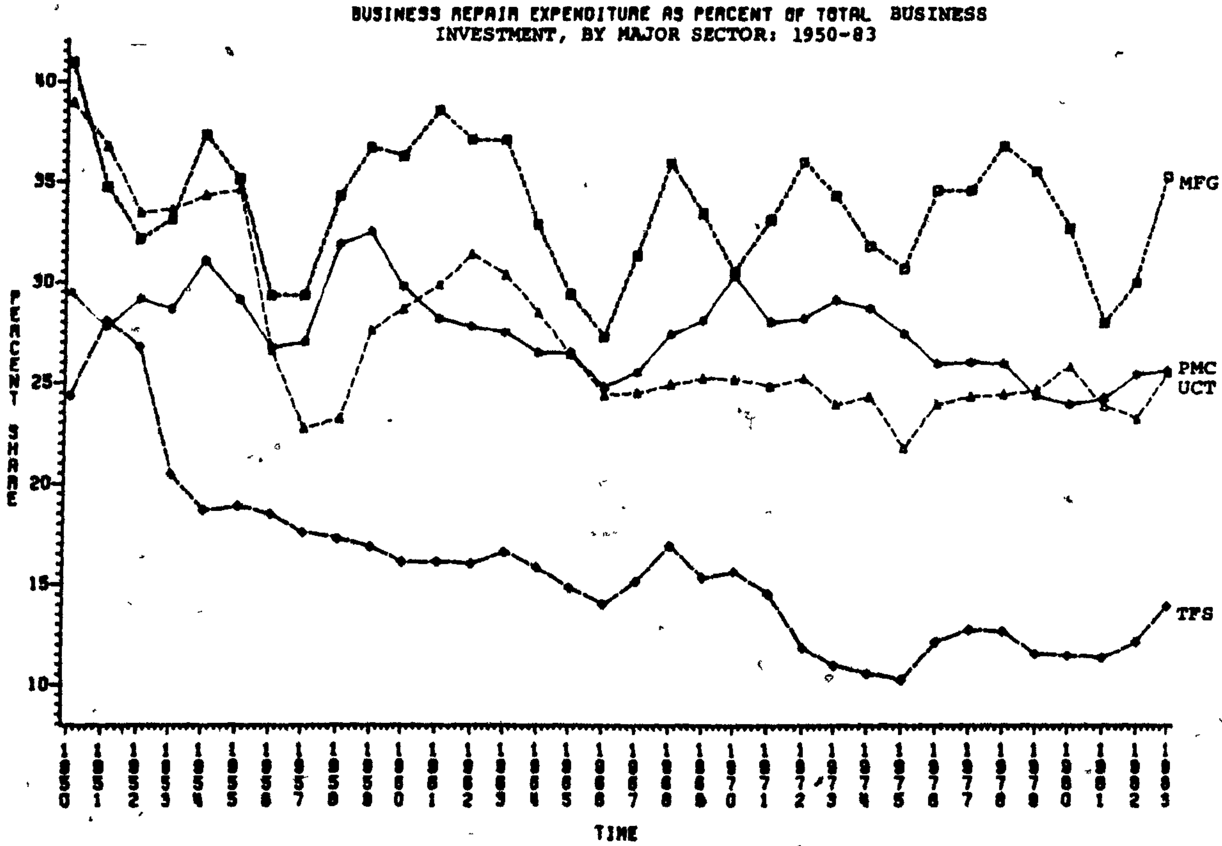


FIGURE 4-14
BUSINESS REPAIR EXPENDITURE AS PERCENT OF TOTAL BUSINESS
INVESTMENT, BY MAJOR SECTOR: 1950-83



5. Distribution of Plant and Equipment Expenditures

Investment expenditures--whether for capital or repair purposes--are composed of two broad categories: construction expenditures for buildings and engineering structures or plant investment, and expenditures on machinery and equipment or equipment investment. Statistics Canada and the Department of Commerce in the U.S.A., collect separate figures for these components. Plant investment consists of construction expenditures on industrial buildings, office buildings and commercial buildings (stores, restaurants, etc.) and on all types of engineering structures such as roads, dams, transmission lines and pipelines, as well as oil drilling and mine installations. Equipment investment consists of all types of machinery and equipment used either in producing goods or providing services. Examples are transportation, construction and agricultural equipment, general industrial machinery (pumps, compressors, furnaces, etc.) custom-designed industrial machinery, metalworking machinery, steam and electrical engines, fabricated metals (pipes, valves, boilers, etc.), materials handling equipment, as well as office and photocopy equipment, communications equipment, computers, data processing equipment, food processing and packaging equipment, among others.

Figures 4-15 to 4-22 and Appendix E of this chapter provide information on the composition of business investment by plant vs. equipment expenditures. Here figures 4-15 to 4-18 plot the levels of plant and equipment capital spending. in constant (1971) dollars for each of the four major business sectors of the economy during the 1947-1983 period.

FIGURE 4-15
REAL BUSINESS PLANT INVESTMENT VS REAL BUSINESS EQUIPMENT:
PRIMARY, MINING AND CONSTRUCTION : 1947-83

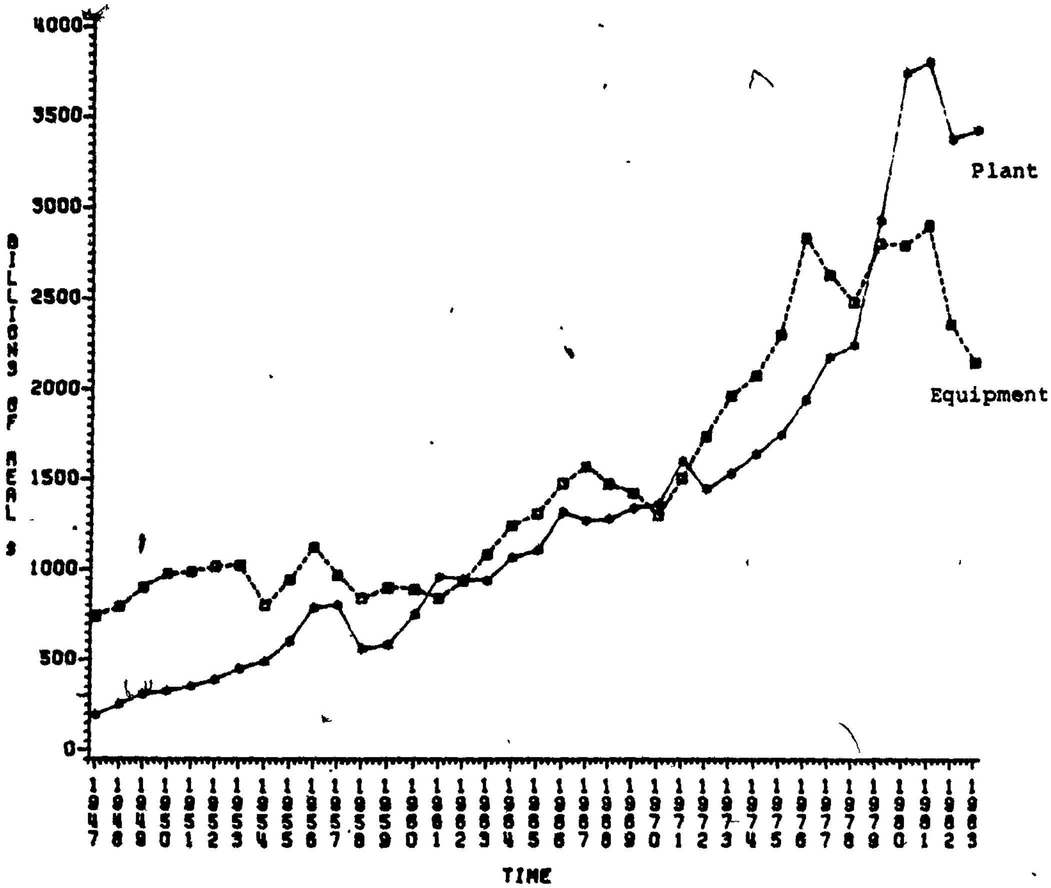


FIGURE 4-16
REAL BUSINESS PLANT vs. REAL BUSINESS EQUIPMENT
INVESTMENT: MANUFACTURING, 1947-83

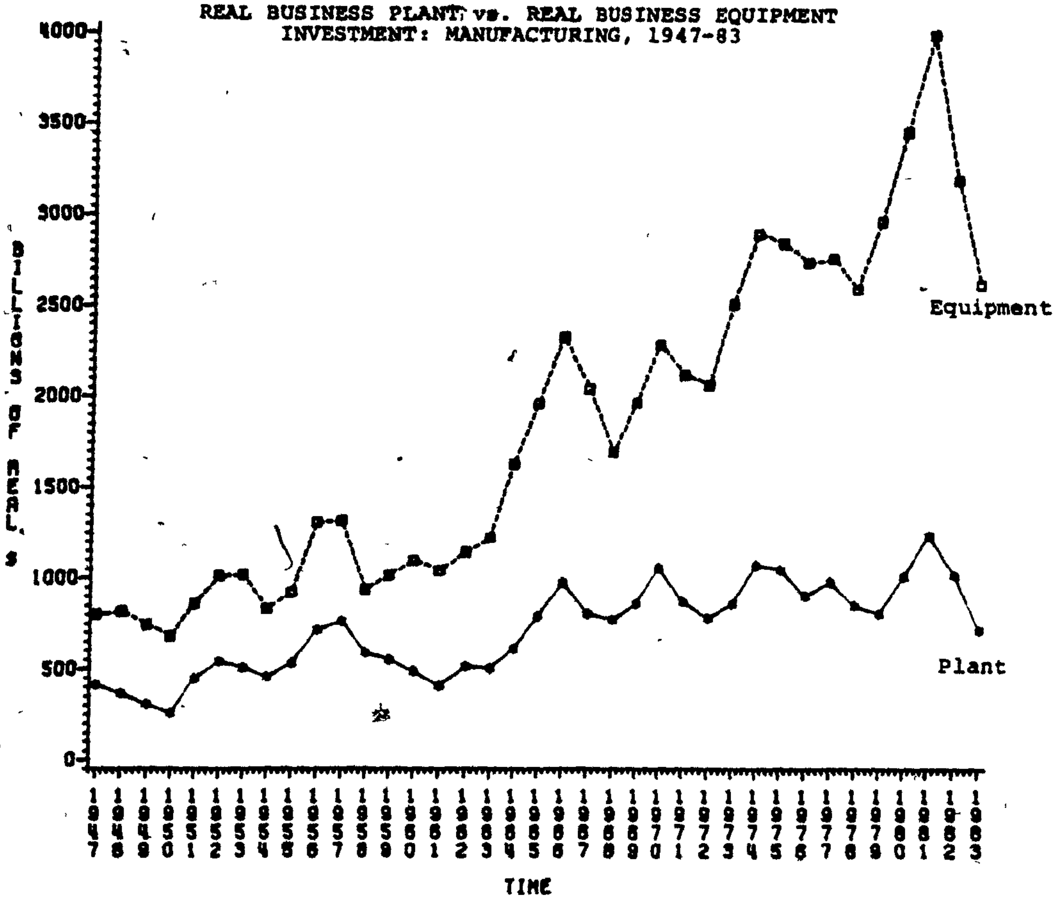


FIGURE 4-17

REAL BUSINESS PLANT vs. REAL BUSINESS EQUIPMENT INVESTMENT: UTILITIES, 1947-83

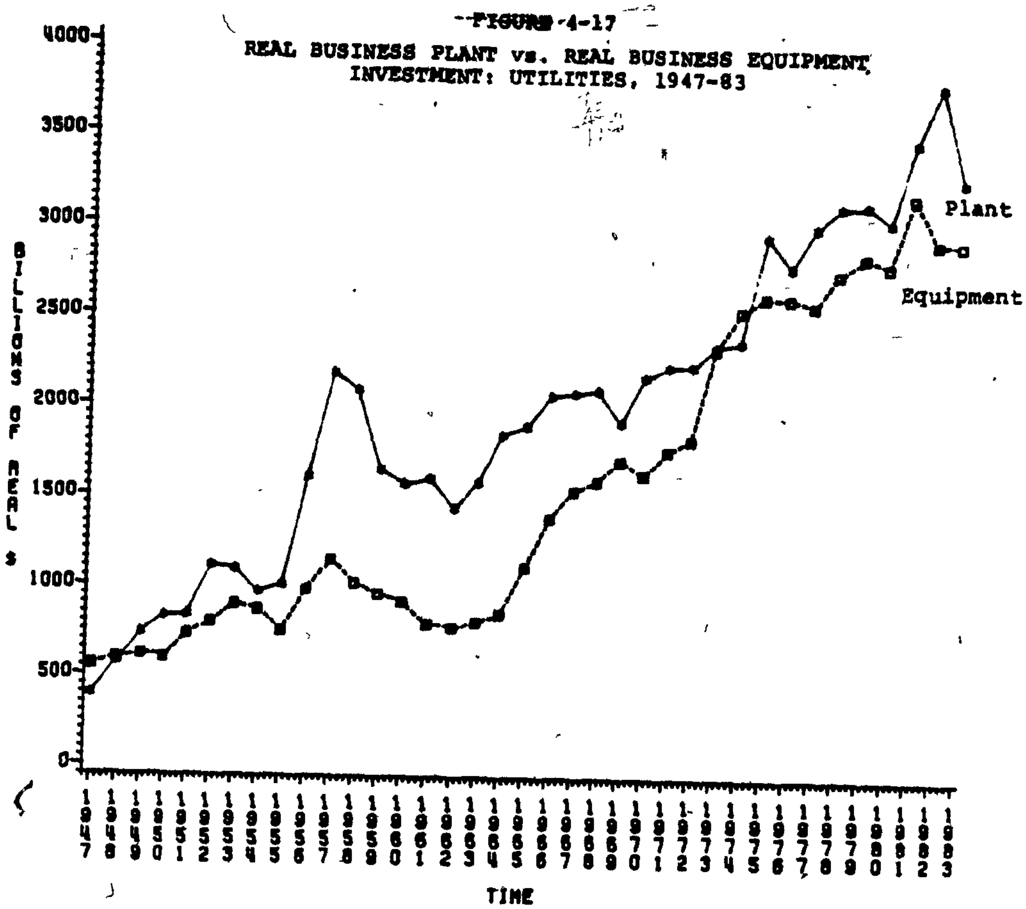


FIGURE 4-18

REAL BUSINESS PLANT vs. REAL BUSINESS EQUIPMENT INVESTMENT: TRADE, FINANCE & COM. SERVICES 1947-83

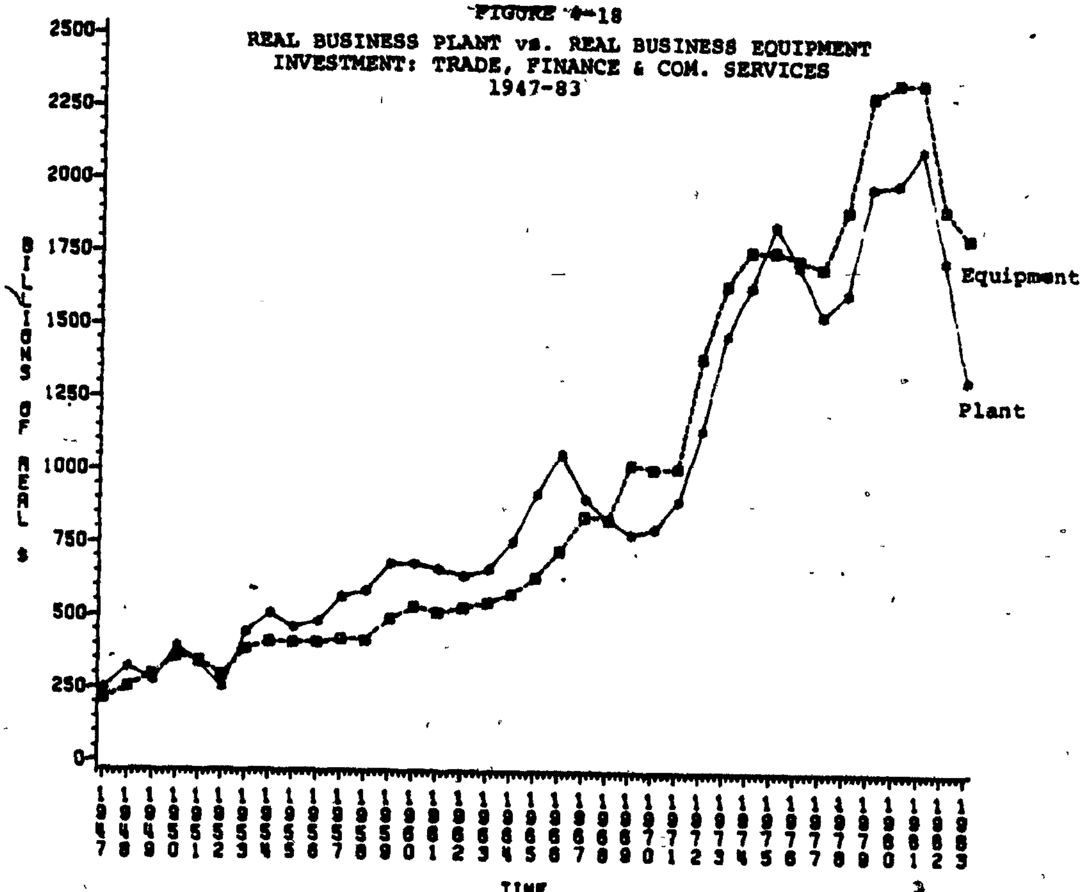


Figure 4-19 shows the percentage share of equipment capital investment out of total capital spending for each sector. Figures 4-20 to 4-22 provide information on equipment and plant shares for the manufacturing sector out of total investment (capital plus repair) for the period 1956-1984. Appendix E decomposes the information on equipment shares to the 2-digit S.I.C. level for 20 manufacturing industries.

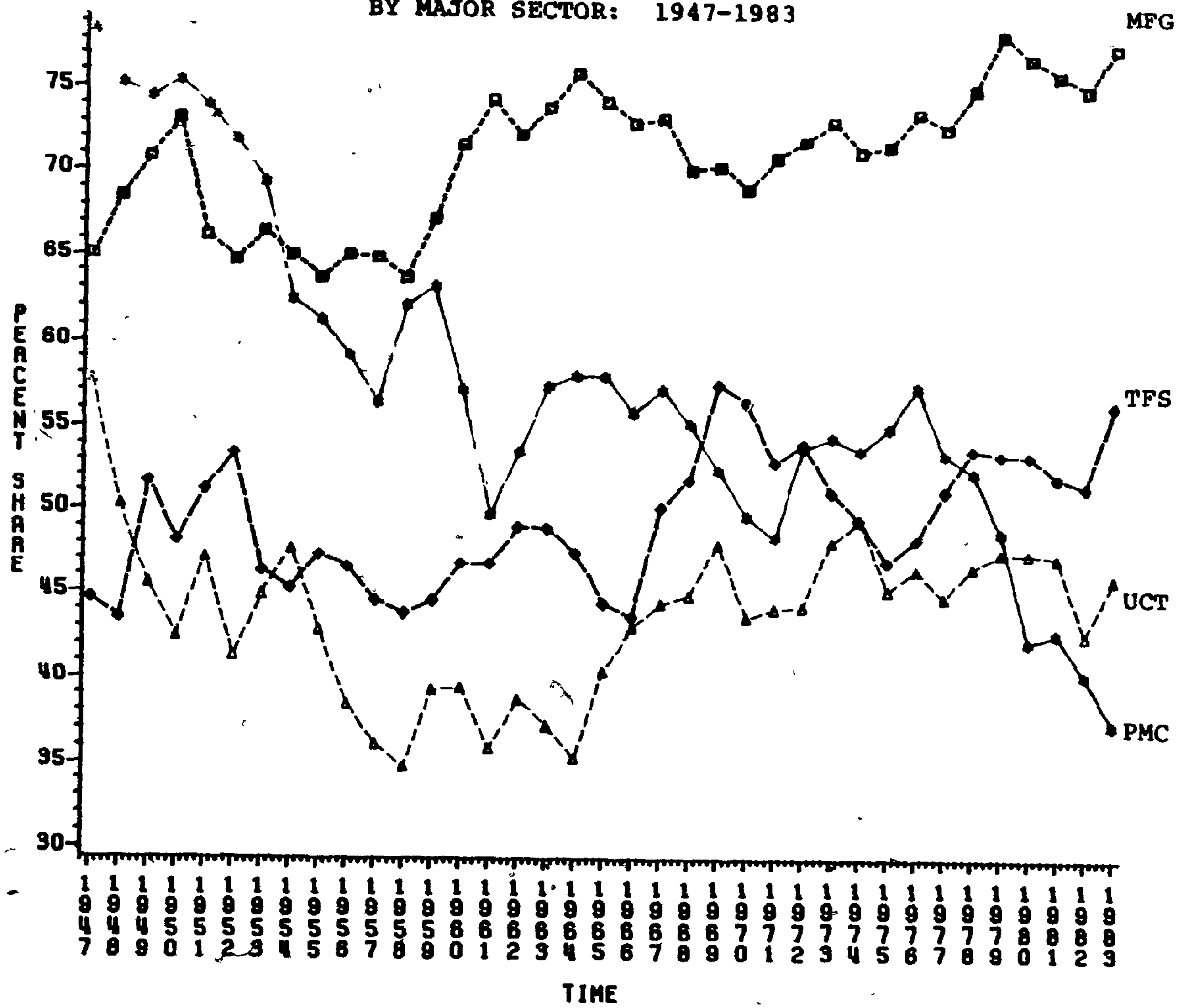
Examination of these figures indicates that each sector of the economy exhibits its own distinct composition of real capital. The equipment-to-plant mix varies considerably across sectors and industries, as well as across time. It is highest in manufacturing (MFG) at about 65-75% of capital spending; lowest in utilities, communications and transportation (UCT) at about 35-40% and next lowest in trade, finance and services (TFS) between 45 and 55%. The equipment-to-plant ratio for the primary goods, mining and construction sector (PMC) is a composite of industries with widely different ratios. In agriculture it averaged 78.4% during 1970-79; in forestry 54.1%; in mining 24.8% and in construction 86.9%[4]. Significant variations in the equipment-to-plant ratio are also in evidence among 2-digit manufacturing industries. The lowest is the petroleum refining industry with about 28% in the 1970-80 period while among the higher are pulp and paper, primary metals, metallic minerals, knitting mills and textiles industries with about an 82-85% equipment-to-plant ratio[5]. Tables

---

[4] See Statistics Canada, Current Economic Analysis, September, 1984, Catalogue 13-004 E, Volume 4, No. 9. The same variability is found in the trade, finance and other service sector. The corresponding equipment ratios are 65.5%, 14.2% and 77.3% respectively.

[5] Appendix E at the back of this thesis provides additional detail for 20 manufacturing industries.

FIGURE 4-19
PERCENT DISTRIBUTION OF BUSINESS MACHINERY AND
EQUIPMENT EXPENDITURES,
BY MAJOR SECTOR: 1947-1983



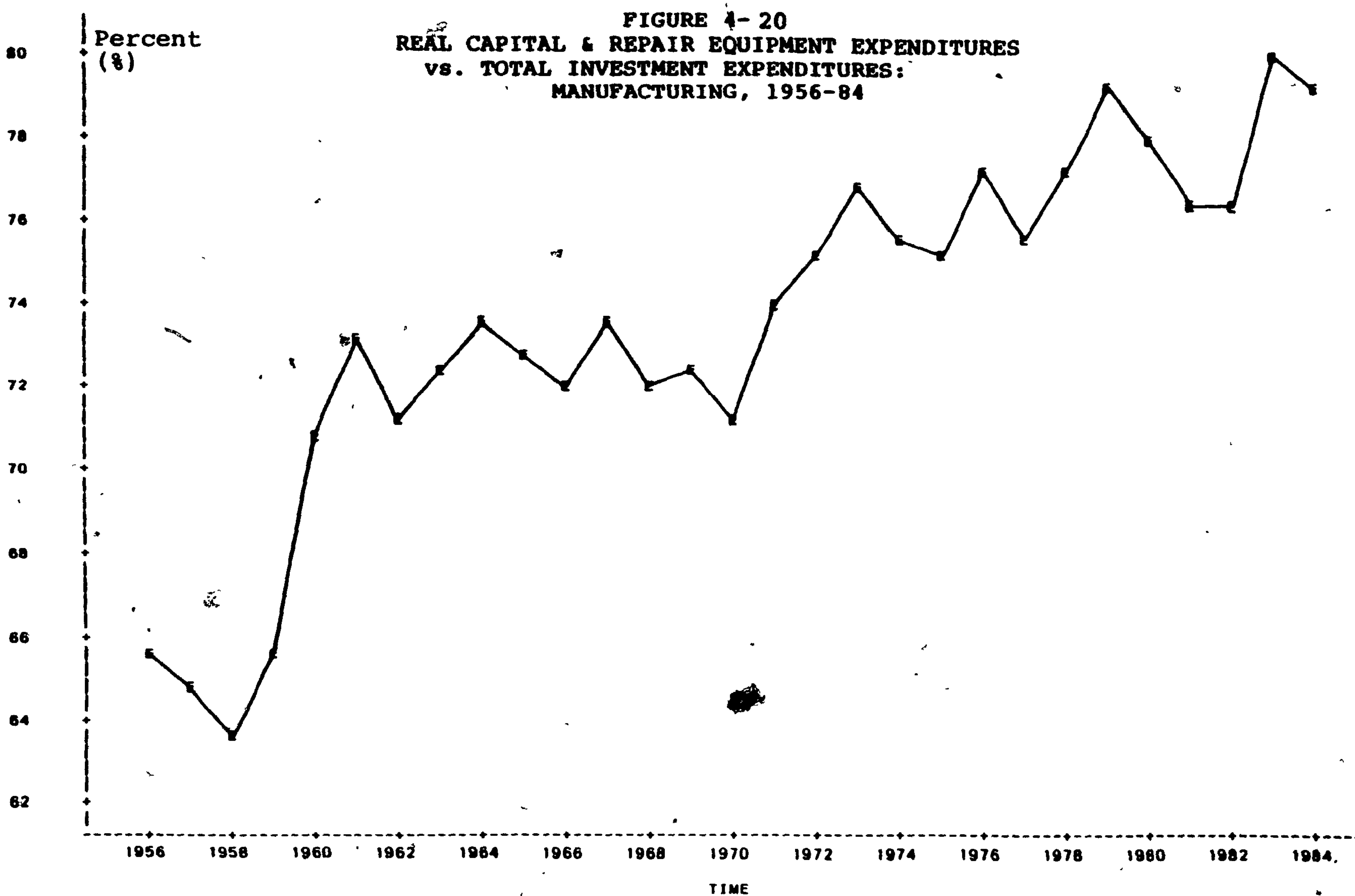


FIGURE 4-20
REAL CAPITAL & REPAIR EQUIPMENT EXPENDITURES
vs. TOTAL INVESTMENT EXPENDITURES:
MANUFACTURING, 1956-84

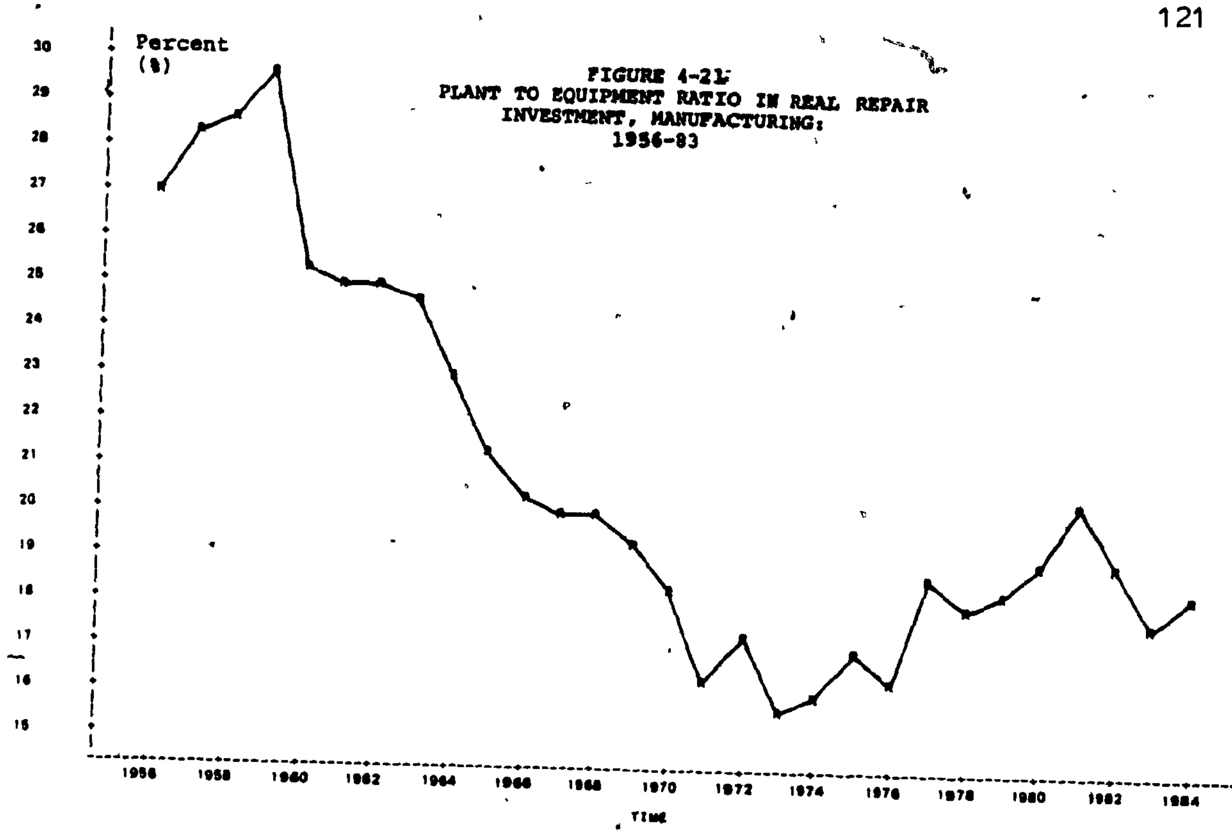


FIGURE 4-21
PLANT TO EQUIPMENT RATIO IN REAL REPAIR INVESTMENT, MANUFACTURING: 1956-83

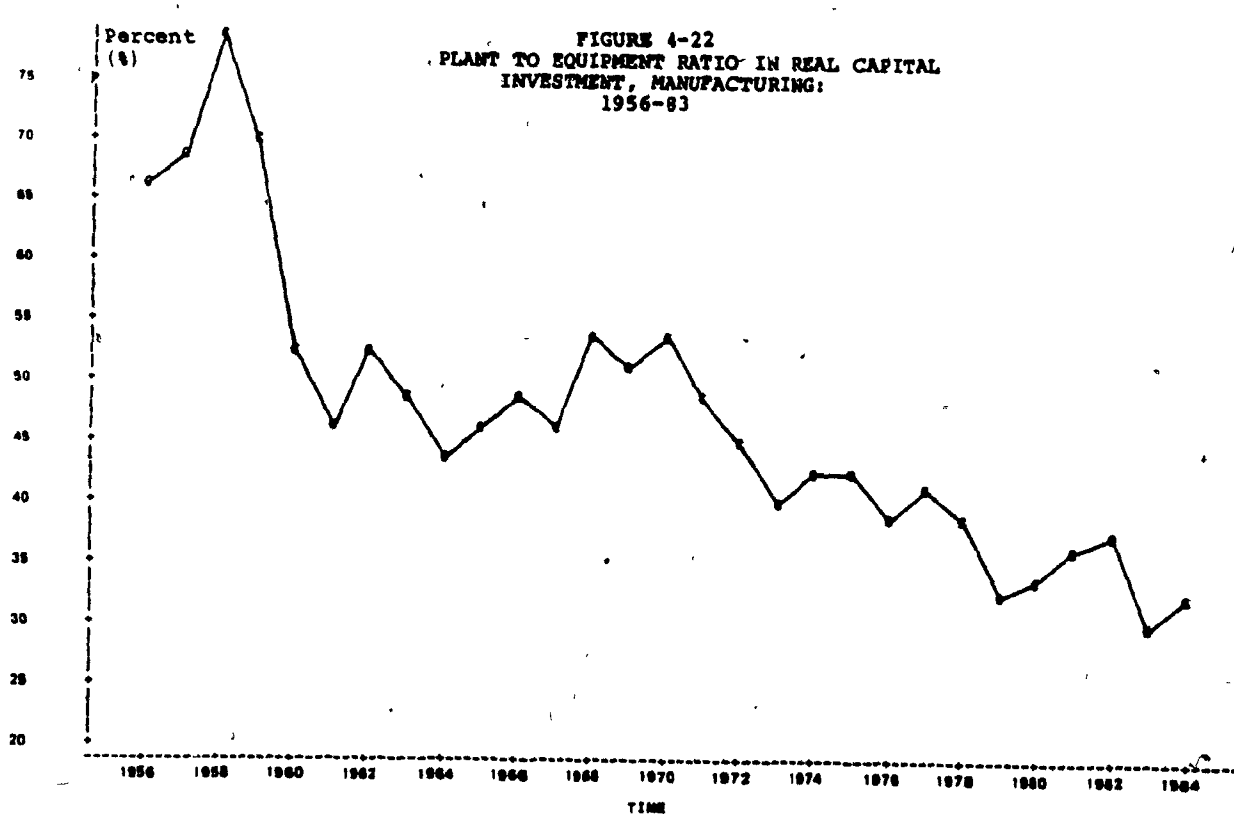


FIGURE 4-22
PLANT TO EQUIPMENT RATIO IN REAL CAPITAL INVESTMENT, MANUFACTURING: 1956-83

4-1 to 4-4 in the next section show the partition of capital stock in Canada by equipment, building structures and engineering structures in 1981, and provide further evidence of the degree of variability in the equipment-to-plant mix across industries. This evidence clearly indicates that each industry is defined by its own idiomorphic capital-input structure. Wide differences are evident among industries.

The composition of fixed capital input requirements does not only vary across industries but varies over time among industries and sectors as well. During the period 1947-83 there is a clear trend in favour of equipment in at least two sectors of the economy. In manufacturing, the equipment-to-plant ratio rose secularly from about 65% in the early 1950s to 75% in the early 1980s. This pattern is evident for virtually all of the 20 two-digit manufacturing industries as well, as can be seen in Appendix E. The same process took place in the trade, finance and services sector where the equipment-to-plant ratio rose from about 45% to 55% over the same period. In the utilities, communications and transportation sector (UCT) the equipment-to-plant mix seems to have remained stable over the period at about 45%. In primary goods, mining and construction (PMC), and opposite trend is in evidence for the ratio of equipment expenditures to total capital spending declined from about 70% in the 1950s to 50% in the 1970s and because even less in the early 1980s. One of the important causes of the decline in the equipment-to-plant mix in this particular sector was developments in the oil and gas sector, particularly since 1974. Between 1976 and 1983 the equipment ratio fell from over 55% to under 40%, largely due to increased mining exploration and development, which is classified as non-residential construction. In the late 1970s exploration and development spending accounted for over 30% of non-residential investment[6].

What may account for the secular rise in the equipment to plant ratio in the manufacturing and trade, finance and services sector? Two hypotheses may be advanced to account for this change. First, the shift in favour of equipment can be explained by changes in the composition of fixed capital input requirements over time. For example, to the extent that changes in technology and/or competition induce firms to substitute capital for labour or substitute more advanced capital for less advanced capital (computer-controlled machine tools vs. manually-operated machine tools), then one is likely to observe a positive capital spending program aimed at upgrading, re-fitting and modernization. Since investment on on-site replacements and modernizations is primarily oriented toward equipment, one would expect that in mature industrial sectors like food, tobacco, rubber, textiles, wood, pulp and paper, printing, metal fabricating, transport equipment and metallic minerals, there would be a higher rate of up-grading and modernization investment and hence an increase in the equipment to plant ratio. This is born out by the data. While the share of manufacturing investment dropped from over a third to a little over a fifth of total capital spending, the share of equipment to plant has risen from about 65% to 75%. This trend is evident all across the twenty two-digit manufacturing industries, as illustrated by the figures in Appendix E.

---

6 Statistics Canada, Current Economic Analysis, September 1984, p. xvii.

Data on the purposes for which investment is undertaken collected by the Department of Industrial Expansion in Canada[7] since 1977, as well as similar U.S.A. data collected by McGraw-Hill, provide powerful confirmation of this hypothesis. The share of replacement and modernization has risen from 27.4% in 1977 to 43.7% in 1985 in Canada. The share of new-site expansions dropped from 21.8% in 1977 to 5.0% in 1985, while the share of investment for purposes other than expansion or replacement rose from 17.7% to 31.5% during the same period.

Statistics Canada, in its analysis of current economic developments in Canada[8] is one of many[9] commentators on this trend:

> "The fact that exporting industries are anxious to improve productivity is reflected in machinery and equipment outlays; increases in the latter type of investment and cuts in non-residential construction are planned (for 1984) by the paper and allied and the machinery industries. The wood industry, whose capacity utilization rate is at pre-recession levels, intends to boost both types of investment. ... The drive to increase productivity rather than capacity seems to be widespread among other manufacturing industries and other sectors (excluding mining exploration and development).

A more detailed analysis and discussion of these developments is given in Chapter 5. At this point we can generally note the gradual transformations taking place in manufacturing: the shift from labour-

---

[7] See Tables 3-1 and 3-2 of Chapter 3 and Tables 4-5 and 4-6 of Section 7 in this chapter.

[8] Statistics Canada, Survey of Current Business, September, 1984, pp. xvii.

[9] They are too many to mention in detail here, but some include Schnorbus (1985) of the Federal Reserve Bank of Cleveland; the Department of Industrial Expansion and McGraw-Hill investment intentions surveys, Business Week, among others.

operated machine tools to numerically-controlled (NC) and computer-numerically-controlled (CNC) machine tools; from rigid mass-production to flexible mass-production, and to increased factory automation such as computer-aided design and manufacturing (CAD/CAM) and robotics. Business Week (June 16, 1986) recently published the results of a survey undertaken by Dataquest, a market research firm. It reveals that investment on shop-floor automation (computer-aided manufacturing) has risen from about $6.8 billion U.S. in 1980 to $15.4 billion in 1985 in the U.S.A. Such expenditures, which have more to do with productivity enhancement than capacity expansion, are expected to double by 1990 to $32.2 billion.

The second reason that may be given to account for the increased share of equipment over plant expenditures is the non-neutral treatment accorded to equipment and structures by the tax system. Investment in equipment can be depreciated over two years for tax purposes while investment in plant can only be depreciated over five years. This provision, effective in Canada since 1972 along with other similar provisions temporarily applied in Canada during the 1950s and 1960s[10] as well as similar legislation in the U.S.A. (Tax Reform Act of 1969, Revenue Act of 1971 and Economic Recovery Tax Act of 1981) may have favoured investment in equipment. While there is some empirical support for the U.S.A., see for example Aaron, Russek and Singer (1972), there is little conclusive evidence for Canada. To the extent that the tax laws have favoured equipment spending over investment in plant, the effect is likely to be small in relation to other

[10] For a more extensive discussion of tax provisions enacted to induce additional capital spending in Canada see Matziorinis (1979, 1980) and Matziorinis, Kollintzas and Rowley (1980, a,b).

factors. It is our belief that tax factors have exercised a positive but small role in the shift to equipment, at least in Canada[11].

Figures 4-20 to 4-22, unlike the previous set of figures, include both capital and repair expenditures on plant and equipment. They reveal that the shift in favour of equipment is also evident for repair expenditures at least in the manufacturing sector during the 1965-1984 period. When repair expenditures are examined separately, the plant-to-equipment ratio has dropped from over 27% in the late 1950s to about 16% in the early 1970s.

Some final comments are in order. The shift in the equipment-to-plant ratio taking place may be causing a gradual shortening in the average life of capital stock and might hold significant consequences for future replacement spending. Secondly, since a much higher proportion of machinery and equipment is imported into Canada, compared to buildings and structures which are supplied domestically, the shift towards equipment also holds significant results for final domestic demand in Canada and the balance of payments. The trend towards equipment seems to favour foreign suppliers of capital goods.

---

[11] The tax treatment of capital expenditures differs considerably between Canada and the U.S.A. Provisions in the U.S.A. have been generally much less generous than corresponding Canadian ones and they have been only gradually broadened. It is quite possible that the further liberalization of tax provisions over the years in the U.S.A. may have played a more significant role there than in Canada, where provisions were more generous from the outset.

6. Capital Heterogeneity and Functional Specificity

This section examines the morphological properties of capital stock in Canada. Capital investment refers to the acquisition of durable goods which are used for further production. No analysis of investment is complete without a look at on what investment dollars are spent and at what use these capital goods are intended to serve. It is well known that fixed or "real capital"--as opposed to money capital--is a generic concept defining an agglomeration of heterogeneous units of capital. Capital goods are heterogeneous not only in terms of their physical properties but in terms of their functional purpose as well. Each type of capital good can only be used for a limited number of purposes. We shall refer to this as functional specificity of capital.

The theory of investment, as it presently stands, almost always ignores morphological characteristics of capital. It is often based on the assumption of a quantifiable and homogeneous capital stock. By its restricted form, it can only deal with quantitative capital change, investment, disinvestment and replacement but it cannot deal with the change in the composition of capital stock. This is awkward since replacement investment cannot be properly understood if the morphologic properties of capital formation are not considered.

Clearly mineral extraction utilizes different types of equipment than leather goods manufacturing; automobile manufacturing utilizes different types of equipment than chemical process firms; and aircraft production utilizes different types of equipment than steel production. Everyone would agree that production functions differ from industry to industry and often from one firm to another, in the same industry. A useful classification is proposed by Drucker (1974). He distinguishes four major types of production processes: (1) rigid mass-production (building materials, iron and steel); (2) flexible mass-production or batch production (automobiles, appliances, furniture, clothing, shoes, cosmetics); (3) continuous-process production or flow production (petroleum refining, chemical products, pulp and paper, alumina, aluminum, nickel, glass, cement, beer, milk); (4) unique-product production (steam turbine, ship-building, satellites, space vehicles, engineering, accounting and professional services, building and engineering construction). We consider this classification more extensively in the next chapter. It is evident that different products require different amounts of capital input (rigid mass-production and continuous-process production are far more capital intensive than the others); different levels of skill and technical expertise (rigid mass-production does not require skilled labour whereas unique-product production does); and different rates of capital utilization (oil refineries and aluminum smelters operate 24 hours a day, 7 days a week throughout a year whereas the others cease work over night, on weekends and holidays)[12]. Capital goods themselves also are produced goods. Further, most buildings and engineering structures are custom-made as are many types of machinery and equipment (turbines, boilers, furnaces, among others). On the other hand, capital goods like vehicles, trucks, standardized machinery

---

[12] For an insightful analysis of capital utilization see Marris (1963).

and equipment like machine tools, computers, typewriters are mass-produced.

The purpose of the foregoing discussion is to emphasize the diversity of producer durable equipment in the economy, and their functional specificity. Appendix F reproduces the standard forms used in Japan for their capital stock survey. It contains a vast list of different capital goods used in the production of different products. No such list is available for Canada which would permit collection of capital stock data at a finer degree of detail, although the feasibility of setting up a survey to collect such data is presently under consideration, see Koumanakos _et al._ (1983).

From the little data available in Canada, we make a tentative effort to provide some general information on the morphology of capital stock. The approach used is to derive capital-output (K/Q) ratios and capital-labour (K/L) ratios for different sectors and major manufacturing industries, as well as to compute that percentage share of capital stock for each industry which is composed of buildings, engineering structures and machinery and equipment. The year for which these data have been computed is 1981. _As we are only interested in differential structural properties, the actual level of values computed is not as important as the differences in the levels of these values across major sectors of the economy and across major industries in the manufacturing sector_. Given the high level of aggregation of the data used in these computations, the conclusions though valid are only suggestive at this stage of analysis. A much finer degree of detail is required before we can adequately map the morphology of capital stock in Canada.

Measuring the capital-output (K/Q) and capital-labour (K/L) ratios of the economy is not a simple matter because of definitional and measures issues. We are not concerned here with the theoretical issues but rather with more practical issues of measurement of capital stock and also with its validity as used in econometric models of investment. The issues are significant and bear directly on the subject of this thesis. For a complete review of the capital stock measures, methodology, assumptions and issues see the Appendix to this Chapter.

The approach used to compute capital-output (K/Q) and capital-labour (K/L) ratios is determined by availability of data and our constraint on computational costs. As a measure of capital we use Statistics Canada's <u>gross fixed capital stock</u> (mid-year). This measure of capital is derived using the perpetual inventory method. It uses data on gross capital investment over a period of years along with estimates of service lives; it assumes a one-hoss-shay retirement process[13]. Statistics Canada also derives measures of <u>net capital stock</u>, i.e., gross capital stock minus accumulated depreciation. Here we use the gross concept of capital stock, because even though depreciation is deducted for accounting purposes, capital goods are still retained in the capital stock and continue to yield capital services in each current period. To the extent that repair expenditures maintain the productive efficiency of capital stock intact, gross capital stock is a more appropriate measure of the flow of the

---

[13] The meaning and implication of these assumptions and the nature of the perpetual inventory method are discussed in the Appendix to this Chapter.

economy's capital services in the short-run[14]. Furthermore, as is shown in the Appendix (Tables 4A-5 and 4A-6), gross measures of capital stock are more robust to different assumptions regarding service lives and retirement patterns than are net measures.

Output is defined as real value added or real gross domestic product (GDP) at 1971 constant prices, and is based on the system of national accounts. Statistics Canada breaks down GDP by major sector, and industries, at both the two and three-digit S.I.C. level for each industry[15]. Direct labour is defined as non-salaried, hourly paid wage earners, as estimated by Statistics Canada in its publication Employment, Earnings and Hours[16]. The amount of labour employed in an industry includes two categories. Direct labour, which involves workers directly engaged in the production process and therefore tied to the production function. Indirect labour consists of administrative, clerical and sales workers, who are not directly engaged in the production process. Differences in the ratios of direct-to-indirect labour across industries is likely to affect our estimates. Direct labour is a more appropriate measure of labour input for our purposes than total labour employed. However, the employment data compiled by Statistics Canada are not broken down along this line. Rather, Statistics Canada compiles separate series

---

[14] Net capital stock is more appropriate as a measure of capital stock services "stored-up" in the capital stock and therefore available for future periods.

[15] See Statistics Canada, Gross Domestic Product by Industry, (Annual Catalogue 61-213).

[16] Statistics Canada, Employment, Earnings and Hours, Catalogue 61-213.

for salaried and non-salaried labour. We shall use the non-salaried series as a proxy for direct labour because direct labour is predominantly remunerated on an hourly basis.

Tables 4-1 and 4-2 present our estimates of capital-output and capital-labour ratios across different sectors of the Canadian economy and across the twenty major manufacturing industries comprising the manufacturing sector. Before we examine these results, a number of qualifications are in order. First, these results are subject to statistical measurement errors in all variables which is unavoidable. Second, the results depend on the quality of our capital stock estimates. As the Appendix to this chapter makes clear, our estimates of capital stock are sensitive to the methodology and the assumptions used in their derivation[17]. Unfortunately, due to lack of census or survey type data, there is no way of validating our capital stock figures. Therefore, our estimated values here are only as good as the capital stock data used in their construction. Third, our labour data are not in the most appropriate form needed for calculating capital-labour ratios. What is needed ideally, is a measure of direct labour only and should be adjusted for working hours. As already mentioned, sufficient sectoral data on direct labour are not available. The capital-labour ratios calculated in Tables 4-1 and 4-2 differ, in that the former use total labour as compared with direct labour. Fourth, both capital-output and capital-labour ratios

---

[17] The perpetual inventory method used by Statistics Canada values capital stock in terms of the historical or acquisition cost. Alternatively, one can value capital stock in terms of its market value or insured value. Also, an alternative to relying on investment time series is the survey method used in Japan.

TABLE 4-1

FIXED CAPITAL INTENSITY IN SELECTED SECTORS OF CANADIAN ECONOMY, 1981

Sector	Gross Domestic Product	Direct & Indirect Labour	Capital Output Ratio	Capital Labour Ratio
	Millions 1971 $		1971$	1971$
Agriculture	3,189	--	8.06	--
Forestry	768	51,000	2.89	43,529
Fishing	190	--	4.47	--
Agricult. Fores. & Fish	4,148	--	6.94	--
Mining	3,272	164,900	11.39	225,913
Manufacturing	26,078	1,657,400	2.65	41,738
Construction	7,448	224,300	0.65	21,543
Air Transport	1,607	48,000	1.66	55,625
Rail Transport	2,060	114,600	7.29	130,977
Urban Transport	285	34,400	8.50	70,494
Ripelines	486	--	14.77	--
Broadcasting	--	31,800	--	42,296
Telephones	3,646	116,700	5.75	179,614
Electric & Gas Util.	3,924	117,800	13.66	454,898
Trade (Retail & Wholesale)	15,213	910,200	1.06	17,787
Finance, Insurance	16,013	397,900	1.26	50,709
Commercial Services	23,861	691,900	0.85	29,310

SOURCES: Statistics Canada, Fixed Capital Flows & Stocks, 13-211
Gross Domestic Product by Industry, 61-213
Employment, Earnings and Hours, 72-002

TABLE 4-2

FIXED CAPITAL INTENSITY IN CANADIAN MANUFACTURING SECTOR, 1981

Manufacturing Industry	Gross Domestic Product	Direct Labour(1)	Capital Output Ratio	Capital Labour Ratio	GDP per Direct Labour
	Mil. $				
1. Food & Beverage Products	3,236	174,400	2.51	46,600	18,555
2. Tobacco Products	207	4,700	1.43	63,000	44,043
3. Rubber & Plastic Prod.	875	18,600	1.65	77,700	47,043
4. Leather Products	193	20,300	1.15	10,900	9,507
5. Textile Mills	890	49,500	2.36	42,500	17,980
6. Knitting Mills	207	15,800	1.20	15,800	13,101
7. Clothing Mills	746	73,300	0.41	4,200	10,177
8. Wood Industries	1,213	64,600	2.83	53,204	18,777
9. Furniture Industries	492	30,600	0.86	13,900	16,078
10. Paper & Allied Indust.	1,966	90,600	5.25	113,900	21,700
11. Printing, Publishing	1,594	44,900	1.16	41,400	35,501
12. Primary Metals	1,972	99,100	4.78	95,200	19,900
13. Metal Fabricating	2,144	90,600	1.46	34,700	23,665
14. Machinery	1,732	53,400	1,02	33,100	32,435
15. Transport Equipment	3,090	125,600	1.83	45,000	24,602
16. Electrical Products	1,872	73,800	1.18	30,000	25,366
17. Non-Metallic Minerals	893	36,100	3.84	95,100	24,737
18. Petroleum & Coal	264	8,900	18.75	556,200	29,663
19. Chemicals & Chemical	1,769	40,300	5.16	226,500	43,896
20. Miscellaneous Manuf.	724	50,900	0.94	13,400	14,224
Total Manufacturing	26,078	1,665,800	2.65	59,300	22,370

SOURCES: Statistics Canada, Fixed Capital Flows & Stocks, 13-211
Gross Domestic Product by Industry, 61-213
Employment, Earnings and Hours, 72-002

Note 1: Direct labour is defined here as wage-earners or non-salaried employees.

are sensitive to fluctuations in the level of production. For example, variations in the capacity utilization rate significantly affect the capital-output ratio over time. The measured capital-output ratios rise during recessions and fall during expansions. Since we are only interested in cross-sectional differences in the capital-output ratio, the magnitude of errors from this source are likely to be small to the extent that all industries are uniformly affected by fluctuations in the general level of business activity. The results presented in Tables 4-1 and 4-2 seem to provide a reasonable view of structural patterns of capital use in the Canadian economy.

Tables 4-1 and 4-2 show that capital intensity, measured by either the K/Q or the K/L ratio, varies considerably among sectors and manufacturing industries. Measured in real 1971 dollars, the four most capital intensive sectors are pipeline transportation (K/Q ratio of $14.77), electric and gas utilities ($13.66), mining ($11.39) and agriculture ($8.06). The four least capital intensive sectors are construction ($0.65), commercial and personal services ($0.85), retail and wholesale trade ($1.06) and finance, insurance and real estate ($1.26)[18]. For the manufacturing sector, the

---

[18] The curious result that the construction sector's K/Q ratio is only $0.65 may have to do with the fact that a high proportion of equipment used in this sector is leased. One estimate by Koumanakos et al. (1983) places the proportion of leased assets in this industry to 46.6% of total assets, in 1979. Since assets are classified by industry of ownership rather than industry of use in the capital stock statistics, the utilization of capital in construction may be substantially higher than the one measured here, while the corresponding figure for finance, insurance and real estate, where leasing firms are classified, may be lower. The growing practice of leasing in recent years may introduce significant errors in the distribution of capital investment and stock across sectors, but would not affect the total for the economy. One estimate of Koumanakos et al., (1983) for 1979 places the capitalized value of equipmentleasingat $12.3

capital output ratio is estimated at $2.65.

Although wide diversity in capital-output ratios is in evidence sectorially, it conceals an even greater diversity at a lower level of aggregation. Table 4-2 presents capital intensity indicators across twenty major manufacturing industries. There capital intensity varies from a high of $18.75 in the petroleum and coal products industry, to a low of $0.41 in the clothing industry. An analysis of the data shows that very wide diversities are also evident among sub-industry groups which are not shown.

The four most capital intensive manufacturing industries are petroleum and coal products (capital-output ratio of $18.75), paper and allied industries ($5.25), chemicals and chemical products ($5.16) and primary metals ($4.78). The four least capital intensive industries are clothing ($0.41), furniture and fixtures ($0.68), miscellaneous manufacturing ($0.94) and machinery industries ($1.02).

The above figures provide strong evidence of differences in the structural composition or morphology of capital among industries which validate our underlying assumption that the capital stock incorporates structural patterns. To the extent that these structural patterns are linked to the pattern of investment and especially "replacement" investment, far-reaching implications for the theory of investment and replacement investment in particular are embedded in the composition of capital.

---

billion for all industries, equivalent to 5.1% of gross book value of assets other than buildings.

Tables 4-3 and 4-4 reveal another dimension of the structural composition of capital. Gross capital stock is partitioned into its three components: buildings, engineering structures and machinery and equipment. The percentage share out of total capital has been computed for each component by sector and major manufacturing industry.

In five sectors, there is no investment in engineering structures: agriculture, highways, grain elevators, finance, insurance and real estate and commercial and personal services. Of the rest, the five sectors with the highest proportion of engineering capital are, respectively, water systems (95.8%), pipelines (87%), mining (69.7%), electric and gas utilities (68.2%) and rail transport (64.7%). The five sectors with the lowest proportion of engineering capital are, respectively, construction (0.8%), air transport (1.5%), motor transport (2.5%), retail and wholesale trade (3.6%) and agriculture, forestry and fishing (6.1%).

Turning to machinery and equipment, the following five sectors account for the highest proportions. They are, respectively, fishing (93.9%), air transport (83.9%), construction (80.4%), motor transport (75.6%) and commercial and personal services (70.6%). The five sectors with the lowest proportion of equipment expenditures are, respectively, water systems (3.1%), pipelines (7.1%), finance, insurance and real estate (11.8%), highways (12.4%) and mining (19.9%).

In the manufacturing sector, 60.2% of total capital stock consists of machinery and equipment, 26.6% of building capital while the remaining 10.3% is engineering capital. Within the manufacturing sector, as shown in Table 4-4, one again observes substantial variation in these shares among

TABLE 4-3

MORPHOLOGY OF FIXED CAPITAL IN SELECTED SECTORS OF CANADIAN ECONOMY, 1981

Sector	Gross Capital Stock	Buildings as % of Gross Capital Stock	Engineering Structures as % of Gross Capital	Machinery & Equip. as % of Gross Capital
	Millions 1971$	%	%	%
Agriculture	25,708	39.8	0.0	60.2
Forestry	2,220	6.7	58.7	34.6
Fishing	849	0.0	6.1	93.9
Agricul. Forest. & Fishing	28,777	36.0	4.8	59.2
Mining	37,253	10.4	69.7	19.9
Manufacturing	69,176	26.6	10.3	60.2
Construction	4,832	18.8	0.8	80.4
Air Transport	2,670	13.8	1.5	83.9
Rail Transport	15,010	5.4	64.7	29.7
Water Transport	4,096	6.2	37.3	56.1
Motor Transport	1,814	20.2	2.5	75.6
Urban Transport	2,425	15.4	54.7	29.5
Pipelines	7,172	0.2	87.0	7.1
Highways	938	87.6	0.0	12.4
Grain Elevators	1,025	73.0	0.0	26.7
Broadcasting	1,345	19.3	21.9	58.5
Telephones	20,961	6.2	33.9	59.6
Electric & Gas Utilities	53,587	1.8	68.2	29.9
Water Systems	4,461	1.2	95.8	3.1
Retail & Wholesale Trade	16,190	48.9	3.6	44.0
Finance & Insurance	20,177	88.2	0.0	11.8
Commercial Services	20,280	29.4	0.0	70.6

SOURCE: Statistics Canada, Fixed Capital Flows and Stocks, Annual Catalogue, 13-211.

TABLE 4-4

MORPHOLOGY OF FIXED CAPITAL IN CANADIAN MANUFACTURING SECTOR, 1981

Manufacturing Industry	Gross Capital Stock (Constant 1971 $)	Buildings as % of Gross Capital Stock	Engineering Structures as % of Gross Capital	Machinery & Equip. as % of Gross Capital(1)
1. Foods & Beverage Products	8,124	35.3	1.1	61.4
2. Tobacco Products	296	40.5	1.4	55.1
3. Rubber & Plastics	1,445	31.8	1.2	63.3
4. Leather Products	222	52.7	2.7	42.3
5. Textile Mills	2,102	28.0	0.3	69.8
6. Knitting Mills	249	16.1	0.0	81.2
7. Clothing Mills	307	28.3	0.0	69.4
8. Wood Industries	3,437	22.2	4.4	69.7
9. Furniture Industries	425	40.0	0.0	58.6
10. Paper & Allied Industries	10,321	25.2	4.5	66.9
11. Printing, Publishing, etc.	1,858	26.4	0.1	71.5
12. Primary Metals	9,434	30.3	3.2	62.5
13. Metal Fabricating	3,141	35.2	1.9	60.3
14. Machinery	1,767	35.6	1.1	60.7
15. Transport Equipment	5,648	27.4	3.5	66.1
16. Electrical Products	2,210	30.3	1.4	65.9
17. Non-Metallic Minerals	3,432	27.8	2.1	65.3
18. Petroleum & Coal	4,950	3.2	79.8	16.2
19. Chemicals & Chemical	9,128	21.0	18.5	57.1
20. Miscellaneous Manuf.	682	42.4	2.0	52.8
Total Manufacturing	69,176	26.6	10.3	60.2

SOURCE: Statistics Canada, Fixed Capital Flows and Stocks, 1984 (Annual Catalogue 13-211).

Note 1: Percentages do not add-up to 100% due to "capital items changes to operating expenses"; they range between 0.8 and 4.8%.

industries. Five industries employ virtually no engineering capital: textile and knitting mills, clothing, furniture and printing and publishing. The four industries with the highest proportion of engineering capital are, respectively, petroleum and coal products (79.8%), chemicals and chemical products (18.5%), paper and allied industries (4.5%) and wood industries (4.4%). The four industries with the lowest proportions are food and beverages, machinery, rubber and plastics and tobacco products (1.1% - 1.4%).

The five industries with the highest proportion of equipment capital are, respectively, knitting mills (81.2%), printing and publishing (71.5%), textile mills (69.8%), clothing mills (69.4%) and paper and allied products (66.9%). The five industries with the lowest proportion of equipment capital are petroleum and coal products (16.2%), leather products (42.3%), miscellaneous manufacturing (52.8%), tobacco products (55.1%) and chemicals and chemical products (57.1%).

The picture that emerges from these tables is the extensive diversity in both the amount of capital and the type of capital employed across industrial sectors of the economy. As we show in the next chapter, the morphology of capital is of essence in the understanding of the investment process.

7. Purpose of Business Investment

The customary approach in economic theory has been to distinguish between net or expansion investment and replacement investment. One component expands production capacity while the other maintains intact the production capacity in the face of wear, tear and obsolescence. This two-fold categorization of investment is conceptually appealing and deeply entrenched. In practice, however, the world does not fit neatly into this categorization. If one approaches the issue inductively through observation of the real world of economics, rather than deductively as is prevalent, one finds that, firms invest for a variety of purposes, so the distinction between expansion and replacement is not always operationally valid and is indeed subject to a number of limitations. If the pronouncements of firms concerning their objectives are to be believed, firms are motivated by a variety of factors in their capital investment decisions. Firms incur capital expenditures not only to expand or sustain capacity, but to improve profitability, withstand competition, improve growth prospects, introduce new products, modify or improve existing products, retool for the production of new models, improve pollution emissions into the environment and improve the quality of the work environment especially occupational health and safety. Thus, when firms invest, it is not always to add or sustain existing production capacity but also to alter the structure of fixed capital assets and achieve these other objectives.

What makes the foregoing more interesting is the fact that in practice it is not always possible to distinguish between expansion and other objectives due to overlapping. A pulp and paper producer for example, may decide to modernize outdated equipment partly to reduce water pollution in a tourist area, partly to substantially improve labour productivity, partly to achieve some expansion of its production capacity. The weight given to these various factors is a matter of judgment. Here, we are not dealing with a simple set of mutually-exclusive alternatives but with mutually-inclusive arrays of alternatives which are combined and yield composite outcomes. When one approaches the matter inductively from field observations one does not find just a "black or white" distinction but many shades of different and interesting colours.

In this section we present data on fixed capital expenditures by purpose. In 1977 the Canadian Department of Regional Industrial Expansion (DRIE) began a systematic classification of capital expenditures by purpose as part of its bi-annual Survey of Capital Investment Intentions and Outlays. This was not the first time this was done. The Economic Council of Canada has recognized this issue in some of its work, for example in its now discontinued Medium Term Capital Investment Survey. The Economics Department of McGraw-Hill has collected information on expansion versus modernization investment since 1950, and information on expenditures devoted to automation since 1955 in its well-known Spring and Fall Surveys of Business Plans for New Plants and Equipment. Although McGraw-Hill's data are the oldest, the survey of DRIE provides a broader classification by purpose of investment[19]. In European countries the classification of investment by purpose is more common practice, especially in Sweden, France and Germany. This long-established practice by prestigious institutes such as the IFO Institute for Economic and Business Research in the Federal Republic of Germany testify to the validity of distinguishing among the various purposes of capital outlays with their different motivations and effects.

Tables 4-5 to 4-8 provide a rare, at least for Canada, perspective on the purposes for which firms commit capital expenditures. Broadly speaking these purposes fall into three categories: (a) capital investment which does not entail an expansion of capacity (research and development capital expenditures; pollution abatement expenditures and work environment related expenditures); (b) capital investment whose primary purpose is an expansion of facilities (expansion facilities at existing sites and expansion of facilities at new sites or greenfield expansion) and (c) capital investment whose primary purpose is upgrading and replacement of existing facilities. It should be remembered that expansion at existing sites and up-grading and replacement always leads to some--often considerable--expansion of capacity while expansion usually entails some degree of up-grading and replacement. In practice a pure distinction between the two is untenable.

Table 4-5 indicates that over the 1977-86 period 32.5% of total spending was devoted to expansion of facilities at existing sites; 33% to expansion at new sites; 19% to up-grading and modernization; 4% to research

[19] For a description of the survey see any DRIE April and October Capital Investment Intentions Survey (DRIE, Ottawa). Also, see Chinfen (1982, 1984) and Byleveld (1981).

TABLE 4-5

CAPITAL EXPENDITURES, BY PURPOSE: CANADA, 1977-1985
(Percentage Distribution of Total)

	1977	1978	1979	1980	1981	1982	1983	1984	1985*
Resrch. & Devel.	0.7	1.1	0.8	0.8	0.8	1.1	1.2	1.5	1.3
Poll. Abate.	2.3	2.3	2.8	1.8	1.6	1.8	2.0	1.4	1.7
Work. Environ.	0.5	0.7	0.6	0.6	0.7	0.6	0.6	0.7	0.7
Exp. of Facil. Existing Sites	26.8	30.7	28.9	30.3	42.2	35.7	34.8	35.1	34.0
Upgr. & Replac. of Exist. Facil.	16.8	21.2	17.6	17.6	17.2	16.4	19.5	22.2	24.2
Exp. of Facil. New Sites	47.6	29.1	40.1	35.8	26.6	34.5	31.0	22.8	20.5
Other**	5.2	14.9	9.2	13.0	10.6	9.8	10.9	16.2	17.6
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*Figures for 1985 only are intentions as of April, 1985
**Includes capital spending on retooling and plant conversions, among others.

SOURCE: DRIE, Business Capital Investment Intentions Surveys, April 1978 to April 1985 and development, pollution abatement and work environment. 11% was devoted to purposes other than the above. Certain trends over the period are also visible. The share of new-site expansions (greenfield expansions) has tended to decline while the shares of expansion at existing sites, up-grading and replacement and "other" have all tended to rise.

Table 4-6 provides similar information. Here, a different pattern is at work. The expansion share of capital spending in the manufacturing sector is significantly lower when compared to the economy in general. It averages 43% over the period versus 65.5% for the economy in general (manufacturing plus non-manufacturing). The share of up-grading and replacement on the other hand is substantially higher for manufacturing. It averaged 36% as compared to 19% for all sectors. The same is true for the other shares: research and development, pollution abatement and working environment spending is 8% while investment for all other purposes is 13% of the total manufacturing capital spending. Clearly, the manufacturing sector exhibits different structural characteristics as compared to non-manufacturing. This result serves to reinforce our earlier conclusions.

Another interesting pattern clearly evident over the period 1977-1986 is that the share of expansion investment has been rapidly diminishing (from 54.9% in 1977 to 24.8% in 1985), while the up-grading and replacement share has been rising (from 27.4% to 43.7%). The share of investment for all other purposes has also been rising (from 17.7% to 31.5%). This new evidence is entirely consistent with that presented earlier, namely, that manufacturing investment has lagged in relation to that of other sectors;

TABLE 4-6

CAPITAL EXPENDITURE SHARES IN CANADIAN MANUFACTURING, BY PURPOSE: 1977-1985
(Percentage Distribution of Total)

	1977	1978	1979	1980	1981	1982	1983	1984	1985*
Resrch. & Devel.	1.3	1.4	1.4	1.3	1.3	2.2	4.4	6.4	4.2
Poll. Abate.	6.5	4.9	3.7	3.8	4.4	5.3	3.8	1.9	1.8
Work. Environ.	1.1	1.6	1.2	1.4	1.3	2.1	2.1	2.4	2.0
Exp. of Facil. Existing Sites	33.1	32.0	33.1	33.9	36.3	26.7	24.9	27.2	19.8
Upgr. & Replac. of Exist. Facil.	27.4	31.0	36.3	31.4	33.5	36.7	38.8	44.9	43.7
Exp. of Facil. New Sites	21.8	17.6	12.9	18.1	14.1	15.3	6.3	3.9	5.0
Other	8.8	11.6	11.4	10.0	9.0	11.7	19.7	13.3	23.4
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*Figures for 1985 only are intentions as of April, 1985

SOURCE: DRIE, Business Capital Investment Intentions Surveys, April 1978 to April 1985 that the share of repair expenditures in the manufacturing sector is higher than those of others; that the proportion of equipment to plant expenditures has been higher than that of other sectors and rising over the period. For example, the share of greenfield expansion has dropped from 21.8% in 1977 to 5.0% in 1985. Since greenfield expansions engage a greater proportion of investment in buildings and engineering structures, one would expect the share of plant to equipment expenditures also to fall over the period.

Why the shares of expansion investment are higher in the non-manufacturing sector and the corresponding shares of up-grading and replacement lower there can be accounted for by the fact that investment outlays are dominated by major greenfield projects of electricity and gas utilities and of firms in the petroleum production and distribution sector. For example, electric utilities typically devote about two-thirds of their total capital spending to greenfield expansion projects while in the oil and gas sector the ratio is about 50% as described by Byleveld (1981) for example.

The above data reveal that there is a major structural change in progress in the Canadian manufacturing sector. New-site expansion projects are declining in favour of on-site expansion and modernization. Industry specialists attribute this switch in the orientation of fixed investment to two factors. The first of these is that spending on advanced equipment and the modernization of existing equipment make it possible to achieve higher production within the same or even smaller factory space. The automobile and pulp and paper industries are a case in point. In 1980, the forest products industry in Canada devoted as much as 70% of its capital program to modernization and replacement of facilities and less than 15% to expansion. The chemical industry on the other hand requires new sites in search of burgeoning markets or to be closer to feedstock but nevertheless, prefers to maintain an existing site so long as it is possible to expand capacity there by widening bottlenecks in an often continuous production process. The second factor has to do with the spreading use of NC (numerically controlled) and CNC (computer numerically controlled) equipment, the spread of computer-aided design and engineering, computer-aided flexible manufacturing systems and the introduction of robots in the automobile and other industries as described for example by Byleveld (1981), McGraw-Hill (1982), Statistics Canada (1984), Canadian Manufacturers' Association (1982, 1984), Schnorbus (1985), <u>Time</u> (1980) and <u>Business Week</u> (1986 a,b).

Table 4-7 provides a more detailed breakdown by major industry group of trends in the composition of capital spending in the manufacturing sector. Between 1977 and 1985, the expansion share of business investment (on-site and greenfield expansions) dropped from 50% to 24.6% while capital spending for up-grading, modernization and other investment rose from 40.9% to 67.5% of total spending[20]. The forest products industries and the transportation equipment industries have the highest share of non-expansion investments. Of interest is the very high proportion of "other" investment

---

[20] "Other" spending excludes spending on R&D, pollution abatement and work environment. It groups all other miscellaneous purposes of investment spending and includes spending on special tools like dies used in the automotive sector.

TABLE 4-7

CAPITAL EXPENDITURES IN CANADIAN MANUFACTURING, BY PURPOSE & INDUSTRY: 1977 & 1985

	1977				1985			
Industry	Capital* Expenditures	% Share Expansion	% Share Upgrading	% Share Other**	Capital Expenditures	% Share Expansion	% Share Upgrading	% Share Other**
Food & Beverage	172.1	47.0	48.3	0.0	53.1	33.3	58.0	2.0
Forest Products	644.9	37.3	43.4	0.9	1,066.7	15.9	64.4	16.5
Primary Metals	563.0	73.0	13.6	12.2	1,132.6	38.9	44.0	5.9
Chemicals	426.4	73.4	14.7	7.1	420.9	42.3	44.9	3.6
Transportation Equipment	343.9	40.0	20.2	35.4	1,256.9	8.6	19.2	69.5
Other Manufacturing	413.9	49.6	32.1	10.4	1,035.5	25.7	46.9	11.7
Total Manufacturing	2,564.2	50.0	32.9	8.0	5,443.7	24.6	44.3	23.2

* In millions of current dollars

** Represents capital spending for purposes other than expansion, upgrading, R&D, Pollution Abatement and Work Environment. Includes re-tooling & plant conversions.

SOURCE: DRIE, Business Capital Investment Intentions Surveys, April 1978 and April 1985.

in the transportation equipment sector (35.4% in 1977 and 69.5% in 1985). These are expenditures directly linked to model change-over in the automobile industry and are incurred to adapt production facilities to the production of new models. Table 4-8 translates these shares to capital expenditure figures to reveal the magnitude in current dollar terms of investment for purposes other than expansion. Thus, the expansion share is relatively small and of decreasing importance in recent years while the remaining expenditures--given their extremely high magnitude--could not possibly all be accounted by pure "replacements". Clearly, a major proportion of capital spending is incurred for purposes other than pure expansion or pure replacement.

In 1983, the Canadian Manufacturers' Association undertook a special survey of its members to gauge reactions to fiscal measures enacted in the November, 1981 Budget. 394 firms participated in the survey. Their responses are instructive of the shift in corporate investment objectives currently in process. The following quotations are from a letter of the CMA addressed to the then Minister of Finance, the Honourable Marc Lalonde:

> "One important piece of information flowing from this survey is the dramatic swing in investment plans by purpose. According to Statistics Canada, in 1982 manufacturers invested $7.5 billion in new machinery and equipment, while $2.5 billion was invested in buildings. From our survey results, extended to the total manufacturing sector, plans for 1985 show an even greater emphasis on machinery and equipment compared to buildings. The investment focus is obviously on productivity and new and improved products and processes.
>
> Clearly this is an important consideration when viewing the relationship between manufacturing capacity utilization and investment. Indeed, it is because considerable manufacturing capacity remains idle that investment in modern machinery becomes so very important. Manufacturers can only maintain existing jobs, and create new ones, if they are able to put in place best-practice, state-of-

PAGE 151 OMITTED IN PAGE NUMBERING.

FEUILLET 151 NON INCLUS DANS LA PAGINATION.

the-art equipment to keep pace with competition throughout the world."

To emphasize these points, subjective comments on the survey by CMA members included in the letter were the following:

1. "We are like many other market sectors not solely trying to invest in capital assets for the purposes of increased capacity but are addressing the areas of productivity and firm efficiency. Our largest expenditures, even during the recessionary period, were to increase productivity."

2. "Capital investment in our business is made in order to keep pace with competition throughout the world. It must be made in order to improve productivity, enhance quality and maintain competitiveness. Capital investment is absolutely necessary if we are to survive in the long-term."

3. "We're embarking on two projects even though we are currently operating well below full capacity. Manufacturers cannot merely wring their hands and worry about idle capacity. They must do whatever is necessary to fill their plants and frequently this will mean new products and investment in additional capital equipment."

APPENDIX TO CHAPTER FOUR

CAPITAL STOCK MEASUREMENT: ASSUMPTIONS, METHODS AND ISSUES

1. The Measurement of Fixed Business Capital Stock

The concept of capital stock has been used for a number of purposes. It is used in the short-run production function at the firm, industry and aggregate level. It is also used in growth models and is used to estimate changes in productivity. Further, it is used to measure both capacity utilization and total capacity as well as being extensively used in the theory of investment. Most empirical formulations of the investment demand function rely on alternative versions of a "capital stock adjustment" model. The quality, and perhaps the validity, of much of our empirical and theoretical results must therefore depend on the quality of our measures of the real stock of capital. It is thus important that we critically examine the nature of the assumptions and measurement procedures which underlie our measures of real capital stock.

Most countries in the world measure their stock of fixed capital assets[1]. In the United States and Canada, such measurements have been undertaken by public agencies as well as by a number of private investigators[2]. Public agencies responsible for such measurement are the Bureau of Economic Analysis (BEA) in the United States and Statistics

---

[1] See OECD (1976, 1983).

[2] Among the private studies in the U.S.A. are Boddy and Gort (1973, 1974); Christensen and Jorgenson (1973); Coen (1980); Vreamer (1961); Denison (1957, 1974); Jack Faucett Associates Inc. (1973, 1975); Goldsmith (1962); Hickman (1965); Kendrick (1976 a,b) and Tice (1967). All of these studies utilize variants of the "perpetual inventory" method. For brief descriptions of them see Young and Musgrave (1980). In Canada, Hood and Scott (1957) and Lithwick (1963) have undertaken measurement of capital stock.

Canada[3]. The most widely used method of measurement of capital stock is known as the "perpetual inventory" method, developed by Goldsmith (1951). This is the method utilised by both BEA and Statistics Canada.

The "perpetual inventory" method uses data on gross investment over a period of many years along with estimates of service lines--the period of years over which an asset is expected to yield productive services--to calculate the gross stock of capital. Gross stocks at the beginning of any year are obtained by cumulating gross investment in prior years and subtracting from this accumulation the gross investment in those assets that have completed their useful lives and are deemed to have been discarded or withdrawn. Depreciation charges are derived by applying a depreciation rate to gross stock. Net investment is equal to the gross investment for the period minus the amount of depreciation for the period. Net capital stock for a period is the difference between cumulated gross investment and cumulated depreciation on that gross investment. By applying an investment goods price index over the period spanning the accumulation of gross investment one derives a constant dollar measure of both gross and net capital stock[4].

---

[3] The BEA estimates are published periodically in the U.S. Department of Commerce Survey of Current Business. See Musgrave (1976), Grosse, Rottenberg and Wasson (1966) and BEA (1967-1969). The Statistics Canada (1967) estimates can be found in Fixed Capital Flows and Stocks, Manufacturing, Canada, 1926-1960 - Methodology and Statistical Supplement (two volumes), catalogue No. 13-522; Fixed Capital Flows and Stocks, 1926-1978, catalogue No. 13-568 and annual catalogues 13-211. For estimates of Canada's capital stock utilizing alternative assumptions, see Koumanakos (1980).

[4] For detailed descriptions of the measurement process according to the "perpetual inventory" method, see Young and Musgrave (1980) and Statistics Canada Catalogues 13-211 and 13-522.

As can be seen from the above description, the "perpetual inventory" method does not take inventories of capital stock at the end of period t and at the end of period t-1 to compare them as is the standard accounting procedure for stocks of finished or unfinished goods. Classification, and valuation problems make this approach difficult, aside from the potentially high cost of conducting annual surveys of capital stock. Instead, these problems are circumvented by treating total capital stock in periods t or t+1 as the sum of the increments in every preceeding year. The advantage of this procedure is that it never fails to yield estimates of capital stock, year after year. The disadvantage is that errors in the estimation of any particular year's increment in capital stock reverberate throughout the capital stock time series. In the absence of any periodic checks, there is no way of knowing the extent to which our estimate of capital stock may have deviated away from actual values. Alternatives to the "perpetual inventory" method are annual surveys of physical assets, surveys of book values and surveys of insured values.

Now, let us examine the variables used or implied in the calculation of gross capital stock according to the "perpetual inventory" method. They include (a) historical time series of current dollar gross investment by type of investment (usually machinery and equipment and buildings and structures); (b) price indexes pertaining to the types of investment; (c) data on the "average economic life" of capital goods, that is the length of time which, on average, similar capital goods remain in useful economic service before discarding or scrapping occurs; (d) an assumption regarding the retirement pattern of discarded capital goods; (e) an assumption regarding the pattern in which capital goods depreciate; (f) an assumption regarding quality change in the stock of capital goods over time and (g) the method used in the valuation of capital goods.

2. Service Lives

Data for the average length of time that a given type of asset remains in use in a given industry are crucial in the determination of the capital stock. Clearly, shorter service lives result in a smaller estimate of capital stock than longer service lives. Data on service lives used in the calculation of both the United States and Canadian capital stock data are mainly based on the U.S.A. Treasury Department's Bulletin "F" Tables, issued in 1942[5]. These data have been supplemented to a minor extent by Department of Agriculture actuarial studies in the U.S.A. and by the data from the Department of Trade and Commerce in Canada[6]. The Bulletin "F" estimates of average service lives are not based on a census or survey type investigation. Rather, they reflect the Treasury Department's perception

---

[5] United States Department of Treasury (1942), Bulletin "F" Tables of Useful Lives of Depreciable Property, Washington, D.C., U.S. Government Printing Office. In 1962, the Treasury Department issued revised guidelines which allowed service lives 30% to 40% shorter than those used under Bulletin "F". See U.S. Department of Treasury (1962) Depreciation: Guidelines and Rules, Publication No. 456, U.S. Government Printing Office.

[6] See Department of Trade and Commerce (1949), A Study of Depreciation of Machinery and Equipment Containing Estimates of Value of Domestic Disappearance and Average Life Expectancy, Ottawa, Queen's Printer. This report provides ranges of lives and median lives for a large number of capital goods in Canada.

of service lives based on taxation data supplied to them by corporations. As Terborgh (1954, p. 15) reports, "not uncommonly the final determination has been the result simply of 'horse trading' between the taxpayer and the Treasury, often in deals involving issues other than depreciation rates"[7]. According to one assessment of the Treasury Department's service life estimates, the 1942 Bulletin "F" lives were longer than those used in practice whereas the 1962 revised guidelines were shorter than those used in practice[8].

Whether the service life estimates used in the capital stock surveys conform to actual experience is not known because there are no objective census-generated data that can be used to assess them[9]. In addition, service lives may be influenced by economic, political or technological factors. For example, during wars or other periods of high capacity utilization, capital goods may continue in use beyond their normal average lives. The average length of life may also change because of changes in technology such as process innovations, or changes over time in the composition of assets[10]. There is little information on changes over time in the average service lives of individual assets[11]. Table 4A-1 presents

---

[7] For an account of the history leading to the development of these guidelines see Terborgh (1954).

[8] Statistics Canada (1967), Catalogue 13-522 p. 87.

[9] Japan is the only OECD-member country to conduct large-scale asset surveys to establish service lives. Such surveys, however, are standard practice in Eastern Europe.

[10] Tenglad, A. and N. Westerlund (1976).

[11] OECD (1983) provides some evidence of a shortening in recent years in the average life of assets.

the service life assumptions used in the estimation of capital stock in the Canadian manufacturing sector and Table 4A-2 presents one of a number of alternative sets of assumptions derived from the Treasury Department's Bulletin "F" in the United States.

The tables show that the data on service lives used to estimate our capital stock are not based on empirical facts and to the extent that they are approximations of actual lives, they are based on actual conditions of the 1940s and 1950s, which may not adequately represent Canadian reality in the 1970s and 1980s. Statistics Canada, offers the following assessment of its own service life estimates[12]:

> "The weakest link in the set of capital stock estimates ... are the estimates of 'average economic lives' of the various types of capital goods ... The life data used in this report must be regarded as very imperfect ... (and) must be regarded with skepticism."

Therefore, given that the size of the capital stock depends directly on the service life assumptions, the same skepticism inevitably should carry over to the quality of our capital stock estimates.

Given this inadequacy, the BEA and Statistics Canada have produced alternative estimates of capital stock based on alternative assumptions regarding useful lives[13]. Table 4A-3 shows the impact on the level of capital stock of the different assumptions. It reveals that a 1% change in the average service life is associated with roughly a 0.40 to 0.45% change in the level of capital stock, which indicates that our measures of the

---

[12] Statistics Canada (1967), pp. 87 and 89.

[13] See Grosse, Rottenberg and Wasson (1966), Musgrave (1976) for the U.S.A. and Statistics Canada (1967).

TABLE 4A-1

ESTIMATES OF AVERAGE SERVICE LIFE OF FIXED CAPITAL GOODS:

MANUFACTURING, CANADA

(in years)

Industry (2-digit-S.I.C.)	Plant		Equipment	Capital Items Charged to Operating Expenses
	Building Construction	Engineering Structures	Machinery & Equip.	
1. Food & Beverages	50	55	29	5
2. Tobacco Products	50	55	15	5
3. Rubber & Plastic Prods.	50	65	15	5
4. Leather Products	50	55	15	5
5. Textiles	45	50	26	5
6. Knitting Mills	45	50	26	5
7. Clothing	30	--	21	5
8. Wood Products	30	35	26	5
9. Furniture & Fixtures	30	35	26	5
10. Paper & Allied Products	50	55	22	5
11. Printing & Publishing	50	55	30	5
12. Primary Metals	45	50	22	5
13. Metal Fabricating	45	50	21	5
14. Machinery	45	50	21	5
15. Transportation Equipment	40	45	30	5
16. Electrical Products	40	45	22	5
17. Non-Metallic Minerals	35	40	26	5
18. Petroleums & Coal	35	40	26	5
19. Chemicals & Chemical	50	35	22	5
20. Miscellaneous Mfg.	30	35	13	5

Source: Statistics Canada (1967) Fixed Capital Flows and Stocks, Manufacturing, Canada, 1926-1960, Methodology and Statistical Supplement, 2 volms., Catalogue 13-522, Occasional, Ottawa.

TABLE 4A-2

ESTIMATES OF AVERAGE SERVICE LIFE OF FIXED CAPITAL GOODS:
MANUFACTURING, U.S.A.*
(in years)

Major Industry (2-digit S.I.C.)	Plant	Equipment
1. Food & Kindred Products	50	15
2. Textiles & Products	50	22
3. Leather & Products	50	15
4. Rubber Products	50	12
5. Forest Products	50	20
6. Paper, Pulp & Products	50	18
7. Printing & Publishing	50	14
8. Chemicals & Products	50	19
9. Petroleum Refinery	50	15
10. Stone, Clay & Glass Prod.	50	15
11. Iron & Steel Products	50	17
12. Machinery	50	18
13. Non-Ferrous Metals	50	22
14. Transportation Equipment	50	15
15. Miscellaneous	50	18

SOURCE: Statistics Canada (1967).

* Derived from Bulletin "F" and used by Creamer *et al.* (1960).

Table 4A-3

SENSITIVITY OF FIXED CAPITAL STOCK ESTIMATES TO DIFFERENT ASSUMPTIONS REGARDING AVERAGE SERVICE LIVES: MANUFACTURING, MACHINERY & EQUIPMENT, 1960

Average Service Life	Capital Stock Measure	Sensitivity
L = Years	In millions 1949 Dollars	dK/dL . L/K
A1: L = 27.85	8,100	0.39
A2: L = 23.3	7,556	0.51
A4: L = 18.8	6,763	0.40
A5: L = 14.1	6,036	

Source: Statistics Canada (1967), Fixed Capital Flows and Stocks, Occasional Catalogue 13-522, Ottawa, pp. 108 & 132.

level of capital stock are possibly quite sensitive to alternative assumptions regarding service lives.

Table 4A-4 presents similar results for the United States. Here the sensitivity of gross capital stock is between 0.6 and 0.65% for each 1% change in the average service life. Shorter service life assumptions reduce the size of the estimated capital stock while increasing the size of capital consumption. Similar results have been produced for the United Kingdom by Hibbert et al. (1977). In Table 4A-5, we present findings by this author regarding the impact on estimates of capital stock and consumption of a gradual shortening in the length of life of assets over time. If the average length of life of assets has been shrinking in the

TABLE 4A-4

IMPACT ON CAPITAL STOCK MEASURES OF DIFFERENT ASSUMPTIONS REGARDING LENGTH OF SERVICE LIVES: NON-RESIDENTIAL CAPITAL STOCK, 1970, U.S.A.
(Billions of U.S. Dollars)

Service Life Assumptions	Gross Capital Stock	Net Capital Stock	Capital Consumption
Long Lives (1)	1,485	875	68
Standard Lives (2)	1,339	785	71
Short Lives (3)	1,235	719	74

Source: Musgrave, J.C. (1976) "Fixed Non-Residential Business and Residential Capital in the United States, 1925-1975", Survey of Current Business, vol. 56, No. 4 (April).

1. Long lives refers to 100% of Bulletin "F" service lives.
2. Standard lives refers to 85% of Bulletin "F" service lives.
3. Short lives refers to 75% of Bulletin "F" service lives.

TABLE 4A-5

IMPACT ON CAPITAL STOCK MEASURES OF CHANGE OVER TIME
IN AVERAGE SERVICE LIVES:
CHEMICAL AND ALLIED PRODUCTS INDUSTRY, U.K.

Assumptions	Gross Capital	Net Capital	Capital Consumption
Service lives fall from 37 to 30 years between 1947 and 1973	-2.7%*	-8.9%	+19.5%
Service lives fall from 37 to 22 years between 1947 and 1973	-6.5%	-19.2%	+43.7%

SOURCE: Hibbert et al. (1977)

*Percent changes refer to reductions (-) or increases (+) over the 1973 actual estimates of capital stock.

post-war period then there are significant implications for our measures of capital stock and capital consumption. In particular, Table 4A-5 clearly suggests that failure to incorporate lower service lives in our calculations may produce substantial errors in our measures of gross and net capital stock and, especially, in our measures of capital consumption.

3. Retirement Patterns

Service lives refer to averages. Underlying the average service life of a given type or group of assets is a distribution of retirements known as mortality distribution. For example, a piece of fixed capital has an average useful life of 10 years. What proportion of this type of asset is retired at the 10th year, what portion prior to the 10th year and what portion after? Our knowledge on the actual retirement patterns for different types of assets is rather scant. The principal empirical studies in this area are by Kurtz (1930), Winfrey and Kurtz (1931), Winfrey (1935) and Russo and Cowles (1981). Due to lack of extensive empirical data on actual patterns, a number of alternative assumptions of retirement have been employed to derive estimates of capital stock[14].

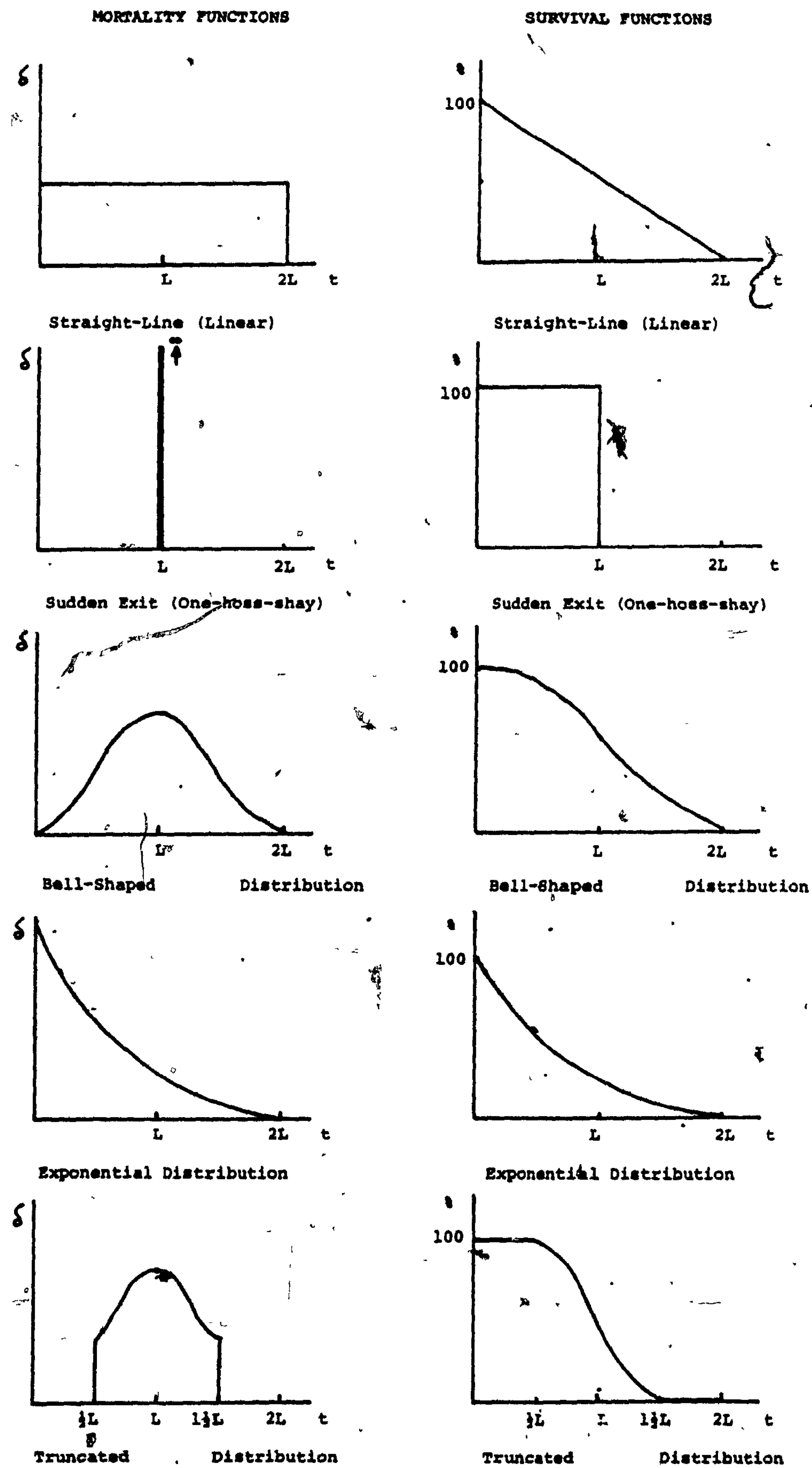
Figure 4A-1 shows standard typical mortality and survival functions underlying the various retirement patterns used in the estimation of capital stock. The mortality functions, in the first column, show rates of

---

[14] See OECD (1983), Koumanakos (1980), Grosse, Rottenberg and Wasson (1966) and Musgrave (1976).

FIGURE 4A-1

TYPICAL MORTALITY AND SURVIVAL FUNCTIONS



L = Average Life 2L = Maximum Life

retirement over the lifetimes of the longest-lived member of a group of assets of a particular type installed in a given year: they are essentially probability density functions with the area under each curve equal to unity. The survival functions, in the second column, show the proportion of the original members of the group of assets which are still in service at each point during the lifetime of the longest-lived member of the group.

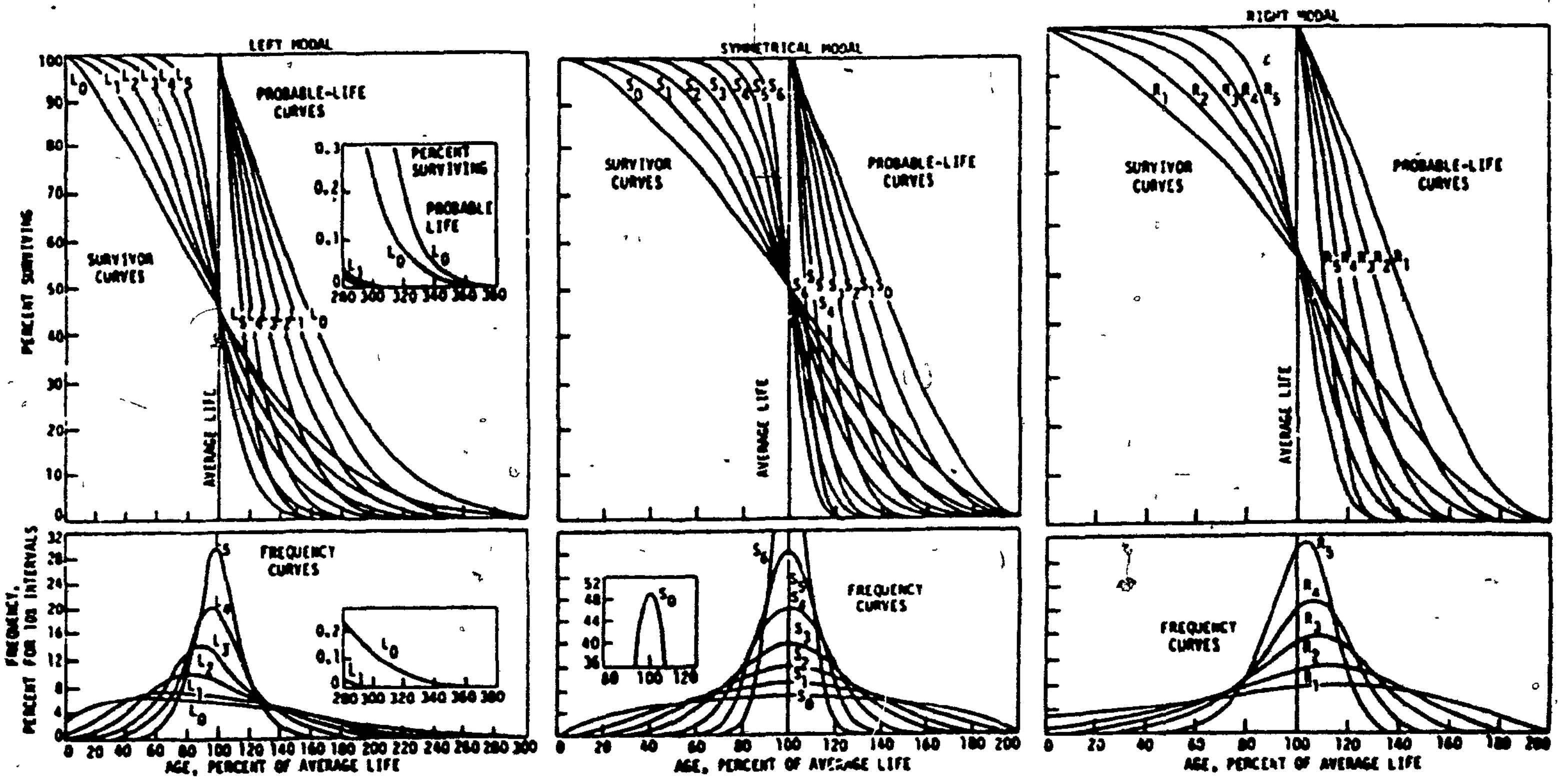
With the linear or <u>straight-line</u> pattern, assets are assumed to be discarded at the same amount each year from the time of installation until twice the average service life (2L). The mortality function is a rectangle whose height--the rate of retirement or depreciation (δ)--is $\frac{1}{2}$L where L is the average service life. The survival function shows that the surviving assets are reduced by a constant amount each year, equal to 50%/L of the original group of assets. With the alternative <u>sudden exit</u> pattern, also known as <u>one-hoss-shay</u>, assets are assumed to be retired all at once, specifically at the moment they reach the average service life for the type concerned. The survival function therefore shows that all assets of a given type remain in the stock until time L, at which point they are retired simultaneously. With the <u>exponential pattern</u>, assets are assumed to be discarded at the same rate each year from the time of installation until infinity. The mortality function is a geometric distribution, whereby the rate of retirements is very large at first but declines at a decreasing rate over time. For the survival function, assets decline rapidly at first but this rate diminishes over time.

With the <u>bell-shaped</u> pattern, the retirement pattern of assets is assumed to be a bell-shaped density distribution with the mean at or close to the average service life (L). The best known of such functions are the Winfrey-class functions. These are the only retirement distributions based on empirical data. Work on them was actually began in 1916 by Kurtz, who with Winfrey later published (in 1931) the original 13 empirically determined survivor curves. Between 1931 and 1935, Winfrey expanded data collection and added 111 property group curves to the 65 used in 1931. From these 176 curves, 18 standard curves emerged, and these now bear his name. Figure 4A-2 shows the standard Winfrey mortality functions, of which six are skewed to the left (L), seven are symmetrical (S) and five are skewed to the right (R). The subscripts 0 to 6 refer to the degree of flatness of the curves. The Winfrey S_1 function, for example, gives a flattish symmetrical curve with retirements spread over the period ±95% of the average service life; the Winfrey S_4 function is again symmetrical, but it is more peaked with retirements occurring around ±70% of the average service life.

While Winfrey curves are empirically well based, many of the underlying data used in their construction were collected between 1916 and 1935 and are now 50-70 years old. Also, almost a third of the 176 asset types analyzed by Winfrey consisted of railway equipment and structures, and the list covered relatively few manufacturing assets. Therefore, the obvious question that emerges is whether Winfrey-type retirement distributions are still valid today in our changed environment. The only attempt to empirically test whether the Winfrey-type curves are still valid was undertaken by Russo and Cowles (1981). Employing the same methodology as Winfrey, they collected data from over 2,000 property accounts from

FIGURE 4A-2

WINFREY MORTALITY DISTRIBUTION FUNCTIONS



Final survivor, probable life, and frequency curves for the left-modal, symmetrical-modal, and right-modal types

Source: Russo and Cowles (1981)

which they chose 490 property types. These data collected were for the period 1965-75. They found that the Winfrey-type curves remain and that from the more recent data they have collected, there is no need to either modify or extend them. Since the data they collected were for assets similar in type as those used by Winfrey we may conclude that as far as these types of assets are concerned, Winfrey-type distributions are still valid today. However, no firm conclusion can be drawn regarding assets like those used in the manufacturing sector which were not sufficiently represented in Winfrey's sample.

Other type of retirement functions employed in capital stock measurement are modified versions of the straight-line and bell-shaped curves. One is the delayed linear pattern, whereby retirement is assumed to occur at a constant rate over some period shorter than 2L. Retirements start later and finish sooner than in the simple linear case, some ±50% of L. The other is the truncated bell-shaped distribution, whereby assets are retired anywhere between ±50% of L.

The retirement pattern assumed in the estimation of capital stock holds significant implications for the quality of measures produced. In Canada, Statistics Canada employs the unsatisfactory sudden-exit assumption in its Fixed Capital Flows and Stocks measures. In the U.S.A., symmetrical Winfrey functions are used. For residential buildings, retirements are spread over the period ±95% of the average service life; for all other assets, retirements are spread over the period +45% of the average service life. See for example, Musgrave (1976)[15]. To ascertain the extent to

[15] For the assumptions used in other countries see OECD (1983).

which capital stock data are sensitive to different assumptions used for retirement of assets, a number of studies have been done which employed alternative assumptions of retirement patterns. Noteworthy among these are those of Grosse, Rottenberg and Wasson (1966) in the U.S.A. and Koumanakos (1980) in Canada.

Koumanakos (1980) of Statistics Canada produced alternative estimates of Canada's gross and net capital stock and capital consumption allowances for the period 1926-80 employing alternative retirement distribution assumptions. Table 4A-6 presents some of his estimates for the entire economy in 1980 in real 1971 dollars. His results confirm the sensitivity of capital stock measures to the underlying assumptions employed. All three series are significantly affected in differing degrees. Estimates of gross capital stock range from a low of $231.4 billion using the exponential retirement assumption to a high of $397.5 billion using the sudden-exit assumption. Since Canada's official capital stock estimates employ the sudden-exit assumption in their calculation, Table 4A-6 also expresses the estimates derived from each of the alternative retirement assumptions as a percent of those derived from the sudden-exit assumption. Similar results have been reported by Grosse, Rottenberg and Wasson (1966) for the U.S.A.

Clearly, the capital stock data published officially by our statistical agencies are not straight-forward survey data but <u>simple estimates</u>, derived from gross investment figures using numerous assumptions. Changing the underlying assumptions results in quite significant differences in the values of capital stock. Therefore, capital

TABLE 4A-6

IMPACT ON CAPITAL STOCK OF DIFFERENT ASSUMED RETIREMENT DISTRIBUTION PATTERNS: TOTAL CANADIAN MANUFACTURING AND NON-MANUFACTURING, 1980
(Millions of Real 1971 Dollars)

Retirement Assumptions	Mid-Year Gross Stock	Mid-Year Net Stock	Capital Consumption
Straight-line (% of Sudden exit)	358,060.4 (90)	292,811.9 (113)	11,586.1 (87)
Exponential (% of Sudden exit)	231,360.4 (58)	202,951.6 (78.5)	15,984.8 (120.5)
Bell-Shaped (% of Sudden exit)	382,338.5 (96)	316,909.1 (123)	10,398.1 (78)
Sudden Exit* (% of Sudden exit)	397,457.4 (100)	258,484.7 (100)	13,264.1 (100)
Truncated Bell-Shaped (% of Sudden exit)	388,706.9 (98)	301,752.8 (117)	11,094.5 (84)

SOURCE: Koumanakos (1980).

*The retirement assumption employed in Canada for the capital stock estimation purposes is the "sudden exit", see Statistics Canada, Fixed Capital Flows and Stocks, Catalogue 13-211, Annual.

stock data should be viewed as rough estimates, and extreme caution is in order when we begin employing these data in econometric models of investment behaviour, of capacity utilization or productivity change. No one, perhaps, is more aware of this than the statisticians themselves. Aware of the weaknesses inherent in the capital stock estimates Koumanakos et al. (1984) reports that a joint pannel of experts drawn from Statistics Canada, the Economic Council of Canada, the Department of Finance and the Bank of Canada has been formed to examine alternative and more reliable methodologies for measuring capital stock. Among the alternatives being considered is a quinquennial capital stock survey, similar to decennial censuses.

4. Valuation of Capital Stock Measures

There are three approaches to the valuation of capital stock: (a) in physical terms such as weight or horsepower; (b) in capacity terms such as output produceable at any given point in time; and (c) in value terms such as the amount of expenditure incurred in acquiring real capital and putting it in place. What is required--as in any aggregation problem--is a standard unit of measuring the heterogeneous pieces of capital goods--various types of machinery, equipment, structures and buildings--composing the economy's capital stock. Traditionally, the third approach has been preferred, that of measuring capital stock in value terms.

Inherent in this type of aggregation are a number of methodological problems. First, how are quantities to be valued? At historical (original) current or constant prices? Second, how does one account for quality change over time in each type of capital goods? Third, how does one treat the introduction of new types of capital goods? Fourth, how does one treat the pricing and classification of infrequently purchased or custom-made capital goods? Fifth, how does one account for changes in the composition of capital goods during the period?

Regarding the first problem, it is preferred to value capital stock at constant or current year prices rather than historical cost, because aggregating historical costs, in an inflationary environment, involves heterogeneous prices which violates our requirement for standard units of measurement. Regarding the second problem, it is widely acknowledged that the quality and engineering specification of most types of capital goods changes over time. Quality changes are usually though not always reflected in price changes. To the extent that quality change is reflected in price change, Denison (1957) has suggested to account only for the quality change which is reflected in the price change. However, to the extent that quality change is not reflected in price change serious omissions may result. Gordon (1971) for example has shown that by ignoring "cost unassociated" quality change results in a significant overstatement of price inflation and concomitant significant understatement of growth in real capital stock.

A related issue is the treatment of new types of capital goods, e.g. computers, robots, fiber optics, etc. Differentiating a new capital good from an improvement in an existing capital good can be quite difficult.

One problem particular to new products is determining which product they are replacing, which portion of the market for that type of product they are acquiring and the pricing of the new product. Frequently, new products appear on the market at a high price, but as they gain acceptance and are mass-produced their price falls while their quality improves. To the extent that new capital goods account for a large share of investor outlays, the problem assumes wider significance.

The fourth problem is how to price infrequently purchased, custom-made capital goods, such as ships, aircraft and engineering structures. In such cases the usual practice has been to represent the price of such items by a weighted average of the cost of the materials and labour used to produce them, both adjusted for changes in productivity, after making judgments with respect to what represents quality change and what represents a new product. Concerning the fifth problem which involves changes over time in the composition of capital goods, if firms shift their purchases of capital goods from low-priced types to high-priced substitutes, the measured price index will record an increase in prices when in fact no change in prices has occurred in the absence of an adjustment of weights.

The implications of the above troublesome difficulties is that even in the presence of a valid conceptual framework of capital measurement, methodological and practical problems may impede the construction of unbiased measures of capital stock. Worse still, in the absence of any measurable data, we have no way of knowing the magnitude of the possible biases or the accuracy of our estimates of the economy's capital stock.

CHAPTER FIVE

THE EMERGING VIEW OF "REPLACEMENT INVESTMENT": STRUCTURAL INVESTMENT AND ADAPTATION

1. Introduction

In the preceding three chapters, we have reviewed and critically analyzed the literature on "replacement investment" and examined the pertinent empirical and statistical evidence. Our assessment is that the conventional conception used in the theory and econometrics of replacement investment since Jorgenson (1965, 1974), that is, the rate of replacement investment is a constant proportion of capital stock and equal to the rate of depreciation (PRH), is clearly unsatisfactory. Many objections have been raised on both theoretical and empirical grounds to this view by, for example, Feldstein and Foot (1971), Feldstein (1974), Feldstein and Rothschild (1974), Eisner (1972, 1978), Nickell (1975, 1978), Rowley and Trivedi (1975) and Helliwell (1976). Inspite of the numerous objections to this approach, no comprehensive alternative formulation has yet emerged. The few attempts that were made, notably by Feldstein and Foot (1971), Eisner (1972) and Cowing and Smith (1977) did not go very far. In this chapter, we attempt to develop such an alternative perspective of the replacement process.

The view we propose is broader in scope and more accurate than the conventional approach which partitions gross capital investment into expansion and replacement components, the latter an outcome of the PRH. We reject the notion that the "other half of gross investment" is necessarily replacement investment. We have found, as reported in Chapter Four, that replacement expenditures are generally <u>not</u> capitalized by firms, but charged to operating accounts in the form of "repair expenditures." To the extent that such expenditures are in fact replacements, and not capitalized for accounting purposes, it leaves the "other half of gross (capital) investment" unexplained! To fill the void, we propose the insertion of a new category of capital investment, namely structural investment. Structural investment can be defined as fixed capital investment expenditures induced by the firm's need to adapt to changes in the composition of demand (output-mix), production technology and relative prices for factor inputs, the level of total demand remaining constant.

Unlike replacement investment, which is non-capital repair expenditures to maintain the productive efficiency of fixed capital stock intact and therefore in the short-run, a matter of "technical necessity", structural investment, like expansion investment, is a behavioural variable conditioned by economic factors. In fact, structural investment often acts to supplant or supersede the necessity for replacement investment. In the real world, firms are not constrained by some extraneously imposed rule that obliges them to invest in the maintenance of their capital stock. Ours is not a command economy. Firms are free to choose whether they want to maintain intact their stock of physical assets through repair expenditures. Obviously, even the decision to maintain the existing stock of capital is an economic decision, at least in the long-run, and therefore linked to the decision to commit structural investment.

Our view builds on both the "static" and "dynamic" approaches to replacement found in the literature. Rather than treating both types of "replacement" as equivalents, we differentiate between the two. "Static" replacement, expenditures intended to maintain the stock of capital intact, is confined to its conventional role, that is to "like-for-like replacement", and is defined as non-capitalized repair expenditures, or replacement investment if we still choose to use the same term. "Dynamic" replacement on the other hand, assumes a new identity as structural investment. Since structural investment entails change in the structure of production (both capital-output and capital-input specificity), it bears little resemblance to replacement in the traditional sense, where the line of activity and the technology being used by the firm remain constant. To avoid confusing the two and to foster a more accurate and meaningful understanding of the latter, the term structural investment is introduced. The existence of structural investment should pose no difficulty to those who accept the notion of "structural unemployment." If labour succumbs to unemployment due to changes in the composition of demand and technological change, why should not the other factor in the firm's production function? If retraining and relocation of labour help reduce structural unemployment, why should not structural investment in plant and equipment help restore the utilization and economic productivity of real capital? Clearly, the two notions are analogous.

The components that make up the theory of structural investment are five-fold. The first of these is the concept of capital-output specificity, as elaborated by Matziorinis (1985). Here the composition of capital stock is functionally linked to the composition of demand. Changes in the structure of final demand induce changes in the structure of capital. Therefore, the rate of investment expenditure is not only a function of change in the level of demand (the accelerator theory), but also a function of change in the composition of demand, the level of total output remaining constant. While change in the level of demand (product-mix remaining constant) induces expansion investment, change in the structure of demand (level of output remaining constant) induces structural investment.

Second, product and process innovations (a joint outcome of technological change and economic necessity) are frequent. Combined with changes in the competitive environment in which any firm operates, they impose a constraint on the useful life of assets well before wear and tear and aging terminate their life. Assets are more often displaced, modernized or refitted for alternative uses than replaced. The minimal extent of replacement in the real world does not justify the continued use of the term "replacement" to describe the "other half of gross investment." What is more common in practice is that firms incur expenditures on the maintenance and repair of existing assets. Through a continuous policy for maintenance and repair, firms ensure that the productive capacity of their stock of fixed assets remains intact until such time as changes in technology, changes in product line, changes in corporate objectives or changes in economic conditions warrant adjustments. Almost always, the form taken by these adjustments in capital stock is that of structural investment.

Third, each product is defined by its own product life cycle. From the time of introduction, many products undergo a logistic (S-shaped) pattern of growth. A maturity phase usually follows the initial growth phase. Once the maturity phase has been reached, further growth in sales will depend on what the firm does. If the firm recycles the product by improving its quality, style and packaging or if the firm finds new uses for the product and develops new markets, sales will grow. If it reinvests in more advanced and efficient production machinery, it will be able to maintain sales in the face of stiff competition that prevails at the maturity stage of the product's life cycle. If the firm does none of the above, sales of the product are likely to stagnate and perhaps decline. New products will eventually bring displacement from the market and initial production facilities will likewise be displaced. Unless the same firm finds a new product to replace the earlier one or another firm acquires the equipment, some of the fixed capital equipment will be abandoned and scrapped. No replacement can occur here. If on the other hand, the same or another firm can find an alternative use for the idle equipment, investment funds will first have to be committed to up-grade, refit and adapt the plant to an alternative use. Expenditures for this purpose can be classified as structural investment. Consequently, the product life cycle by generally setting an upper constraint on the life of the product, also sets an upper constraint on the useful life of assets. But by the same token, efforts by firms to extend the product life cycle gives rise to a flow of structural investment outlays.

Fourth, whether a firm will invest in the extension of its product's life cycle through product development and structural investment in the up-grading, re-tooling, re-fitting and modernization of its production facilities is also a matter of corporate policy. Investment decisions of this nature do not lend themselves to the type of marginalist capital-budgeting techniques common in standard textbooks. Due to the uncertainties entailed and the break in the continuity of the firm's production, these investment decisions are of a strategic nature. The firm's options are (a) to abandon production entirely; (b) to restructure production through off-shore production of parts and domestic assembly and marketing of the product; and (c) to invest in product development and, simultaneously, in structural investment to modernize and adapt production facilities to produce re-cycled products. These investment strategies have defensive and offensive elements. While change in the structure of demand will certainly affect the relative profitability and utilisation of the capital stock, the change in this stock that is induced will depend on both the change in the structure of demand and the firms' willingness and ability to adapt by incurring the necessary capital outlays.

Fifth, the rate of growth in aggregate production in an economy is obviously a function of the individual rates of growth for constituent industries. As any economy has both expanding and mature industries, the degree of adaptation and rate of structural investment in the mature industries will influence the economy's overall rate of growth and standard of living. Unfortunately, adaptation and structural change have historically proven difficult processes to manage effectively.

In this chapter we develop a framework to explain the nature and determinants of the "other half of gross investment," namely structural investment, and we supply convincing empirical support for our position. Section 2 examines the role and the extent of output heterogeneity and product life cycles in conditioning structural investment in the context of capital-output specificity. Section 3 examines the link between capital heterogeneity and output heterogeneity and their relationship to structural investment. Section 4, building on a simple stock-adjustment investment function, illustrates mathematically the relation between structural investment and change in the structure of demand in the context of capital-output specificity. Section 5 provides strong empirical support for the proposition of structural investment. Section 6 completes the presentation by considering the role of corporate policy in the process to undertake structural investment outlays.

2. Output Heterogeneity and Product Life Cycles

Since the Keynesian revolution and the development of national income accounting, the preoccupation of the economic profession has been aggregative analysis of economic behaviour and modelling. Concepts such as "total output", "gross capital stock", "aggregate supply function" and "gross capital investment" have become standard instruments in the economist's kit of conceptual tools. Though useful for many purposes, these concepts have served to detract attention away from the equally important issues concerning the underlying structure and composition of total output, capital stock and gross investment. Although every economist will agree that "total output" and "capital stock" are in fact generic concepts defining an aggregation of heterogeneous units, they will attest to the important role that change in their composition plays in the economy. Unfortunately, not much effort has been devoted in recent years to the structural composition of output and capital and its relationship to the flow of capital investment. In this section we examine the implications of the <u>composition of output</u> on capital investment, while in the following section we examine the same with respect to the <u>composition of capital</u>.

It is our view that the composition of total demand for the economy's output matters, at least as far as the volume and composition of capital investment are concerned. Our view is based on the simple proposition that a changing structure of demand induces changes in the desired composition of capital--the concept of capital-output specificity, Matziorinis (1984)--which in turn affects the composition and volume of gross fixed capital formation. Change in the composition of demand would imply first, a reduction in desired replacement investments as the capital stock used to produce the declining or "sunset" products is no longer in demand; and second, an increase in desired expansion investment as new types of capital goods are required to produce the newer products. Third, to the extent that the economically obsolete stock of capital is still <u>physically</u> capable of rendering production services, change in the composition of demand implies that firms will, to the extent it is technically feasible, redeploy such physical assets to new functions such as the production of the type of products now being favoured by the market. Redeploying older capital goods to new functions, however, is not a costless process. Firms will have to commit additional funds for the modernization, up-grading, re-tooling and refitting of the older equipment to their new uses, and consequently will extend their economically useful life into the future. This type of investment spending, the outcome of the firm's adaptive response to a changing economic environment, can neither be characterized as expansion nor as replacement (repair) investment. To the extent that the funds are not being spent to add to existing capacity, it is not expansion investment. To the extent that the up-graded assets are used to produce a different line of products, they are not replacement either. The distinction with replacement (repair) investment is further accentuated by the fact that investment outlays incurred for the modernization, refitting or upgrading of a plant are not expensed in practice--as is the case with repair expenditures--but they are, in fact, capitalized. This flow of capital spending can best be depicted by the terms "renewal", "adaptation" or "structural investment." Here we use the latter term in order to differentiate it from replacement investment, which we have already identified as being non-capital repair expenditures incurred to maintain the operating efficiency of the existing stock of durable physical assets.

To the extent that total output has, in fact, undergone structural change in recent years, and to the extent that we can provide some explanation of how and why the composition of output changes over time, then we have the basis for a simple theory of structural investment. In the next few pages we supply a possible theory of output change,--the concept of the Product Life Cycle (PLC)--which we link to structural investment, and we furnish evidence for Canada showing that total output has undergone considerable change during the post-war period.

It is a well established fact of empirical research, as shown early on by Kuznets (1930) and Burns (1934) and more recently by Lee (1971) and van Duijn (1983), that the growth path of total output in the economy differs significantly from the pattern of growth at the industry level. While the long-term growth path in total output exhibits a rising linear trend for the economy as a whole, at the industry level, long-term growth paths in output exhibit a logistic (S-shaped) pattern, with high rates of growth in the early years of an industry's development but with diminishing rates of growth as the industry approaches its maturity phase. Kuznets (1930) suggested that the long-term economic development path of a nation is not characterized by a linear expansion of all industries (as we implicitly assume in modern growth models), but by a succession of leading sectors. As Rosenberg (1982) states:

> "Kuznets argued that high aggregative growth rates in industrial economies have reflected continuous shifts in product and industry mix. All rapidly growing industries eventually experience a slowdown in growth as the cost-reducing impact of technical innovation diminishes. Furthermore, because of the typically low long-term income and price elasticity of demand for old consumer goods, further cost-reducing innovations in these industries will have a relatively small aggregative impact. Therefore, continued rapid growth requires the development of new products and new industries." (1982, pp. 4-5).

It is an equally well established fact that most products undergo a logistic, S-shaped, pattern of development from the time of their introduction until maturity, a phenomenon which was elaborated by Dean (1950). It has since found a primary role in the marketing literature and the theory of international trade.

Let us then provide a brief review of the literature on the PLC concept and the S-shaped pattern of growth. The review which follows is largely based on Levitt (1965), Gist (1971), Wind (1982), Lee (1971) and van Duijn (1983). The idea of an S-shaped pattern of growth can be traced to Tarde (1903) who formulated a three-stage model (slow advance, accelerated and decelerating progress) through which every innovation, whether a new product, an idea or a belief must pass. Prescott (1922) applied the idea to forecasting the demand for automobiles. Kuznets (1930) and Burns (1934) applied it to business-cycle research and tested the growth retardation hypothesis. In recent times, Dean (1950) was the first to take and refine the idea and apply it to the theory of marketing. He is credited with coining the term "product life cycle." He distinguished three stages in a product's life cycle (introduction, rapid expansion and maturity) and argued that the length of this cycle is conditioned by the rate of technical change, the rate of market acceptance and the ease of competitive entry. Subsequently, the concept of the PLC was further explored by Forrester (1959), Patton (1959) and Mickwitz (1959) until it acquired a central place in the modern theory of marketing, as revealed for example by Levitt (1965), Gist (1971) and Wind (1982). The PLC concept has also been successfully applied in the theory of international trade and investment, in order to explain the pattern of trade of manufactured products. This particular application originated with Vernon (1966) who used it to explain the well known Leontief Paradox. Other contributors to this literature have been Wells (1968), Hirsh (1967), Claudon (1977) and Vernon (1970).

In contrast to Dean's three-stage model, the standard marketing literature now distinguishes four phases in a product life cycle, although five-phase models are also used. See Figures 5-1 and 5-2. According to Levitt (1965), the four stages are, for example, characterized in the following way:

1. <u>Introduction</u>. This is when a new product is first brought to market, before there is a proven demand for it, and often before it has been fully proven technically. Sales of the product are slow.
2. <u>Growth</u>. Demand begins to grow rapidly and expands from year to year often at an exponential rate. The market penetration of the product expands substantially.
3. <u>Maturity</u>. Demand levels off and for the most part grows only at the rates of replacement and new family formation.
4. <u>Decline</u>. The product begins to lose consumer appeal, sales of the product begin to decline.

The path taken by the product life cycle beyond the maturity stage have considerable diversity. These depend on the strategic responses taken by firms when faced with increased competition at the maturity stage. Through product and process improvements, a firm might for example, succeed in extending the maturity phase and preventing a major decline in sales. Alternatively by product differentiation, application to new needs or development of new markets, a firm might even succeed in extending the growth phase. The marketing literature is full of such rival strategies to amend a product's life cycle. The U.S.A. nylon industry is an excellent illustration of actual product life extension or "stretching". Figure 5-3,

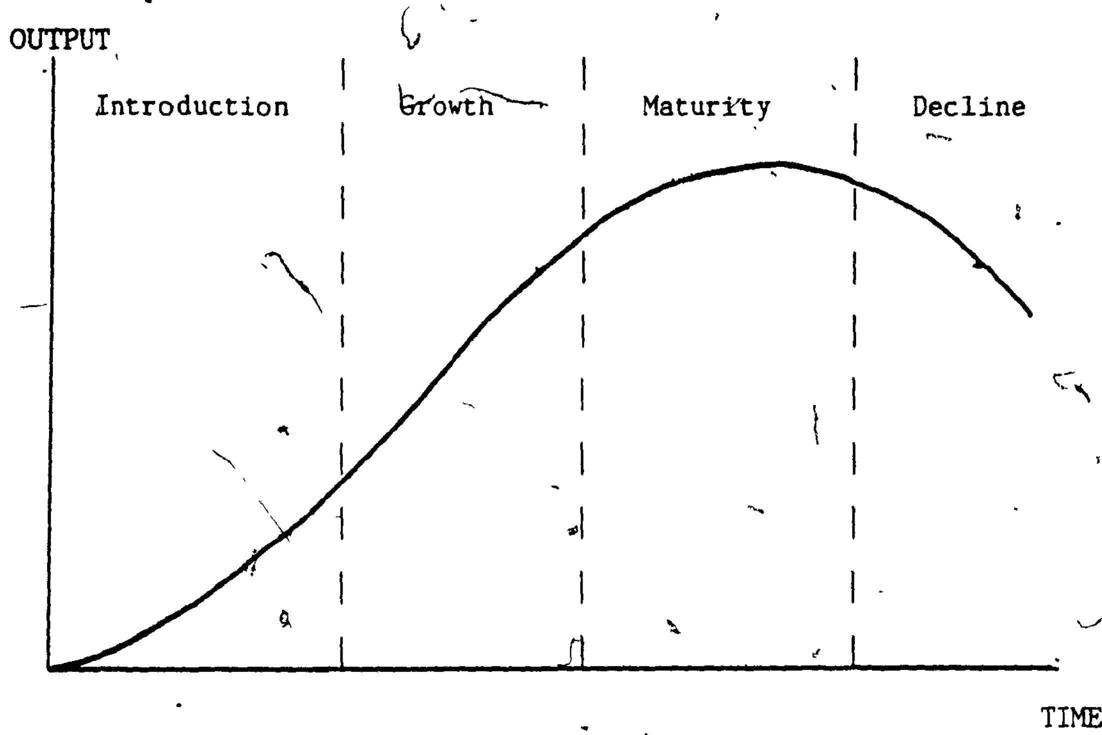


FIGURE 5-1 PRODUCT LIFE CYCLE: FOUR PHASE MODEL

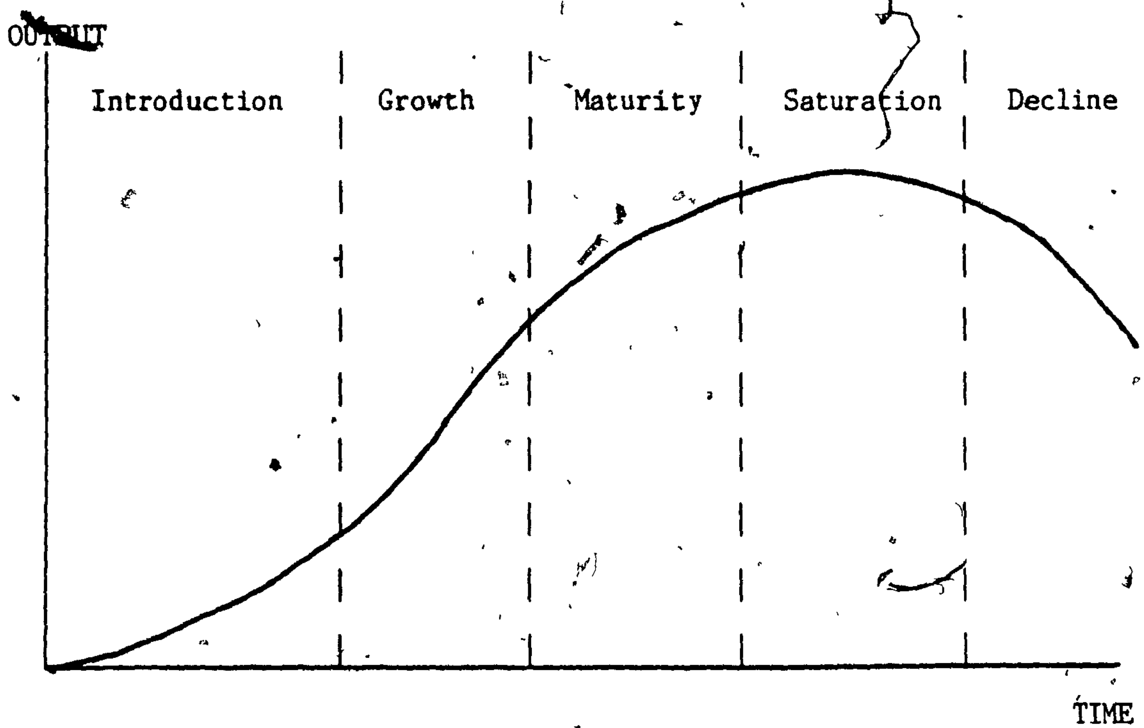


FIGURE 5-2 PRODUCT LIFE CYCLE: FIVE PHASE MODEL

reproduces the growth of the nylon industry during the period from 1942 to 1962 and shows how the product cycle was extended by changes in the composition of output and thus contributed to the persistent growth of the industry. Figure 5-4 shows various possible permutations of life-cycle extension after the primary S-shaped phase has been attained.

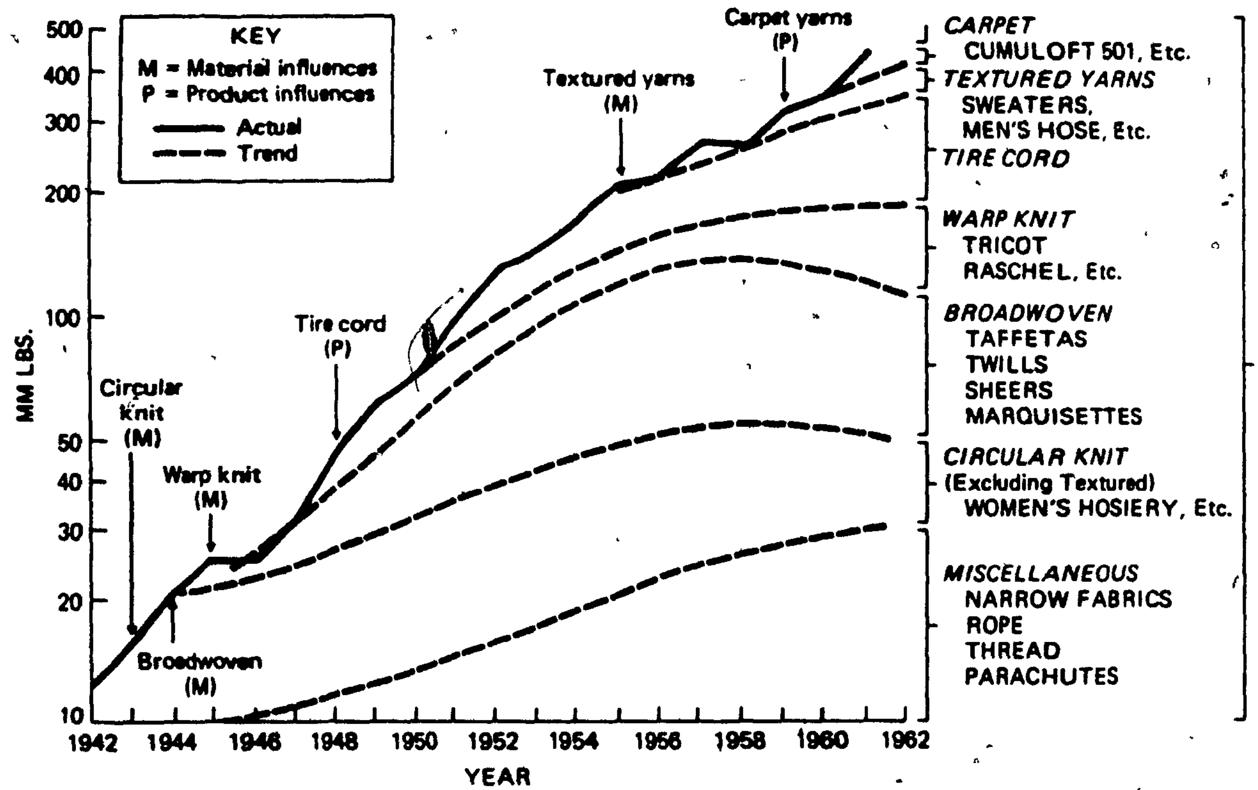
The existence of the primary S-shaped product life cycle has been empirically confirmed in a number of studies. Buzzell and Cook (1969) examined the sales histories of 192 consumer products and found that 52% of the products (non-food grocery products, food products and durables) followed the general pattern of the PLC model. Some of the products for which the PLC model was found to be representative are automobiles (Kovac and Dague, 1972), sales of foods, cosmetics and refrigerators in the United Kingdom, (Cunningham, 1969), tea and rum (Albach, 1965), and black and white television sets (Patton, 1959). The PLC model has been found to apply to industrial products as well. Cunningham (1969) found that trends of automobile components, chemicals, and general engineering products in the U.K. are represented fairly accurately by the general PLC model, while Frederixson (1969) found that 41% of 27 new industrial chemical products followed the general PLC pattern. In addition, these and other studies found evidence of modified S-shaped PLC functions. Buzzell (1966) for example, found the model to be consistent with actual trends in processed food products. New food products pass through a period of slow growth followed by a stage of rapid growth. Sales of "mature" products however, did not necessarily follow the predicted pattern. Three patterns were observed: (a) the expected stable maturity; (b) a growth maturity due to

FIGURE 5-3

AN EXAMPLE OF PRODUCT LIFE STRETCHING: THE CASE OF THE NYLON INDUSTRY

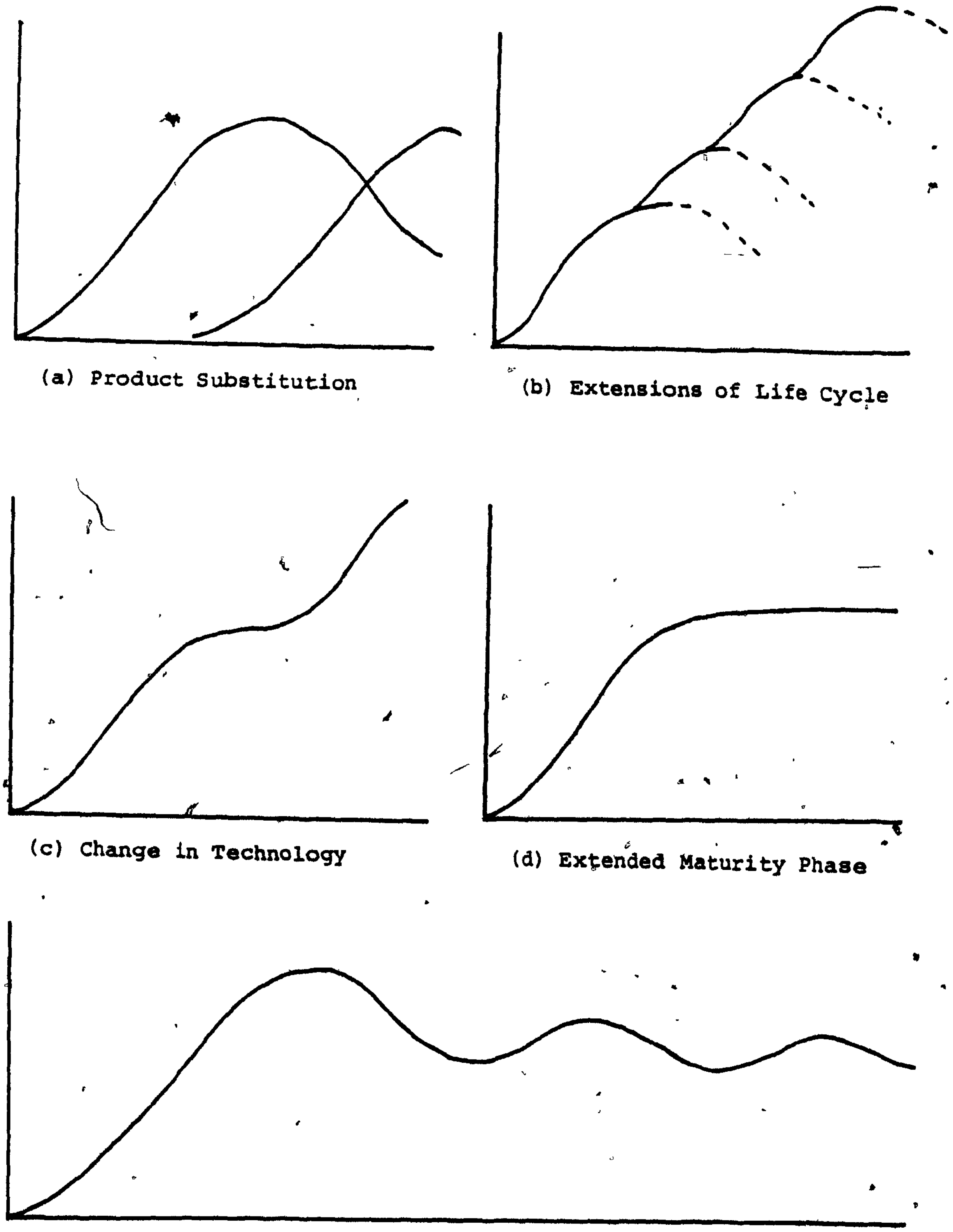
Innovation of new products postpones the time of total maturity

Source: Jordan P. Yale, "The Strategy of Nylon's Growth: Create New Markets," *Modern Textiles Magazine*, (February 1964,) p. 33. Copyright © 1962 by Jordan P. Yale. Reproduced by permission.



Source: Wind (1982)

FIGURE 5-4 VARIATIONS TO BASIC LIFE CYCLE PATTERN



(a) Product Substitution

(b) Extensions of Life Cycle

(c) Change in Technology

(d) Extended Maturity Phase

(d) Product Re-cycling

some changes in market conditions, and (c) innovative maturity, which is due to some product innovation or differentiation by the producers.

The S-shaped pattern of growth that Kuznets (1930) and Burns (1934) found to be representative of long-term growth patterns at the industry level can be approximated by a logistic function or a Gompertz curve, illustrated in Figures 5-5 and 5-6. The logistic function was first popularized by Pearl and Reed (1920) in the 1920s and applied to a variety of biological phenomena, population and other growth situations such as the spread of epidemics and rumors. The equation of the logistic function is:

$$Q = \frac{1}{1 + ae^{-bt}} \qquad (a, b > 0)$$

where Q is output, a and b are fixed parameters and t is a time index. The Gompertz curve is similar to the logistic function since it is an asymptotic growth curve with decreasing rates of growth past the inflection point. However, it differs from the latter in that it is non-symmetrical with respect to its inflection point, which is reached earlier. The equation of the Compertz curve is:

$$Q = ae^{bt} \qquad (a > 0, b < 1)$$

Using these functions which imply a continually decreasing rate of growth, Kuznets (1930) and Burns (1934) tested the hypothesis that output at the industry level grows at a decreasing rate (growth retardation hypothesis). Kuznets explored 57 production series from five early industrialized nations (Britain, France, Germany, Belgium and the U.S.A.)

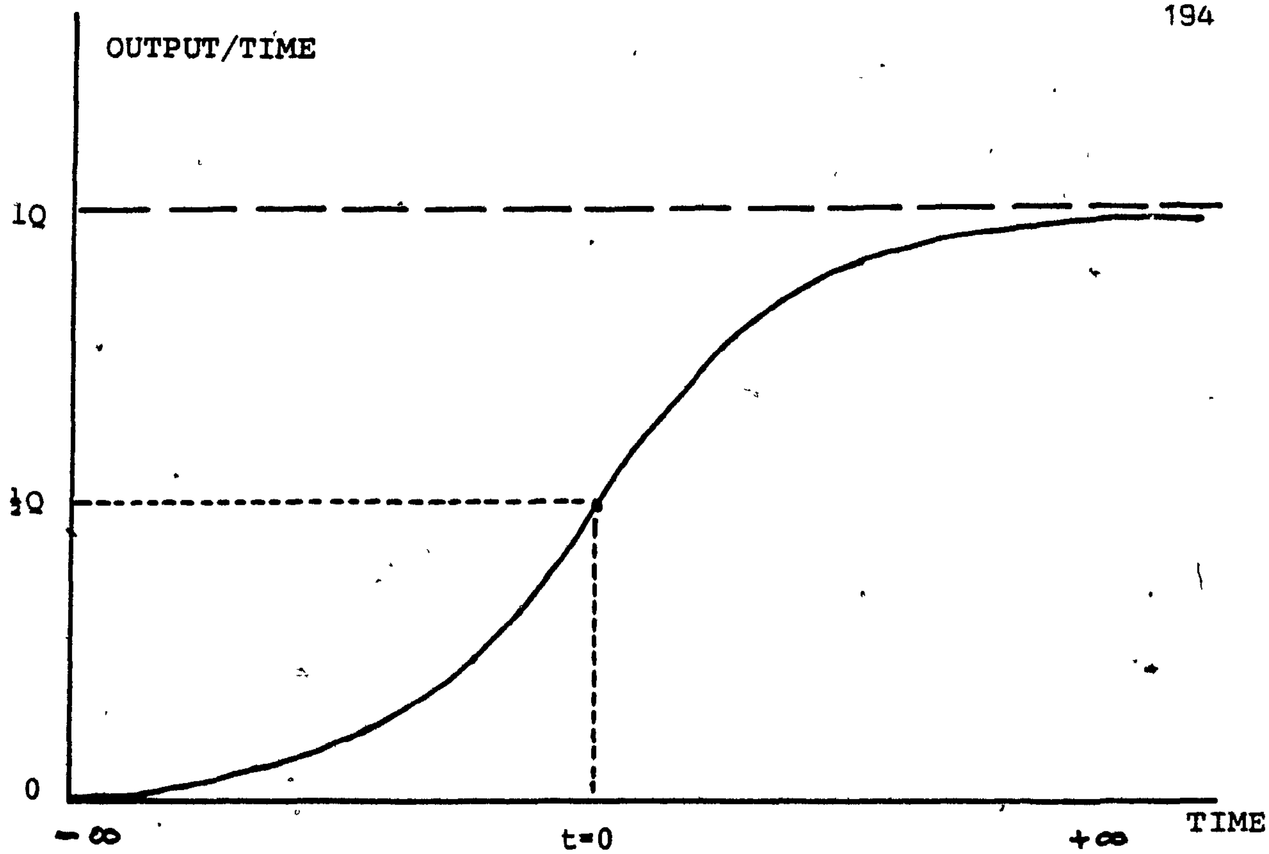


FIGURE 5-5 THE S-SHAPED LOGISTIC FUNCTION

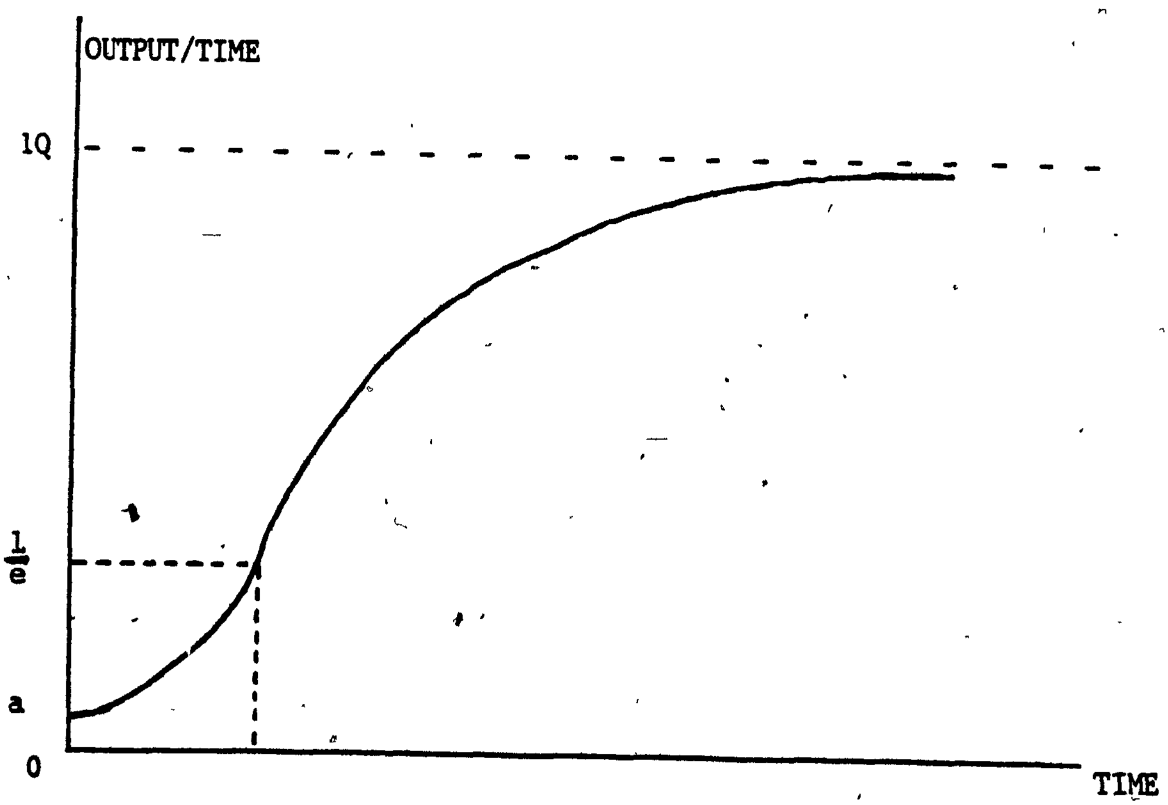


FIGURE 5-6 THE GOMPERTZ CURVE

and found confirmation of his S-shaped logistic and Gompertz growth patterns. Burns considered 104 continuous production series in the U.S.A. for the period from 1870 to 1929 and found that 92 of these series exhibited a decreasing rate of growth. Kuznets suggested three basic factors as accounting for the retardation of growth: (a) population growth, (b) changes in demand and (c) technological changes including improvements in business organization. Burns (1934) also inserted the following qualifications: (1) the rule of retardation may not hold in the late life cycle stages of some industries; (2) in the introduction phase, growth may accelerate rather than abate; (3) the rule of retardation does not hold throughout for the secular trends even of established industries, though it does hold for their primary trends (movements of longer duration than secular trends); (4) an industry may be invigorated or rejuvenated as a result of a structural change, such that the rule of retardation may only hold for the periods prior to and following the structural change.

Clearly, the role of technological and market change in altering the composition of output and the structure of markets has been recently ignored. Incorporating these factors in the "replacement" demand function leads to a different understanding of the process and forces which condition the composition and volume of capital spending at the maturity phase of an industry's life cycle, and compels us to re-assess the validity of the proportional replacement hypothesis (PRH).

The view that emerges from our re-examination of the literature is the following:

1. Firms do not incur capital expenditures to replace worn assets by

exact replicas of these assets, because non-capital repair expenditures--which include replacements of parts--ensure that the operating efficiency of the existing stock of capital goods remains intact, perhaps for an indefinite period.

2. Technological and market change are the rule rather than the exception. Product innovations, process innovations, change in consumer tastes and preferences, change in prices of factor input, changes in business organization and market structure continually take place. The main threat to the economically useful life of assets does not come from physical decay of assets (input or output decay) but from market change. While repair expenditures act to postpone the physical ability of assets to supply production services, they cannot offset the deterioration in the economic value of assets which results from obsolescence. If there is a constraint to the maximum useful life of assets it is not so much physical decay as it is obsolescence. It is the loss in an asset's economic ability to contribute to profit that determines the timing of the asset's retirement, and not so much the loss in its physical ability.

3. In their attempt to enhance the profitability of assets and assure their long-term survival, firms will find it necessary not to invest in replicas of the existing assets ("like-for-like" replacement) but to invest in new types of assets. The form that such investments generally take is re-tooling, refitting, upgrading, modernization, automation, computerization and robotization of production. Such investments, however, have the effect of altering any one or more of the following: production function, capital-input specificity, source and type of feedstock and

materials, capital-output ratio, production process, product line and plant location, to name only a few. In short, "obsolescence" investments result in alterations of the structure of production for the purpose of enhancing the profitability of the firm by reducing costs of production, by shifting the output-mix away from low value-added to high value-added products, by shifting away from high-cost factor inputs to low-cost inputs (labour, raw materials and energy). This type of investment is motivated and conditioned by forces different from those which condition expansion investment and repair (replacement) investment. Since the operant word is structural change, it is preferable that we identify it as a separate category of investment and accord it the importance which it deserves, namely structural investment.

4. In the introduction and expansion phase of a product's or industry's life cycle, the investment demand is conditioned by the change in output, the accelerator principle. In these stages, firms engage in expansion investment. Once the product or industry attain the maturity stage of their development, the market becomes saturated and competition intensifies. All the more so as the innovation spreads internationally and more low-cost countries embark on the production of the product. At this stage, the continued profitability of firms becomes dependent not on further expansion of production, or maintenance of production capacity, but on structural change. Only by investing in productivity enhancement and product development can the firm or industry succeed to defend itself from the rising tide of low-cost imitators that enter the market.

5. Whether firms choose to defend their market position through

aggressive or defensive structural investments also depends on the firm's perception and strategy. Not all firms in an industry will choose to reinvest in the structural up-grading necessary to defend or enhance their position. For many reasons, some valid and others not so valid, many firms will choose to abandon the production of the product and along with it, their capital goods. If no other firm can find a productive use for this equipment, they become scrap and are retired from the capital stock. Thus, the amplitude of structural investment is likely to be smaller than that of expansion investment for the following reasons: (a) plant and engineering structures will require less modification than equipment, (b) some equipment can be refitted and re-deployed while others cannot, and (c) not all firms in the industry will decide to commit themselves to a strategy of structural investment.

The emerging view on "replacement investment" summarized here is entirely consistent with the views expressed by Einarsen (1938), Bain (1939), Terborgh (1945, 1949), Dean (1951) and Schumpeter (1942). For example, both Einarsen and Terborgh were reluctant to use the term "replacement" to describe what they perceived took place in practice. Einarsen chose to use the term "reinvestment" because he did not find much evidence of "like-for-like" replacement in practice and also found that not all firms chose to reinvest in their assets. Terborgh (1949) on the other hand retained the term "replacement" but went out of his way to explain that it did not imply "like-for-like" replacement. Bain (1939) did not attempt to describe replacement investment in practice, but was correct in pointing out that replacement was not a technically determined parameter, but a variable endogenous to economic forces. He examined the various factors that influence replacement investment and concluded that the most important factor is technological change. Dean (1951) provided a meaningful classification of investments and identified four major categories of investment activity: (a) expansion, (b) replacement, (c) product and (d) strategic investments. Regarding replacement investment, he identified two sub-categories: (i) "like-for-like" replacement, where the underlying assumption is that the firm is committed to the continuance of the same line of activity and (ii) "obsolescence" replacement, where the firm modifies the production process, the product line or both. The distinction between "like-for-like" and "obsolescence" investment parallels our own distinction between "repair expenditures" and "structural" investment.

Schumpeter (1939, 1942), throughout his work, has placed much emphasis on the role of innovation and structural change as the engine which propels growth in capitalist economies. For example, he argued the following:

> "The essential point to grasp is that in dealing with capitalism we are dealing with an evolutionary process. It may seem strange that anyone can fail to see so obvious a fact which moreover was long ago emphasized by Karl Marx ... Capitalism ... is by nature a form or method of economic change and not only never is but never can be stationary ... The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates. ... the contents of the laborer's budget, say from 1760 to 1940, did not simply grow on unchanging lines, but underwent a process of qualitative change. Similarly, the history of the productive apparatus of a typical farm, from the beginnings of crop rotation, plowing and fattening to the mechanized thing of today - linking up elevators and railroads - is a history of revolutions. So is the history of the productive apparatus of the iron and steel industry ... or the industry of power production ... or the history of transport-

ation from the mailcoach to the airplane. The opening up of new markets, foreign or domestic, and the organizational development from craft shop and factory to such concerns as U.S. steel, illustrate the same process of industrial mutation - if I may use that biological term - that incessantly revolutionizes the economic structure from within, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism." (1942, pp. 82-84).

Schumpeter went on to describe the kind of analysis which would be more appropriate to the real world of economics. It is reproduced here because it is a particularly fitting critique of Jorgenson's neo-classical theory of optimal capital accumulation and his theory of replacement:

> "... the problem that is usually being visualized is how capitalism administers existing structures, whereas the relevant problem is how it creates and destroys them. As long as this is not recognised, his outlook on capitalist practice and its social results changes considerably. ... But in capitalist reality as distinguished from its textbook picture, it is not [price] competition which counts but the competition from the new commodity, the new technology, the new source of supply, the new type of organization (the largest-scale unit of control for instance) - competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms, but at their foundations and their very lives." (1942, p. 84).

Clearly, the modern formulation of replacement as a technical constant, some function of capital stock, ignores a significant side of reality, that of evolutionary structural change. The view suggested in this thesis makes a real attempt to capture this structural change which is inherent in our economies. To the extent that we accept that such change does indeed take place, then it is only reasonable to expect that firms will engage in some restructuring of their capital stock through structural investment. Although much more work will be required to refine the theory of structural investment, Nelson and Winter (1982) have shown that modelling structural change is possible. Based on biological models of behaviour and Markov processes, they have succeeded in developing coherent and powerful models of competitive firm dynamics under conditions of growth, uncertainty and technological change.

Now, let us examine some empirical evidence of structural change in the composition of output in Canada. Figures 5-7 to 5-10 and Tables 5-1 to 5-5 provide a tentative picture on the change in the composition in Canada over the period 1951-1985. They provide strong empirical confirmation of the fact that total output has undergone substantial structural change over the period. They also reveal that growth patterns at the industry level do in fact exhibit a decreasing rate of growth, consistent with the S-shaped growth functions used by Kuznets and Burns to study the growth retardation hypothesis in the 1930s. Before we turn to a detailed discussion of the data, however, certain qualifications are in order. First, we do not claim that the evidence furnished here constitutes direct and sufficient proof of our proposition that output change is generated by product life cycles. Rather, we suggest that the overall pattern <u>is consistent</u> with our hypothesis and that it merits further investigation. Second, the data presented here--industrial production indexes and output shares at the one and two-digit S.I.C. levels--are not in the form which would be most appropriate for the investigation of individual product and industry growth patterns. As van Duijn (1983, pp. 28-30) suggests, a more appropriate framework would be (a) to use longer time series than the ones presented here (1951-1985); (b) to employ a much higher degree of disaggregation which does not combine in the same series a variety of different products;

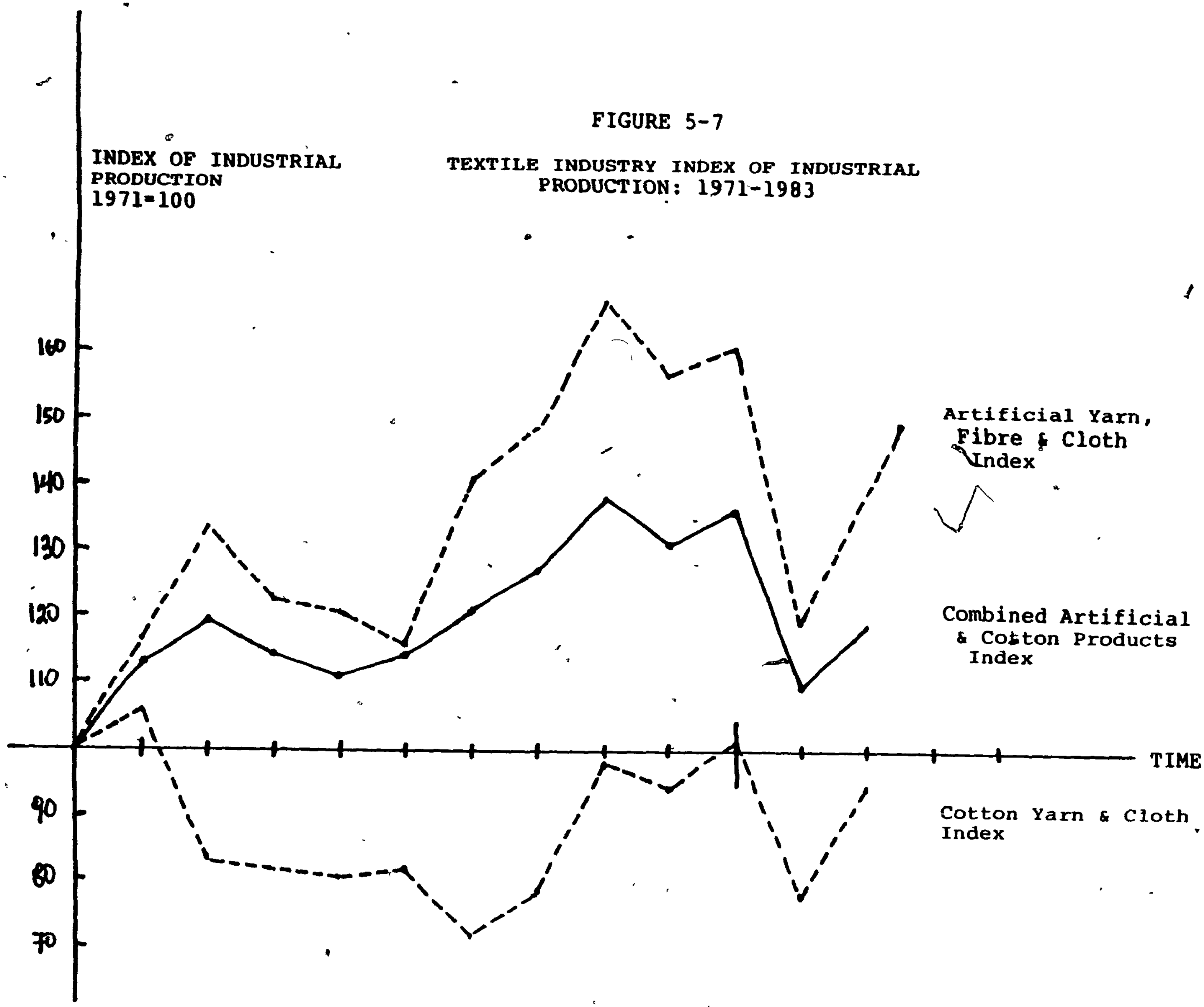
(c) to employ consumption data rather than production data and (d) to convert such data to <u>per capita</u> terms. He states the following:

> "National production figures therefore give no insight into the development of national consumption. Life cycle patterns, including a decline phase, would most likely be found for national per capita consumption; only in a few cases are they to be found for national production.
>
> [The] visibility of decline obviously depends on the industry delineation used. At the 2-digit SIC-level most industries will appear to be growing at all times. Yet within such industries substitution processes will be going on, such as have been illustrated with the steel-making example [crucible - Bessemer - open heart-electric and oxygen steel-making technologies]. Regardless of the level of aggregation selected, however, whether it is the individual product, or the commonly used 2-digit SIC-level, or total industrial production, a constant rate of growth over the entire known life of the unit measured will not be the outcome. We may not be able to foretell what happens past the maturity stage, but retardation of growth following the introduction of a product, production process, or innovation in general, is inevitable." (1983, p. 29 and p. 32).

The textile industry in Canada (5:05 SIC) is a good example of the problem of industry delineation and aggregation level. It is composed of two major product areas: cotton yarn and cloth mills (5:05:181 SIC) and man-made fibre, yarn and cloth (5:05:183 SIC). Although the index of industrial production for the whole industry suggests modest growth during the 1971-1983 period, an examination of the two separate product segments reveals, as illustrated in Figure 5-7, that production of natural fibre textiles has declined while production of the more modern artificial fabric textiles has been expanding over the period, resulting in moderate output growth at the 2-digit SIC industry level. Clearly, to attempt a sound empirical analysis of the growth retardation hypothesis for Canada is beyond the scope of this thesis. All we seek to provide is theoretical and

FIGURE 5-7

TEXTILE INDUSTRY INDEX OF INDUSTRIAL PRODUCTION: 1971-1983



empirical support for our argument that change in the output-mix of the economy is associated with a flow of capital investment.

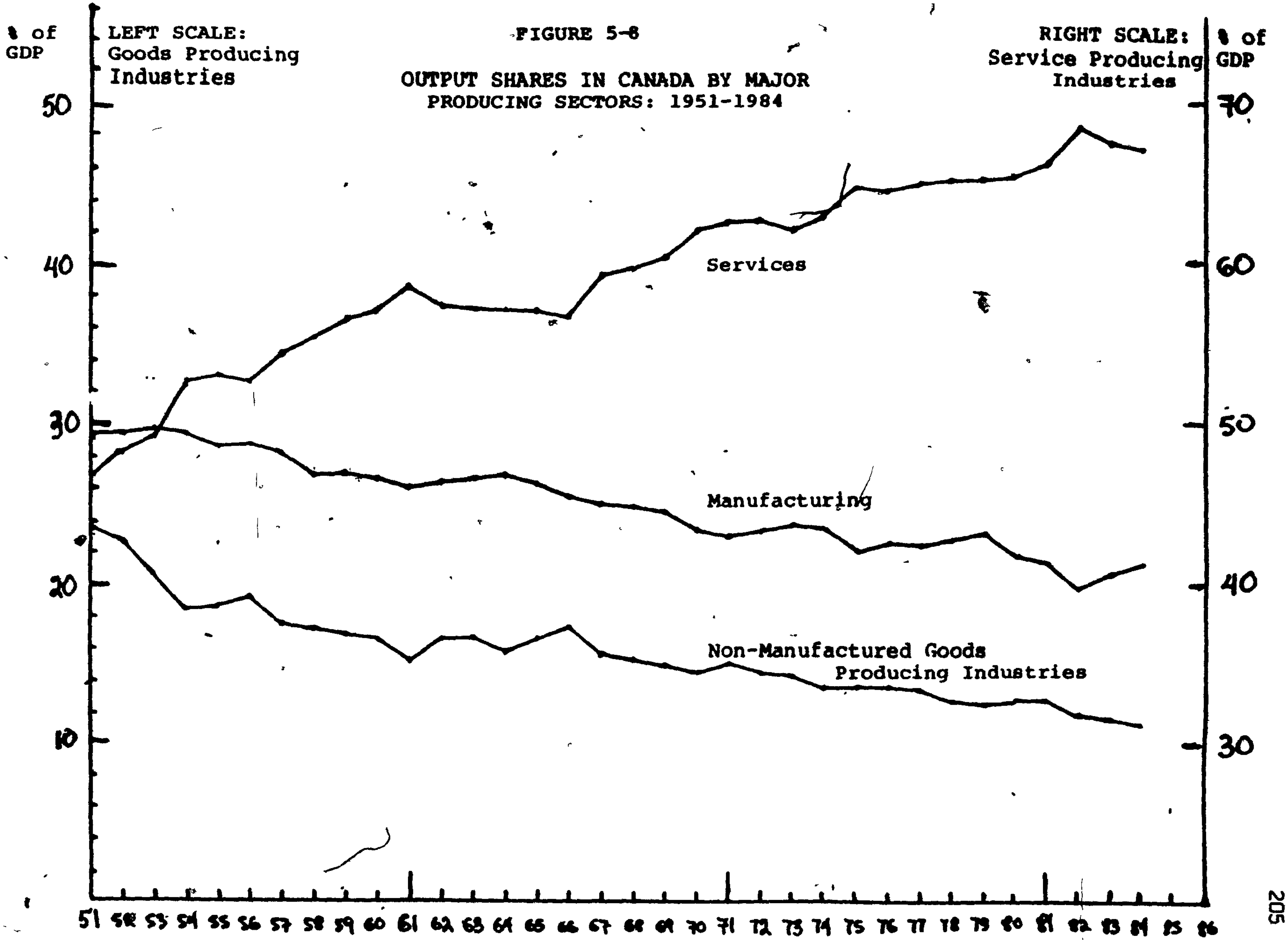
A cursory look at total production as measured by GNP or GDP in Canada during the post-war period suggests that total output has been growing more or less evenly during the post-war period. Once we decompose total output into its three broad components, primary, secondary and tertiary sectors, we can easily observe that growth in each sector has not taken place at the same rate[1]. Figure 5-8, for example, shows that the relative contribution of the service sector to total output has expanded from 46.6% in 1951 to 67.5% in 1984, at the expense of both the primary and secondary goods-producing sectors. The relative share of the non-manufactured goods producing sector (agriculture, fishing, forestry, mining and construction) has declined from 23.9% of total output in 1951 to 11.2% in 1984, while the corresponding share of total output of the manufacturing sector has declined from 29.5% in 1951 to 21.3% in 1984. Clearly, these figures attest to the magnitude of the structural transformation taking place in Canada during the post-war period. To the extent that the service sector is less capital intensive than the primary and secondary sectors, it suggests a decreasing demand for capital goods but an increasing demand for labour. Beeson and Bryan (1986), for example, confirm that output growth

---

[1] In the delineation of the sectors we follow the U.S.A. classification system in that utilities are classified under Services instead of Manufacturing, see Beeson and Bryan (1986) and Shelp (1981). The Primary Sector includes Agriculture, Fishing, Forestry, Mining and Construction. The Service Sector includes, Transportation, Communications, Utilities, Trade, Finance, Insurance, Real Estate, Business, Personal and Community Services and Public Administration.

FIGURE 5-8

OUTPUT SHARES IN CANADA BY MAJOR PRODUCING SECTORS: 1951-1984



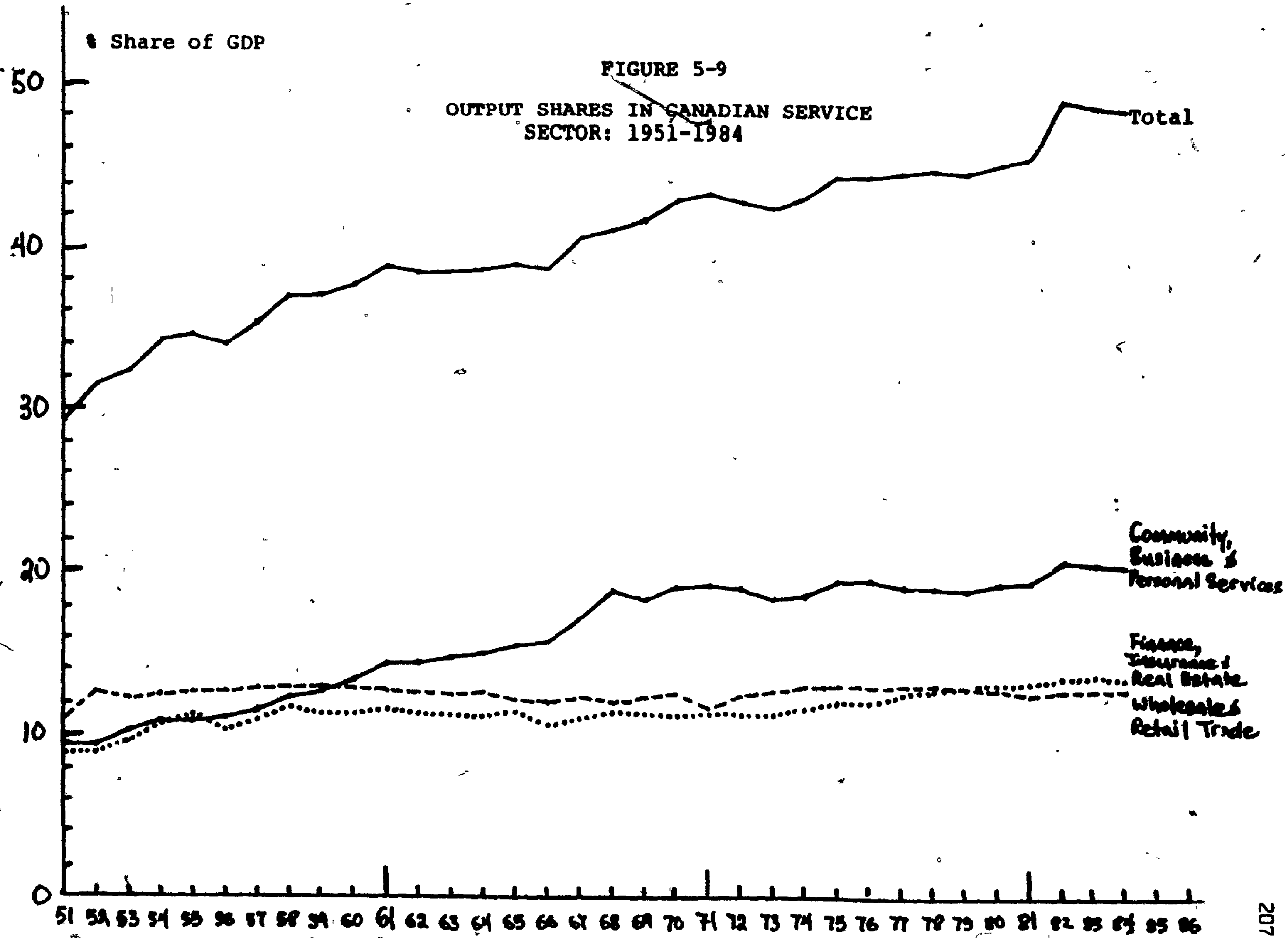
Source: As per Table 5-1

in the service sector has greatly exceeded that of the primary and secondary sectors and resulted in proportionately greater gains in employment in the labour-intensive service sector as compared to the more capital-intensive primary and manufacturing sectors. Therefore, given that each sector is defined by its own capital-output specificity and capital-output requirements, a shift of total output toward less capital intensive goods can affect, ceteris paribus, the total level of capital investment in the economy.

When the output of the service sector is taken separately and broken down to its constituent parts, we find that the share of transportation, communications and utilities has risen from 11.6% in 1951 to 14.1% of total output in 1984 while that of public administration rose from 5.4% to 6.9% respectively. See Appendix G for these and other data used to construct Figures 5-8 to 5-10. The share of the remaining three service industries, i.e., trade, finance, commercial and personal services rose from 29.6% in 1951 to 46.5% in 1984. The industry group chiefly responsible for this growth is community, business and personal services, as can be seen in Figure 5-9. While the wholesale and retail trade sector grew from 10.9% to 12.5% of total output in the 1951-84 period, and the finance, insurance and real estate grew from 8.9% to 13.5%, the corresponding shares for the community, business and personal services sector have grown from 9.7% in 1951 to 20.5% in 1984. Growth in this sector of services has been so rapid that it has long surpassed the primary sector (agriculture, fishing, mining and construction) as a contributor to GNP. In fact, as Figure 5-10 indicates, the value of output being generated by community, business and

FIGURE 5-9

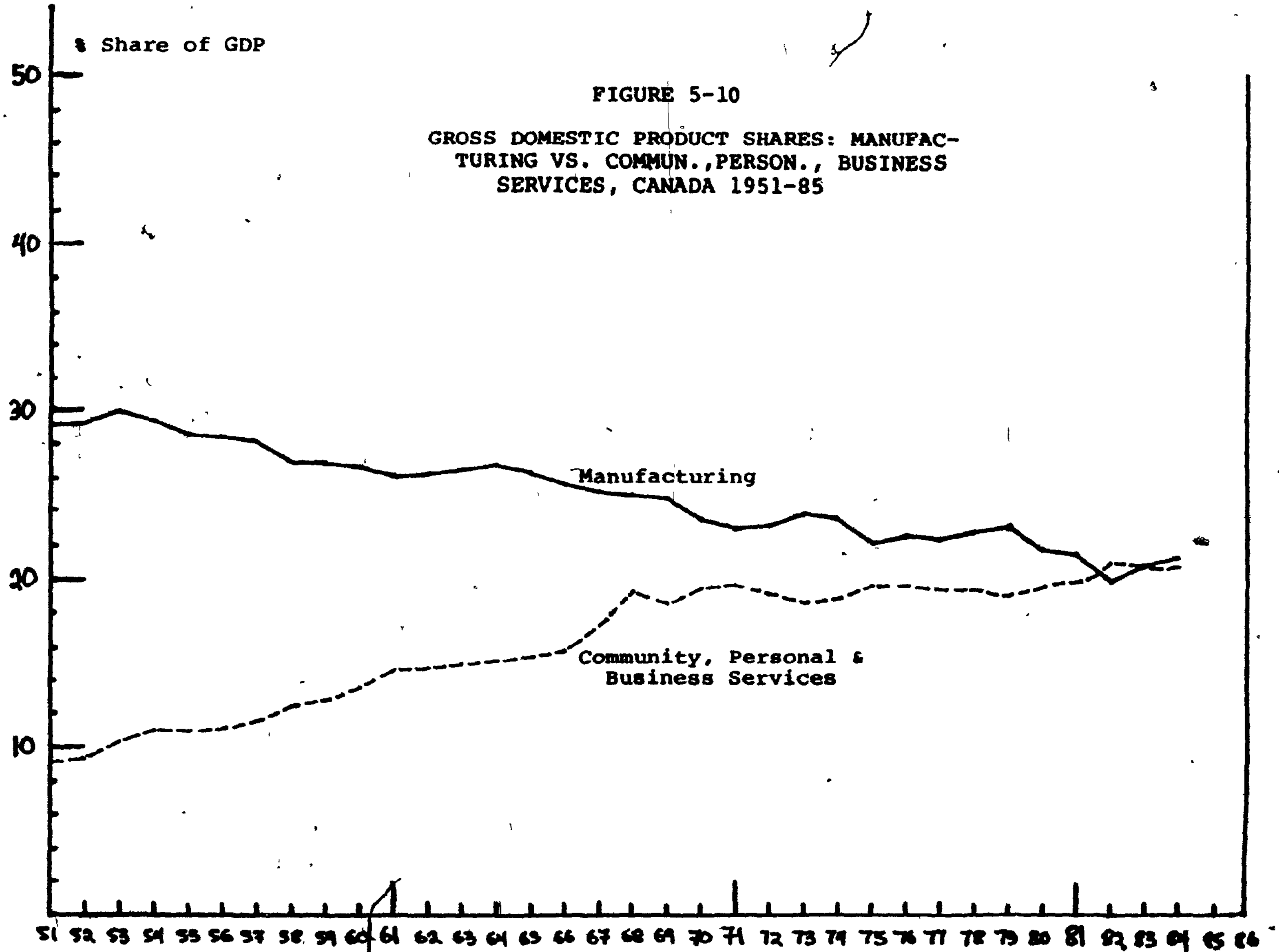
OUTPUT SHARES IN CANADIAN SERVICE SECTOR: 1951-1984



Source: As per Table 5-1

FIGURE 5-10

GROSS DOMESTIC PRODUCT SHARES: MANUFACTURING VS. COMMUN., PERSON., BUSINESS SERVICES, CANADA 1951-85



Source: As per Table 5-1

personal services has reached the same level as the value of total manufacturing output in Canada in the early 1980s. To the extent that the capital-output ratio in the community, business and personal services sector is significantly lower to that of the manufacturing sector, significant implications for our understanding of capital investment are contained here.

Tables 5-1 and 5-2 depict industry growth patterns at the two-digit S.I.C. level of the Canadian manufacturing sector. They show the average annual growth rates in the index of industrial production for each industry during the period 1951-85. The data produced here are drawn from the Statistics Canada publications Gross Domestic Product by Industry (61-213) and Capacity Utilization Rates in Canadian Manufacturing (31-003). As pointed out earlier, it would have been more desirable to examine such patterns at a more detailed level of industrial classification and over a longer span of time. Smoothing of data by computing 3 to 4 year moving averages and adjustment for population change would have also been desirable. Nonetheless, the data provide strong support for the growth retardation hypothesis, regardless of how we slice the data (five year vs. ten year intervals). Table 5-1 for example, indicates that in 9 out of 20 industries, growth rates have been exhibiting a continuously diminishing rate of growth. They are tobacco products, leather products, primary metal products, fabricated metal products, non-electrical machinery, non-metallic mineral products, petroleum and coal products, chemicals and chemical products and miscellaneous products. In nine other industries growth rates peaked in the 1960s but have been diminishing ever since. They are food

TABLE 5-1

AVERAGE ANNUAL GROWTH RATES IN INDUSTRIAL PRODUCTION
IN CANADIAN MANUFACTURING: TEN YEAR PERIODS, 1951-1985

Two Digit SIC	Manufacturing Industry	Annual % Growth 1951-61	Annual % Growth 1961-71	Annual % Growth 1971-81	Annual % Growth 1981-85	Percent Growth 1961-85
5:01	Food & Beverage Products	5.2	5.6	2.3	0.6	95.2
5:02	Tobacco Products	12.1	3.7	1.5	-2.0	44.2
5:03	Rubber & Plastic Products	1.9	15.7	6.2	5.0	401.3
5:04	Leather Products	4.2	1.1	1.0	-2.4	11.8
5:05	Textile Products	3.4	9.3	3.6	-0.1	161.1
5:06	Knitting Mill Products	7.1	10.2	1.6	-1.0*	128.1
5:07	Clothing Products	3.0	3.5	2.3	0.1*	67.1
5:08	Wood Products	2.5	5.6	4.6	3.6	159.5
5:09	Furniture & Fixtures	5.7	7.1	4.1	-1.0	131.0
5:10	Paper & Allied Products	2.9	5.8	2.6	1.5	109.9
5:11	Printing & Publishing	5.8	4.3	7.4	2.7	175.1
5:12	Primary Metal Products	-	6.9	1.9	1.1	110.3
5:13	Fabricated Metal Products	-	8.5	3.1	-3.2	110.9
5:14	Non-Electrical Machinery	-	11.9	10.7	2.0	316.2
5:15	Transportation Equipment	0.0	21.3	3.8	9.0	484.1
5:16	Electrical Products	7.4	10.9	4.0	-0.2	190.2
5:17	Non-Metallic Mineral Products	7.9	6.9	2.0	0.0	102.2
5:18	Petroleum & Coal Products	11.7	6.1	4.1	-3.6	94.8
5:19	Chemicals & Chemical Products	10.7	10.5	5.6	2.7	254.7
5:20	Miscellaneous Products	10.4	7.4	3.3	-2.0	112.2

* For 1981-1984.

Source: Urquhort, M.C. (1983) Historical Statistics of Canada, 2nd Edition, Statistics Canada, Ottawa
Statistics Canada (1983) Gross Domestic Product by Industry, Catalogue 61-213, Annual, Ottawa

TABLE 5-2

AVERAGE ANNUAL GROWTH RATES IN INDUSTRIAL PRODUCTION IN CANADIAN MANUFACTURING: FIVE YEAR PERIODS, 1951-85

Two Digit SIC	Manufacturing Industry	Annual % Growth 1951-61	Annual % Growth 1961-66	Annual % Growth 1966-71	Annual % Growth 1971-76	Annual % Growth 1976-81	Percent Growth 1981-85
5:01	Food & Beverage Products	5.2	5.6	4.3	2.7	1.6	0.6
5:02	Tobacco Products	12.1	4.0	2.9	2.6	0.3	-2.0
5:03	Rubber & Plastic Products	1.9	16.4	8.2	7.6	3.5	5.0
5:04	Leather Products	4.2	2.1	0.2	1.3	0.8	-2.2
5:05	Textile Products	3.4	8.3	7.3	2.8	3.9	-0.1
5:06	Knitting Mill Products	7.1	7.6	9.3	1.1	2.0	-1.0*
5:07	Clothing Products	3.0	4.5	2.0	5.3	-0.5	0.1*
5:08	Wood Products	2.5	6.4	3.6	7.0	1.6	3.6
5:09	Furniture & Fixtures	5.7	11.7	1.6	4.9	2.6	-1.0
5:10	Paper & Allied Products	2.9	7.4	3.0	2.4	2.4	1.5
5:11	Printing & Publishing	5.8	4.4	3.5	7.5	5.2	2.7
5:12	Primary Metal Products	-	9.7	2.8	0.8	2.8	1.1
5:13	Fabricated Metal Products	-	13.2	2.2	4.0	1.8	-3.2
5:14	Non-Electrical Machinery	-	16.6	3.9	8.1	9.4	-2.0
5:15	Transportation Equipment	0.0	20.7	10.7	9.8	-1.5	9.0
5:16	Electrical Products	7.4	16.5	2.9	3.7	3.6	-0.2
5:17	Non-Metallic Mineral Products	7.9	9.0	3.3	4.2	-0.2	0.0
5:18	Petroleum & Coal Products	11.7	5.6	5.2	5.3	2.4	-3.6
5:19	Chemicals & Chemical Products	10.7	11.5	6.0	5.0	5.0	2.7
5:20	Miscellaneous Products	10.4	8.6	4.3	5.0	1.3	-2.0

* For 1981-1984.

Source: Urquhort, M.C. (1983) Historical Statistics of Canada, 2nd Edition, Statistics Canada, Ottawa
Statistics Canada (1983) Gross Domestic Product by Industry, Catalogue 61-213, Annual, Ottawa

and beverages, rubber and plastic products, textiles, knitting mill products, clothing, wood products, furniture and fixtures, paper and allied products and electrical products. Only in two of the industries, printing and publishing and transportation equipment is there no strong evidence of growth retardation but this too can be explained. Printing and publishing is one of the youngest industries whose growth may have peaked only in the 1970s, later than the other industries. Transportation equipment is dominated by the automobile industry. While growth seems to have peaked in the 1960s, the current revival in the 1980s may very well be due to the attempts by the firms to extend their product life-cycles by introducing radically new models (front-wheel drive, lighter weight, improved efficiency, European styling, Japanese quality) and by investing massively in the restructuring of their production facilities. Sections 5 and 6 of this chapter detail the attempts carried out in this industry to enhance profitability and growth through structural investment.

Table 5-3 ranks manufacturing industries by growth in each of the three 10-year periods of post war history, 1951-61, 1961-71, 1971-81 as well as the current period, 1981-85. Of the five leading growth industries of the 1950s only chemicals and chemical products remained on the list of the top five. The other four have been declining steadily in importance. For example, tobacco products, the leading growth industry of the 1950s dropped to 18th place in the 1960s, 19th in the 1970s. Non-metallic minerals dropped from 5th in the 1950s to 12th in the 1960s to 16th in the 1980s. The pattern of decline has been also similar for petroleum and coal products and miscellaneous products industries. By contrast, of the five

TABLE 5-3

RANKING OF LEADING GROWTH INDUSTRIES IN CANADIAN MANUFACTURING: 1951-85

1951-61		1961-71		1971-81		1981-85	
Tobacco Products	121.2	Transport Equipment	212.5	Non-Electrical Mach.	107.2	Transport Equipment	36.0
Petroleum & Coal	117.5	Rubber & Plastics	157.1	Printing & Publishing	73.5	Rubber & Plastics	20.2
Chemicals & Chemical	106.8	Non-Electrical Mach.	118.8	Rubber & Plastics	62.3	Wood Products	14.4
Miscellaneous Prod.	103.5	Electrical Products	108.7	Chemicals & Chemical	56.4	Chemicals	10.8
Non-Metallic Prod.	79.1	Chemicals & Chemical	104.9	Wood Products	45.9	Printing	10.8
Electrical Products	74.1	Knitting Mills	102.4	Petroleum & Coal	41.3	Paper & Allied	6.1
Knitting Mill Prod.	70.8	Textiles	92.7	Furniture & Fixtures	40.8	Primary Metals	4.6
Printing & Publishing	57.6	Fabricated Metals	84.5	Electrical Products	40.0	Food & Beverages	2.4
Furniture & Fixtures	57.4	Miscellaneous Prod.	73.6	Transport Equipment	37.5	Clothing	0.3
Food & Beverages	51.6	Furniture & Fixtures	71.2	Textiles Products	35.7	Non-Metallic Prod.	0.0
Leather Products	41.5	Primary Metals	68.9	Miscellaneous Prod.	32.9	Textiles	-0.4
Textile Products	34.1	Non-Metallic Min.	68.6	Fabricated Metals	30.7	Electrical Products	-0.7
Clothing Products	30.0	Petroleum & Coal	61.3	Paper & Allied	25.5	Knitting Mills	-3.2
Paper & Allied	29.1	Paper & Allied	57.7	Clothing Products	23.4	Furniture & Fixt.	-4.0
Wood Products	24.7	Wood Products	55.8	Food & Beverage	22.6	Miscellaneous	-8.0
Rubber & Plastics	18.6	Food & Beverages	55.5	Non-Metallic Min.	19.8	Non-Elect. Mach.	-8.0
Transport. Equip.	-0.6	Printing & Publishing	43.3	Primary Metals	19.0	Tobacco Products	-8.1
		Tobacco Products	37.0	Knitting Mill Prod.	16.4	Leather Products	-9.6
		Clothing Products	34.9	Tobacco Products	14.6	Fabricated Metals	-12.7
		Leather Products	11.1	Leather Products	10.3	Petroleum & Coal	-14.5

Source: Urquhart, M.C. (1983) Historical Statistics of Canada, 2nd Edition, Statistics Canada, Ottawa
Statistics Canada (1983) Gross Domestic Product by Industry, Catalogue 61-213, Annual, Ottawa

slowest growth industries of the 1950s, only one (clothing products) persists as a laggard industry. The other four have risen in relative importance. Transportation equipment, rubber & plastics and wood products have become leading sectors of growth in the 1960s, 1970s or 1980s, while paper and allied products has steadily improved its relative position.

Finally, Tables 5-4 and 5-5 provide a picture of the 25 fastest growing and 25 slowest growing (three-digit SIC level) industries in Canada during the 1971-1983 period, as measured by the GDP index. 20 of the 25 slowest growth industries have actually experienced an absolute decline in the value of their output since 1971. All except two belong either to the primary (SIC:04) or the secondary (SIC:05) sectors. By contrast, 12 of the 25 fastest growing industries belong to services (SIC:06-10) but only one to the primary sector. The distribution of manufacturing industries is more evenly concentrated, yet again we find that a larger number of manufacturing industries (17 out of 25) belong to the slow-growth group as compared to the fast-growth group (13 out of 25).

The picture which emerges from this evidence is that industries in the economy do not exhibit constant growth patterns through time. One finds that <u>over time</u>, industries tend to exhibit a diminishing rate of growth, while at any <u>point in time</u> one finds both growing and declining industries. Clearly, expansion and replacement investment as conceived in our textbooks are incompatible with diminishing or negative industrial growth patterns. To the extent that firms continue to incur capital expenditures in these industries--and the data show they do--then it follows that the purpose of this flow of capital spending must be for a reason other than expansion or

TABLE 5-4

HIGH GROWTH INDUSTRIES IN CANADA:
1971-1983
(GDP, 1971 = 100)

SIC	INDUSTRY	GDP INDEX 1983
10	Services to Business Management	282.1
07	Air Transport	276.7
05	Plastic Fabricating	236.6
04	Coal Mines	222.9
07	Telephone Communications Systems	221.5
09	Insurance	201.0
07	Electric Power	198.8
10	Amusement & Recreation Services	196.2
09	Banking	193.4
05	Soaps & Cleaning Products	193.3
09	Finance	183.8
05	Motor Vehicles	170.5
05	Commercial Printing & Typesetting	169.8
05	Sawmills, Planing & Shingles	168.6
05	Pharmaceuticals	167.6
05	Miscellaneous Chemicals	166.5
05	Communications Equipment	160.4
09	Securities	160.0
05	Publishing	158.9
07	Gas Distribution	156.1
10	Advertising	151.5
08	Retail & Wholesale Trade	150.7
05	Non-electrical Machinery & Equipment	150.1
05	Man-made Textiles	149.3
05	Scientific & Professional Instruments	148.5
05	Aircraft and Aircraft Parts	143.5

Source: Statistics Canada (1983) Gross Domestic Product by Industry, Catalogue 61-213, Annual, Ottawa.

TABLE 5-5

DECLINING AND LOW GROWTH INDUSTRIES IN CANADA:
1971-1983
(GDP, 1971 = 100)

SIC	INDUSTRY	GDP INDEX 1983
04	Asbestos Mines	40.3
04	Iron Mines	49.5
04	Metal Mines	70.2
05	Concrete Products	73.5
04	Other Metal Mines	74.2
05	Electrical Wire & Cable	79.7
05	Shipbuilding & Repair	83.0
05	Bakery Products	83.9
05	Petroleum Refining	84.3
05	Steel & Pipe Tube	87.2
05	Cement	88.2
05	Truck Body & Trailers	88.2
04	Non-Metal Mines	90.5
05	Miscellaneous Metal Fabricating	91.5
10	Elementary & Secondary Schools	93.5
05	Iron Foundries	94.8
05	Cotton, Yarn & Cloth Mills	95.2
05	Ready Mix Concrete	95.5
10	Laundries & Cleaners	99.3
04	Gold Mines	99.3
05	Iron & Steel	104.2
05	Metal Stamping & Pressing	105.8
05	Smelting & Refining	106.6
05	Veneer & Plywood	106.7
05	Tobacco Products	106.9

Source: Statistics Canada (1983) Gross Domestic Product by Industry, Catalogue 61-213, Annual, Ottawa.

replacement, perhaps structural investment.

3. Capital Heterogeneity and Capital-Output Specificity

In Chapter 4, we presented evidence on the morphological characteristics of capital in Canada. It is evident that the production functions in different sectors and industries of the economy are characterized by their own unique capital structure. For example there is wide variability in capital-output (K/Q) and capital-labour (K/L) ratios across industries, and equally wide variability in the attendant ratios of equipment to plant and building to structures. We reject the notion of capital homogeneity implied in the conventional theory of capital and investment. One meaningful approach is to substitute the more realistic assumption of capital heterogeneity as the underlying hypothesis in our investigation of "replacement" investment.

Our approach is not new. Walras (1926) long ago stressed the heterogeneity of capital ("les capitaux proprement dits"). In recent years, Lachmann (1947, 1956, 1977) vigorously maintained that the composition of capital is of the essence in the theory of investment.

> "A theory of investment based on the assumption of a homogeneous and quantifiable capital stock is bound to ignore important features of reality. Owing to its very character it can only deal with quantitative capital change, investment and disinvestment. It cannot deal with <u>changes in the composition of the stock</u>... By contrast, our conception of capital is that of a complex structure which is <u>functionally differentiated</u> in that the various capital resources of which it is composed have different functions... All this has implications for the theory of investment. We cannot explain how

> either existing resources are being replaced, whether by their replicas or otherwise, or what kind of new capital goods is being created, without having first of all learnt how existing capital is being used. The shape in which new capital goods make their appearance is determined largely by the existing pattern, in the sense that 'investment opportunities' really mean 'holes in the pattern'... [once] we abandon the homogeneity hypothesis we are compelled to adopt a morphological approach to the problems of capital, which must supersede purely quantitative reasoning. For the quantitative concept of a homogeneous stock we have to substitute the concept of a functionally differentiated Capital Structure." (Lachmann, 1956, pp. 6-10).

Our maintained hypothesis is that capital goods, like consumer goods, are primarily built to perform specific functions. Thus the function of a generator is to supply electrical power; the function of a lift truck is to move materials within a plant; the function of a stamping press is to mold a sheet of metal into a specific form; the function of a welding machine is to attach two or more pieces of metal together; the function of a lathe is to cut a piece of material into a desired shape; the function of a photocopier is to reproduce two-dimensional images from one sheet to another, and so on. Much machinery and equipment is built to perform either a unique or a very limited range of functions. The substitutability of capital goods in different functions is extremely limited. This is the <u>functional specificity of capital</u>.

A glance at standard textbooks for students of engineering and production management, as for example Owens (1969), reveals that equipment is generally classified into two categories: (a) general-purpose equipment and (b) special-purpose equipment, depending on the variety of work that can be performed by the machine; and into four categories, depending on the amount of attention required by the operator: (a) manually-operated equipment; (b) semi-automatic equipment; (c) fully automatic equipment and (d) automation. Let us examine each of these categories first.

General-purpose equipment can perform more than one type of work. Examples of such machines are the lathe (used to cut wood, metal or other material), the milling machine (used for shaping and dressing material), the drill press (used for making holes in solid materials), the grinder (used for cleaning castings, welds, or any other type of work) and the shaper (used to finish flat surfaces of small objects). The advantage of general-purpose machines is that they can produce a variety of products by a variety of operations. They lend themselves well to the production of customized products. A second advantage is that a change in product design or the introduction of a new product does not necessitate a change in equipment although they may require changes in tools, dies or attachments. The cost of general-purpose equipment is low because the equipment is standardized and available in stock by capital goods manufacturers. The total investment is low because this type of equipment is easily adaptable to various types of work and can be easily used to capacity. Repair costs are also low because parts are standardized and often interchangeable between equipment. The major disadvantage of general-purpose equipment is that they are slow and uneconomical in the production of large quantities.

Special-purpose equipment, on the other hand, cannot be used for any work other than that for which they were designed. For example, a machine might be especially designed to peel pears, cut peaches in half, remove grapes from stems or test a can for leaks. Such machines are ordinarily most economical in large volume production, and are used in mass-production industries. Special-purpose machines are permanently set up with machine accessories such as jigs, fixtures, tools and dies. A jig holds and guides a cutting tool or drill as it performs its work on the material. A fixture is mounted on the table top of the machine to hold the material or workpiece in position while the work is being performed. A tool is used in the machine to supply the cutting edge, drill point or grinder which performs the work. A die is a metal block which is made with the pattern or contour of the part to be cut. Dies are used to cut or form identical parts. Special-purpose equipment are inflexible because they are built to perform specific functions. Their resale value is low and they easily become obsolete in the event of a major change in product design or the introduction of a new product.

Manually-operated equipment require constant operator involvement from starting the machine, placing the material in position, guiding the tool to perform the required operation and unloading the machine. Examples of manually operated machines are drill presses, lathes, milling machines, typesetting machines, sewing machines, lift trucks, earthmoving and agricultural machines and trucks. In the office, manually operated machines include typewriters, computing machines, photocopiers and switchboard telephone equipment. Manually-operated equipment cannot produce without their operator. The quality of the work depends very much on the skill and experience of the operator. They require careful planning in work flow and supervision. Manually-operated machines are being constantly replaced by equipment requiring less worker attention. The change increases the volume of production, decreases the need for skilled or semi-skilled workers and lowers unit costs of production.

Semi-automatic equipment operate through a cycle of production without attention. A semi-automatic machine requires attention only in loading, starting and unloading it for each successive cycle. The machine may deposit the processed material in a pile which is removed at the convenience of the worker. Limit switches may be installed to shut off a machine and stop the flow of work when the processed material in a bin, tank or hopper reaches a predetermined level. Controls of this kind reduce the amount of worker attention and make the machine semi-automatic. One worker can operate two or more of these machines and thus economize on the labour input.

Fully-automatic equipment operate continuously through successive cycles. They do not stop when they have finished with one cycle of operations or one batch of material but rather continue with the processing of other units. Material is introduced continuously by the machine and extra parts are available when required at any phase of the operation. In some machines, the material (such as paper or cloth) is introduced as continuous stock, for example, paper for wrapping bread and wire for making nails. In other machines, the materials are placed in a magazine from which they are automatically fed into the machine. The magazine may be refilled while the machine is in operation. Examples are automatic stokers, coffee grinders, and flour mills.

Many machines that formerly required worker control are now made fully automatic by means of control by magnetic tape. Numerically-controlled (NC) machines are many times as productive as operator-controlled machines, and scrap losses are reduced because the tape does not make mistakes. The tape also makes possible the control of many machines which perform various operations on a production line. When several fully NC-machines are connected with conveyors which automatically transport the material from one place to another, the factory resembles a single huge machine with highly complicated and fully integrated parts. Worker attention may be limited to supervision, inspection, and possibly a few manual operations at certain stages.

Automation is more than the mere integration of numerically-controlled equipment into a single process. In addition, it requires the automatic self-correction of any machine at any point in the processing. Automation usually includes the five following elements: (a) material is automatically moved from one working station to another; (b) it is automatically fed into the machine; (c) the processing is performed automatically by equipment in accordance to a predetermined sequence or schedule; (d) the materials are automatically discharged from machine; (e) the machine inspects the product or the conditions under which the operation is performed and corrects itself if any adjustment becomes necessary. Clearly, the production of many products does not readily lend itself to automation. However where it is applied, the consequences of automation are far reaching. Plant location becomes less dependent on labour availability and becomes more dependent on proximity to sources of raw materials, service industries, markets or power. The working hours (capital utilization) can be greatly expanded. Less floor space is required because machines can be placed closer together while the number of direct workers is reduced. More skilled workers are required to supervise and maintain the system. A major disadvantage with automation is that it is less flexible. Only one kind of part or product can be made and changes in product design require major modifications in the production line. Changes in markets and competition may require that some designs be altered, some products dropped and new ones added. These factors limit the savings to be made from automation.

Drucker (1974) has provided a very useful classification of production systems into four major classes, namely, unique product production, rigid mass-production, flexible mass-production and process or "flow" production. Each system is characterized by its own production function, cost function, capacity utilization requirement, labour requirement and functional specificity of capital. An understanding of such systems which characterize production processes in different industries is essential for the proper specification of investment functions.

Unique-product production is the oldest production system known to man. Examples of this type of production are illustrated in Table 5-6, and include housing construction, engineering construction, plant construction, production of custom-made capital equipment such as turbines, boilers, blast furnaces, pulp and paper making machines, heavy industrial equipment in general; aerospace (airplanes, satellites, space vehicles), shipbuilding, integrated iron and steel making and many type of services like personal services (restaurants, hairdressers, health clubs), commercial services (management consulting, engineering, accounting, legal, marketing, advertising services) and community services (education, health care). Unique-product production is organized around stages and uses

TABLE 5-6

INDUSTRIAL PRODUCTION SYSTEMS

Unique-Product Production	MASS-PRODUCTION		Continuous-Process Production
	Rigid	Flexible	
Housing	Building Materials	Clothing	Oil Refining
Shipbuilding	Auto Parts	Furniture	Glass
Satellites	Micro Chips	Automobiles	Cement
Aerospace	Fast Food	Appliances	Chemicals
Services: Legal		Household	Aluminum
Accounting, Marketing		Electronics	Alumina
Engineering, Advertising		Computers	Nickel
Custom-Made Equipment		Shoes	Pulp & Paper
Turbines		Agricultural Implements	Beer
Steel		Merchandising	Soaps and Detergents
Restaurants			

general purpose equipment to produce non-standardized products. It requires large amounts of skilled labour, often bordering on craftmanship. Because of the relatively low capital requirements, production can fall to very low levels and still break even. Table 5-7 summarizes the attributes of each major production system in Drucker's classification.

Continuous-Process or Flow Production is the opposite of unique-product production. Here production is highly integrated, automated and highly capital intensive. The classical example of this type of production is the oil refinery. Other examples include the smelting of alumina, aluminum, and nickel, cement, glass, petrochemicals, soaps, pulp and paper, beer and milk. Continuous-process production typically takes place 24 hours a day, 7 days a week. Shut-down and start-up costs are enormous. The production process is highly technical and capital intensive. Labour requirements are low but highly skilled and specialized personnel are required to run the system. The advantage of continuous process production is that it provides substantial economies of scale. The disadvantages however, are that it requires a high level of capacity utilization to be profitable and that it has no flexibility in product design and specification changes or in the production of new products. Consider an oil refinery for example. The end products that a refinery will produce out of crude oil are determined by the process it uses. It can produce only the oil distillates for which it was built and only produces these distillates in definite proportions. If new distillates have to be added or if the proportion of the various distillates is to be significantly changed, major capital expenditures are required.

TABLE 5-7

ATTRIBUTES OF MAJOR TYPES OF INDUSTRIAL PRODUCTION SYSTEMS

Attributes	Unique Product Production (Job Lot Production)	Mass Production (Line Production) Rigid	Mass Production (Line Production) Flexible	Process (Flow) Production
Type of Product	Non-Standardized	Standardized	Variable. Standardized	Variable Standardized
Type of Equipment	General Purpose Standardized Tools	Special Purpose	Special Purpose	Special Purpose
Type of Parts/Materials	Non-standardized	Standardized	Standardized	Either
Type of Labour	Highly Skilled	Unskilled	Semi-Skilled	Skilled
Quantity of Labour/Capital	High	Low	Medium	Low
Process Flexibility (versatility)	High	Low	Low	Low
Capital Integration	Low	High	High	High
Volume Requirement	Low	High	Medium	High

Rigid mass-production employs a highly integrated,automated and capital intensive process and it produces large quantities of a uniform, standardized output. It requires high skill in the technical design and maintenance of the process but very little skilled labour is required in its operation. Like continuous-process production, it relies heavily on special-purpose equipment, specifically designed to perform the specific functions required of the process. The essence of mass-production lies in the standardization of output. By producing and selling the same type of output, you can afford to design and install highly specialized equipment which will bring down the final cost of the product to a minimum. This is what Henry Ford meant when he said that "the customer can have a car in any color as long as it's black". If the manufacturer were to try to appeal to various tastes and segments of the market simultaneously, he would never be able to produce large enough quantities to make the use of special-purpose equipment profitable; and without the use of special equipment, he could not afford to bring the price low enough to create a major market for his product. By the same token, the highly specialized and integrated production process turns out to be its major disadvantage. The process is not flexible enough for the production of diverse products.

Flexible mass-production seeks to take advantage of economies of scale by assembling the final product from mass-produced, standardized components. Without compromising the economies of mass production, it enables a diversity of end products which can be tailored to meet a diverse range of customer needs. What Henry Ford did for rigid mass production, Alfred P. Sloan of General Motors did for flexible mass production. Sloan introduced diversity through different models (Chevrolet, Pontiac, Oldsmobile, Buick and Cadillac), different colours, body styles, seat fabrics and accessories. Yet all GM cars use the same frames, the same engines, chassis, brakes, electrical systems and carburators so then can be produced from the same assembly line.

For most mass-production processes, the preferred principle is flexible mass-production. Until recently, however, mechanization and flexible mass production were very hard to combine, because the tools appropriate to mass production are inherently inflexible. The arrival of the computer, however, has started changing this. With the introduction of micro-computers, capable of being installed on individual machine tools, standard numerically-controlled (NC) equipment are being replaced by computer-numerically controlled (CNC) equipment, which can adjust their function more quickly and at less cost. In traditional mass-production, any change in product specification or process requires stopping the process for days or weeks at a time. Change requires altering the machine set-up, cleaning tools, changing dies, changing the position of work stations, adjusting the rhythm and speed of the production process. With CNC equipment, this change takes only a few hours or days. The computer can make changes quickly so that the flow of production is not disrupted. More recently, the introduction of computer-aided design (CAD), computer-aided engineering (CAE) and computer-aided manufacturing (CAM) in the context of computer-integrated manufacturing systems (CIM) is greatly enhancing the flexibility of mass production systems, while improving product quality and reducing cost of production. Gunn (1981, 1982), <u>Time</u>

(1980), <u>Saturday Night</u> (1983) and <u>Business Week</u> (1986b) provide in-depth descriptions of the new manufacturing processes currently being introduced in industry. See also <u>Scientific American</u> (1982) for a special issue on the "Mechanization of Work" in various sectors of the economy (agriculture, mining, manufacturing, commerce and office work).

It becomes clear from the above review of types of equipment and production systems that much of the output in our economy is produced by special-purpose equipment. Out of the four major production systems, three (rigid and flexible mass-production and process production) rely on special-purpose capital goods. Therefore, if we accept that capital heterogeneity <u>and</u> functional specificity are the rule rather than the exception in any economy, it then follows that the composition of capital is intimately linked to the composition of the economy's demand for output, the capital-output specificity hypothesis. Consequently, a change in the composition of demand will generate a change in the desired composition of capital. As firms attempt to adapt their existing structure of capital to the one favoured by trends in market demand, there will be a need to invest in the modernization, revamping, refitting and transformation of their existing facilities. In short, change in the composition of demand will induce structural investment spending.

4. Capital-Output Specificity and Structural Investment

Capital goods exhibit functional specificity; that is, they are designed and built to perform specific functions. This reflects the association of particular types of output with particular types of capital goods, as clarified in Matziorinis (1985). We can thus express the relationship between the composition of an economy's capital stock and the composition of its output by the notion of capital-output specificity. The consequences of such specificity are evident if we observe the compositional changes in both aggregates that stem from responses to changes in demand, relative levels of factor prices, technology, the regulatory environment and our principal economic institutions. Investment expenditures and related activities permit competitive firms to evolve and they clearly must be partially determined by compositional factors. This evolutionary perspective is complex if dealt with adequately but the impact of compositional shifts in output on investment can be illustrated by a simple modification of common neoclassical models of capital accumulation, such as the stock-adjustment formulation presented in Branson (1979, pp. 224-227).

Under competitive conditions with parametric prices and production possibilities described by a well-behaved Cobb-Douglas function

$$Q = AK^{\alpha} L^{1-\alpha},$$

a representative firm can be assumed to maximize profits so

$$\frac{\partial Q}{\partial K} = \frac{c}{p} = \alpha \frac{Q}{K}$$

where p is the selling price of output, c or q $(r + \delta)$ is the rental price of capital, r is an interest rate, δ is the physical rate of capital depreciation, Q is the level of output, K is an index of capital, q is the acquisition price of the capital good, and both A and α are fixed production coefficients. By invoking an analogy principle, this equilibrium condition has often been used for aggregate magnitudes and functions. The manipulation yields

$$K = \alpha (p/c)\ Q$$

whereby capital is proportional to output but the factor of proportionality depends on the relative price (p/c). Implicit in this simple theory is the assumption that δ, the ratio of replacement investment to capital stock, is a fixed constant.

Among other problems with the theory, it lacks dynamic content. This can be added in several different ways. One of these represents the outcome of the theory as 'desired capital' and then expresses the firm's (or economy's) expansion investment as determined by the change in this desired capital; namely

$$\alpha \Delta[(p/c)Q] \simeq \alpha Q\ \Delta(p/c) + \alpha (p/c)\ \Delta Q$$

Thus gross investment, I, is approximated by

$$I = \alpha_1 \Delta(p/c) + \alpha_2 \Delta Q + \delta K$$

with other ingredients omitted as of a lower order of magnitude. From this basis, it is tempting to recognize gross investment expenditures for two separate capital goods by adding a further subscript:

$$I_i = \alpha_{1i}\,\Delta(p/c_i) + \alpha_{2i}\,\Delta Q_i + \delta_i K_i \qquad \text{for } i = 1,\ 2$$

where capital-output specificity provides the justification for the subscript given to ΔQ_i. Here output Q_i is produced by using K_i and no other capital good. Suppose, for simplicity, it is meaningful to use aggregate magnitudes formed by simple sums of the $\{I_i\}$ and the $\{Q_i\}$. Let these be denoted I, for $(I_1 + I_2)$, and Q, for $(Q_1 + Q_2)$.

$$I = \sum_i \alpha_{1i}\,\Delta(p/c_i) + \sum_i \alpha_{2i}\,\Delta Q_i + \sum_i \delta_i\,K_i$$

Consider the second sum of this mathematical expression of aggregate investment:

$$\alpha_{21}\,\Delta Q_1 + \alpha_{22}\,\Delta Q_2 = \alpha_{21}\,Q_{1t} - \alpha_{21}\,Q_{1t-1} + \alpha_{22}\,Q_{2t} - \alpha_{22}\,Q_{2t-1}$$

This can be re-expressed by a number of 'decomposition formulae' (or shift-and-share formulae) but it is easier to assume a compositional shift that leaves total output unchanged so

$$\Delta Q = \Delta Q_1 + \Delta Q_2 = 0$$

Then the second sum is

$$(\alpha_{21} - \alpha_{22})\,\Delta Q_1$$

which is positive or negative depending on the relative size of the coefficients, α_{21}, and α_{22}, as well as on the compositional shift affecting ΔQ_1. Whereas the acceleration impact of ΔQ in the first model with only one capital good is clearly zero, it has to be augmented by compositional impacts as soon as we enlarge the model to include additional capital goods. These impacts occur even when ΔQ is identically zero so seems inadequate to represent the difference between gross investment and "replacement investment" ($\delta_1 K_1 + \delta_2 K_2$) in this model as "expansion" investment. Such terminology distorts the treatment of these phenomena when we acknowledge multiple capital goods and the attendant constraints of capital-output specificity.

5. Structural Investment: Some Strong Empirical Support

Before we examine more evidence in favour of our hypothesis of structural investment, let us review our definition of structural investment. First, structural investment has nothing to do with expansion or maintenance of production capacity--where the underlying assumption is that the firm is committed to the same line of activity. Where the firm adds to its production capacity, the expenditures incurred are clearly expansion investment. Where the firm maintains production capacity, it does so in large part by replacing components of major pieces of capital equipment. These expenditures are expensed and therefore do not appear in capital investment figures. This leaves us with a major segment of capital investment spending which does not belong to either category. In some industries, for example the U.S. iron and steel and automobile industries, it makes up the majority of capital investment outlays.

Structural investment refers to capital expenditures intended for a variety of purposes, other than expansion or maintenance of production capacity. Structural investment is intended (a) to adjust or modify the firm's production capacity to produce a different product or output-mix; (b) to adjust or modify the firm's production process to utilize a different mix of factor inputs (capital, labour, raw materials, energy) so as to enhance productivity and lower unit costs of production and (c) to improve the quality of the work environment, the quality of the output, and reduce pollution emissions (air, water and sound). Changes in the composition of demand, product and process technology, prices of factor inputs, the social-regulatory environment and the competitive environment of the firm (whether domestic or international) continuously pose a threat to the profitability and the long-term ability to survive of the firm. To adapt to its changing environment, the firm is pressured to find means to enhance its net revenue by substituting among products and to reduce its costs of production by substituting in favour of factors with lower cost. This process of adaptation, generally though not always, entails a flow of capital investment outlays. They appear under a variety of labels including upgrading, modernization, modifications, retrofitting, upgrading and replacement, pollution abatement, productivity enhancement and rationalization. What all these terms have in common is change in the structure of production to enhance profitability and ensure the long-term viability of the firm. Hence, we have grouped them under the heading of structural investment.

Let us turn to some of the evidence. Table 5-8 provides data on replacement and modernization in major United States manufacturing industries for 1985. 73% of total manufacturing investment or $111.8 billion were devoted to some form of structural investment. The share of such expenditures is over 85% in a number of industries, such as iron and steel, nonferrous metals, nonelectrical machinery, autos, trucks and parts, fabricated metals, rubber and plastics and textiles. In the automobile and iron and steel sectors, the share of structural investment is as high as 98% and 97% of total capital outlays. It is interesting to note that in many cases, high structural investment outlays occur despite absolute decreases in production capacity (iron and steel, electric machinery, petroleum) or low rates of capacity utilization (iron and steel, electric machinery, nonelectrical machinery, chemicals and petroleum). Also high shares of structural investment are generally positively correlated with high ratios of equipment to plant outlays. Since much replacement investment takes the form of minor replacements and therefore is expensed, it is highly unlikely that all of these expenditures for replacement and modernization are for "like-for-like" replacement purposes. It is most probable, therefore, that they have been incurred for some form of structural investment, thereby providing strong direct evidence in support of our hypothesis.

Table 3-1, suggests that structural investment outlays have averaged over 50% of capital spending in the U.S.A. since 1950, with this share rising significantly since 1980 to well over 60% of real manufacturing

TABLE 5-8

REPLACEMENT & MODERNIZATION EXPENDITURES & OTHER DATA:
U.S. MANUFACTURING, 1985

	Investment Expenditure $ Billions	Repl. & Modern. Share %	Repl. & Modern. Expenditures $ Billions	Capacity Expansion %	Capacity Utilization Rate*	Equipment vs. Plant Share
Iron & Steel	4.10	97	3.98	-1.83	60.2	94
Nonferrous Metals	1.88	91	1.71	+7.46	98.3	95
Electric Machinery	15.57	65	10.12	-0.90	76.1	77
Nonelectrical Machinery	15.97	87	13.89	+14.14	67.0	84
Autos, Trucks & Parts	14.45	98	14.16	0.00	96.1	93
Aerospace	3.46	78	2.70	--	84.6	75
Other Transp. Equipment	1.38	--	--	+5.80	--	--
Fabricated Metals	3.56	86	3.06	-1.15	68.8	86
Instruments	3.72	75	2.79	-1.15	75.9	65
Stone, Clay, Glass	3.40	78	2.65	+1.56	87.0	87
Other Durables	7.03	59	4.15	--	76.7	87
Total Durables	73.14	81	59.24	--	78.3	84
Chemicals	16.45	72	11.84	+1.63	72.2	84
Paper & Pulp	8.53	64	5.46	+3.12	90.7	86
Rubber & Plastic	3.83	91	3.49	+0.55	89.5	91
Petroleum	26.68	60	16.00	-1.43	87.4	54
Food & Beverages	10.29	70	7.20	+4.40	87.3	80
Textiles	1.78	85	1.51	+2.38	84.8	74
Other Nondurables	12.45	44	5.48	--	88.0	73
Total Nondurables	80.01	64	51.20	--	77.8	72
All Manufacturing	153.15	73	111.80	+5.09	77.2	77

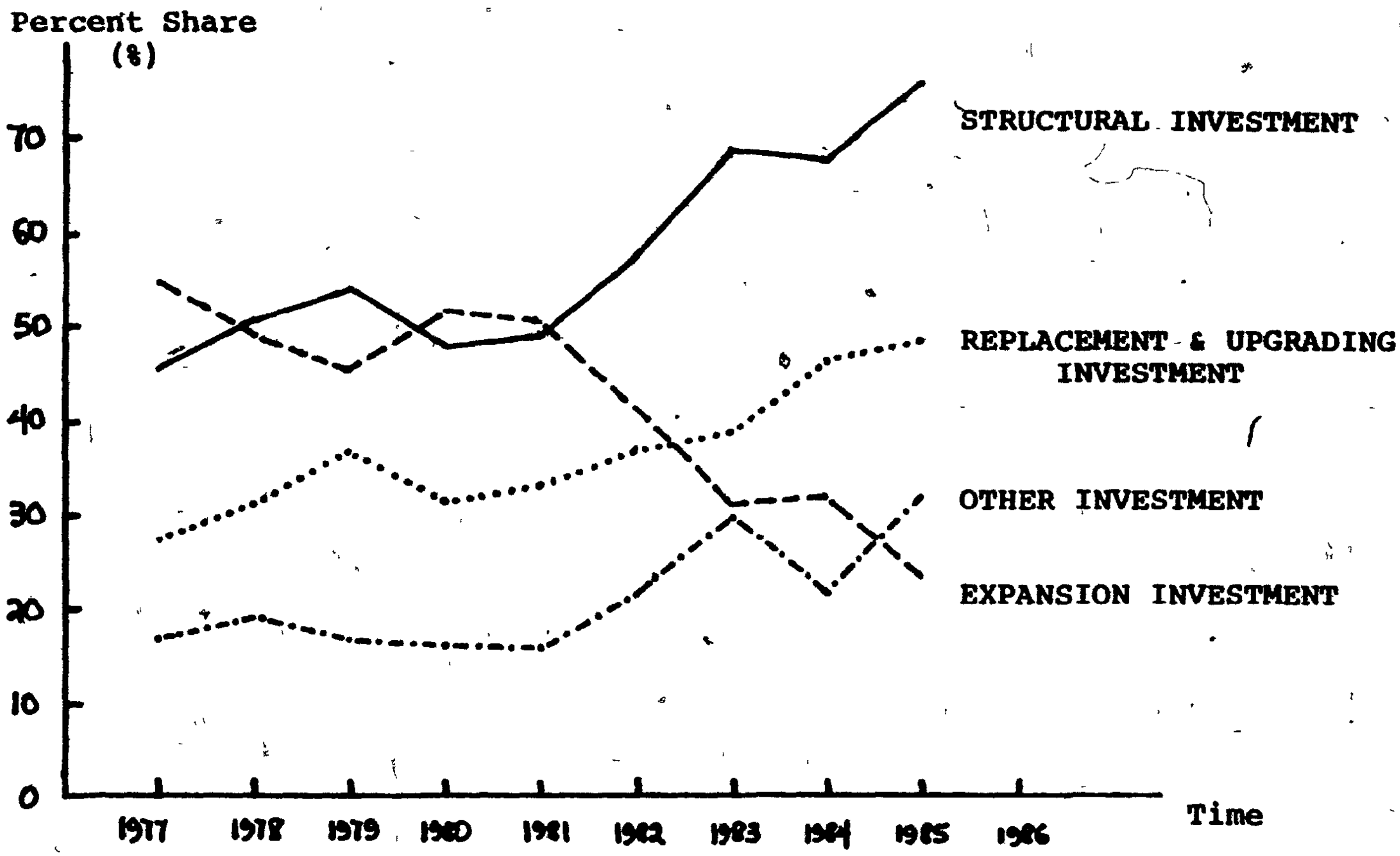
* As of December, 1985

Source: McGraw-Hill (1986) Historical Capital Spending & Related Data, (Economic Dept.), New York capital outlays. Again, it is highly unlikely that such significant expenditures have been devoted for pure replacement purposes. Data spanning a shorter period but with greater detail are available for Canada. Table 3-2 and Figure 5-11 provide a breakdown by major purpose of capital spending in the manufacturing sector of Canada over the 1977-1985 period (as compared with manufacturing and non-manufacturing combined in Table 4-5). Structural investment in Canadian manufacturing has averaged 50% in 1977-1981 and has been rising since 1981, surpassing 70% in 1985. The expansion share has been decreasing over the same period from about 50% of total spending to about 30%. The drop in expansion has been most pronounced in new-site (greenfield) expansions, where the share has dropped from over 20% in 1977 to just 5% in 1985 (see Table 3-2). A break-down of structural investment by purpose is also shown in Figure 5-11, and in Tables 4-6, 4-7 and 4-8. The replacement and upgrading component has risen from under 30% in 1977 to over 35% in 1985 (out of total manufacturing investment) while the "other" investment component has risen from under 20% to over 30% over the same period. As can be seen in Table 4-6, "other" investment includes capital spending in research and development, pollution abatement and working environment but also includes an unspecified component which has risen from 8.8% of total spending to 23.4%. Much of this represents spending on special tooling for model change-overs in the automobile industry and plant conversions. Table 4-7 shows the breakdown of these re-tooling and conversion expenditures by major industry. Major beneficiaries have been the automotive sector, followed by the forest products and primary metals sectors. Clearly here we have additional

FIGURE 5-11

CAPITAL INVESTMENT EXPENDITURE SHARES, BY PURPOSE:

CANADA, 1977-1985



Source: DRIE, Business Capital Investment Surveys, April 1977 - April 1985 evidence of structural investment outlays. At 70% of total manufacturing investment in both Canada and the U.S.A., they certainly deserve more attention.

For further support of the hypothesis of structural investment, let us examine long-term capital spending patterns in two important industries of the U.S.A. economy, namely, the motor vehicle and iron and steel industries during 1957-1985. Both provide convincing evidence of structural investment.

Table 5-9 and Figures 5-12 and 5-13 provide data on capital investment, output, capacity and other variables for the automobile industry. Why these data are so interesting is because the automobile industry is well known for its frequent model changes and consequent re-tooling expenses for plant and equipment. They reveal how change in the composition of output generates a positive level of investment outlays. "Replacement and modernization" spending has averaged 74% over this period, with the level of real spending on structural investment exhibiting a rising trend, particularly since 1976. Firms in the automobile sector have been significantly increasing their outlays for structural purposes despite low capacity-utilization rates and very modest increases in capacity. It appears that structural investment outlays are a key determinant in subsequently raising sales and capacity utilization. This can be seen since 1976. Despite falling rates of capacity utilization and negative profits, firms in the automobile industry massively invested in structural changes. Intuitively, it is not hard to see why the introduction of new car models with new styling, improved fuel efficiency, better road handling

Table 5-9

INVESTMENT, OUTPUT & CAPACITY, U.S.A.
MOTOR VEHICLE INDUSTRY: 1957-1985

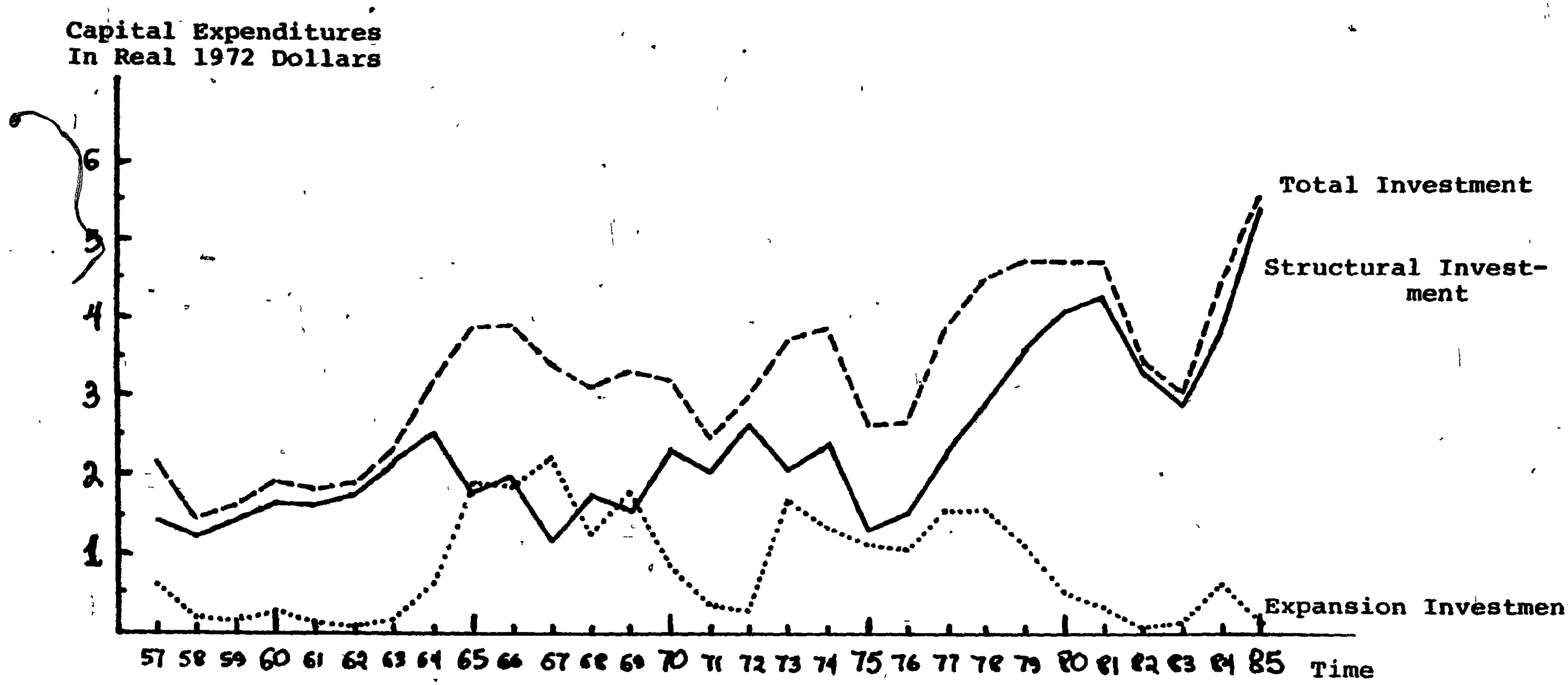
Year	Total* Investment	Expansion Share	Repl. & Mod. Share	Expansion Investment*	Repl. & Mod. Investment*	Total Output	Total Capacity	Capacity Utilization	Plant Share	Equipment Share
	$Bil.	%	%	$Bil.	$Bil.	Millions	1967=100	%	%	%
1957	2.08	30	70	0.62	1.46	7.2	75	76	N/A	N/A
1958	1.48	14	86	0.21	1.27	5.1	77	78	N/A	N/A
1959	1.65	11	89	0.18	1.47	6.7	78	88	17	83
1960	1.94	15	85	0.29	1.65	7.9	81	80	8	92
1961	1.80	10	90	0.18	1.62	6.7	82	86	20	80
1962	1.88	7	93	0.13	1.75	8.2	83	88	21	79
1963	2.34	11	89	0.26	2.08	9.1	85	89	22	78
1964	3.15	21	79	0.66	2.49	9.3	87	95	19	81
1965	3.83	51	49	1.95	1.88	11.1	93	96	21	79
1966	3.88	49	51	1.90	1.98	10.4	96	90	24	76
1967	3.42	65	35	2.22	1.20	9.0	100	89	19	81
1968	3.06	43	57	1.32	1.74	10.6	102	91	25	75
1969	3.33	54	46	1.80	1.53	10.2	105	85	24	76
1970	3.23	27	73	0.87	2.36	8.3	112	87	18	82
1971	2.49	18	82	0.45	2.04	10.7	113	97	12	88
1972	3.00	14	86	0.42	2.58	11.3	119	109	22	78
1973	3.71	45	55	1.67	2.04	12.7	124	90	16	84
1974	3.85	37	63	1.42	2.43	10.1	126	55	25	75
1975	2.57	46	54	1.18	1.39	9.0	131	72	25	75
1976	2.[illegible]1	42	58	1.10	1.51	11.5	136	91	17	83
1977	3.94	40	60	1.58	2.36	12.7	147	90	18	82
1978	4.50	35	65	1.58	2.93	12.9	148	83	16	84
1979	4.71	24	76	1.13	3.58	11.5	150	74	35	65
1980	4.69	13	87	0.61	4.08	8.0	152	61	15	85
1981	4.70	9	91	0.42	4.28	7.9	152	61	21	79
1982	3.44	2	98	0.07	3.37	7.0	152	57	9	91
1983	3.05	3	97	0.09	2.96	9.2	152	84	6	94
1984	4.50	14	86	0.63	3.87	10.9	160	81	13	86
1985	5.59	2	98	0.11	5.48		160	96	7	93

*In billions of 1972 constant U.S. Dollars.

Source: Department of Commerce Bureau of Economic Analysis, Survey of Current Business, Sept. 1981, pp. 26-41.
McGraw-Hill, Department of Economics, Historical Capital Spending & Related Data, June 1986.
Motor Vehicle Manufacturers' Association (1985), Facts and Figures '85, Detroit.
Motor Vehicle Manufacturers' Association (1986), Economic Indicators: The Motor Vehicle's Role in the U.S. Economy, Detroit.

FIGURE 5-12

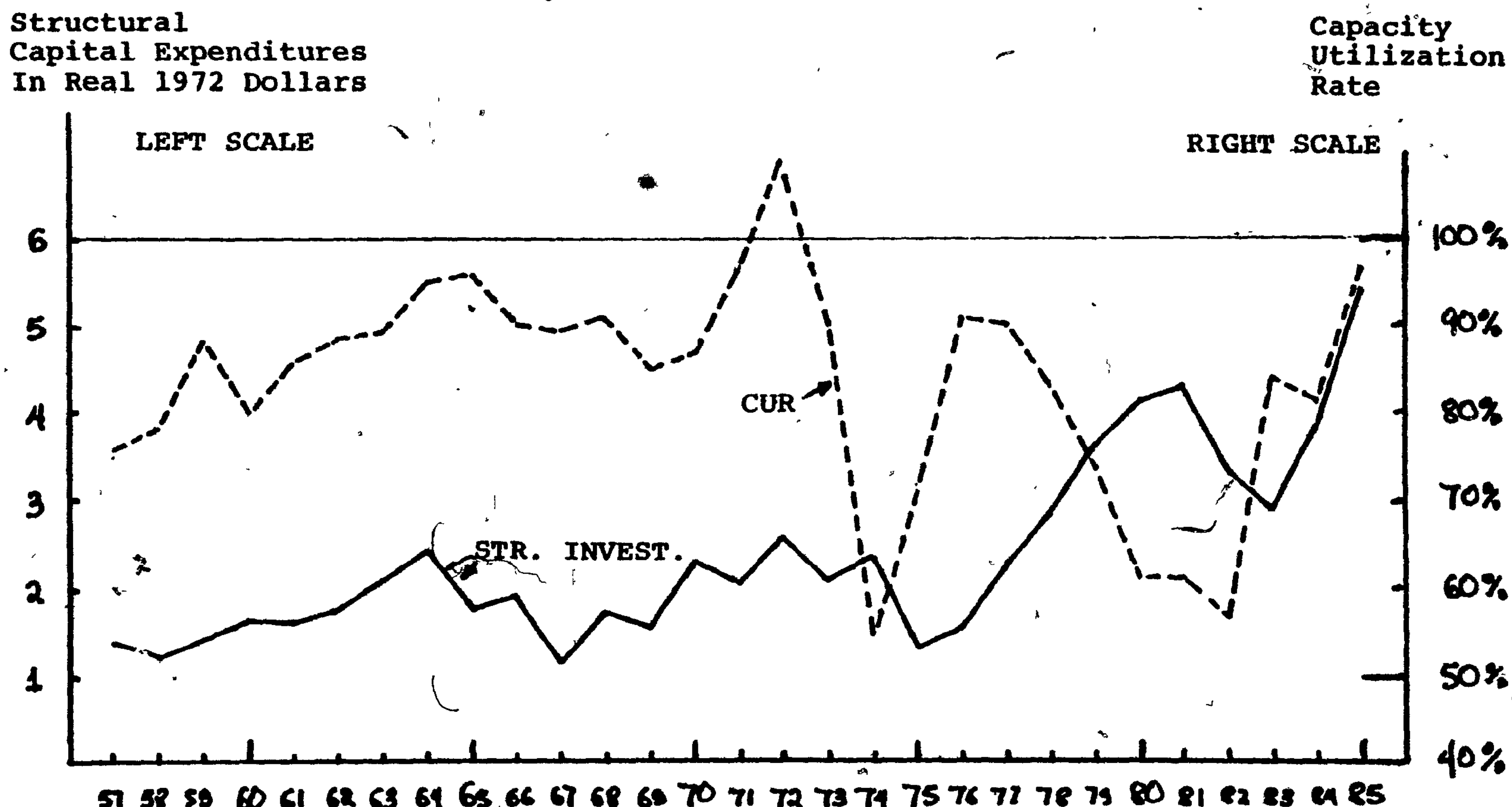
CAPITAL INVESTMENT EXPENDITURES IN U.S. AUTOMOBILE INDUSTRY: 1957-1985



Source: Department of Commerce, BEA, Survey of Current Business, Sept. 1981
McGraw-Hill, Dept. of Economics, Historical Capital Spending & Related Data, June, 1986

FIGURE 5-13

STRUCTURAL INVESTMENT AND CAPACITY UTILIZATION RATE:
U.S.A. AUTOMOBILE INDUSTRY,
1957-1985



Source: Department of Commerce, BEA, Survey of Current Business, Sept. 1981
McGraw-Hill, Dept. of Economics, Historical Capital Spending & Related Data, June, 1986

and improved quality, should subsequently raise the level of sales and consequently the rate of capacity utilization. During the six-year period 1980-85, U.S. automobile producers spent $21 billion (in 1972 dollars) on re-structuring their production processes. During this period the share of "replacement and modernization" averaged 93% of total capital spending, while the share of equipment outlays averaged 88%. Total capacity increased by only 5.3% during this six-year period. Analysis of the changes that have occurred recently by, for example, the Motor Vehicle Manufacturers' Association (1985, 1986) reveals that there has been an unprecedented rise in new model introductions, a massive shift from rear-wheel-drive to front-wheel-drive, substantial reductions in car sizes and weight, substantial improvement in fuel efficiency and quality, as evidenced by vehicle owner satisfaction ratings and extension of automobile warranties. There has also been massive re-tooling in new computer numerically-controlled (CNC) machine tools, robotization (in paint shops and welding), statistical process control (SPC) and just-in-time (JIT) inventory methods[2]. An examination of the Annual Reports of the "Big Four" automakers, as well as industry journals, will impress the reader of the extent and nature of this massive restructuring of the production process. Table 5-10 provides additional evidence from G.M. Canada Ltd., for which national segmented figures are available. Despite a drop in earnings and even losses in 1981 and 1982, G.M. Canada mounted a massive investment

---

[2] For a description of these new technologies see Scientific American (1982) and Economic Council of Canada (1986). The latter publication includes many examples of the application of these technologies in Canada by Chrysler, G.M. and Ford.

TABLE 5-10

SALES, INCOME & CAPITAL INVESTMENT:
GENERAL MOTORS OF CANADA, 1976-1985

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Unit Sales	--	--	852,896	842,785	699,797	677,285	564,704	801,779	825,599	841,446
Net Sales Millions of $	5,198.8	6,115.4	7,721.1	9,409.8	9,451.3	10,416.1	9,570.5	13,805.4	16,297.7	18,993.3
Net Income Millions of $	159.8	180.6	203.0	246.8	55.0	(10.3)	(71.7)	675.6	880.8	713.0
Plant & Equipment Expenditures	38.7	116.5	86.2	177.2	468.5	784.4	201.6	155.0	184.8	541.0
Special Tools Expenditures	122.3	183.0	74.8	141.8	290.6	316.2	122.6	187.1	82.7	133.4
Total Investment Expenditures	161.0	299.5	161.0	319.0	760.1	1,064.6	324.2	342.1	267.5	674.4

Source: General Motors of Canada Limited, Annual Reports, 1981-85.

program to re-tool and modernize its facilities. Specific examples of automotive structural investments are given in Table 5-13 at the end of this section.

Tables 5-11 and 5-12 and Figure 5-14 provide similar data for the U.S. iron and steel industry. While the North American automobile industry is an excellent example of an industry that has successfully adapted to changes in its competitive environment (the market threat posed by European and Japanese producers and the dramatic increase in the price of gasoline) through massive re-tooling and structural investment, the U.S. iron and steel industry is as example of an industry that failed to adapt quickly enough to changes in its market environment. Capital spending in this sector was substantially less than the automobile sector over the 1957-1985 period. As a result, the iron and steel industry failed to introduce the type of newer technologies which provided the competitive advantage to off-shore producers, such as electrical steel making and continuous casting technologies. As a result, iron and steel output has been falling since 1980, steel-making capacity has been diminishing, there have been dozens of plant closings and massive layoffs while the rate of capacity utilization has reached historical lows. Yet even here, U.S. steel makers are now making some efforts to adapt to the competitive challenge. Structural investment outlays have risen since 1975 relative to previous periods. U.S. steel producers are currently in the process of expanding the more cost efficient steel-making technologies. The percent of steel produced by electrical furnaces has jumped from 19.2% in 1976 to 33.9% in 1985 while the percent of steel cast by continuous casting methods has risen from

TABLE 5-11

INVESTMENT, OUTPUT & CAPACITY, U.S.A.
IRON & STEEL INDUSTRY: 1957-1985

Year	Total* Investment	Expansion Share	Repl. & Mod. Share	Expansion Investment	Repl. & Mod. Investment	Total Output	Total Capacity	Capacity Utilization	Plant Share	Equipment Share
	$ 1972 Billions	%	%	$ Bil.	$ Bil.	Tons Millions	1967= 100	%	%	%
1957	2.00	60	40	1.20	0.80	112.7	79	68	-	-
1958	1.48	55	45	0.81	0.67	85.3	83	73	-	-
1959	1.12	39	61	0.44	0.68	93.4	86	96	21	79
1960	1.84	19	81	0.35	1.49	99.3	86	50	22	78
1961	1.20	16	84	0.19	1.01	98.0	87	83	18	82
1962	1.01	18	82	0.18	0.83	98.3	88	75	21	79
1963	1.19	30	70	0.36	0.83	109.3	88	-	15	85
1964	1.90	40	60	0.76	1.14	127.1	90	-	13	87
1965	2.09	30	70	0.63	1.46	131.5	94	-	13	87
1966	2.20	24	76	0.53	1.67	134.1	98	-	12	88
1967	2.36	29	71	0.68	1.68	127.2	100	-	10	90
1968	2.39	49	51	1.17	1.22	131.5	103	-	11	89
1969	2.10	64	36	1.34	0.76	141.3	107	-	12	88
1970	1.76	69	31	1.21	0.55	131.5	108	-	10	90
1971	1.32	46	54	0.61	0.71	120.4	110	-	12	88
1972	1.06	37	63	0.39	0.67	133.2	110	-	14	86
1973	1.19	32	68	0.38	0.81	150.8	111	95	11	89
1974	1.65	74	26	1.22	0.43	145.5	114	82	11	89
1975	2.28	31	69	0.71	1.57	116.6	115	62.5	11	89
1976	2.18	34	66	0.74	1.44	128.0	117	70.5	13	87
1977	1.90	29	71	0.55	1.35	125.3	115	77	12	88
1978	1.56	24	76	0.37	1.19	137.0	116	88	11	89
1979	1.68	26	74	0.44	1.24		117	93	11	89
1980	1.69	33	67	0.56	1.13	111.8	117	82.6	8	92
1981	1.67	32	68	0.53	1.14	120.8	121	71.5	8	92
1982	1.67	15	85	0.25	1.42	74.6	121	43	18	82
1983	1.36	14	86	0.19	1.17	84.6	120	54.3	13	87
1984	1.42	16	84	0.23	1.19	92.5	109	61.9	14	86
1985	1.58	3	97	0.05	1.53	88.3	107	60.2	6	94
	72.9									

* In billions of 1972 constant U.S. dollars.

SOURCE: Department of Commerce, BEA, Survey of Current Business, Sept. 1981, pp. 26-41.
McGraw-Hill Department of Economics, Historical Capital Spending & Related Data, June, 1986.
American Iron & Steel Institute (1985) Annual Statistics Report, Washington, D.C.

Table 5-12

PRODUCTION, INCOME & INVESTMENT STATISTICS,
U.S. IRON & STEEL INDUSTRY:
1976-1985

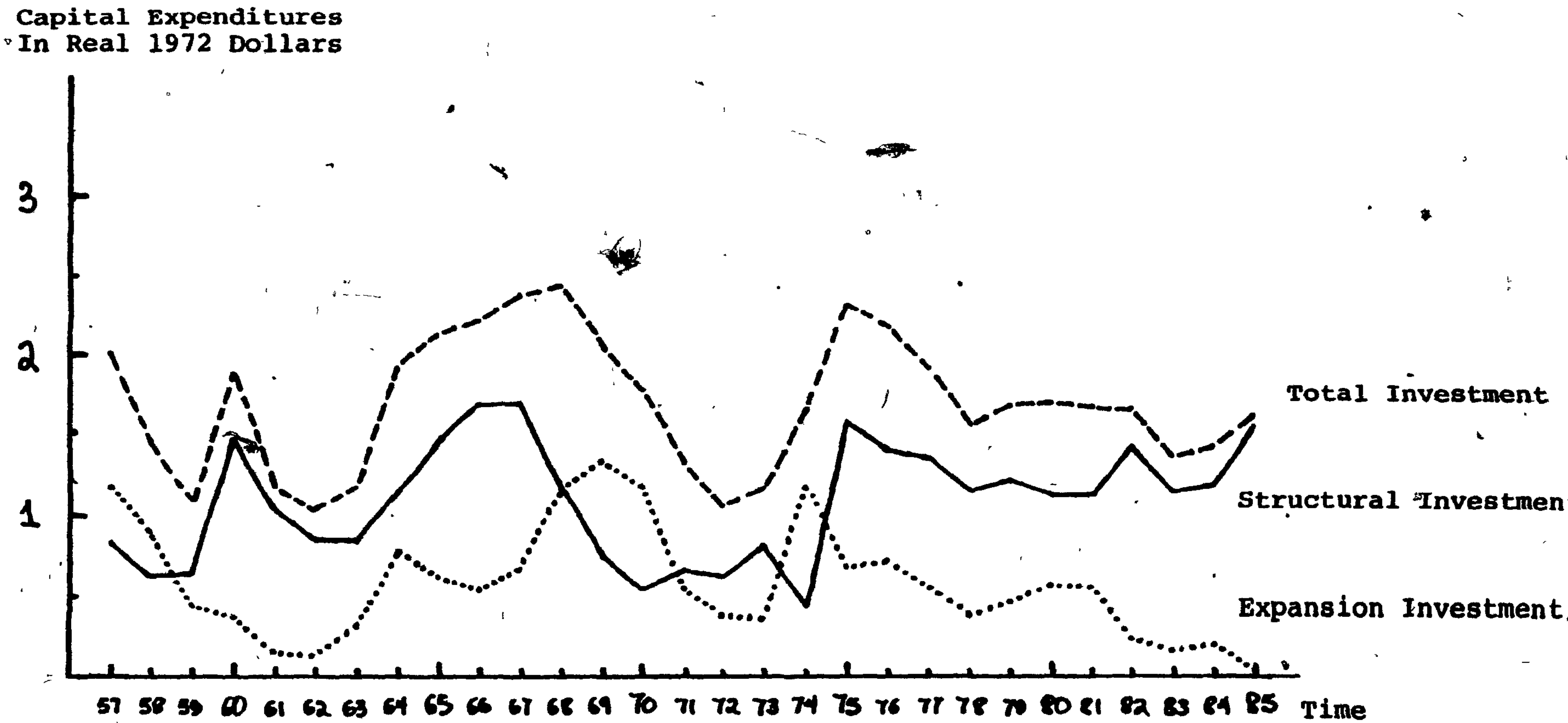
Year	Steel Production	Steel Capability	% of Capability	Import Share	Net Income	Capital Expenditures	Gross Fixed Assets	Average Employment	% of U.S. Production By Tye of Furnace			By Type Cast		BLS Productivity Index*
	Mil. Tons	Mil. Tons	%	%	Mil. $	Millions $		Thousands	OH	BOP	Elect.	Ingots	Continuous	
1976	128.0	158.3	80.9	14.1	-	-	-	454.1	18.3	62.5	19.2	89.3	10.6	99.0
1977	125.3	160.0	78.4	17.8	-	-	-	452.4	16.0	61.8	22.2	87.3	12.5	100.0
1978	137.0	157.9	86.8	18.1	-	-	-	449.2	15.6	60.9	23.5	84.6	15.2	108.3
1979	136.3	155.3	87.8	15.2	806	2,469	36,000	453.2	14.0	61.1	24.9	82.9	16.9	106.9
1980	111.8	153.7	72.8	16.3	681	2,651	37,717	398.8	11.7	60.4	27.9	79.5	20.3	102.9
1981	120.8	154.3	78.3	18.9	1,653	2,371	38,971	390.9	11.1	60.6	28.3	78.2	21.6	112.0
1982	74.6	154.0	48.4	21.8	(3,384)	2,258	38,518	289.4	8.2	60.7	31.1	70.9	29.0	90.9
1983	84.6	150.6	56.2	20.5	(2,231)	1,850	34,283	242.7	7.0	61.5	31.5	67.8	32.1	116.8
1984	92.5	135.3	68.4	26.4	(31)	1,203	35,198	236.0	9.0	57.1	33.9	60.3	39.6	132.0
1985	88.3	133.6	66.1	25.2	(1,743)	1,688	35,469	208.2	7.3	58.8	33.9	55.5	44.4	138.6
1986	72.9													

*Output/Man-hour

Source: American Iron & Steel Institute (1985) Annual Statistical Report, Washington, D.C.

FIGURE 5-14

CAPITAL EXPENDITURES IN THE U.S. IRON & STEEL INDUSTRY: 1957-1985



Source: Department of Commerce, BEA, Survey of Current Business, Sept. 1981
McGraw-Hill, Dept. of Economics, Historical Capital Spending & Related Data, June, 1986

10.6% to 44.4% over the same period. In the meantime, productivity has also been rising. The message is clear: U.S. iron and steel makers either commit themselves to massive structural investments to lower costs and improve quality or they will continue losing share of the domestic and world steel market. It is through capital re-structuring that the U.S. steel industry can survive and prosper in the long-run and this entails structural investment outlays.

Table 5-13 provides some specific examples of structural investment. It contains summaries taken from the press and industry journals in Canada of capital investment projects, whose purpose is to modify or alter the production process, and in most cases, also change the quality or the nature of the product. Aside from the Canadian automotive sector (which parallels trends in the U.S.A.) the Canadian pulp and paper, textile, shoe manufacturing and petroleum refining industries have been excellent examples of structural investment activity. Examine, for example, some of the capital spending projects in the pulp and paper industry. There have been two major developments in this sector. First, pulp and paper makers have been converting their newsprint mills to thermomechanical (TMP) and chemi-thermo-mechanical (CTMP) pulping processes, away from the more expensive traditional groundwood pulping process. Second, many newsprint mills have been converted to the production of different types of paper, for example, super-calendered paper. To quote one industry analyst, Jim Rowland, publisher of the Canadian Paper Analyst:

> "The appeal of the product [super-calendered paper] -used in such materials as advertising flyers, newspaper inserts and television guides- is that outdated newsprint machines can easily be upgraded to

produce the super-calendered paper.

Indeed, anyone with a newer newsprint mill will probably just want to keep it up-to-date and produce newsprint, but someone with an older, or smaller, mill that is going to need massive reworking anyway is likely, nowadays, to consider the conversion to specialty grades." (Montreal Gazette, December 15, 1984).

Other good examples include Dominion Textile, IBM and a number of oil companies. IBM for example, spent $100 million in 1984-85 to convert its Bromont plant from electric typewriter assembly (a field that IBM has been abandoning to shift to more profitable areas) to production of multilayered ceramic components (MLC). A number of oil companies (Imperial Oil, Ultramar, Gulf Oil, Petrosar and Petromont) have incurred capital expenditures to modify their output mix and expand the versatility of their oil refineries in response to changes in the composition of market demand and relative feedstock prices.

The conclusion that emerges from the foregoing evidence is firm. The structural investment hypothesis cannot be rejected and deserves further investigation.

6. Structural Investment as a Strategic Option

Change in the firm's market environment, such as product and process innovation, change in consumer tastes and preferences, shifts in the domestic and international structure of comparative advantage, change in the prices of factor inputs (labour, energy, raw materials), change in the structure of industrial organization, organizational and managerial

TABLE 5-13

STRUCTURAL INVESTMENT CAPITAL SPENDING PROJECTS, CANADA: SOME SPECIFIC EXAMPLES

AUTOMOBILE INDUSTRY

CHRYSLER CANADA LTD. Spent $400 million in 1983 to overhaul its Windsor plant. It gutted the 55-year old car assembly plant and built a highly automated 16 km-long assembly line where shifts of 3,000 workers, aided by 125 robots turn out 912 front-wheel wagons per day. Montreal Gazette, February 25, 1984.

GENERAL MOTORS CANADA LTD. - Spent $36.6 million in 1984 to convert Ste-Thérèse plant from production of Chevrolet Monzas, Oldsmobile Starfires and Buick Skyhawks to Cutlass Supreme and Grand Prix models. Montreal Gazette, April 11, 1985.

- Spent $1 billion to up-grade and modernize Oshawa truck assembly and parts stamping plant. $228 million where spent for modernization of the stamping plant into high-technology operation; $556 million for the modernization and expansion of the truck plant and $220 million to revamp the powerhouse and electrical facilities, increase capacity and product improvements. Montreal Gazette, July 10, 1984.

- Spent $255 million at the St-Catherines engine plant to revamp plant to produce new fuel-efficient V-6 60-degree fuel-injected engine. Financial Post, July 14, 1984. Also, see GMC News Release, July 6, 1984.

- GMC is considering investing between $600 - $700 million at Ste-Thérèse car assembly plant. The plant is to be converted from production of rear-wheel-drive cars to front-wheel-drive cars with a much higher degree of automation. The models considered are the Chevrolet Celebrity, Pontiac 6000, Oldsmobile Sierra and Buick Century. Montreal Gazette, November 9, 1986, August 8, 1986 and Globe and Mail, November, 1986.

- Spent $18 million at Ste-Thérèse plant to increase the line speeds from 42.5 to 46 jobs per hour. This adjustment will allow plant to expand production to 736 cars a day from 680. Montreal Gazette, April 11, 1985.

FORD OF CANADA LTD. - Spent $115 million to retool and convert its 30-year old Oakville Assembly plant for production of front-wheel drive Ford Tempo and Mercury Topaz cars. Ford News Release, August 11, 1981.

- Spent $100 million during 1984 to modernize paint facilities at St-Thomas assembly plant and Oakville truck plant. Ford News Release, April 30, 1985.

- Spent $100 million during 1985-86 at Essex Engine plant for retooling. Ford News Release, May 13, 1986.

PULP AND PAPER INDUSTRY

DOMTAR INC. - Spent $85 million to convert newsprint mill in Dolbeau, Que. to thermo-mechanical pulping in 1985-86. Dolbeau mill will substitute thermo-mechanical pulp in place of mechanical groundwood and chemical pulps. Thermo-mechanical process makes more efficient use of wood fibre; project aimed at "securing the mill's long-term viability" by ensuring competitiveness. Montreal Gazette, June 7, 1985.

- Spent $90 million in 1984 to convert newsprint mill at Donnacona, Quebec to thermo-mechanical pulping. Montreal Gazette, June 7, 1983.

KRUGER INC. - Spent $167 million in 1985-86 for modernization and up-grading of 49-year old Bowater Nfd. plant. Mill was purchased from British owners who instead of re-investing in expensive modernization of the plant opted to re-invest in beefing-up U.S. operations. Montreal Gazette, September 19, 1984.

REED INC. - Spent $260 million in 1983-86 to modernize and up-grade Quebec City newsprint mill, including a 100,000 ton increase in capacity. Capacity increase is "almost a by-product of original $199 million plan begun 3 years ago and designed to bring the 56-year old mill up to industry production and environmental standards. As work progressed we saw that we could increase capacity along with the modernization, so we decided to expand the plan". Out of total sum, $105 million went for modernization; $45 million for quality improvement measures and $10 million for work conditions, to improve work stations, locker rooms and cafeterias. Montreal Gazette, 1984.

CASCADES INC. - REXFOR INC. - Spent $100 million to reopen ITT-Rayonier mill at Port Cartier, Que. which was closed in 1979. Funds used to convert mill to produce a new product, bleached chemi-thermochemical pulp, which requires less wood fibre than conventional pulp. Montreal Gazette, November 14, 1985.

CONSOLIDATED BATHURST INC. - Spent $62 million to convert Trois-Rivières newsprint mill to production of directory paper. Pulp and Paper Magazine of Canada, March 1, 1980.

CANADIAN INTERNATIONAL PAPER Co. - Spent $15.7 million on boardmill production improvements and miscellaneous environmental control projects in La Tuque, Que. and $3.8 million on production machine modernization and facility modifications in Trois-Rivières (total $19.5 million). Canadian Pulp and Paper Institute, May, 1980.

MacMILLAN BLOEDEL LTD. - Spent $197 million on modernization and renovation projects at Powell River, B.C. Canadian Pulp and Paper Institute, May, 1980.

RAYONIER CANADA LTD. - Spent $400 million during 1980-85 on expansion program at its Port-Alice and Woodfibre Mills, B.C. The emphasis of the project is energy efficiency through modernization. Modern Power and Engineering, February, 1980.

ABITIBI-PRICE INC. - Spent $60 million in 1979-80 to convert the linerboard mill at Stephenville, Nfd. to a newsprint mill. Globe and Mail, November 23, 1979.

OTHER INDUSTRIES

DOMINION TEXTILE INC. - Spent $15 million to modernize Long-Sault, Ont. yarn plant near Cornwall, Ont. in 1985-86 and $17.5 million for replacement of traditional ring-spinning equipment by open-end spinners in 1984-85. New equipment will increase capacity by 35%. Montreal Gazette, April 11, 1985.

- Spent $17 million to transfer and consolidate apparel fabric printing operations from Magog finishing plant to more modern facility at Beauharnois. "Market conditions today are such that apparel manufacturers are requiring wider fabrics and a quality of colour reproduction which make copper roll engraving and roller printing obsolete... the new technology calls for rotary screen printing and high temperature colour steaming which the Magog finishing plant (built in 1880) could not accomodate." Montreal Gazette, April 28, 1984.

INTERNATIONAL BUSINESS MACHINES - Spent $100 million in 1984-85 to convert Bromont, Que. plant from electric typewriter assembly to production of multilayered ceramic electronic (MLC) components. Since 1972 the IBM Bromont plant has gone through 4 refittings: a) ceramic substrates; b) electronic typewriter assembly; c) single-layer circuit production and d) multi-layer circuit production. Financial Post, June 4, 1984.

CIL INC. - Spent $20 million over 1985-87 to modernize and upgrade raw materials handling, manufacturing and storage facilities at its Beloeil, Que. plant. Emulsion explosives to replace nitro-glycerine based explosives. Montreal Gazette, November 27, 1984.

CANRON INC. - Spent $11.6 million in Hamilton, Ont. steel plant to substitute electric furnaces to lower production costs and remain competitive. Financial Post, June 4, 1984.

IMPERIAL OIL LTD. - Spent $59 million at Dartmouth, N.S. refinery on water, air and noise pollution control ($18 million), energy conservation ($9 million), process efficiency ($10 million), crude flexibility ($13 million) and $9 million on miscellaneous projects. Oilweek, June 9, 1980.

- Spent $60 million in 1980-81 at Montreal refinery on modifications. To reduce production of heavy fuels oils and asphalt and increase gasoline and diesel output and $12 million on air and water quality control. Oilweek, June 9, 1980.

ULTRAMAR CANADA LTD. - Spent $150 million at its St-Romauld, Que. refinery in an effort to reduce production of residual fuels. Heavy Construction News, May 26, 1980.

GULF CANADA PRODUCTS Co. - Spent $40 million on modification program at the Clarkson, Ont. lube plant. Oilweek, June 9, 1980.

PETROSAR LTD. and SUNCOR INC. - Spent $500 million to upgrade production at their oil refineries at Sarnia in an attempt to deal with overproduction of residual fuels. Heavy Construction News, May 26, 1980.

PETROMONT INC. - Spent $20 million at Varennes plant for modifications which will expand the plant's flexibility in choosing between natural gas liquids and petroleum-based feedstocks, according to market forces. This will allow the plant to lower its costs of production and become competitive. Montreal Gazette, August 27, 1986.

innovations, change in the legal, social and institutional environment as well as change in consumer and managerial attitudes are constant characteristics of capitalist, market or free-enterprise economies. In order to secure an adequate rate of profit (and indeed its long term survival), the firm engages in an on-going process of adaptation, either by actively seeking out and initiating this or by responding to change in its market environment. As we have seen, one of the primary pathways in this process of adaptation is <u>structural investment</u>. That the firm will automatically respond in some predictable fashion to this change is not certain, however. Given some change in its market environment, whether a firm will undertake structural investment is also a function of its willingness and its ability to do so. Structural investment is thus not inevitable.

Let us consider three examples from the U.S. economy, namely, the computer industry, the automobile industry and the iron and steel industry. Over the last fifteen years major changes have been taking place in the world economy: technological change, product and process innovations, shifts in the structure of international comparative advantage and change in the international pattern of production and trade. Europe and South-East Asia (Japan, South Korea, Hong Kong, Singapore and Taiwan) have emerged as major contenders in shared markets for each of these three important industries of the U.S. economy. As we saw in Table 3-3, the import shares in these industries in the U.S. have been rising in recent years, posing a formidable challenge to U.S. producers. How have each of these industries responded to this challenge? The computer industry, as personified by IBM for example, has engaged in a series of offensive responses, designed to pre-empt foreign producers from acquiring a competitive edge over its market. Its response was to introduce new products (personal computers, printers, main-frame computers, interactive systems, and multi-layered ceramic components) while getting out of the production of other products which were deemed less profitable and potentially obsolete (such as typewriters). It invested in automation of its production processes in order to lower cost and improve quality. The Bromont (Quebec) plant, as shown in Table 5-13 for example, has undergone four refittings since 1972. By aggressively responding to change in its market environment IBM succeeded in maintaining a high rate of profitability and, so far, in securing its long-term viability. The import-share of main frame and micro computers has remained low despite aggressive competition from off-shore produced clones. Unlike many other firms in the U.S.A., IBM successfully resisted the choices of relocating production facilities to South-East Asia and of outsourcing the production of certain components to low cost off-shore producers. As a result, the U.S. economy has been spared from the erosion of some production facilities, employment, income and tax revenues to off-shore countries that has been so common in other industries (such as shoes, textiles and consumer electronics).

In stark contrast stands the U.S. iron and steel industry. A mainstay of the U.S. economy for over a century, the steel industry emerged dominant after the Second World War and remained unchallenged through the 1950s and 1960s. Beginning with the early 1970s, it begun facing stiff competition from steel makers in Europe and Japan, and in more recent years from those in South Africa, Spain, Brazil and South Korea. While all foreign producers were increasingly relying on the more efficient electrical steelmaking process and continuous casting technologies, the U.S. industry failed to improve its production processes with the result that imported steel became superior in quality and of lower cost. Foreign-made steel penetrated deeply into U.S. markets, undercutting the profitability of domestic steel producers and threatening their very survival. U.S. steel production has dropped from 136.3 million tons in 1979 to 72.9 million in 1986. Employment has dropped from 453.2 to 181.0 thousand in 1986. Net income was negative since 1982, with multi-billion dollar losses occurring in a few years. Dozens of steel plants were permanently closed. It is ironic that the firm which has been most dramatically affected by this onslaught, U.S. Steel, was the one which decided to invest $6 billion in a takeover of Marathon Oil in 1982. Had its management the foresight to assess the extent of the threat of foreign competition and the commitment to reinvest in modernizing its facilities and cutting its costs, it may not have ended up in this present predicament. Clearly, the lack of willingness or ability on the part of integrated U.S. steel firms to respond to the change in the environment has resulted in losses to the industry, layoffs, reduction in income, tax revenue and a diminution of production capacity. Not only has foreign-made steel displaced domestically-made steel from the market but foreign production facilities have also displaced U.S. production facilities. While the U.S. steel industry has now embarked in the process of restructuring its real capital, (for example, continuous-cast steel in 1986 accounted for 54.1% of total steel as compared to 16.9% in 1979) the response has been too late in coming and is being hampered by insufficient levels of internally-generated funds.

The U.S. automobile industry stands between the two cited cases. In the early 1970s, it was slow to respond to the competitive challenge being mounted by European and Japanese automobile makers. As a result in the early 1980s, it lost market share to imported cars which were of better quality, lower cost and more fuel efficient. Chrysler Corporation's very survival was at stake in 1980. Despite their slow response, the major three automobile producers (G.M., Ford and Chrysler) managed to salvage both their profitability and long-term viability by massively reinvesting in new product and process technologies. Without major structural investments which made possible the introduction of new models of improved quality, fuel efficiency and competitive price, a large proportion of U.S. automobile production capacity, employment and incomes would have gone to foreign producers.

Clearly, these three cases reveal the willingness and ability of firms to respond to change in market environments varies and depends on entrepreneurial perceptions and attitudes, the types of which are discussed by Peters and Waterman (1982) and Reich (1983). Some firms respond to change more quickly than others. Those that do respond quickly experience a higher profitability and grow, while others face the prospect of lower profitability and eventual decline. Clearly, as we have said, structural investment is not an automatic response to market forces but a strategic option, and a matter of corporate policy.

In mature industries facing constant or slowly growing markets, the flow of structural investment is more difficult to model econometrically than the flow of expansion investment in young industries facing growing markets. This relative difficulty, however, should not detract from the importance of structural investment. As we have shown earlier, structural change is an on-going challenge, therefore the notion that firms undertake structural investment in order to adapt to their environment should not be too difficult to accept. Furthermore, as a large component of capital expenditures of firms is neither induced by expansion nor replacement considerations, structural investment remains a possible explanation for the inducement of firms to carry out capital spending when output is stationary or declining, or when profits are low or negative and capacity utilization below normal levels.

CHAPTER SIX

CONCLUSION

1. Summary and Conclusion

The standard textbook view of investment is that it is made up of two distinct and well-defined components; namely expansion (net) investment and replacement investment. Expansion investment implies an addition to the existing stock of capital and is often expressed as a function of change in the level of output in the economy. Replacement investment implies expenditures aimed at the maintenance of the production capacity of capital stock. It is often expressed as some function of the existing level of capital stock alone. This thesis has focused on the nature and determinants of the latter component: replacement investment.

Replacement investment, important as it may be, has not received the same attention in the literature as expansion investment. Economists have produced a vast volume of literature on the nature and determinants of expansionary investment activity. However very little research has gone into exploration of the nature and determinants of replacement investment. The little work that has gone into this subject is reviewed and critically discussed in Chapters Two and Three above. As this review makes apparent, there are significant conceptual and empirical issues that make investigation into the nature and determinants of replacement activity extremely difficult. What are these issues?

At the empirical level, there are no objective, directly measurable data on replacement investment. Apparently, statistical agencies have found it difficult--both conceptually and empirically--to measure replacement investment. The reporting firms for statistical surveys have also found it difficult to make a clear conceptual and operational distinction between net and replacement investment. At the conceptual level, there is no clear and uniform definition of replacement investment. Different investigators have used the same term to describe different types of investment activities, which led to confusion and ambiguity. Essentially, by the term replacement investment, investigators have defined two types of investment activity, namely, "like-for-like" replacement and "dynamic" replacement.

Like-for-like replacement can be defined as spending on fixed capital goods which are used to replace older capital goods which have depreciated due to wear and tear in production. Implied in this view are the following necessary conditions:

i) the firm's motivation is to maintain its flow of capital services (capacity) intact and not to add to productive capacity, nor to change the specification of capital-input services or the specification of the finished output;

ii) the asset being replaced is retired from service and presumably scrapped;

iii) the firm maintains the same line of activity, i.e., the capital-output specificity remains constant.

Feldstein and Rothschild (1974) have used the terms "output decay" and "input decay" to describe the nature of deterioration in the firm's assets. "Output decay" is defined as the reduction on the asset's capacity to yield production services, other variables such as maintenance, repair and operating expenses remaining constant. "Input decay" is defined as the drop in the productivity of an asset due to an increase in the maintenance, repair and operating cost of keeping the asset in use, capital services remaining constant. According to Feldstein and Rothschild (1974) it is the combined effect of both "output" and "input" decay which leads to the asset's replacement. Jorgenson (1965, 1974) defines replacement as the dual of depreciation, where depreciation is defined solely as "output decay", i.e., the decline in the efficiency of the asset to yield capital services due to wear and tear.

"Dynamic" replacement is defined more loosely. It involves the acquisition of new capital goods in order to maintain the firm's production capacity intact. However, unlike the like-for-like replacement view, no further assumptions are made here. The new capital goods may bear no resemblance to the old ones; the capital goods being "replaced" may not be retired from service and, even more, the new capital goods may be used to produce products which are different from those being produced by the old capital goods. Finally, the new capital goods may also serve to expand production capacity, although this is strictly a by-product of the replacement decision. This is the sense in which investigators such as Einarsen (1938 a,b; 1946), Terborgh (1949, 1954) and, in part, Dean (1951) have employed the term "replacement". To these authors, replacement investment is synonymous to "reinvestment", "reequipment", "displacement", "up-grading", and "modernization".

Of the two conceptions of replacement, it is the former that has dominated theoretical development and empirical research in this area in recent years. It has received the most complete enunciation by Jorgenson (1965, 1974) and his associates in the context of the neoclassical theory of investment. He postulated the very restrictive view that replacement investment is a constant function of capital stock where the constant is equal to the rate of depreciation of fixed capital stock in the economy. This view has come to be known as the proportional replacement hypothesis (PRH). This view, however, has received a great deal of criticism from a number of investigators, for example, Feldstein and Foot (1971), Feldstein (1974), Feldstein and Rothschild (1974), Eisner (1972, 1978), Nickell (1975, 1978), Rowley and Trivedi (1975) and Helliwell (1976). Although useful in many empirical applications, the PRH has been challenged on both theoretical and empirical levels. The chief objection, however, with Jorgenson's PRH is that it views replacement strictly in mechanistic terms, and does not allow for the influence of any other economic variable except depreciation. As such, Jorgenson's PRH hardly constitutes an "economic" theory of replacement.

The purpose of this present thesis is to take stock of where we stand in our understanding of replacement and to investigate the available empirical evidence for clues on the actual nature and determinants of this significant component of gross fixed capital formation. Our approach has consisted of examining the available evidence at two levels: (a) the theoretical and empirical work in the area and (b) the available statistical data including qualitative reports of firms, trade journals and industry practitioners. Our analysis has led us to two important findings.

First, <u>most replacement investment</u>, at least in Canada, <u>takes the form</u>

of replacements of minor parts and repair and overhaul of major parts. Though considered as investment by the reporting firms and Statistics Canada in its Private and Public Investment Survey, these expenditures are actually charged to operating account (expensed) and are not capitalized for book purposes. These expenditures, called "repair expenditures", are different from "routine maintenance and repair expenditures" which are also charged to operating accounts. They are defined by Statistics Canada (1984) as "non-capitalized outlays made to maintain the operating efficiency of the existing stock of durable physical assets". As Figures 4-7, 4-10 and 4-11 demonstrate, repair investment accounts for about 25% of total investment in Canada today, 35% of total manufacturing investment and about 50% of capital investment in the Canadian manufacturing sector (see also Appendix C). In 1984 for example, non-capitalized repair expenditures were over $5 billion compared to capitalized investment expenditures of $8.6 billion. These expenditures are defined in the same sense in which "like-for-like" replacement is defined. The only difference is that, unlike our conventional view where the whole of the asset is replaced, what happens in practice is that firms replace major components as they wear out, without necessarily replacing the entire asset. Otherwise, there is no further difference between "like-for-like" replacement as defined in the literature and repair investment as defined by Statistics Canada. That repair investment is not treated as a capital expenditure but as an operating expense is a matter of accounting and tax treatment and not necessarily of economic theory. But that repair expenditures are not capitalized for accounting or tax purposes does not necessarily imply that they should not be considered as investment for economic purposes. This does not seem to be a hindrance to Statistics Canada which, for over 40 years, has collected figures on repair expenditures and treated them as investment in its Private and Public Investment Survey.

That these repair expenditures are actually replacement investment can also be seen from the evidence in Figures 4-7, 4-8, 4-10 and 4-11. As Figure 4-7 reveals, repair outlays have been a stable component of total investment over the 35-year period. Repair investment expenditures have been rising gradually in absolute terms (real 1971 dollars) but diminishing as a share of total investment activity. Although the share of repair investment has been decreasing in relation to total investment in the economy as a whole, it has remained relatively stable in the manufacturing sector at about one third of total investment (see Figures 4-10 and 4-14). The patterns depicted in Figures 4-7 and 4-11 for repair investment are remarkably close to what theory would expect to find for replacement investment. Since data on "replacement" investment are not collected anywhere in North America, the data depicted in these figures are rare empirical confirmation of replacement investment, provided of course that we accept the fact that (a) replacing a component of a machine is replacement in the same sense as replacing the entire machine and (b) that the accounting treatment of replacement (expensing vs. capitalization) in practice may differ substantially from what economic theory would suggest.

While repair investment conforms to our theoretical notions of replacement investment and indeed even with Jorgenson's PRH, repair investment has been far from a constant proportion of capital stock, at least in so far as the short run is concerned. Figures 4-8, 4-9 and 4-12 provide strong empirical confirmation for the findings of Feldstein and Foot (1971) and Eisner (1972). They reveal that the annual rate of change in repair expenditures has varied considerably, although within a range of 10%, and that the rate of change is positively correlated to the rate of change in both capital investment and gross national product (GNP). This is impressive evidence in support of the view that replacement investment is an economic variable and endogeneous to the economic process. Further empirical research is necessary to uncover the economic determinants of repair investment, given that repair investment and "like-for-like" replacement investment are essentially the same and therefore measurable.

The second major finding of this thesis is that replacement investment in the other sense of "dynamic" replacement is in fact neither replacement investment nor expansion investment but a new category of investment activity. We propose the term structural investment.

Structural investment is defined here as fixed capital investment spending induced by the firm's need to adapt to (a) change in the composition of demand (output-mix); (b) change in production technology, and (c) change in relative factor prices. We have seen that most "dynamic" replacements are motivated by considerations other than the mere maintenance of the production efficiency of fixed capital stock. Although "dynamic" replacements are in some general sense replacements, this is where the similarity ends. The "replaced" equipment are not necessarily retired from service. They are more often displaced rather than replaced. The production technology and, hence, the capital-input specificity does change and so does the output being produced. Change in the composition of market demand induces a change in the capital-output specificity of firms, while changes in both production technology and prices of factor inputs induce changes in the capital-input specificity. When firms change either their capital-output specificity or their capital-input specificity, the capital expenditures entailed bear no resemblance to replacement (repair) expenditures. In replacement investment, as conventionally defined, specificities remain constant. Structural investment can also be clearly distinguished from expansion investment. Expansion investment responds to the change in output with the two specificities remaining constant. The firm here adds to production capacity but the production process and the composition of output remain constant. When technical change occurs or compositional shifts affect demand for either consumption or capital goods, the situation is more complicated but the inadequacy of the conventional distinction between expansion and replacement persists and we must search for a structural alternative.

The term structural investment depicts more accurately the nature of investment spending undertaken by a firm when it modernizes, upgrades, retools, converts, or refits a plant. Here, the structure of production changes either on the output side or the input side. When a firm instals new equipment to save on a more expensive labour, energy or raw material input, the firm's primary motivation in doing so is neither the maintenance nor the expansion of its capacity. It is to adapt to the changing economic environment by lowering unit costs of production and enhance the short-term profitability and long-term survival of the firm. When a firm instals new equipment to produce a new-to-the-firm product or a different version of an existing product, its primary motivation is not to maintain nor expand production capacity for a given product, but to enhance its revenue and profitability. By adapting to change in consumer tastes and preferences and new product innovations, the firm aims at ensuring its long-term profitability and viability in a changing world. In Sections 4-7 and 5-5, we have provided empirical evidence to this effect. Capital spending in the automobile industry provides an excellent example of structural investment. In recent years, for example, U.S. firms reported in the McGraw-Hill survey that only a minute fraction of their investment spending was intended for expansion. On the other hand, the billions of dollars spent annually hardly classify as replacement investment. The McGraw-Hill and DRIE surveys both use the compound terms "up-grading and replacement" and "modernization and replacement" respectively, to depict this type of investment activity. What we have proposed here is to differentiate up-grading and modernization from pure replacement by introducing the term structural investment for the former, while retaining the term replacement investment for "like-for-like" replacement spending. Thus, we proposed the term structural investment as a substitute for "dynamic" replacement.

In Chapter Five we have made a first attempt to provide for an economic theory of structural investment. Our underlying hypothesis is that the composition of output and the functional specificity of capital both matter. In a world of output heterogeneity and functional specificity of capital, change in the composition of output will affect investment expenditures because of imperfect substitutability of capital in different functions. A firm can respond to a change in the composition of output only if it invests in new capital goods with a functional specificity appropriate to the new output. This also applies to changes in the capital-input specificity. Changes in production technology and factor prices will induce the firm to invest in new capital goods and modify the structure of its production if it is to lower costs of production and expand profitability. Sections 2 and 3 of Chapter Five have provided evidence in support of our view that the world is characterized to a significant degree by output and capital heterogeneity. Indeed our economy is characterized not by static equilibrium but by structural change, where the composition of both output and capital frequently undergo significant change. Heterogeneity, specificity and structural change imply structural investment.

In Section 6 of Chapter Five, we point out that the firm's response to this changing environment is also a function of its willingness and ability to respond, so a further motivational element produces more heterogeneity. One firm may respond quickly to the change in the market conditions while another may not. Moreover, a firm need not be a passive agent simply responding in a defensive manner to exogenous change in its environment. It may indeed contribute to the transformation of this environment. Change in the market is also initiated by firms in search of new technologies (both product and process technologies), new forms of management or industrial organization and new markets. When a firm initiates a change, its investment in new capital equipment can be viewed as an offensive action. Generally, as Dean (1951) has pointed out, one can distinguish between <u>offensive investments</u>--those that introduce new products or production technologies to the market--and <u>defensive investments</u>--those designed to bring a product or production technology up to par with the standards of the competition. It is this interplay of offensive and defensive investments by firms in the market which generates the flow of structural investment spending. Those firms which fail to keep up over time with this process of product competition ultimately face the prospect of decline and displacement by more aggressive firms. <u>Structural investment, therefore, is an important instrument of product and strategic competition, which conditions the profitability and eventually the viability of the firm</u>.

In conclusion, this thesis strongly suggests that the conventional approach of identifying only two distinct components of gross investment is inappropriate in practice. A more meaningful approach is to acknowledge the relevance of a structural element (that is unrecognized in the conventional approach) and to redefine replacement as non-capital repair expenditures, some function of the level of capital stock. Structural investment consists of capital expenditures which reflect all those discretionary types of "dynamic" replacement such as upgrading, modernization, refitting, revamping, retooling, conversion or automation. Replacement expenditures incurred to replace or repair minor and major components of fixed capital goods are not discretionary when they are necessary to maintain the operating efficiency of the firm's existing stock of capital goods. As long as the firm is committed to a given line of activity and production technology, these expenditures must be incurred.

Decisions regarding replacement investments emanate from plant managers who are most informed of the operating efficiency of capital goods. Through a continual maintenance policy, replacement expenditures can maintain--at least theoretically--the operating efficiency of capital goods indefinitely. From time to time, however it is changes in the composition of demand, product and process technology, or factor prices and change in the regulatory, institutional and competitive environment of the firm that will dictate whether or not the firm should put an end to the life of its plant and equipment, or seek to renew their life through a policy of structural investment spending.

2. Policy Implications

A number of important policy implications for government and individual firms emerge from this enlarged perspective. The foremost implication for business policy is that if a firm is to maintain its desired level of profitability and assure its long-term economic viability, then it has to pay close attention to changes in the composition of market demand, changes in production technologies and process innovations, to changes in factor prices and to other changes in the competitive environment. Since our economies are characterized by output and capital heterogeneity, the profitability of the firm's stock of capital goods will depend on a) how well the firm adapts its <u>output-mix</u> to changes in the composition of demand and the evolving pattern of consumer tastes and preferences and b) how well the firm adapts its input-mix to changes in factor prices, production technology and competitive conditions both domestically and internationally.

To keep up with changing consumer needs and product innovations a firm must invest funds in product development and new capital goods. Since it takes a certain type of capital good to produce a given product (capital-output specificity), new product introductions and product improvements necessarily entail investments in the appropriate capital goods, i.e., structural investment. By committing itself to a program of structural investment spending, the firm ensures that there is continuous demand for the services of its capital goods in the face of a changing market demand, even though the total level of demand remains unchanged. The same attentiveness applies to changes in technology, changes in factor prices or changes in the institutional and regulatory environment. To keep up with such changes the firm must invest in new production technologies, incorporate process innovations and adjust its capital-input mix to changes in factor prices. Since capital goods have a limited functional specificity, any change in the specification of capital inputs again entails the acquisition of new capital goods or the modification of existing capital goods through up-grading, revamping, modernization and up-dating (hence structural investment outlays). Only by committing itself to a program of structural investment can the firm hope to maintain its cost competitiveness and economic viability in the face of stiffer competition. These implications become all the more relevant at the maturity stage of the firm's product life-cycle, and apply more to mature products and developed markets than to new products and developing markets.

The implications of the new perspective for government policy are the following. First, in mature industrial economies, the share of both replacement and structural investment is high in relation to expansion investment, and higher than in developing economies. This implies that the purpose of investment and the motivation underlying investment activity in mature industrial economies is different from those of growing economies. Since stimulating a high rate of investment spending has traditionally been a major objective of economic policy, a better understanding of the nature and motivation underlying replacement and structural investment spending can help in the design of more effective measures to encourage and stimulate these appropriate types of investments. For example, tax-based measures such as accelerated depreciation and investment tax credits may be less useful to firms undertaking expansion investments as compared to those undertaking structural investments. If demand for a certain line of activity is growing, firms earn higher profits and feel more confident, and in light of the growing opportunities presented to them by the market are likely to invest in the expansion of their capacity whether tax-incentives are available or not. However firms operating in mature markets and faced with declining or stable demand for their goods are less likely to be in a position financially or psychologically to commit themselves to major investment programs. Since structural investment allows firms in these sectors to modify their output-mix and bring it in line with the current pattern of consumer tastes and preferences as well as improve the quality of their products and lower production costs, selectively assisting firms in mature industrial sectors to update their product and process technologies may prove more useful than trying to assist all sectors equally. By targeting government assistance to those sectors that need it most, the efficacy of government expenditure and tax-based measures can be improved. Inducing a higher level of structural investment not only raises the overall short-run level of output, employment and income in the economy but it also helps enhance the long-term competitiveness of firms in the economy by allowing them to compete more effectively with foreign producers. In the process, jobs which would have been lost to foreign competition are secured and consumers benefit through lower prices.

Another example of how a better understanding of the nature and motivation underlying structural investment can be valuable is seen in the tax treatment of capitalized structural investment outlays as compared to non-capitalized replacement (repair) expenditures and the tax-treatment of mergers and acquisitions. By allowing firms to "expense" replacement (repair) expenditures in the year they occur, the tax system inadvertently provides a powerful stimulus in favour of repairs as opposed to up-grading and modernization. Since replacement expenditures do not alter the capital-output nor the capital-input specificity of the production process, they do not assist firms in being product and cost competitive in the long-run. A policy of favouring structural investment as opposed to replacement investment can stimulate new product introductions and product improvements and hence accelerate the rate of diffusion of new technologies and process innovations.

The tax system also discriminates against structural investment when the tax treatment of financial investments (such as mergers, acquisitions and leveraged buyouts) is considered. A number of tax benefits accrue to the purchasing firm: first, it can deduct the interest on funds borrowed to make the financial investment; second, the flow of inter-corporate dividends are not taxed by government; third, it allows the purchasing firm to benefit from tax loss provisions whereby it assumes the loss carry-forwards of the target firm and reduces the overall corporate tax payable. In mature industries with stable or declining demand, the short-term profitability and long-term survival of firms is in question. In order to enhance their profitability and assure their long-term survival, firms are faced with two options. First, they can undertake financial investments such as mergers and acquisitions which can reduce competition and reduce capacity through plant closings (e.g., the recent purchase of the Montreal Gulf refinery by Ultramar and ultimate closing of the facility). Doing so not only provides the buyer with ready access to another firm's technology, patents, knowhow and facilities but, by closing down the less efficient facilities, it also leads to a reduction in supply and the restoration of profit-margins for the surviving firms. The second option available to firms is to undertake structural investments, such as modernization, plant conversions or automation so as to expand the range of products offered, improve product quality and lower unit costs of production. While firms will have to amortize their structural investment over three years for tax purposes and over many more for book purposes, the cost of financial investments can be amortized over a shorter period. Clearly then, by differentiating structural investment from expansion and replacement investments, economic theory can help guide public policy to design and implement measures which are appropriate to mature industrial sectors of the economy.

The new perspective also suggests that certain government programs such as the (now defunct) Canadian Industrial Renewal Board and other programs provided by the Department of Regional Industrial Expansion are justifiable. The increased incidence of assistance to firms undertaking modernizations in recent years by both federal and provincial governments seems to indicate that pragmatic governments do recognize the differential nature of firms in mature industrial sectors undertaking structural investments. Our empirical findings provide support for such policies.

Finally, gross fixed capital formation (GFCF) is defined in our system of national accounts in a way that ignores the non-capitalized repair expenditures which are in fact replacements. Since repair expenditures are defined as those outlays necessary to maintain the operating efficiency of the capital stock intact they are no different than replacement investment as defined in economic theory. So far, official statistics are produced under the mistaken assumption that GFCF is composed solely of expansion and replacement investment. In fact, as GFCF is measured, it is composed of expansion and structural investment only. A more appropriate treatment may be to incorporate repair (replacement) expenditures too under GFCF (even if they are expensed for book purposes by firms). This suggests, of course, that the real extent of investment activity in Canada may have been much higher than we have previously thought, indeed about 25% higher in recent years. The implications for the manufacturing sector are even stronger, given that repair expenditures account for about 50% of capital expenditures. Total investment in this sector (capitalized expansion and structural plus non-capitalized replacement investment outlays) may in fact be twice as high as we presently think!

3. Suggestions for Further Research

The contribution of this thesis has been to clarify the nature of "replacement investment" and separate conceptually and empirically the two views of replacement: "like-for-like" replacement and "dynamic" replacement. By identifying replacement investment as non-capital repair expenditures and defining "dynamic" replacement as structural investment, new paths for research have been opened.

One path of fruitful future investigation concerns the nature and determinants of repair expenditures. Now that we know that repair expenditures are indeed replacement investment and that objective, measurable data are available for this component of investment, econometric investigation can proceed to examine the short-run determinants of repair investment. We have seen that although relatively stable in the aggregate, repair expenditures are positively correlated with changes in the level of capital investment and with gross national product. Other variables which may be considered as determining influences include liquidity, capacity utilization, and expectations. Since measurable data on most of these variables are also available, time-series and cross section empirical studies are feasible.

Another path of productive future research concerns the nature and determinants of structural investment in mature industrial economies. How developed economies go about renewing their stock of capital goods and adapt to change in their environment at a world scale is an important issue facing the North American and West European economies. Data on capital investment by purpose (like those collected by McGraw-Hill in the U.S.A., DRIE in Canada, the IFO Institute in Germany) provide useful data with which to work. It is encouraging that Statistics Canada, in its Private and Public Investment Survey has begun collecting data on capital spending by purpose, although it will be some time before these data appear in publications on an on-going basis. By expanding our understanding of the nature and determinants of structural investment, we may be in a position one day to provide more concrete guidance to economic policy makers, both at the business and public-policy level.

A third path of future research concerns the mapping of the morphologic or structural characteristics of capital. It is about time that economists acknowledged that output and capital are heterogeneous entities and accorded qualitative characteristics of output and capital the same importance now attached to aggregate quantitative characteristics.

PAGE 280 OMITTED IN PAGE NUMBERING.

FEUILLET 280 NON INCLUS DANS LA PAGINATION.

BIBLIOGRAPHY

Aaron, H.J., Russek, F.S. & Singer, N.M. (1972a) "Tax Reform and the Composition of Investment" National Tax Journal Vol. 25, pp. 1-13.

Aaron, H.J., Russek, F.S. & Singer, N.M. (1972b) "Tax Changes and Composition of Fixed Investment: An Aggregative Simulation" The Review of Economics and Statistics, Vol. 54, pp. 343-56.

Aftalion, A. (1908) "La realité des surproductions générales, Essai d'une théorie des crises générales et périodiques Revue d'Economie Politique, pp. 698-704.

Akerman, J. (1928) Om det Ekonomiska Livrets Rytmic, Stockholm.

Albach, H. (1965) "Zur Theorie des Wachsenden Untermehmens" Schriften des Vereins fur Socialpolitic, 34NS, Berlin: Duncker and Mumblot.

Alchian, A.A. (1952) "Economic Replacement Policy", The Rand Corporation, Report R-224.

American Iron & Steel Institute (1986) 1985 Annual Statistical Report, A.I.S.I., Washington, D.C.

Bank of Canada (1985) Bank of Canada Review, Ottawa.

Bain, J.S. (1939) "The Relation of the Economic Life of Equipment to Reinvestment Cycles", The Review of Economics and Statistics, Vol. 21-22, pp. 79-88.

Beeson, P.E. & M.F. Bryan (1986) "The Emerging Service Economy" Economic Commentary, Federal Reserve Bank of Cleveland, June 15, 1986.

Bitros, G.C. & H.H. Kelejian (1974) "On the Variability of the Replacement Investment Capital Stock Ratio: Some Evidence from Capital Scrappage" The Review of Economics and Statistics, Vol. 56, pp. 270-278.

Boddy, R. & M. Gort (1973) "Capital Expenditures and Capital Stocks" Annals of Economic and Social Measurement, Vol. 2, pp. 245-261.

Boddy, R. & M. Gort (1974) "Obsolescence, Embodiment, and the Explanation of Productivity Change," Southern Economic Journal, Vol. 40, pp. 553-562.

Braithwaite, C. (1983) The Impact of Investment Incentives on Canada's Economic Growth, Economic Council of Canada, Ottawa.

Branson, W.H. (1979) Macroeconomic Theory and Policy, 2nd edition, Harper & Row, New York.

Burns, A.F. (1934) Production Trends in the United States Since 1870, NBER, New York.

Business Week (1986) "The Hollow Corporation", Business Week, March 3, 1986.

Business Week (1986b) "High-Tech to the Rescue", Business Week, June 16, 1986.

Buzzell, R.D. (1966) "Competitive Behavior and Product Life Cycles", AMA Proceedings, American Marketing Association, pp. 46-68.

Buzzell, R.D. & V. Cook (1969) Product Life Cycles, Marketing Science Institute, pp. 29-35.

Byleveld, H.C. (1981) "Why Canadian Industry Invests", Canada Commerce, December, pp. 14-16.

Cagan, P. (1971) "Measuring Quality Changes and the Purchasing Power of Money: An Exploratory Study of Automobiles" in Price Indexes and Quality Change, ed. by Z. Griliches, Harvard University Press.

Canadian Manufacturers' Association (1982) Competing in the Global Village, CMA, Ottawa.

Canadian Manufacturers' Association (1984) A letter to the Honourable Marc Lalonde, Minister of Finance, unpublished, mimeo.

Chinfen, N. (1982) "Business Investment Trend in the Seventies and Prospective for the Early Eighties", Canada Commerce, July-August, pp. 28-30.

Chinfen, N. (1984) "The DRIE Survey of Business Capital Investment Intentions" a paper delivered at the 18th International Conference of the Atlantic Economic Society.

Christensen, L.R. & D.W. Jorgenson (1973) "Measuring Economic Performance in the Private Sector" in The Measurement of Economic and Social Performance, ed. M. Moss, Studies in Income and Wealth, Vol. 38, NBER, New York.

Clark, J.M. (1923), Studies in the Economics of Overhead Costs, Chicago.

Claudon, M.P. (1977) International Trade and Technology: Models of Dynamic Comparative Advantage, University Press of America.

Coen, R.M. (1971) "The Effect of Cash Flow on the Speed of Adjustment" in G. Fromm (ed.) Tax Incentives and Capital Expending, The Brookings Institution, Washington, D.C., pp. 131-198.

Coen R.M. (1975) "Investment Behavior, The Measurement of Depreciation, and Tax Policy" American Economic Review, Vol. 65, pp. 59-74.

Coen, R.M. (1980) "Alternative Measures of Capital and its Rate of Return in United States Manufacturing" in the Measurement of Capital, ed. D. Usher, NBER, University of Chicago Press, pp. 121-149.

Cowing, T. and K. Smith (1977) "A Note on the Variability of the Replacement Investment Capital Stock Ratio", The Review of Economics and Statistics, Vol. 59, pp. 238-43.

Creamer, D., Dobrolovsky, S.P. & I. Borenstein (1960) Capital in Manufacturing and Mining, NBER, Princeton University Press.

Creamer, D. (1961) Capital Expansion and Capacity in Postwar Manufacturing, Studies in Business Economics, No. 72, National Industrial Conference Board, Washington, D.C.

Cunningham, M.T. (1969) "The Application of Product Life Cycles to Corporate Strategy: Some Research Findings" British Journal of Marketing, Spring, pp. 32-44.

Dean, J. (1950) "Pricing Policies for New Products", Harvard Business Review, Vol. 28, pp. 45-53.

Dean, J. (1951) Capital Budgeting: Top-Management Policy on Plant, Equipment and Product Development, Columbia University Press.

Dean, J. (1967) "Measuring the Productivity of Investment in Persuasion", Journal of Industrial Economics, Vol. 15, pp. 81-108.

Denison, E.F., (1957) "Theoretical Aspects of Quality Change, Capital Consumption, and Net Capital Formation" in Problems of Capital Formation, Studies in Income and Wealth, Vol. 19, NBER, Princeton University Press, pp. 215-284.

Denison, E.F. (1974) Accounting for United States Economic Growth: 1929-1969, Brookings Institution, Washington, D.C.

Department of Finance (1985) Economic Review, Supply & Services, Ottawa.

Department of Regional Industrial Expansion, (1979-1985) Business Capital Investment Surveys, Ottawa.

Department of Trade & Commerce (1949) A Study of Depreciation of Machinery and Equipment Containing Estimates of Value of Domestic Disappearance and Average Life Expectancy, Queen's Printer, Ottawa.

Drucker, P.F. (1974) Management: Tasks, Responsibilities, Practices Harper & Row, New York.

Duijn, J.J. van (1983) The Long Wave in Economic Life, George Allen & Unwin, London.

Economic Council of Canada (1986) Workable Futures: Notes on Emerging Technologies, Supply & Services, Ottawa.

Einarsen J. (1938a) Reinvestment Cycles and Their Manifestation in the Norwegian Shipping Industry, Institute of Economics, University of Oslo, Oslo.

Einarsen, J. (1938b) "Reinvestment Cycles" The Review of Economics and Statistics, Vol. 20, pp. 225-230.

Einarsen, J. (1946) "Replacement in the Shipping Industry" The Review of Economics and Statistics, Vol. 28-29, pp. 225-230.

Eisner, R. & R. Strotz (1963) "Determinants of Investment Behavior" in Commission on Money and Credit: Impacts of Monetary Policy, Prentice-Hall, Englewood Cliffs, pp. 60-338.

Eisner, R. & M.I. Nadiri (1968) "Investment Behavior and Neo-Classical Theory" The Review of Economics and Statistics, Vol. 50, pp. 369-382.

Eisner, R. (1972) "Components of Capital Expenditures: Replacement and Modernization versus Expansion" The Review of Economics and Statistics, Vol. 54, pp. 297-304.

Eisner, R. (1978) Factors in Business Investment, NBER Gen. Series, No. 102.

Feldstein, M.S. & D.K. Foot (1971) "The Other Half of Gross Investment: Replacement and Modernization Expenditures", The Review of Economics and Statistics, Vol. 53, pp. 49-58.

Feldstein, M.S. & M. Rothschild (1974) "Towards an Economic Theory of Replacement Investment", Econometrica, Vol. 42, pp. 393-423.

Feldstein, M. (1974) "Tax Incentives, Stabilization Policy, and the Proportional Replacement Hypothesis: Some Negative Conclusions", Southern Economic Journal, Vol. 40, pp. 544-552.

Forrester, J.W. (1959) "Advertising: A Problem of Industrial Dynamics", Harvard Business Review, Vol. 37, pp. 100-110.

Frederixon, M. (1969) An Investigation of the Product Life Cycle Concept and its Application to New Product Proposal Evaluation within the Chemical Industry, Unpublished Doctoral Dissertation, Michigan State University.

Gist, R.R. (1971) Marketing and Society, Holt, Rinehart & Winston.

Goldsmith, R.W. (1951) A Perpetual Inventory of National Wealth, Studies in Income and Wealth, Vol. 14, NBER, New York.

Goldsmith, R.W. (1962) The National Wealth of the United States in the Postwar Period, NBER, New York.

Gordon, R.J. (1971) "Measurement Bias in Price Indexes for Capital Goods", Review of Income and Wealth, Ser. 17, No. 2, pp. 121-174.

Gould, J.P. (1968) "Adjustment Costs in the Theory of Investment of the Firm", Review of Economic Studies, Vol. 35, pp. 47-56.

Griliches, Z. (1970) "The Demand for a Durable Input: U.S. Farm Tractors, 1921-57" in the Demand for Durable Goods, ed. by A.C. Harberger, University of Chicago Press, Chicago.

Grosse, L., Rottenberg, I. & R.C. Wasson (1966) "New Estimates of Fixed Business Capital in the United States, 1962-65" Survey of Current Business, Vol. 46, December, pp. 34-40.

Grosse, R.N. & E.B. Berman (1957) "Estimating Future Purchases of Capital Equipment for Replacement" in Problems of Capital Formation, Conference of Universities - NBER Committee, Princeton University Press, pp. 389-417.

Gunn, T. (1981) Computer Applications in Manufacturing, Industrial Press.

Gunn, T. (1982) "The Mechanization of Design and Manufacturing" Scientific American, September, pp. 115-130.

Haavelmo, J.A. (1960) A Study in the Theory of Investment, University of Chicago Press, Chicago.

Hall, R.E. (1971) "The Measurement of Quality Change from Vintage Price Data" in Price Indexes and Quality Change, ed. by Z. Griliches, Harvard University Press.

Hart, A.G. (1940) Anticipations, Uncertainty and Dynamic Planning, University of Chicago Press, Chicago.

Helliwell, J.F. & G. Glorieux (1970) "Forward-looking Investment Behavior" Review of Economic Studies, Vol. 37, pp. 499-516.

Helliwell, J.F. (1976) "Aggregate Investment Equations: A Survey of Issues" in J.F. Heliwell (ed.) Aggregate Investment, Penguin Books, London, pp. 13-53.

Hendriksen, E.S. (1982) Accounting Theory, 4th edition, R.D. Irwin.

Hibbert, J., Griffin, T.J. & R.L. Walker (1977) "Development of Estimates of the Stock of Fixed Capital in the United Kingdom", Review of Income and Wealth, June.

Hickman, B.G. (1965) Investment Demand and U.S. Economic Growth, The Brookings Institution, Washington, D.C.

Hirsch, F. (1967) Location of Industry and International Competitiveness Clarendon Press, London.

Hirshleifer, J. (1958) "On the Theory of Optimal Investment Decision", Journal of Political Economy, Vol. 66, pp. 329-352.

Hood, W.C. & A. Scott (1957) Output Labour and Capital in the Canadian Economy, A Study for the Royal Commission on Canada's Economic Prospects", Queen's Printer, Ottawa.

Hotelling, H. (1925) "A General Mathematical Theory of Depreciation" Journal of the American Statistical Association, Vol. 20, pp. 340-353.

Jack Faucett Associates, Inc. (1973) Development of Capital Stock Series by Industry Sector, Office of Emergency Preparedness, Washington, D.C.

Jack Faucett Associates, Inc. (1975) Fixed Capital Stocks by Industry Sector: 1947-1970, U.S. Department of Labor, Bureau of Labor Statistics, Washington, D.C.

Johnson, D. (1981) "Capital Formation in the United States: The Postwar Perspective" Public Policy and Capital Formation, Board of Governors of the Federal Reserve System, Washington, D.C., pp. 47-58.

Jorgenson, D.W. (1963) "Capital Theory and Investment Behavior" American Economic Review, Vol. 53, pp. 247-259.

Jorgenson, D.W. (1965) "Anticipations and Investment Behavior" in the Brookings Quarterly Econometric Model of the United States, Rand McNally, Chicago, pp. 35-91.

Jorgenson, D.W. & J.A. Stephenson (1967) "The Time Structure of Investment Behavior in United States Manufacturing: 1947-1960", The Review of Economics and Statistics, Vol. 49, pp. 16-27.

Jorgenson, D.W. & R.E. Hall (1967) "Tax Policy and Investment Behavior", American Economic Review, Vol. 62, pp. 391-414.

Jorgenson, D.W., J.J. McCall & R. Radner (1967) Optimal Replacement Policy, Rand McNally, Chicago.

Jorgenson, D.W., J. Hunter & M.I. Nadiri (1970) "A Comparison of Alternative Econometric Models of Quarterly Investment Behavior" Econometrica, Vol. 38, pp. 187-212.

Jorgenson, D.W. (1971) "Econometric Studies of Investment Behavior: A Survey", Journal of Economic Literature, Vol. 9, pp. 1111-1147.

Jorgenson, D.W. & R.E. Hall (1971) "Application of the Theory of Optimal Capital Accumulation" in G. Fromm (ed.) Tax Incentives and Capital Spending, Brookings Institution, Washington, D.C., pp. 256-269.

Jorgenson, D.W. (1974) "The Economic Theory of Replacement and Depreciation" in Essays in Honour of Ian Tinbergen, ed. by W. Sellykaerts, International Arts and Sciences Press, White Plains, New York.

Kendrick, J.W. et al (1976) The National Wealth of the United States by Major Sector and Industry, The Conference Board, New York.

Kendrick, J.W. et al (1976 b) The Formation of Stocks of Total Capital, NBER, New York.

Keynes J.M. (1936) The General Theory of Employment, Interest and Money, MacMillan-St. Martin's Press.

Koumanakos, P. (1980) Alternative Estimates of Non-Residential Capital in Canada, 1926-1980, Construction Division, Statistics Canada, Ottawa.

Koumanakos, P.; Lapointe, P.H.; O'Reilly, B. & K. Patterson (1984) "Some Issues to be Addressed in Examining the Feasibility of a Capital Stock Survey in Canada", mimeo Joint Contribution: Statistics Canada, Department of Finance, Bank of Canada and Economic Council of Canada.

Kovac, F.J. & M.F. Dague (1972) "Forecasting by Product Life Cycle Analysis" Research Management, July.

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

Kurtz, E.G. (1930) Life Expectancy of Physical Property, The Ronald Press Company, New York.

Kuznets, S. (1930) Secular Movements in Production and Prices, Houghton Mifflin, Boston.

Lachmann, L.M. (1947) "Complementarity and Substitution in the Theory of Capital", Economica, Vol. 14, pp. 110-121.

Lachmann, L. (1956) Capital and its Structure, reprinted by Sheed Andrews & McMeel, Kansas City, 1978.

Lachmann, L.M. (1977) Capital, Expectations and the Market Process, Sheed Andrews & McMeel, Kansas City.

Lamfalussy, A. (1961) Investment and Growth In Mature Economies: The Case of Belgium, Macmillan, London.

Lee, M.W. (1971) Macroeconomics: Fluctuations, Growth and Stability, 5th Edition, Irwin Series in Economics.

Levitt, J. (1965) "Exploit the Product Life Cycle", Harvard Business Review, Vol. 43, pp. 81-94.

Lioukas, S.K. (1980) "Factors Affecting Capital Retirement: Evidence from Capacity Decommissionig Plans in a Publicly Owned Corporation", The Journal of Industrial Economics, Vol. 28, pp. 241-254.

Lioukas, S.K. (1982) "The Cyclical Behaviour of Capital Retirement: Some New Evidence", Applied Economics, Vol. 14, pp. 73-79.

Lutz, F. & V. Lutz (1951) The Theory of Investment of the Firm, Princeton University Press.

Marris, R. (1964) The Economics of Capital Utilization, Cambrige University Press.

Marx, K. (1887) Capital: A Critical Analysis of Capitalist Production, Vol. 1, (ed.) F. Engels, International Publishers Co., New York.

Marx, K. (1893) Capital, Vol. 2, (ed.) Frederick Engels, International Publishers, New York, pp. 185-186.

Matziorinis, K. N. (1979) Corporation Income Tax Legislation as an Instrument of Economic Policy in Canada: 1945-77, Unpublished M.A. Thesis, McGill University, Montreal.

Matziorinis, K. N. (1980) "The Effectiveness of Tax Incentives for Capital Investment" Canadian Taxation, Vol. 2, pp. 172-79.

Matziorinis, K., T. Kollintzas & R. Rowley (1980a) Taxation of Canadian Manufacturing Industries: The Income Tax for Corporations, Research paper No. 80-3, Social Sciences Statistical Laboratory, Montreal.

Matziorinis, K., T. Kollintzas & R. Rowley (1980b) Taxation of Canadian Manufacturing Industries: Depreciation Rules for Investment

Expenditures, Research Paper No. 80-4, Social Sciences Statistical Laboratory, Montreal.

Matziorinis, K.N. & J.C.R. Rowley (1984) An Outline of Anticipatory Data in Connection with Fixed Capital Formation, Department of Economics Working Paper Series, McGill University, Montreal.

Matziorinis, K.N. (1985) "Capital-Output Specificity, Adaptation and Renewal Investment", Atlantic Economic Journal, Vol. 13, p. 82. Abstract of paper presented in the 18th International Atlantic Economic Conference, Montreal.

McGraw-Hill (1982) Capital Spending Memo, Department of Economics, McGraw-Hill, New York.

McGraw-Hill (1986) Historical Capital Spending and Related Data, Department of Economics, McGraw-Hill, New York.

Meyer, J.R. & E. Kuh (1957) The Investment Decision: An Empirical Study, Harvard University Press.

Mickwitz, G. (1959) Marketing and Competition, Centraltryckeriet, Helsingfors, Finland.

Moonitz, M. (1943) "The Risk of Obsolescence and the Importance of the Rate of Interest", Journal of Political Economy, Vol. 51, pp. 348-355.

Motor Vehicle Manufacturers' Association (1985) Facts and Figures '85, Detroit.

Motor Vehicle Manufacturers' Association (1986) Economic Indicators: The Motor Vehicle's Role in the U.S. Economy, Detroit.

Musgrave, J.C. (1976) "Fixed Non-Residential Business and Residential Capital in the United States, 1925-1975" Survey of Current Business, Vol. 56, April, pp. 46-52.

Nelson, R.R. & S.G. Winter (1982) An Evolutionary Theory of Economic Change, Harvard University Press, Cambridge.

Nickell, S. (1975) "A Closer Look at Replacement Investment", Journal of Economic Theory, Vol. 10, pp. 54-88.

Nickell, S. (1978) The Investment Decisions of Firms, James Nisbet, London.

O.E.C.D. (1976) The Measurement of Capital, OECD, Paris.

O.E.C.D. (1983) "Service Lifes of Fixed Assets", OECD Working Papers, No. 4, Economics and Statistics Department, Paris.

Owens, R.N. (1969) Management of Industrial Enterprises, 6th Edition, Irwin, Homewood, Illinois.

Patton, A. (1959) "Stretch your Product's Earning Years: Top Management's Stake in the Product Life Cycle", The Management Review, Vol. 48, pp. 67-79.

Peters, T.J. & R.H. Waterman Jr. (1982) In Search of Excellence, Warner Books, New York.

Preinreich, G.A.D. (1938) "Annual Survey of Economic Theory: The Theory of Depreciation", Econometrica, Vol, 6, pp. 219-241.

Preinreich, G.A.D. (1939) "The Practice of Depreciation", Econometrica, Vol. 7, pp. 235-265.

Preinreich, G.A.D. (1940) "The Economic Life of Industrial Equipment", Econometrica, Vol. 8, pp. 12-44.

Prescott, R.B. (1922) "Law of Growth in Forecasting Demand", Journal of American Statistical Association, Vol. 17, pp. 471-79.

Ramm, W. (1971) The Valuation and Estimation of Automobile Services, 1961-1968, Unpublished Ph.D. dissertation, Northwestern University.

Reich, R.B. (1983) The Next American Frontier, Times Books, New York.

Robertson, D.H. (1915) A Study of Industrial Fluctuation, London.

Rothschild, M. (1971) "On The Cost of Adjustment" Quarterly Journal of Economics, Vol. 85, pp. 605-622.

Rowley, J.C.R. & P.K. Trivedi (1975) Econometrics of Investment, Wiley, London.

Russo, J.G. & H.A. Cowles (1981) "Revalidation of the Iowa-Type Survivor Curves", The Engineering Economist, Vol. 26, pp. 1-16.

Saturday Night (1983) "The Painful Realities of the New Technology", Saturday Night, December, pp. 24-32.

Schnorbus, R.H. (1985) "Major Trends in Capital Formation", Economic Commentary, Federal Reserve Bank of Cleveland, June 15, 1985.

Schonheyder, K. (1927) "Produksjonssyklene oj Krisene", Statsokonomisk Tids-Krisene, pp. 57-116.

Schumpeter, J.A. (1934) The Theory of Economic Development, Reprinted by Oxford University Press, 1969.

Schumpeter, J.A. (1939) Business Cycles, McGraw-Hill, New York.

Schumpeter, J.A. (1942) Capitalism, Socialism and Democracy, Reprinted by Harper Torchbooks, 1950.

Scientific American (1982) The Mechanization of Work, September, 1982.

Shelp, R.K. (1981) Beyond Industrialization, Praeger Publishers.

Smith, V.L. (1961) Investment and Production, Harvard University Press.

Spiethoff, A. (1902)) Vorbemerkungen zu einer Theorie der Überproduktion, Schmollers, Jahrbuch.

Statistics Canada (1967) Fixed Capital Flows and Stocks Manufacturing, Methodology, Canada 1926-1960, 2 Volumes, Catalogue 13-522 Occasional, Ottawa.

Statistics Canada (1980) Fixed Capital Flows and Stocks, 1926-1978, Catalogue No. 13-568 Occasional, Ottawa.

Statistics Canada (--) Fixed Capital Flows and Stocks, Catalogue 13-211, Annual, Ottawa.

Statistics Canada (1983) Gross Domestic Product by Industry, Catalogue 61-213, Annual, Ottawa.

Statistics Canada (1983) Employment Earnings and Hours, Catalogue 72-002, Monthly, Ottawa.

Statistics Canada (1984) Corporation Financial Statistics, Catalogue 61-207, Annual, Ottawa.

Statistics Canada (1984) Current Economic Analysis, Vol. 4, No. 9, Ottawa.

Statistics Canada (1984) Private and Public Investment in Canada, Catalogue 61-205, Annual, Ottawa.

Statistics Canada (1985) Capacity Utilization Rates in Canadian Manufacturing, Catalogue 31-003, Quarterly, Ottawa.

Tarde, G. (1903) The Laws of Imitation, Henry Holt, London.

Taubman, P. & M. Wilkinson (1970) "User Cost, Capital Utilization and Investment Theory", International Economic Review, Vol. 11, pp. 209-215.

Taylor, J.S. (1923) "A Statistical Theory of Depreciation", Journal of the American Statistical Association, Vol. 18, pp. 1010-1023.

Terborgh, G. (1949) Dynamic Equipment Policy, McGraw-Hill, New York.

Terborgh, G. (1954) Realistic Depreciation Policy, Machinery & Allied Products Institute, Washington, D.C.

Tice, H.S. (1967) "Depreciation, Obsolescence, and the Measurement of the Aggregate Capital Stock of the United States, 1900-1961", Review of Income and Wealth, Vol. 13, pp. 119-154.

Time (1980) "The Robot Revolution", Time, December 8, 1980.

Treadway, A.B. (1969) "Optimal Entrepeneurial Behavior and Distributed Lag Investment Equations" Review of Economic Studies, Vol. 36, pp.227-240.

Tugan-Baranowsky, M. (1901) Studien zur Theorie und Geschichte der Handelskrisen in England, Jena.

United States Department of Commerce (1967 a) "Fixed Business Capital in the United States", Survey of Current Business, Vol. 47, February, pp. 20-24.

United States Department Of Commerce (1969) "Fixed Business Capital in the U.S., 1925-1968" Survey of Current Business, Vol. 49, February, pp. 20-27.

United States Department of Commerce (1971) Fixed Non-Residential Business Capital in the United States, 1925-1970. A Supplement to the Survey of Current Business, U.S. Government Printing Office, Washington, D.C.

United States Department of Treasury (1942) Bulletin "F": Tables of Useful Lives of Depreciable Property, U.S. Government Printing Office, Washington, D.C.

United States Department of Treasury (1962) Depreciation Guidelines and Rules, Publication No. 456, U.S. Government Printing Office, Washington, D.C.

Urquhart, M.C. (1983) Historical Statistics of Canada, Statistics Canada, Ottawa.

Usher, D. (1980) The Measurement of Capital, NBER, University of Chicago Press.

Vernon, R. (1966) "International Investment and International Trade in the Product Life Cycle" Quarterly Journal of Economics, Vol. 80, pp. 190-207.

Vernon, R. (1970) The Technology Factor in International Trade, NBER, New York.

Vorlander, M.O. & F.E. Raymond (1932) "Economic Life of Equipment" Transactions of the American Society of Mechanical Engineers, Vol. 54, pp. 29-51.

Walras, L. (1926) Elements of Pure Economics, Reprinted by Augustus M. Kelley, Fairfield, 1977.

Wells, L.T. (1968) "A Product Life-Cycle for International Trade?" Journal of Marketing, Vol. 32, pp. 1-6.

Wicksell, K. (1934) Lectures on Political Economy, Vol. I, George Routledge & Sons, London.

Wind, Y.J. (1982) Product Policy: Concepts, Methods and Strategy, Addison-Wesley.

Winfrey, R. & E.B. Kurtz (1931) Life Characteristics of Physical Property, Iowa State College, Iowa Engineering Experiment Station Bulletin 103.

Winfrey, R. (1935) Statistical Analysis of Industrial Property Retirements, Iowa State College, Iowa Engineering Experiment Station, Bulletin 125.

Wykoff, F.C. (1970) "Capital Depreciation in the Postwar Period: Automobiles", The Review of Economics and Statistics, Vol. 52, pp. 168-72.

Young, A.H. & J.C. Musgrave (1980) "Estimation of Capital Stock in the United States" in the Measurement of Capital, ed. D. Usher, NBER, University of Chicago Press, pp. 23-58.

APPENDIXES

Sources: Appendix A: Statistics Canada (1984) Private and Public Investment in Canada , Catalogue 61-205

Appendix B: Statistics Canada, Construction Division

Appendix C: Department of Finance (1985) Economic Review, Supply and Services Canada.

SECTION V

STATISTICAL NOTES

Definitions

The main emphasis of the report is on new capital rather than on non-capitalized repair expenditures. New capital expenditures include the cost of procuring, constructing and installing new durable plant and machinery, whether for replacement of worn or obsolete assets, or as net additions to existing assets. Included are all capitalized costs such as architectural, legal and engineering fees, as well as the value of work on capital assets undertaken by firms with their own labour force. Gross outlays are reported without any deduction for scrap or trade-in value of old assets. Excluded are expenditures made for the acquisition of previously existing structures, for used machinery and equipment unless imported and for land since outlays of this type involve only the transfer of property and not the creation of a capital asset.

Construction includes building construction and all types of engineering construction such as roads, dams, transmission lines and pipelines, as well as oil drilling and mine development. The machinery and equipment category takes into account the purchase of all such items which are used either in producing goods or providing services but does not cover durable goods purchased for personal use. Included, as well as industrial machinery, are transportation equipment, agricultural implements, professional and scientific equipment, office and store furnishings and other similar capital goods. Excluded, for the purpose of this report, are outlays for machinery and equipment by the Department of National Defence.

The intention is to include the costs of all new plant and equipment which normally has a life of more than one year. For this reason companies were asked to report, as capital expenditures, all purchases to be charged to fixed asset accounts. This method of reporting omits certain types of equipment which are bought regularly out of ordinary revenue and charged to current account. Adjustments have been made where necessary to take account of such omitted capital items and separate figures are shown in the relevant tables under "Capital items charged to operating expenses".

RENSEIGNEMENTS STATISTIQUES

Définitions

Le rapport vise moins les réparations non-capitalisées que les immobilisations neuves. Celles-ci comprennent le coût d'acquisition, de construction et d'installation de nouvelles usines et machines durables, qu'il s'agisse de remplacer des biens usés ou désuets ou d'ajouter aux installations existantes, ainsi que tous les frais portés au compte de capital, comme les honoraires d'architectes, d'avocats et d'ingénieurs, et la valeur des travaux effectués par le propriétaire par l'entremise de ses propres ouvriers. Le rapport indique les dépenses brutes, sans déduction pour la valeur des biens mis au rancart ou cédés en échange de biens nouveaux, mais il ne comprend pas les achats de constructions existantes, de machines ou d'équipement usagés, à moins qu'ils n'aient été importés, ni de terrains, puisque dans ces cas il s'agit d'une simple cession des droits de propriété et non de la création d'un bien nouveau.

La construction comprend les bâtiments et tous les travaux de génie, comme les routes, les barrages, les lignes de transmission et les pipelines, ainsi que le forage de puits de pétrole et la mise en exploitation des mines. Dans le secteur des machines et de l'outillage, les achats comprennent tous les articles employés à la production de biens et de services mais non les biens durables achetés pour usage personnel. Sous cette rubrique sont inclus, en plus des machines industrielles, le matériel de transport, les instruments agricoles, le matériel professionnel et scientifique, les ameublements de bureaux et de magasins et autres biens capitaux du même genre. Toutefois, le présent rapport ne tient pas compte des montants consacrés à l'acquisition de machines et d'outillage par le Ministère de la Défense nationale.

On a visé à inclure le prix de toutes les nouvelles usines et de nouvelles machines et outillage d'une durée normale de plus d'un an. C'est pourquoi on a demandé aux sociétés d'inscrire comme immobilisations tous les achats devant être portés au compte de capital fixe. Ainsi, il n'est pas tenu compte de certains éléments d'actif achetés régulièrement au moyen de recettes ordinaires et postés au compte courant. Des rajustements ont été faits lorsqu'il a semblé nécessaire de tenir compte de ces éléments et les sommes en cause figurent aux tableaux pertinents sous le titre "Biens-capitaux imputés sur les dépenses d'exploitation".

Housing is not generally considered a capital expenditure in the sense mentioned above but it has been included in this report because it forms a large proportion of construction expenditures and has cyclical fluctuations similar to those which characterize business, institutional and government capital expenditures.

The repair expenditures shown in the tables represent the non-capitalized outlays made to maintain the operating efficiency of the existing stock of durable physical assets. Where the repair costs are large enough to materially lengthen the expected serviceable life of the assets, increase its capacity or otherwise raise its productivity, they are treated as capital expenditures on new construction or on new machinery and equipment.

Methods

The figures in the various tables of this report are estimates of total expenditures. In order to approximate full coverage for Canada, adjustments were made to allow for the smaller establishments which are not surveyed and for establishments which did not report. In manufacturing, the method used to inflate the reported expenditures was to multiply the known expenditures by a factor obtained by dividing the total value of shipments for the most recent year available of all the establishments in each industry by the corresponding total for the establishments reporting in the current surveys. The use of shipments as a related indicator provides a framework of analysis in the estimation procedures to take account of relevant industry characteristics such as the size of establishments. In the utilities, trade, finance and institutional and commercial services sectors the same principle has been followed using appropriate basic data for the sector concerned. Expenditures reported by establishments for which no production or other basic data are available are included as "net additions". It is believed that the estimating procedures for non-reporting establishments and the sectors not covered by direct survey, do not introduce any great margin of error into the total. Estimates for individual industries or regions are, of course, subject to greater error than the total figures for Canada.

In a few areas, where the survey approach is not considered to be practical, expenditure estimates were arrived at independently on the basis of current trends and expert

La construction d'habitations n'est pas habituellement considérée comme une immobilisation au sens indiqué ci-dessus mais on l'a incluse dans ce rapport parce qu'elle représente une forte proportion des dépenses en construction et que le cycle de ses fluctuations est analogue à celui qui caractérise les immobilisations des entreprises commerciales, des inqtitutions et des gouvernements.

Les dépenses en réparation, figurant dans les tableaux, représentent les déboursés non-capitalisés effectués en vue de maintenir les biens matériels durables en bon état de fonctionnement. Lorsque ces dépenses atteignent des sommes suffisantes et 'elles ont pour effet d'accroître la durée prévue ou la productivité d'éléments d'actif, elles sont considérées comme des immobilisations en constructions neuves ou en machines et outillage neufs.

Méthodes

Les chiffres qui apparaissent dans les divers tableaux sont des estimations des dépenses globales. Afin de se rapprocher le plus possible du total pour tout le Canada, on a effectué des rajustements de façon à faire la part des plus petits établissements qui n'ont pas fait partie de l'enquête ou n'y ont pas répondu. Pour le secteur de la fabrication, la méthode employée pour gonfler le montant des dépenses en immobilisation déclarées consiste à multiplier ce dernier par le facteur du rapport de la valeur totale des expéditions, pour l'année la plus récente, de tous les établissements ayant répondu à l'enquête courante, suivant la disponibilité des données. L'utilisation des expéditions comme indicateur connexe insère une analyse d'ensemble dans les procédures d'estimations afin de tenir compte des caractéristiques pertinentes tel que la grosseur d'un établissement. Pour les services d'utilité publique, le commerce, la finance, les institutions et les services commerciaux, on a appliqué le même principe en cherchant des données de base appropriées au secteur en cause. Les projets mentionnés par les établissements à l'égard desquelles aucun renseignement en matière de production ou autre ne pouvait être obtenu, sont inscrits comme "additions nettes". Il y a lieu de croire que la formule d'estimation employée à l'égard des établissements qui n'ont pas répondu au questionnaire et des secteurs que le relevé n'a pas atteint directement, n'a pas pu fausser sensiblement le montant global.

Dans certains secteurs, où la méthode d'enquête n'a pas semblé pratique, les montants ont été calculés séparément d'après la tendance courante et l'opinion de spécialistes en la matière.

opinion in these fields. Some of the areas so estimated are agriculture and fishing investment. The estimates of total outlays in the groups covered by survey are thought to be of better quality than the independent estimates which are based on much less complete information.

Housing estimates were made on a different basis from those derived from information submitted directly by businesses and governments. Last year's estimates of the volume of residential construction were prepared on the basis of results from surveys conducted by the Canada Mortgage and Housing Corporation, and the value estimates were prepared by Statistics Canada. These value estimates were calculated by means of a sensitive methodology making use of the duration of construction and monthly measures of work put in place for various types of construction.

Appraisal of the probable volume of new housing construction in the current year was made by representatives of the Corporation who assessed market conditions, mortgage facilities, current and proposed housing policies. Finally an allowance was made for other housing expenditures such as home conversions, mobile homes, alterations, home improvements and acquisition costs which currently account for approximately 20% of total expenditures. Allowing for probable change in construction costs, estimates were then prepared for the value of construction work carried over from last year and the value of work expected to be undertaken this year.

Construction Expenditures - By Type of Structure

For details of construction activity by type of structure see the publication **Construction in Canada** (Catalogue 64-201).

The statistics for these types of structure come from the same capital and repair expenditures surveys that produce **Private and Public Investment in Canada, Intentions.**

matière. Cette méthode d'évaluation a été employée surtout à l'égard des investissements agricoles et de ceux de l'industrie de la pêche. Dans le cas des groupes atteints par le relevé, les estimations semblent plus sûres que pour les groupes ayant été estimés par des tiers d'après des renseignements beaucoup moins complets.

Pour l'habitation, les estimations n'ont pas été établies sur la même base que celles qui découlent des renseignements fournis directement par les entreprises ou les pouvoirs publics. Pour l'année dernière, Statistique Canada a estimé les dépenses d'habitation en se basant sur les résultats des enquêtes menées par la Société canadienne d'hypothèques et de logement et au moyen d'une méthodologie sensible fondée sur la durée des travaux et sur les réalisations mensuelles des différents types de construction.

Pour l'année courante, des estimations du volume probable des travaux de construction domiciliaire ont été faites par des représentants de la société, lesquels se fondent sur les conditions du marché, les disponibilités de financement et les politiques d'habitation proposées. Enfin, on a tenu compte des autres dépenses d'habitation telles que les transformations, les maisons mobiles, les modifications, les améliorations et les frais d'acquisition qui représentent environ 20% des dépenses totales. En tenant compte de l'évolution probable des coûts de la construction, on a pu alors estimer la valeur des travaux reportés pour l'année dernière et celle des travaux attendus cette année.

Dépenses de construction - Par genre de construction

On trouvera dans la publication **La construction au Canada** (n° 64-201 au catalogue) le détail des travaux de construction selon le genre.

Les enquêtes sur les dépenses d'immobilisations et de réparations, dont les résultats apparaissent dans la publication **Investissements privés et publics au Canada - Perspective,** nous fournissent également les statistiques pour ces genres de construction.

APPENDIX B

PRICE INDEXES FOR PLANT AND EQUIPMENT INVESTMENT IN CANADA: 1946-1984

Year	Machinery & Equipment	Non-Residential Construction
1946	38.2	39.9
1947	42.7	44.5
1948	48.0	49.7
1949	51.1	51.3
1950	54.0	52.8
1951	60.9	59.7
1952	62.1	63.2
1953	63.2	63.7
1954	63.9	62.9
1955	65.0	64.4
1956	69.0	67.7
1957	72.7	67.6
1958	73.8	67.3
1959	75.5	67.7
1960	76.5	68.3
1961	77.0	68.1
1962	79.6	68.4
1963	81.8	70.3
1964	85.1	72.2
1965	88.4	76.2
1966	91.2	80.8
1967	90.7	84.1
1968	90.8	84.9
1969	92.7	89.6
1970	97.4	94.2
1971	100.0	100.0
1972	102.6	105.7
1973	106.9	114.3
1974	121.8	133.1
1975	139.0	149.5
1976	146.7	159.2
1977	160.2	169.0
1978	178.7	180.7
1979	196.7	198.0
1980	216.9	221.9
1981	242.1	247.7
1982	261.4	271.6
1983	269.5	294.3
1984	283.0	298.5

Reference Table 19

Private and Public Investment in Canada
1960 – 1984

Year	Capital expenditures: Construction	Capital expenditures: Machinery and equipment	Capital expenditures: Sub-total	Repair expenditures	Total	Capital expenditures: Construction	Capital expenditures: Machinery and equipment	Capital expenditures: Sub-total	Repair expenditures	Total
	Primary and construction industries					Manufacturing				
	(Millions of dollars)									
1960	511	680	1,191	506	1,697	335	843	1,178	671	1,849
1961	654	647	1,301	512	1,813	279	806	1,085	682	1,767
1962	647	745	1,392	536	1,928	353	916	1,269	750	2,019
1963	659	885	1,544	586	2,130	355	1,003	1,358	801	2,159
1964	769	1,059	1,828	660	2,488	443	1,388	1,831	896	2,727
1965	844	1,161	2,005	724	2,729	604	1,736	2,340	974	3,314
1966	1,066	1,348	2,414	796	3,210	788	2,126	2,914	1,096	4,010
1967	1,069	1,427	2,496	854	3,350	677	1,857	2,534	1,156	3,690
1968	1,086	1,341	2,427	914	3,341	657	1,542	2,199	1,232	3,431
1969	1,203	1,323	2,526	985	3,511	772	1,828	2,600	1,306	3,906
1970	1,284	1,268	2,552	1,112	3,664	997	2,226	3,223	1,417	4,640
1971	1,605	1,508	3,113	1,212	4,325	873	2,121	2,994	1,483	4,477
1972	1,528	1,785	3,313	1,304	4,617	829	2,119	2,948	1,657	4,605
1973	1,756	2,102	3,858	1,582	5,439	986	2,682	3,668	1,919	5,587
1974	2,184	2,529	4,713	1,899	6,612	1,425	3,525	4,950	2,310	7,260
1975	2,619	3,205	5,824	2,198	8,022	1,569	3,953	5,521	2,445	7,967
1976	3,094	4,168	7,262	2,540	9,802	1,440	4,026	5,465	2,891	8,357
1977	3,683	4,219	7,902	2,772	10,674	1,659	4,422	6,081	3,216	9,297
1978	4,058	4,440	8,498	2,972	11,469	1,544	4,635	6,178	3,596	9,774
1979	5,798	5,510	11,308	3,629	14,937	1,611	5,833	7,444	4,098	11,541
1980	8,302	6,061	14,363	4,501	18,864	2,256	7,491	9,747	4,731	14,478
1981	9,426	7,024	16,451	5,256	21,707	3,074	9,665	12,739	4,955	17,694
1982	9,622	6,523	16,145	5,087	21,231	2,909	8,584	11,493	4,854	16,347
1983	9,465	6,124	15,589	5,112	20,701	1,869	6,933	8,802	4,898	13,699
1984	10,140	6,209	16,349	5,465	21,813	1,913	6,672	8,584	5,085	13,669
	Utilities					Trade, finance and commercial services				
	(Millions of dollars)									
1960	1,074	698	1,772	713	2,485	466	409	875	168	1,043
1961	1,088	610	1,698	723	2,421	451	396	847	162	1,009
1962	982	619	1,601	734	2,335	438	422	860	164	1,024
1963	1,111	660	1,771	774	2,545	468	450	918	183	1,101
1964	1,332	727	2,059	822	2,881	548	494	1,042	195	1,237
1965	1,443	980	2,423	867	3,290	705	564	1,269	220	1,489
1966	1,666	1,260	2,926	945	3,871	860	667	1,527	248	1,775
1967	1,748	1,397	3,145	1,019	4,164	764	770	1,534	272	1,806
1968	1,774	1,446	3,220	1,070	4,290	710	762	1,472	300	1,772
1969	1,719	1,586	3,305	1,113	4,418	704	952	1,656	299	1,955
1970	2,044	1,584	3,628	1,218	4,846	760	985	1,745	323	2,068
1971	2,228	1,760	3,988	1,318	5,306	901	1,014	1,915	324	2,239
1972	2,357	1,872	4,229	1,424	5,653	1,212	1,430	2,642	355	2,997
1973	2,673	2,484	5,157	1,617	6,774	1,685	1,759	3,445	420	3,864
1974	3,154	3,087	6,241	2,002	8,243	2,184	2,145	4,329	510	4,839
1975	4,403	3,630	8,033	2,229	10,262	2,768	2,448	5,216	591	5,807
1976	4,426	3,828	8,254	2,588	10,842	2,724	2,546	5,270	724	5,994
1977	5,073	4,115	9,188	2,948	12,136	2,605	2,730	5,335	775	6,110
1978	5,626	4,900	10,526	3,393	13,918	2,925	3,402	6,327	912	7,239
1979	6,184	5,576	11,760	3,830	15,590	3,932	4,516	8,449	1,099	9,548
1980	6,717	6,047	12,763	4,439	17,202	4,430	5,079	9,509	1,222	10,731
1981	8,588	7,655	16,244	5,066	21,309	5,236	5,670	10,906	1,395	12,301
1982	9,610	8,243	17,853	5,442	23,295	4,820	5,044	9,864	1,472	11,336
1983	8,078	7,955	16,034	5,746	21,779	4,133	5,199	9,332	1,491	10,823
1984	7,566	7,693	15,259	6,271	21,530	3,666	5,712	9,378	1,563	10,940

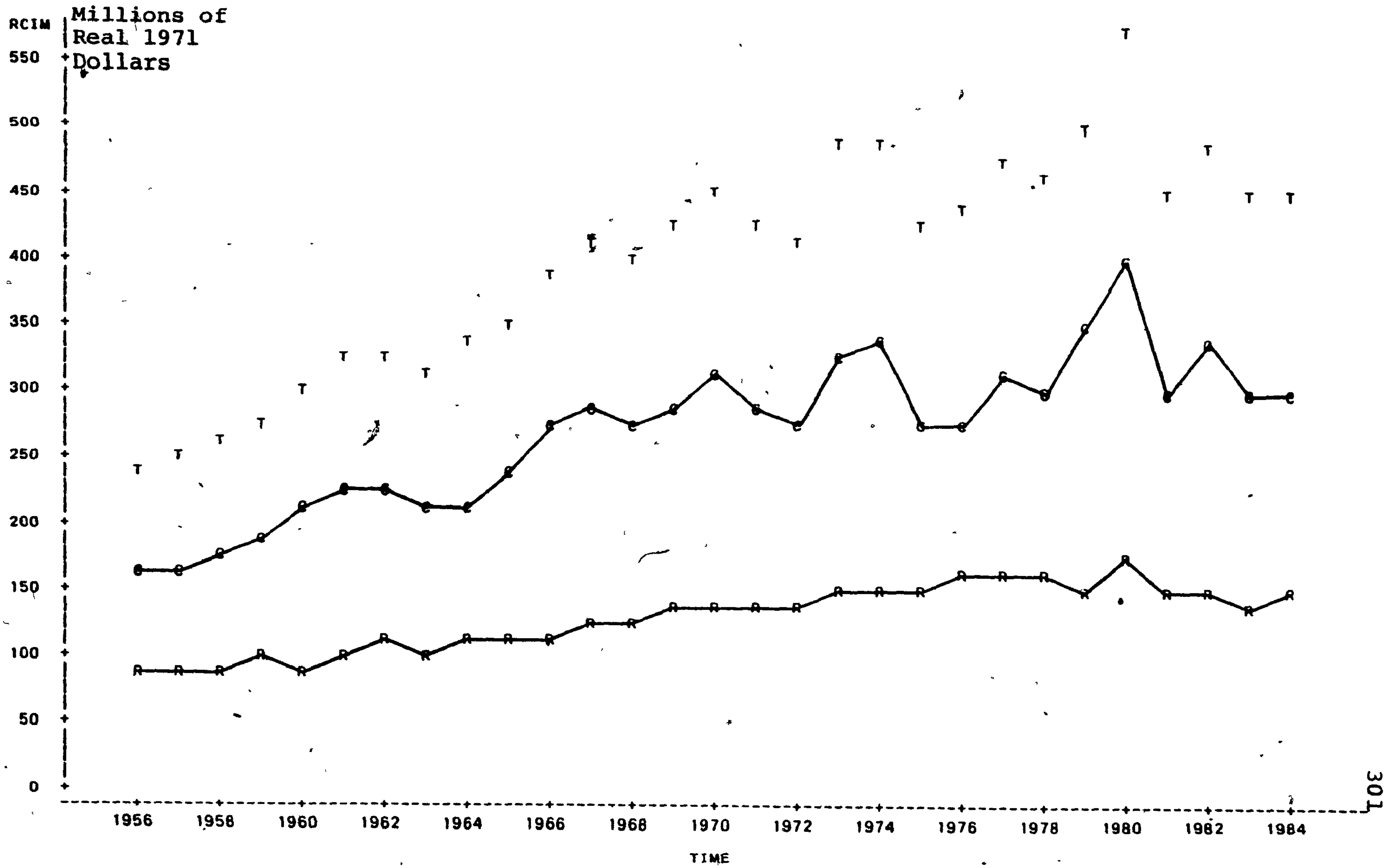
APPENDIX D

CAPITAL, REPAIR AND TOTAL INVESTMENT EXPENDITURES BY TWO-DIGIT SIC MANUFACTURING INDUSTRIES: 1956-1984

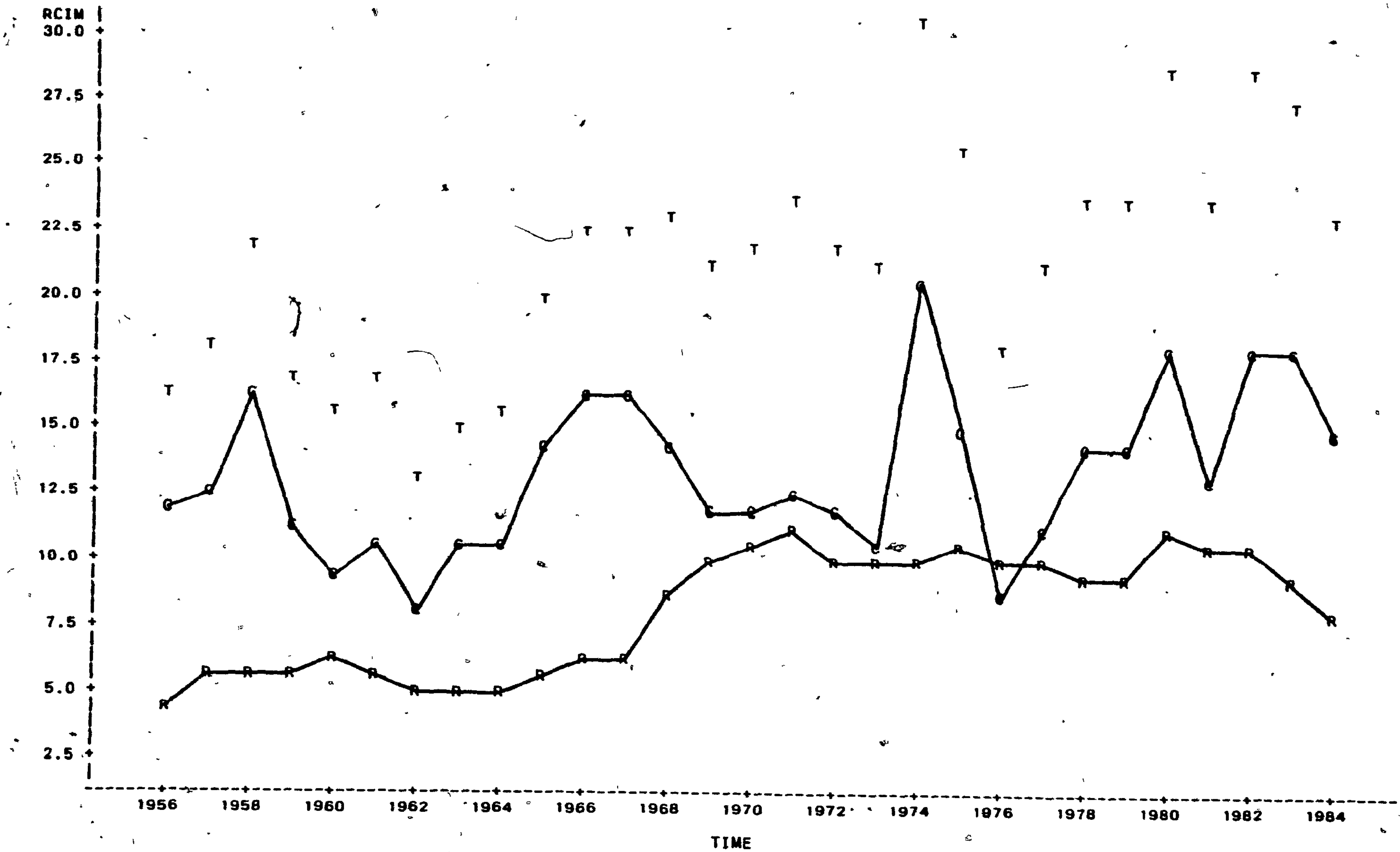
-I-

REAL CAPITAL VS. REAL REPAIR INVESTMENT EXPENDITURES, BY MANUFACTURING INDUSTRY

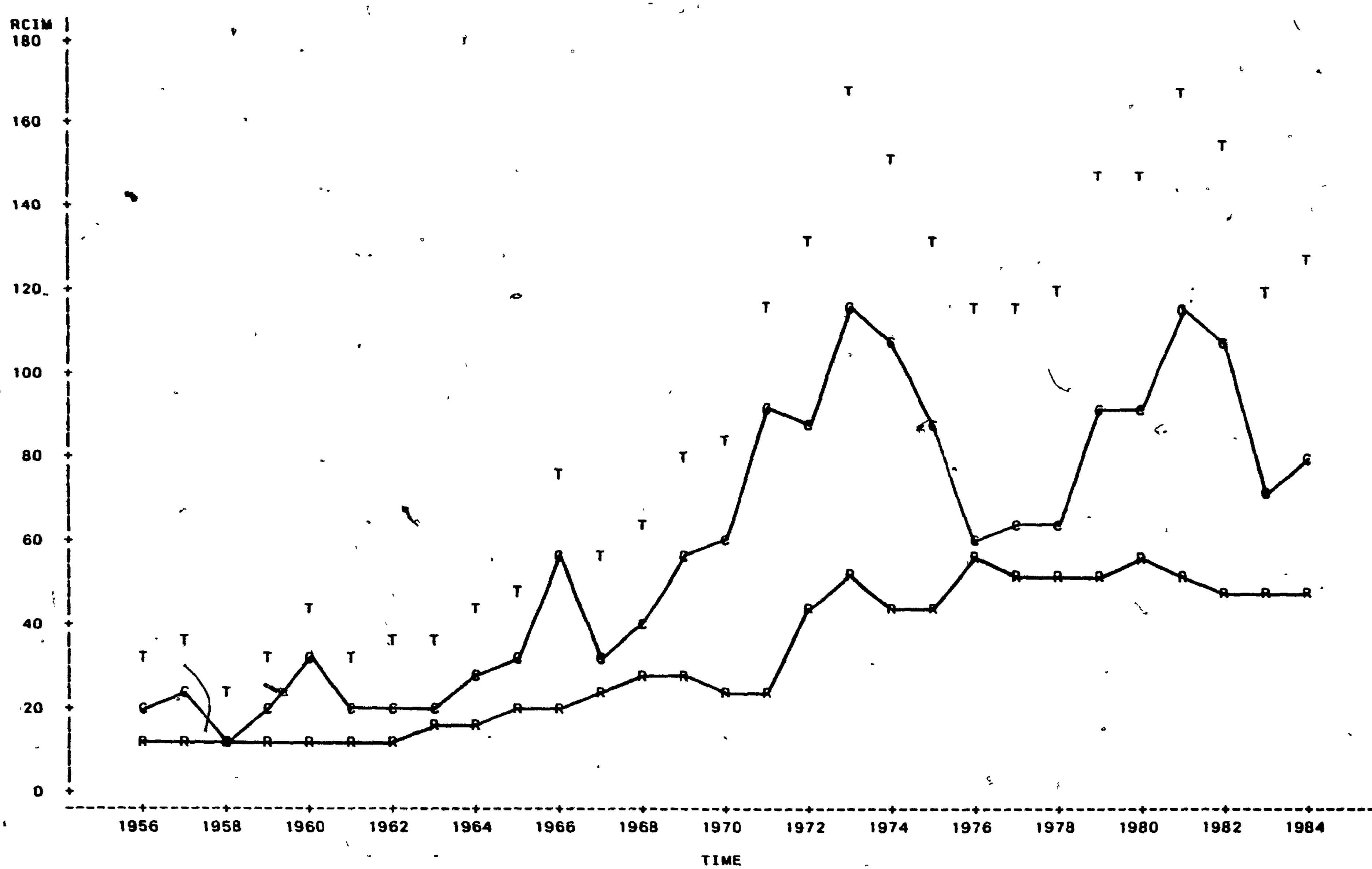
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=FOOD



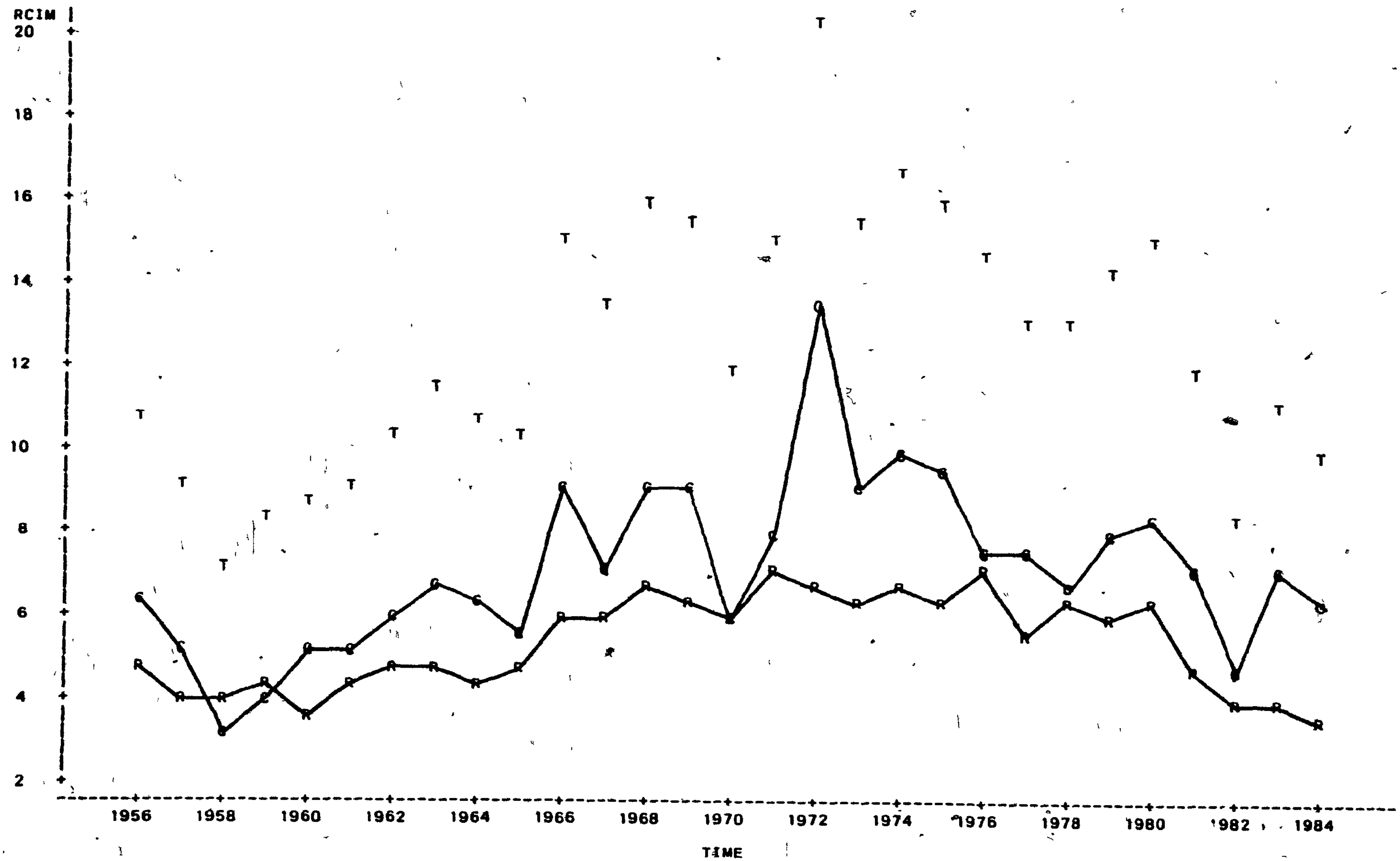
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=TOBACCO



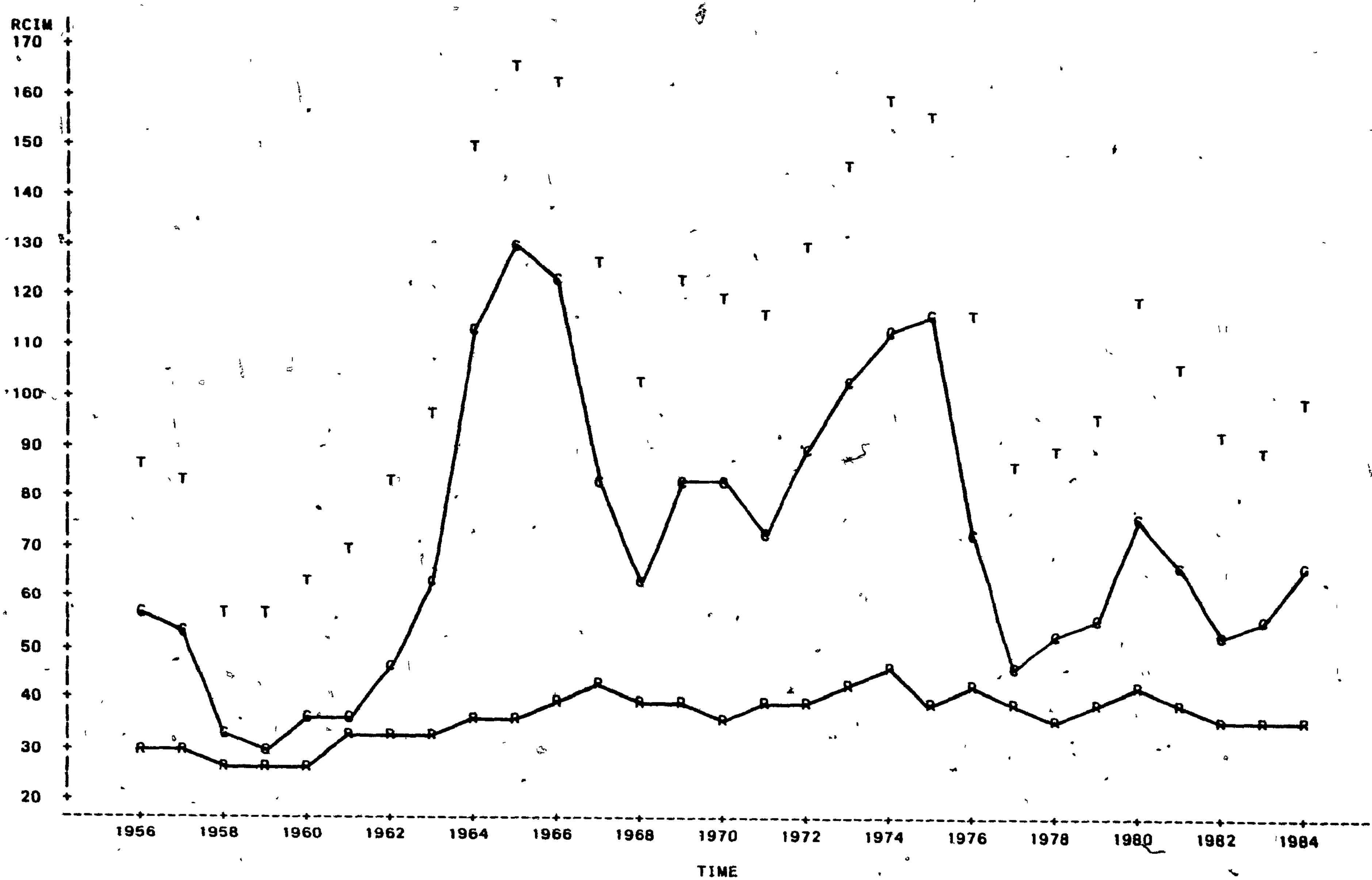
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=RUBBER



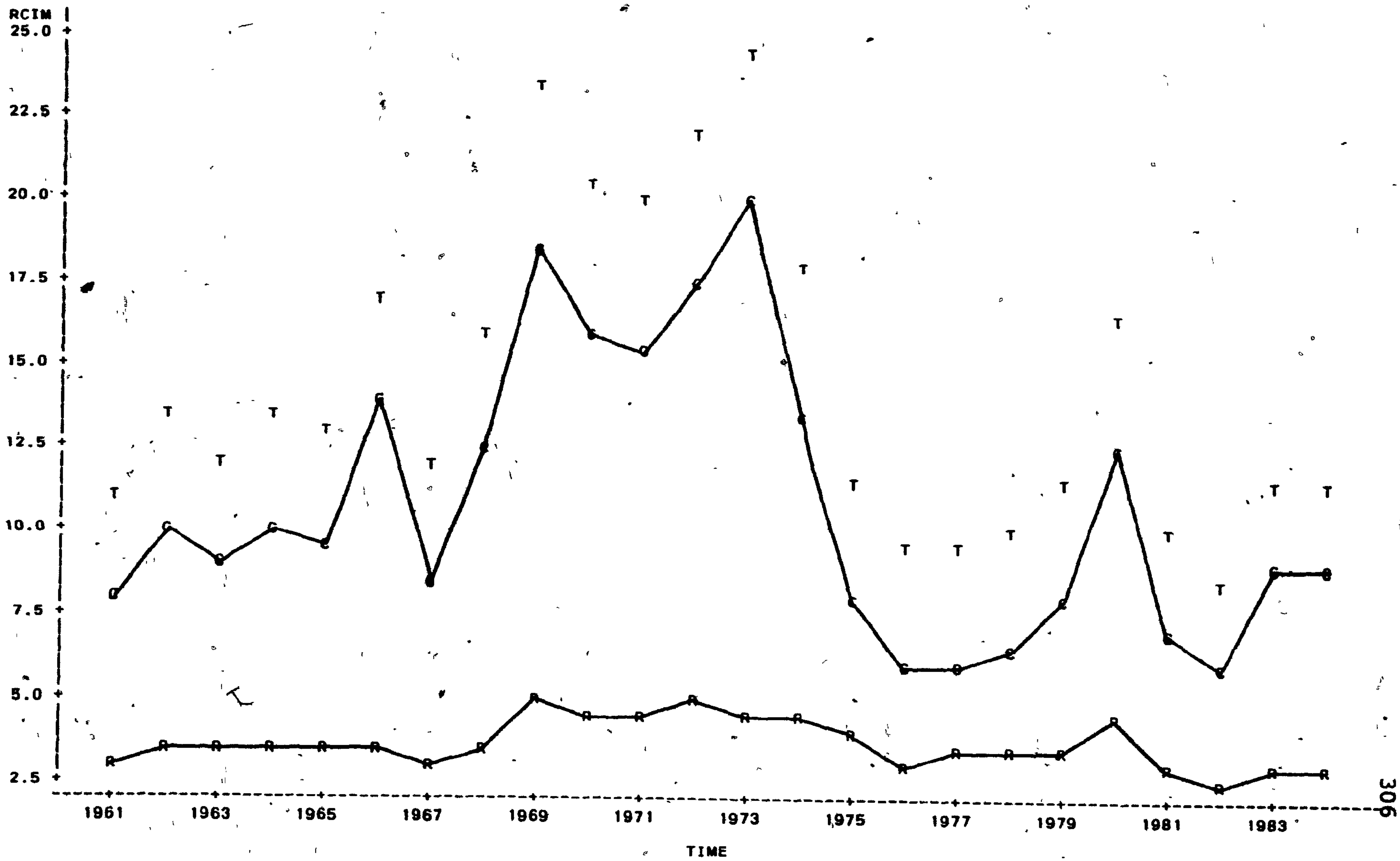
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=LEATHER



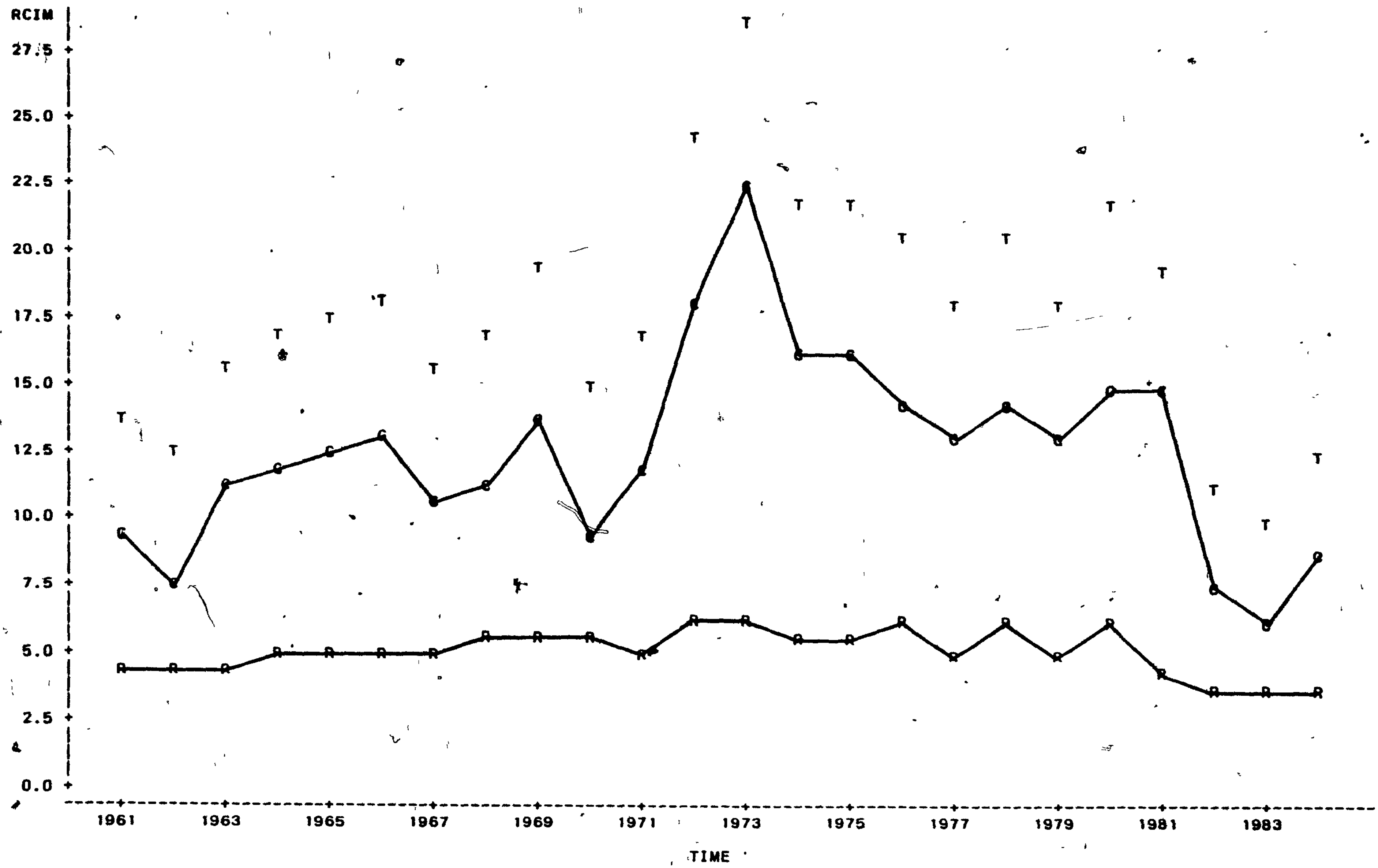
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=TEXTILES



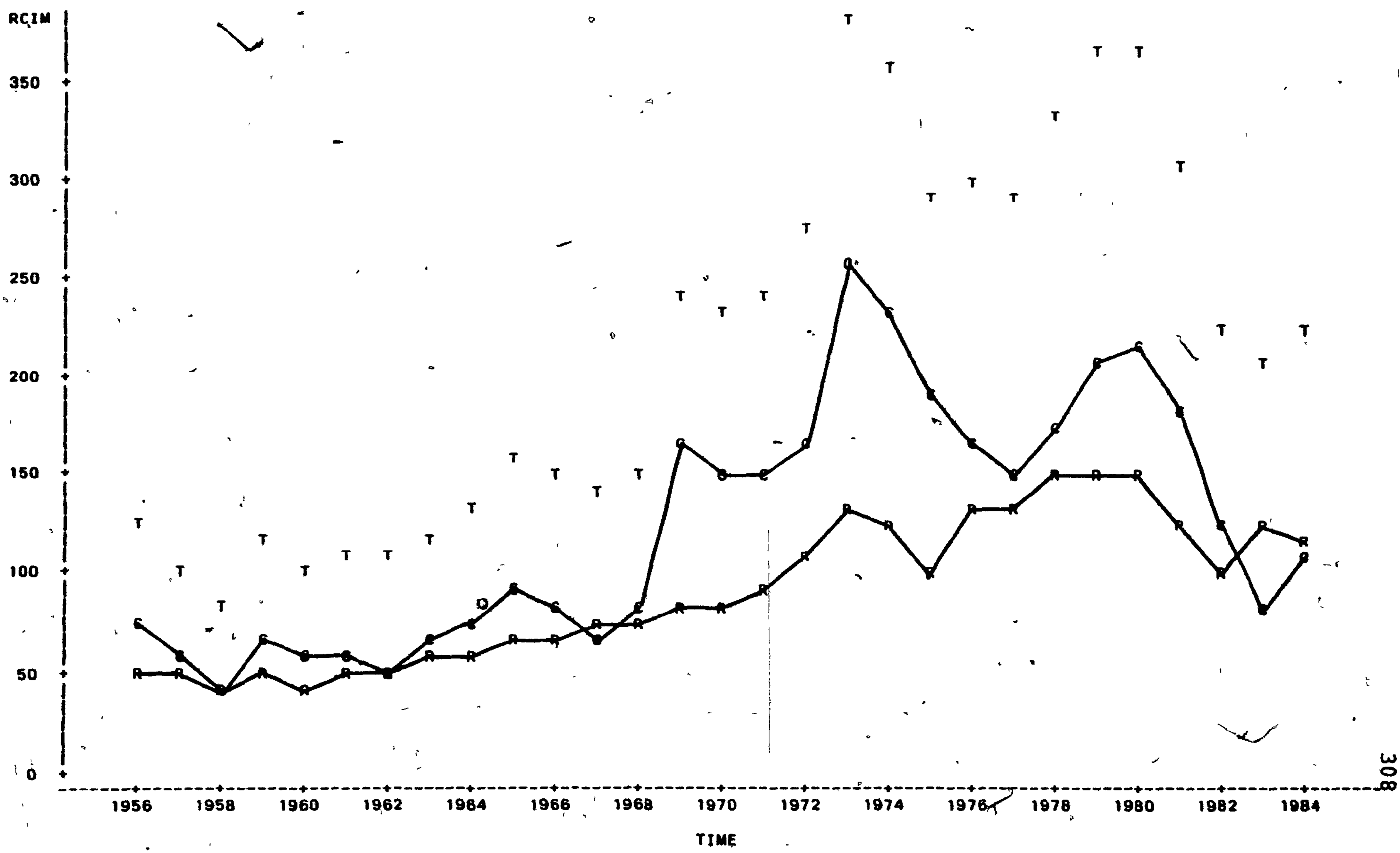
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=KNITTING MILLS



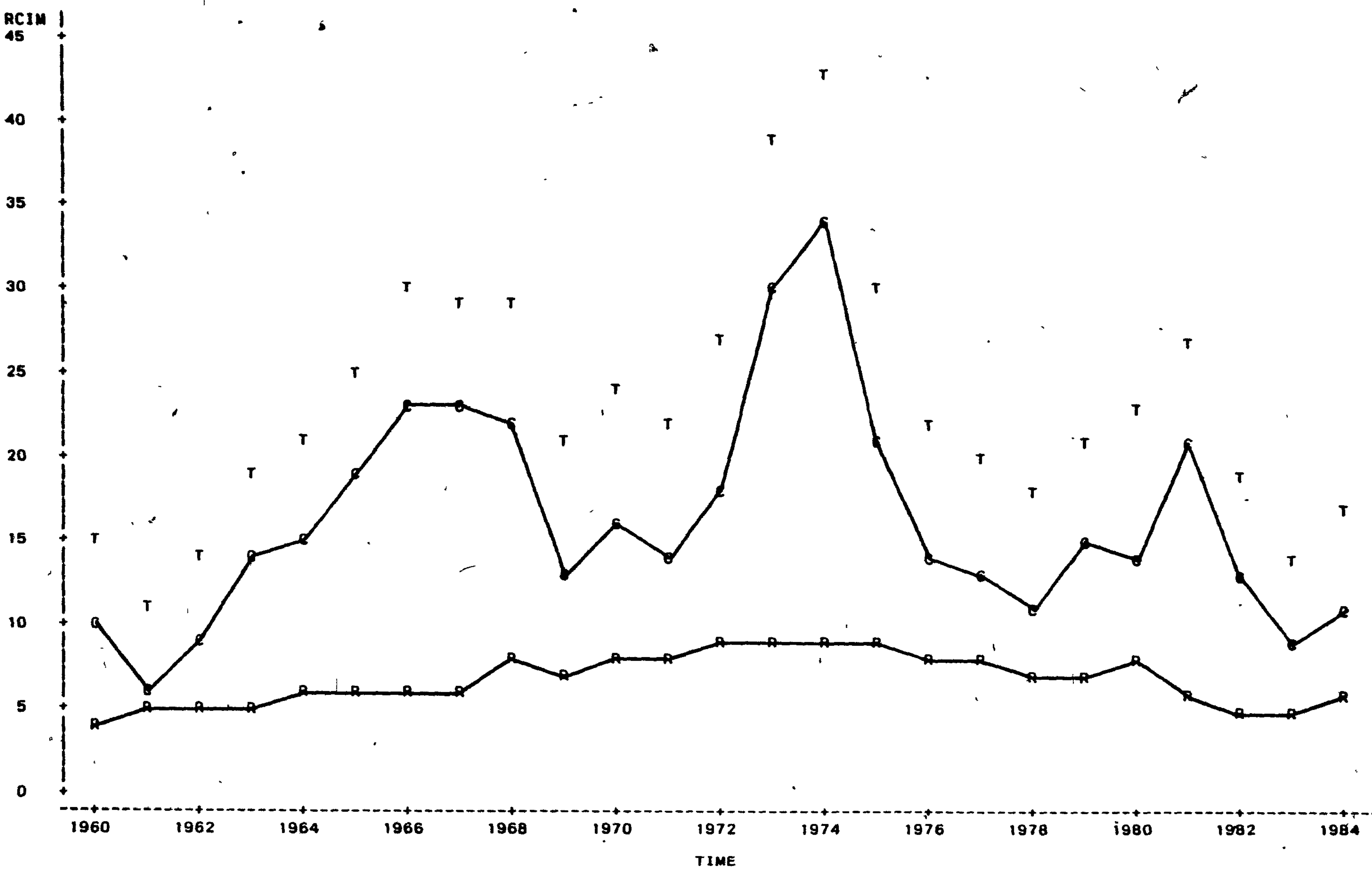
REAL MANUFACTURING CAPITAL, REPAIR AND TOTAL INVESTMENT
INDUSTRY=CLOTHING



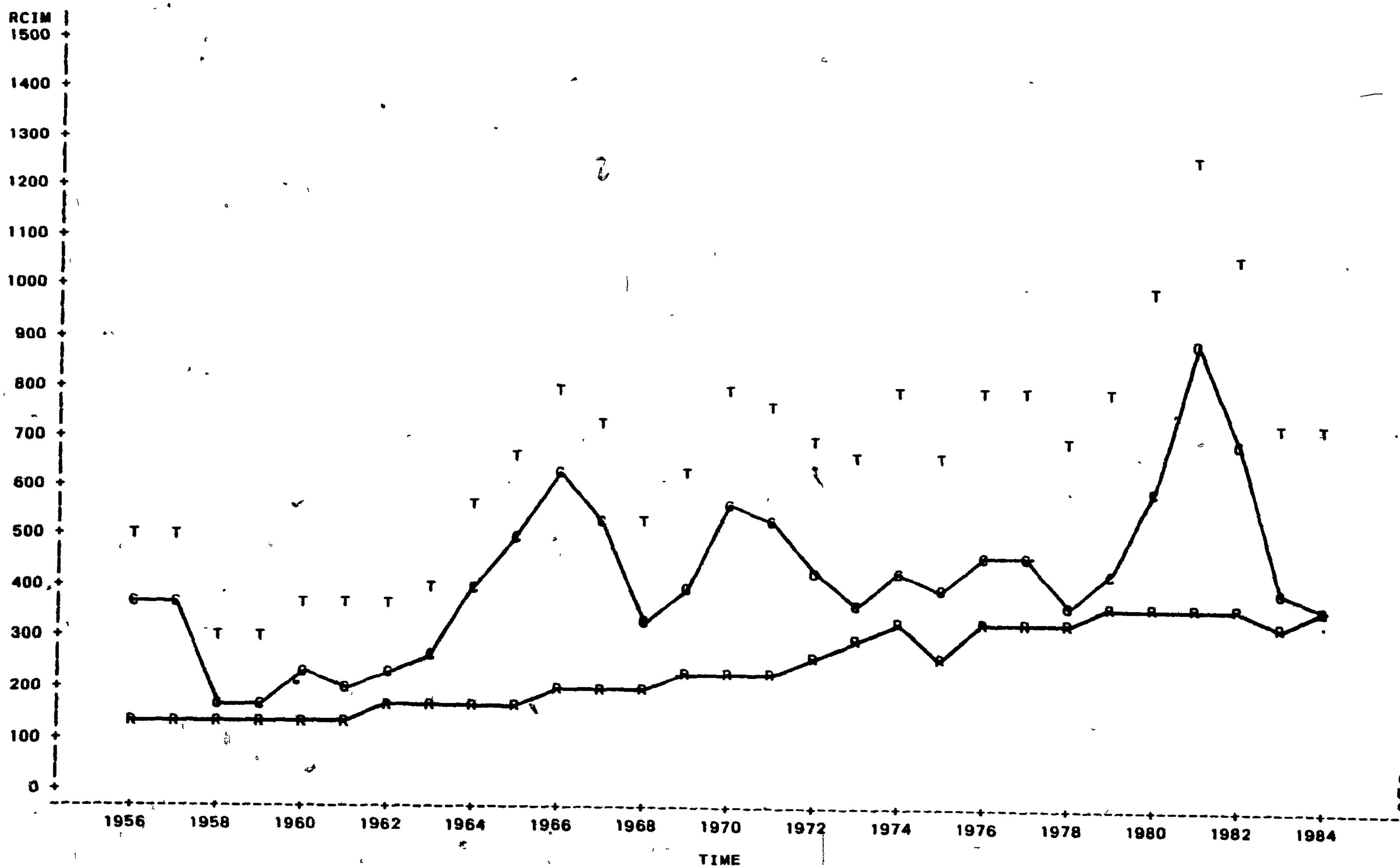
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=WOOD



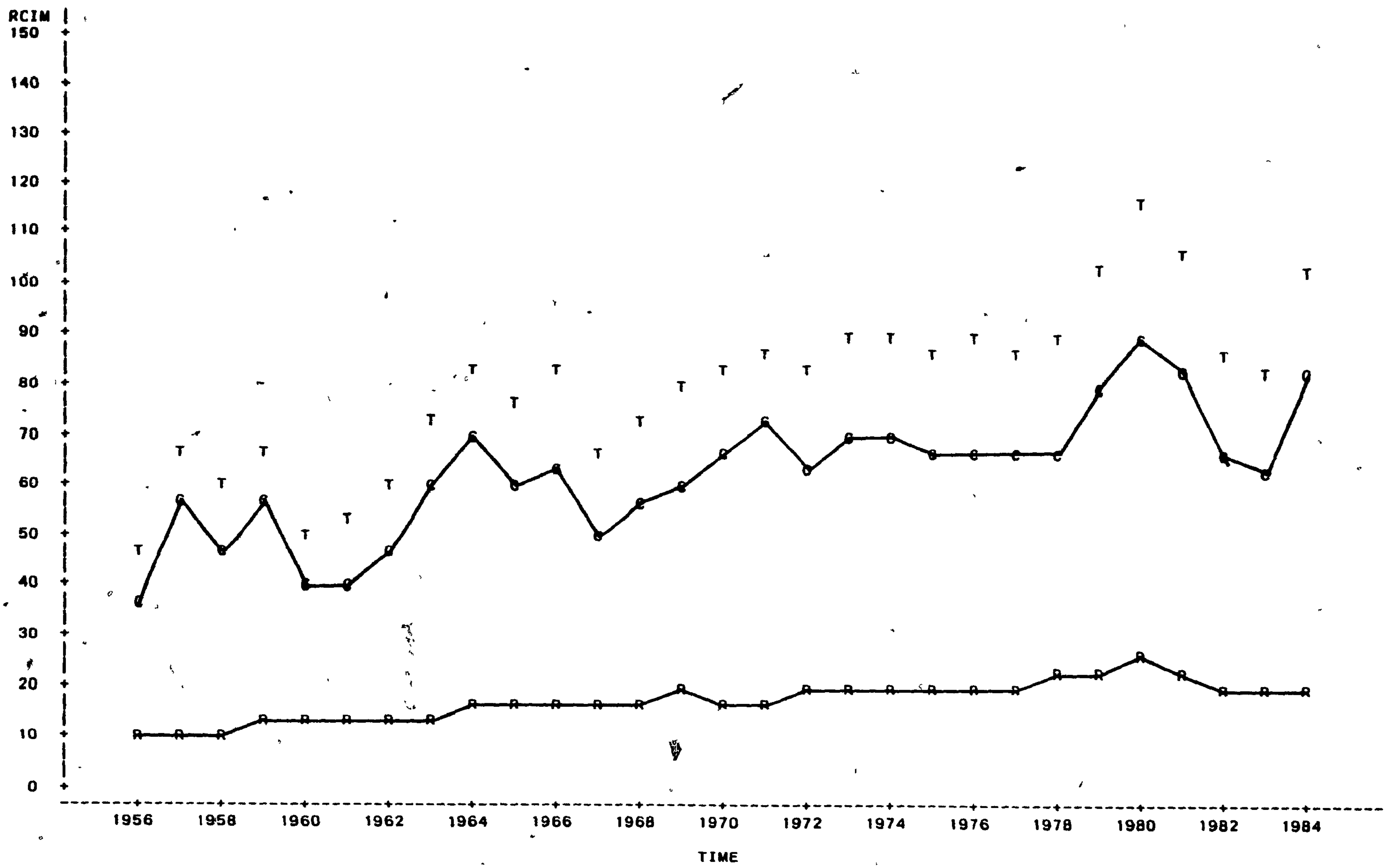
REAL MANUFACTURING CAPITAL, REPAIR AND TOTAL INVESTMENT
INDUSTRY=FURNITURE



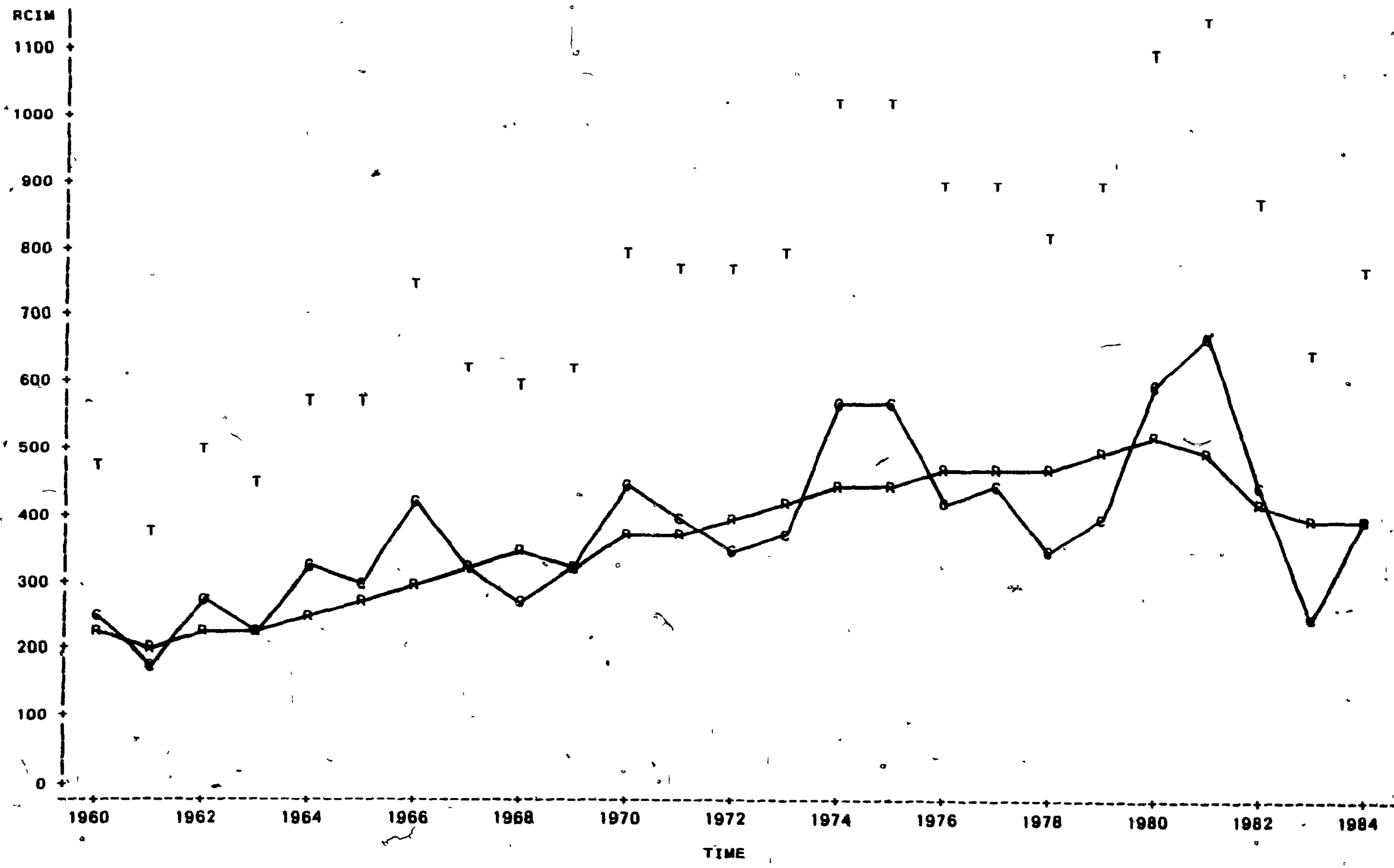
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=PAPER



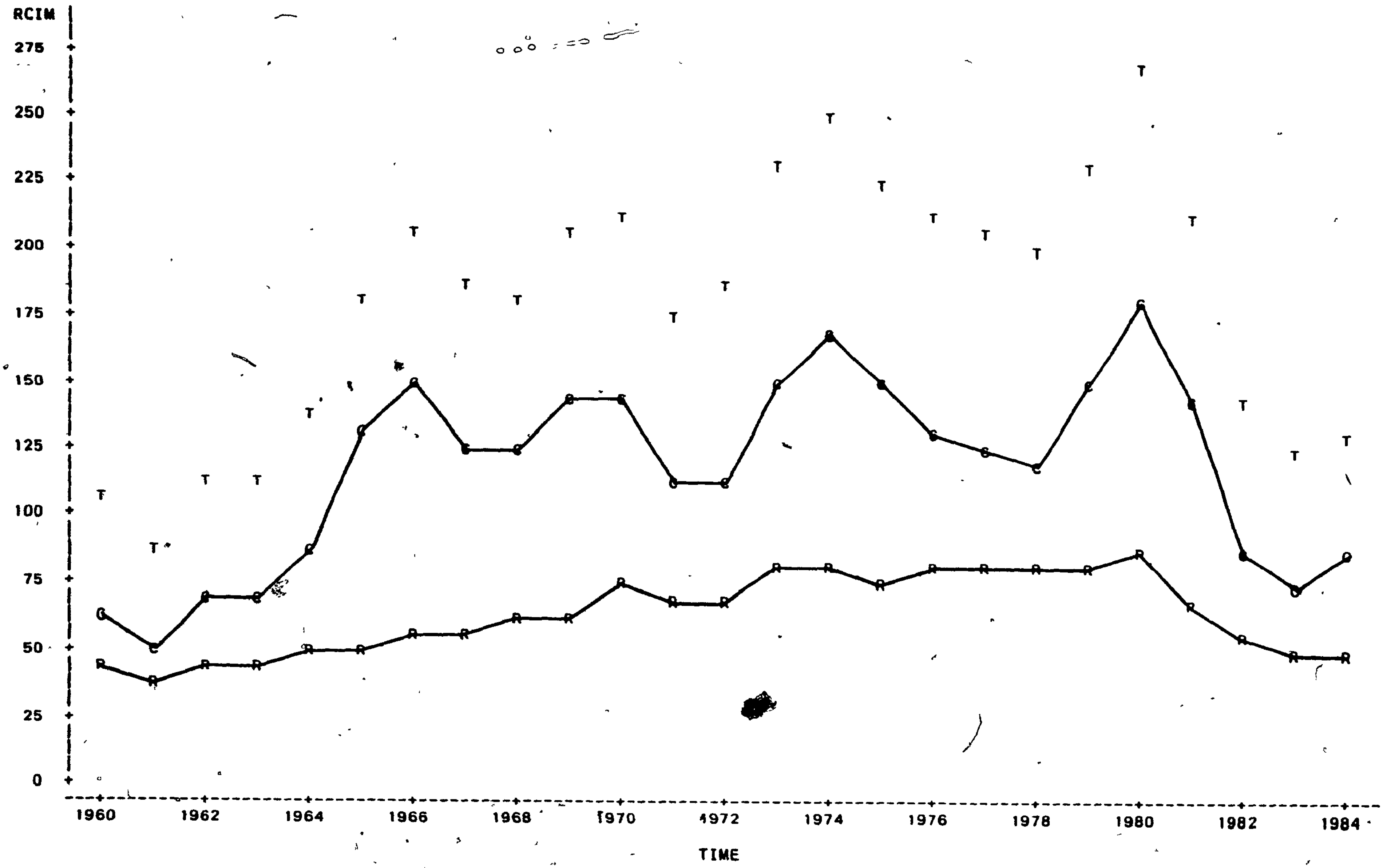
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=PRINTING



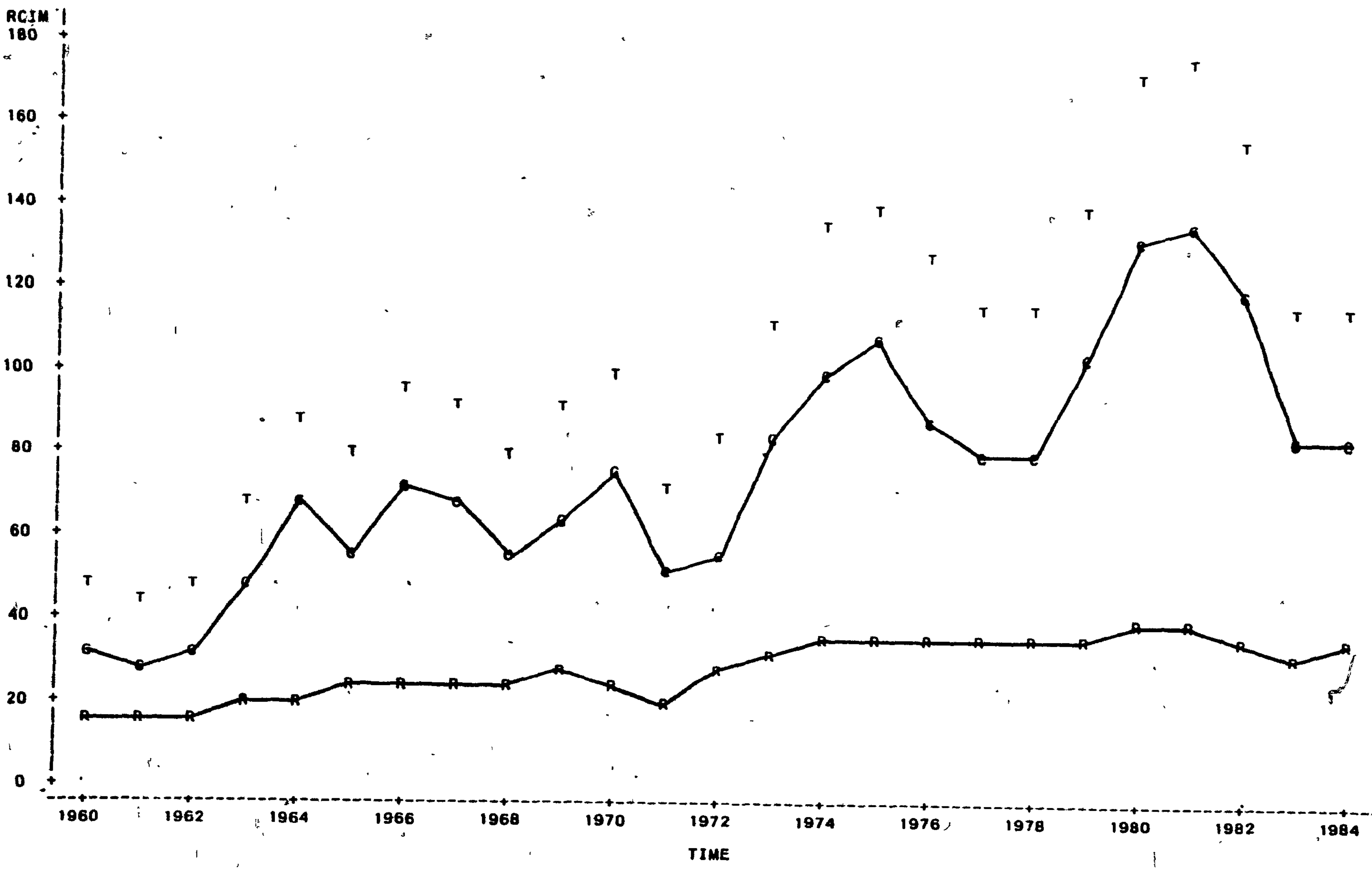
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=PRIMARY METALS



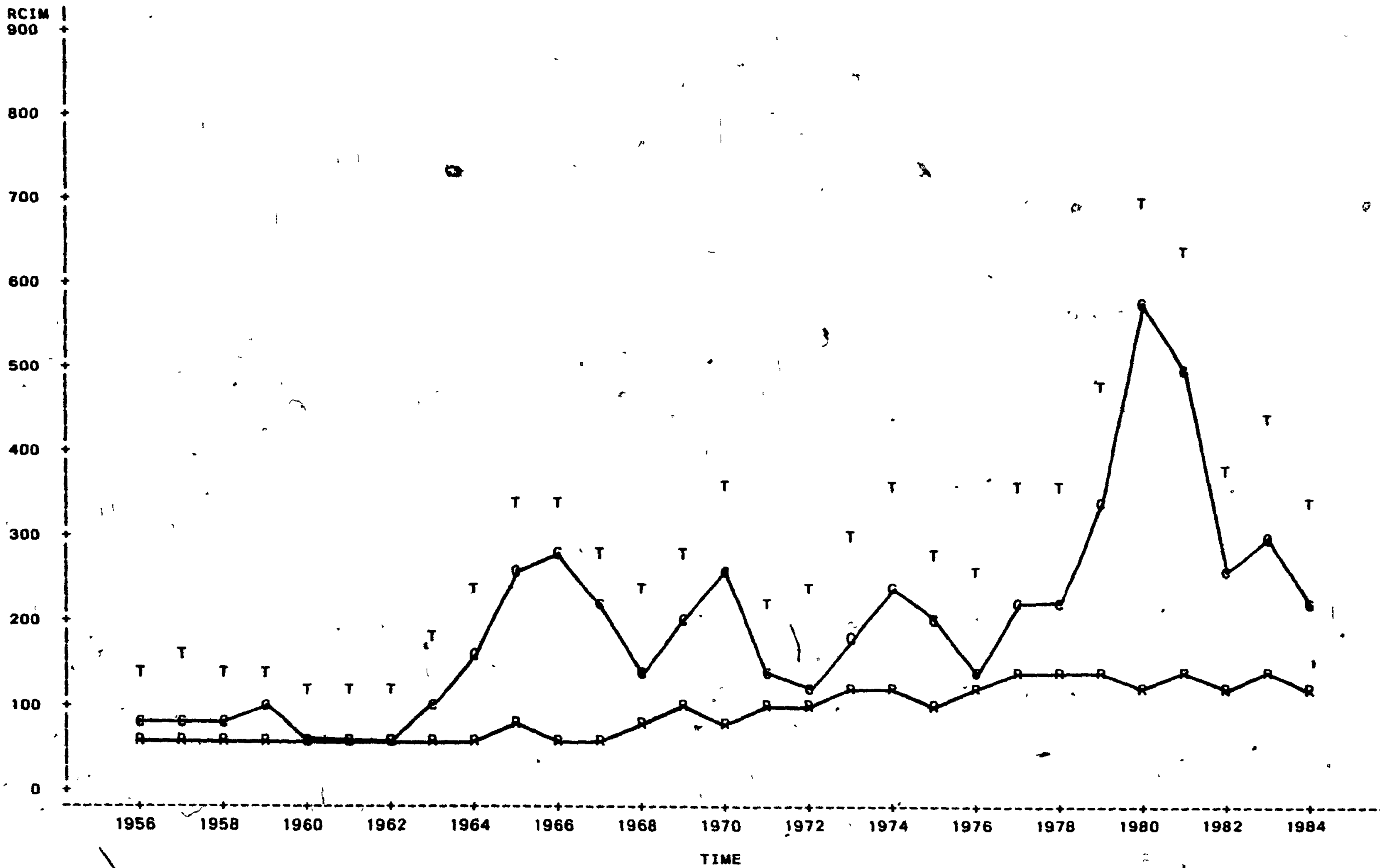
REAL MANUFACTURING CAPITAL, REPAIR AND TOTAL INVESTMENT
INDUSTRY=METAL FABRICATING



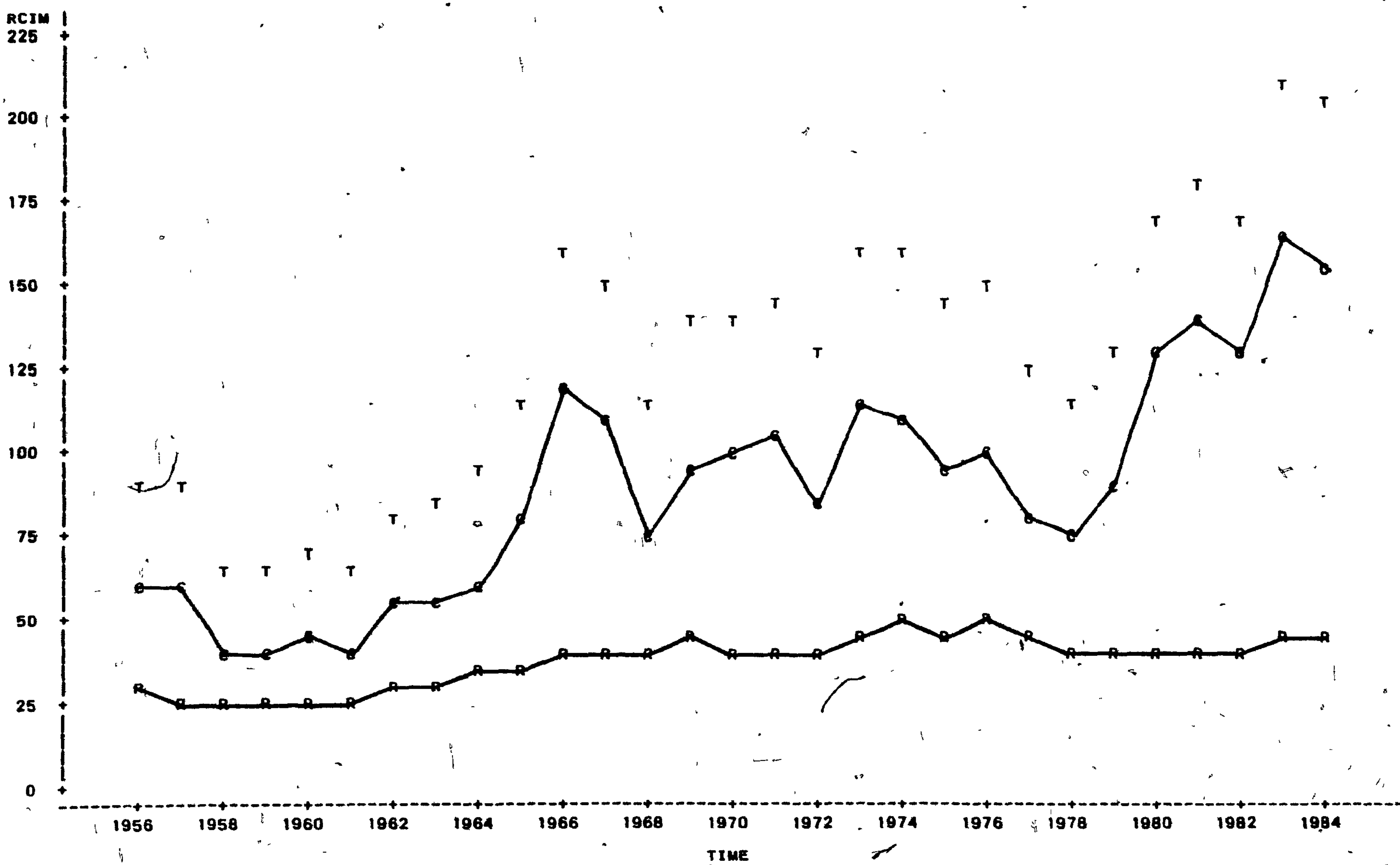
REAL MANUFACTURING CAPITAL, REPAIR AND TOTAL INVESTMENT
INDUSTRY=MACHINERY



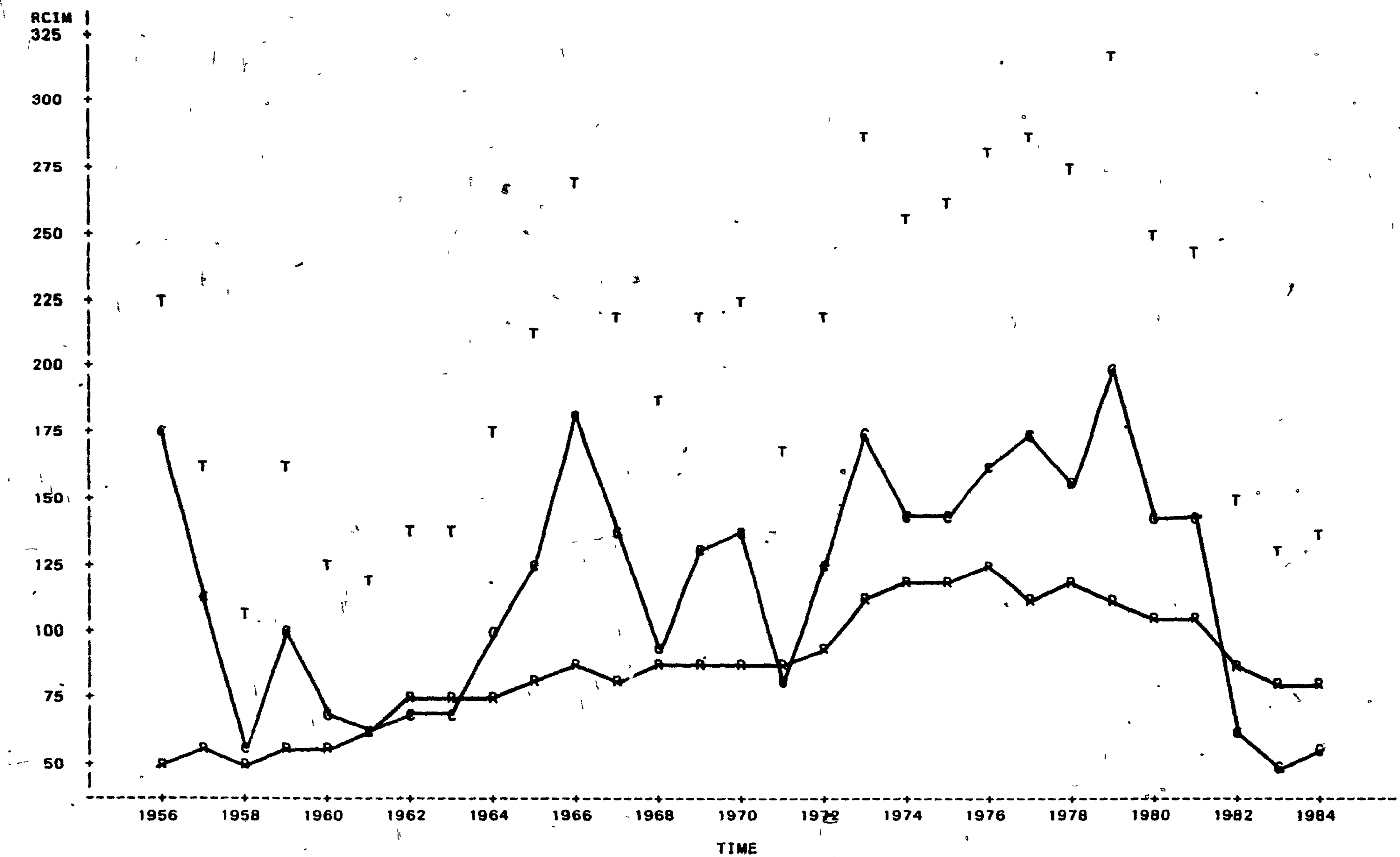
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=TRANSPORT EQUIPMENT



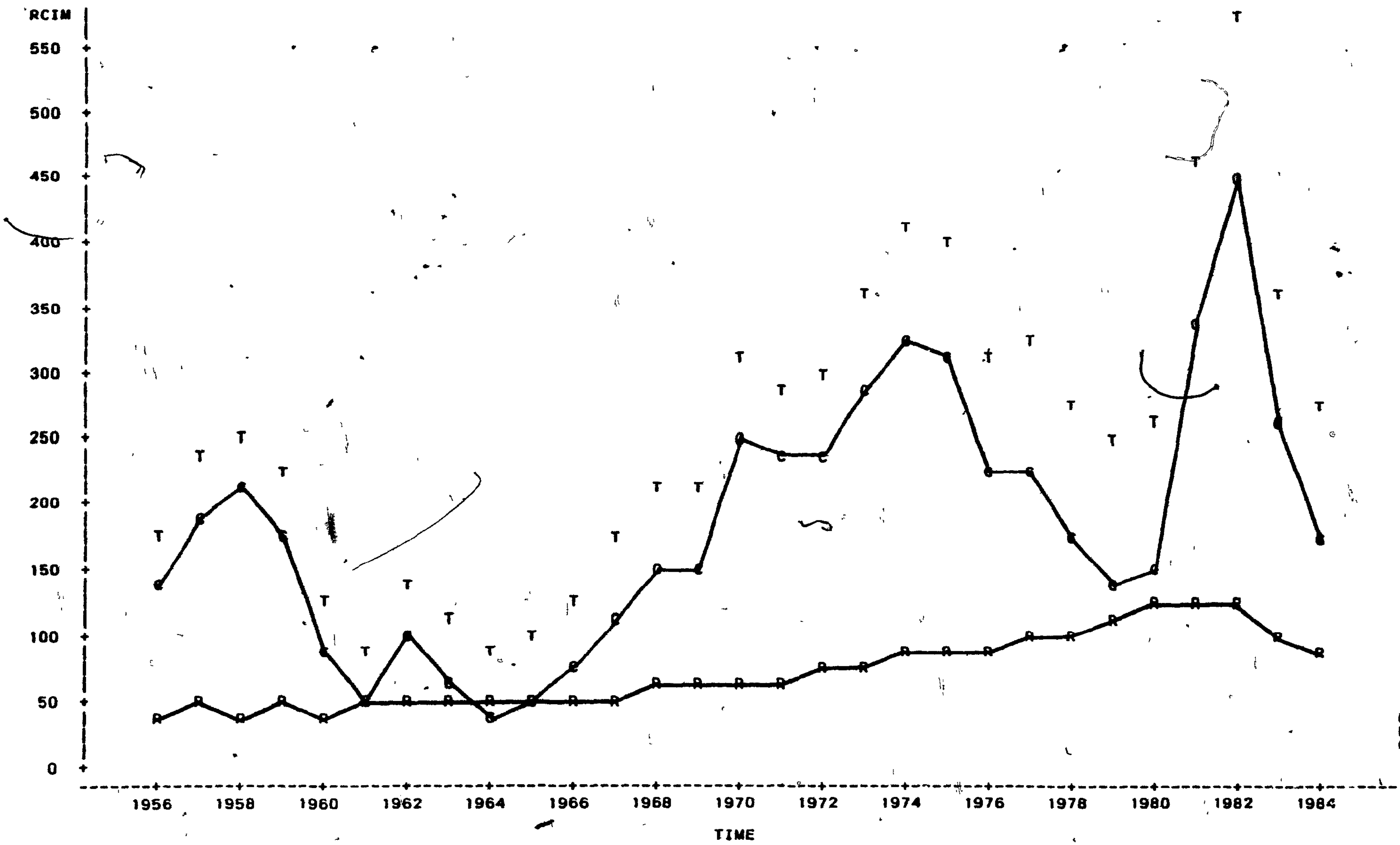
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=ELECTRICAL



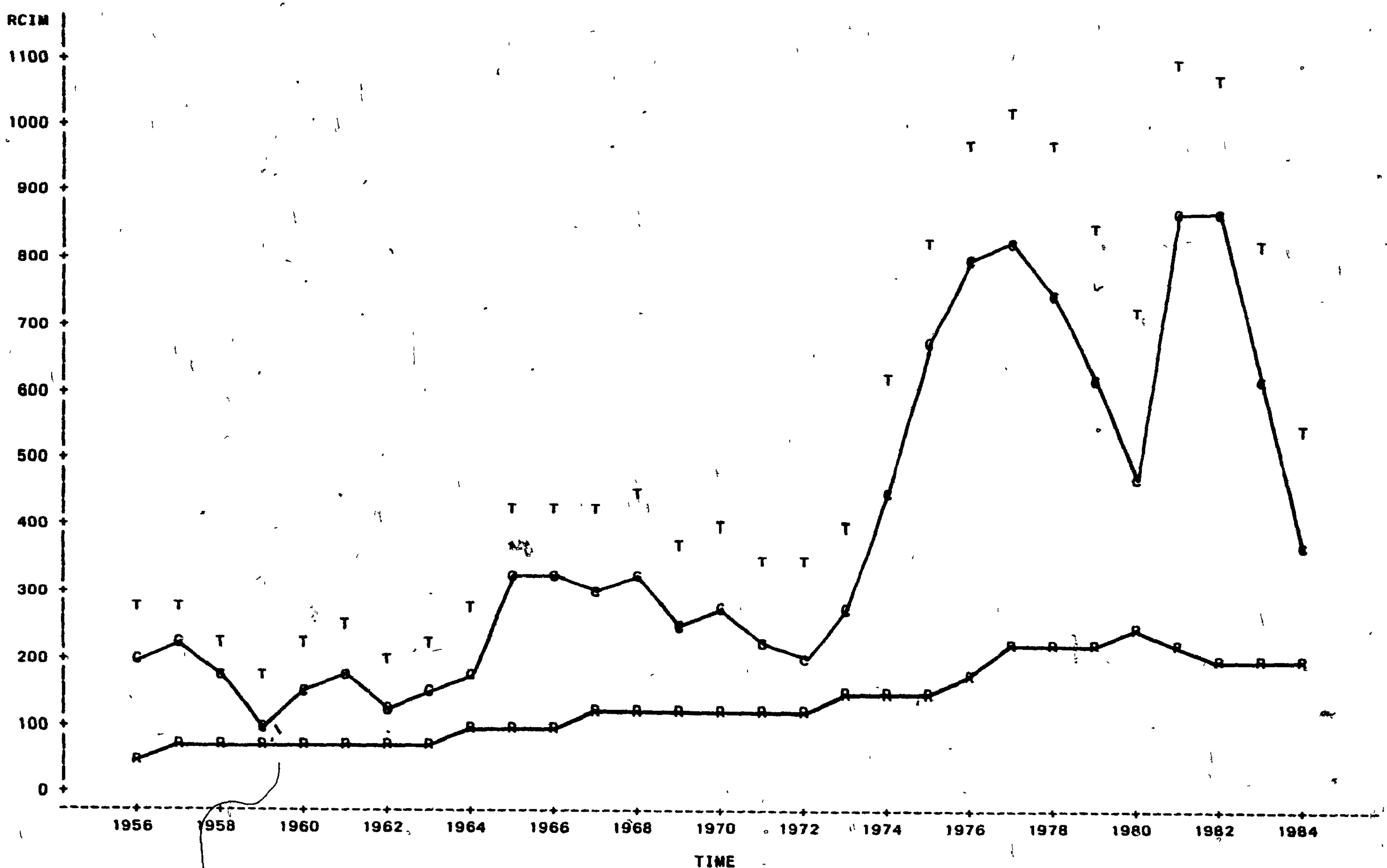
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=NON-METALLIC MINERAL



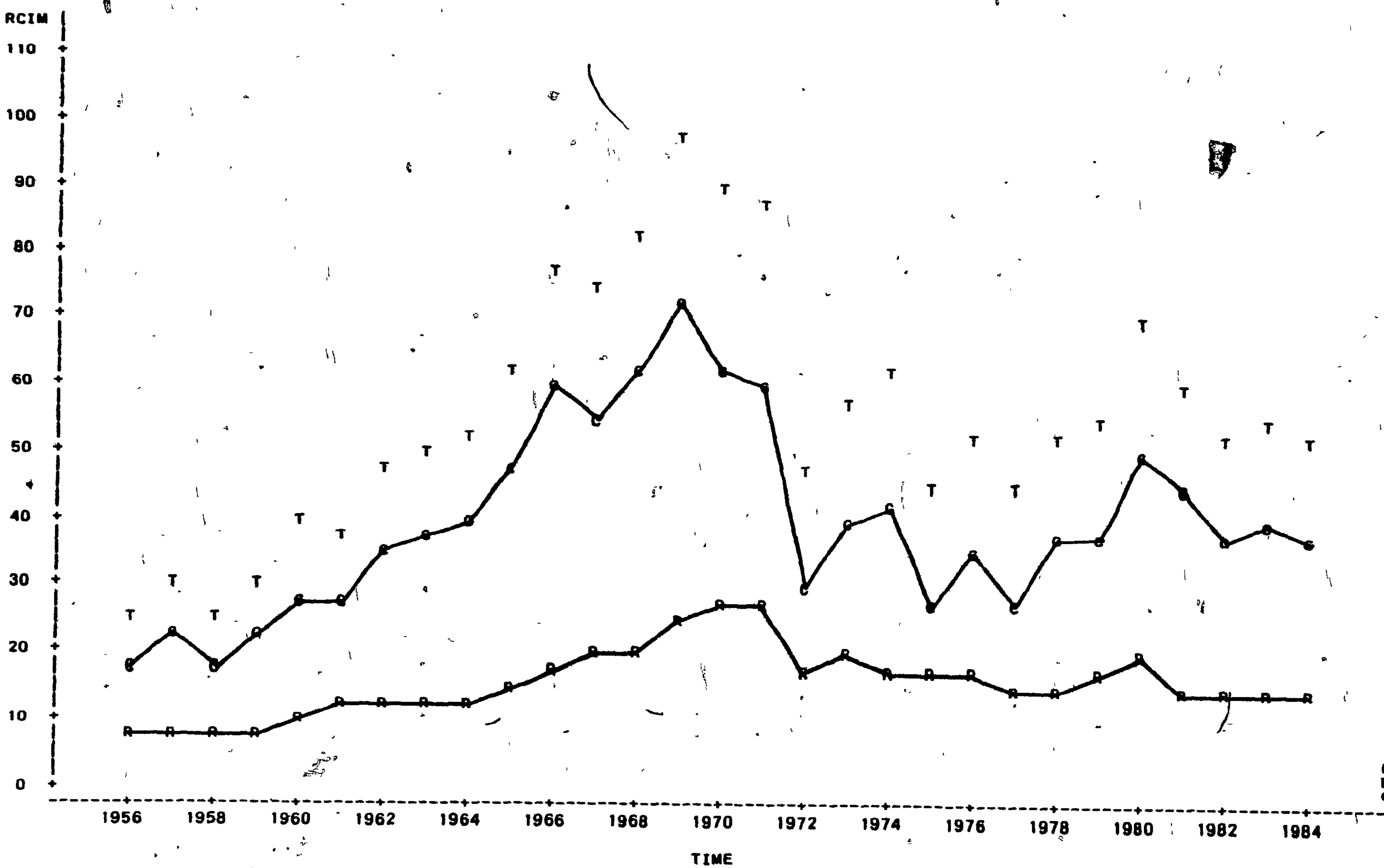
REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=PETROLEUM



REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=CHEMICAL



REAL MANUFACTURING CAPITAL,REPAIR AND TOTAL INVESTMENT
INDUSTRY=MISCELLANEOUS



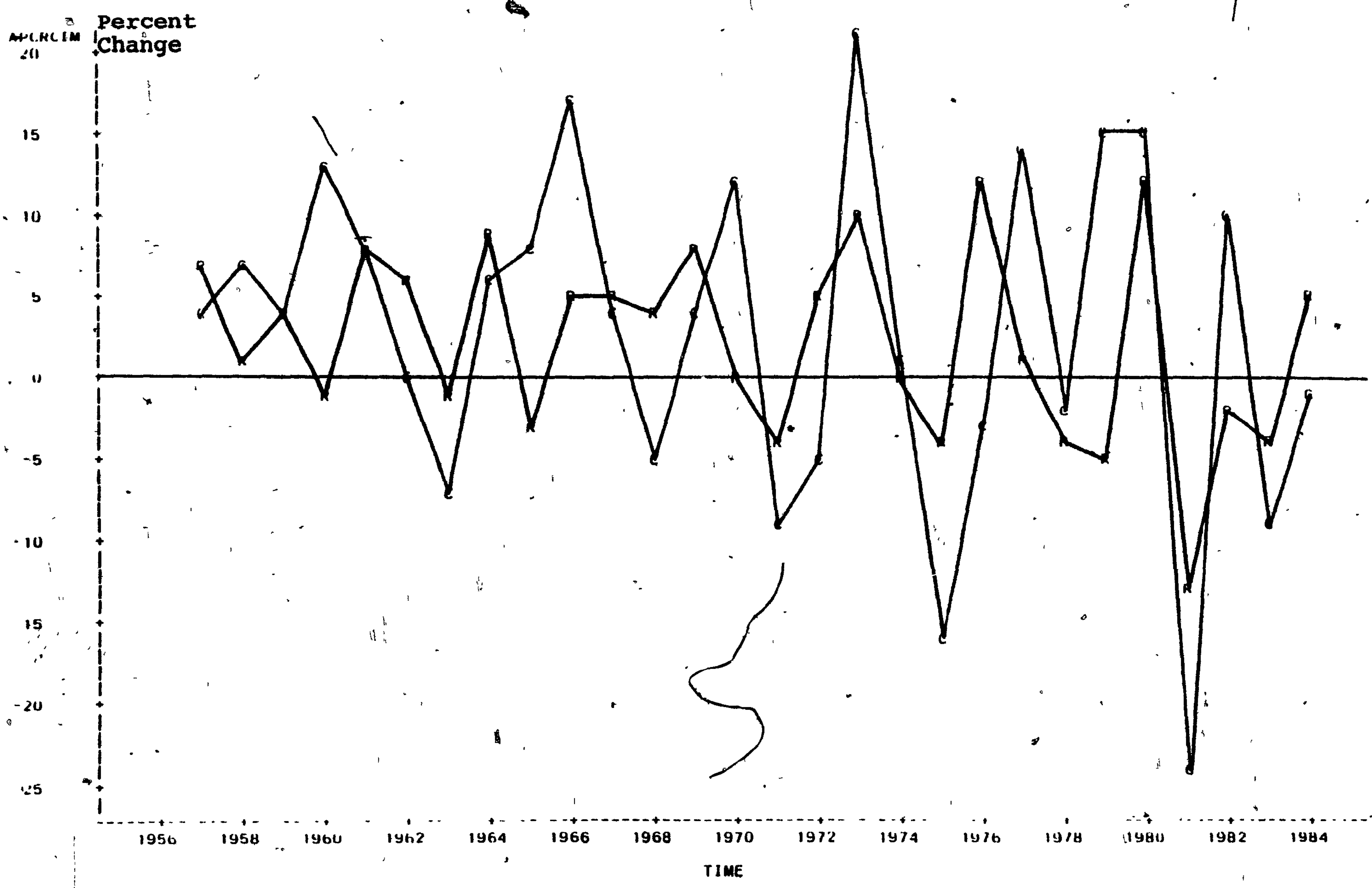
-II-

ANNUAL PERCENT CHANGE IN REAL CAPITAL

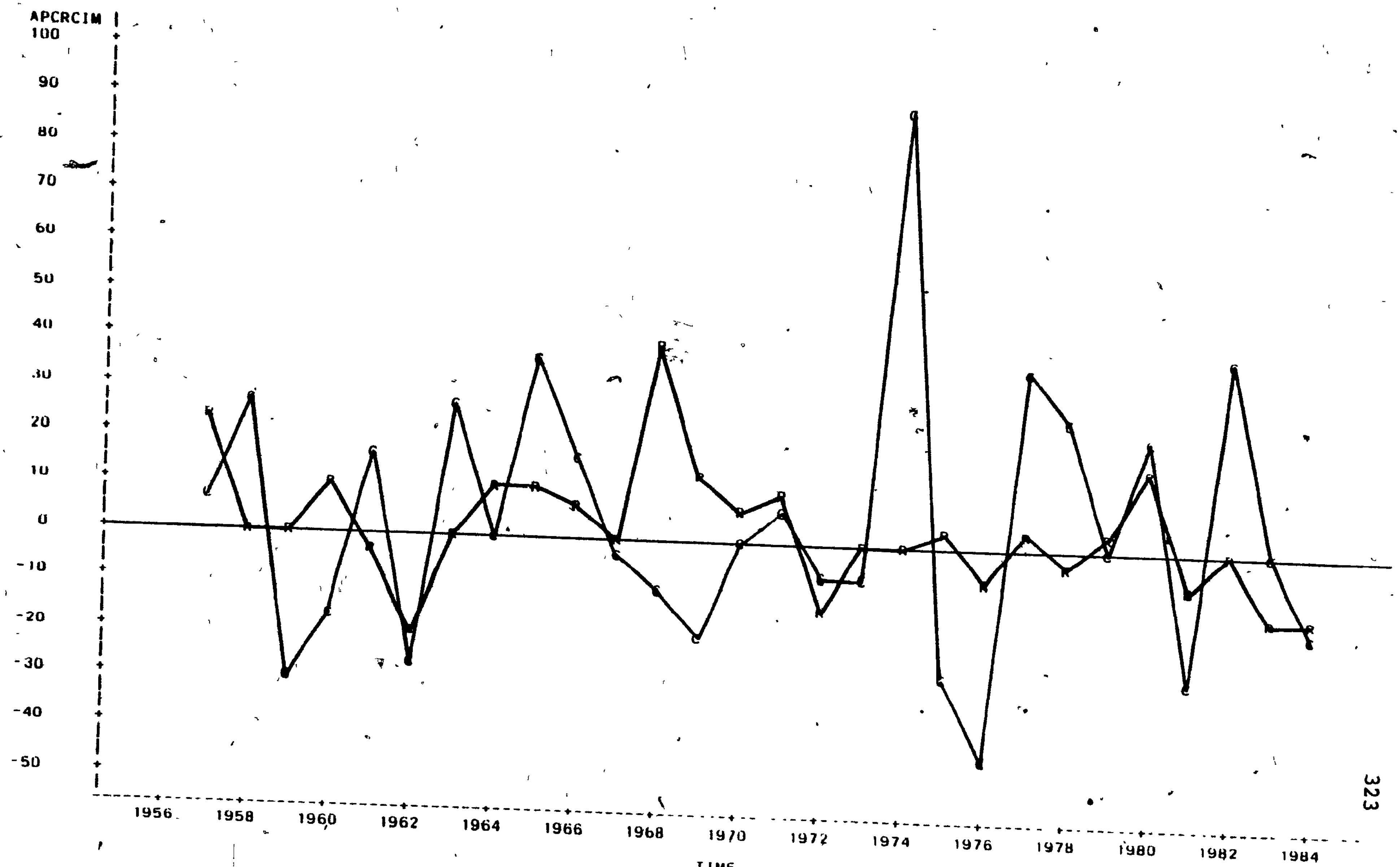
VS. REAL REPAIR INVESTMENT EXPENDITURES,

BY MANUFACTURING INDUSTRY

ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=FOOD

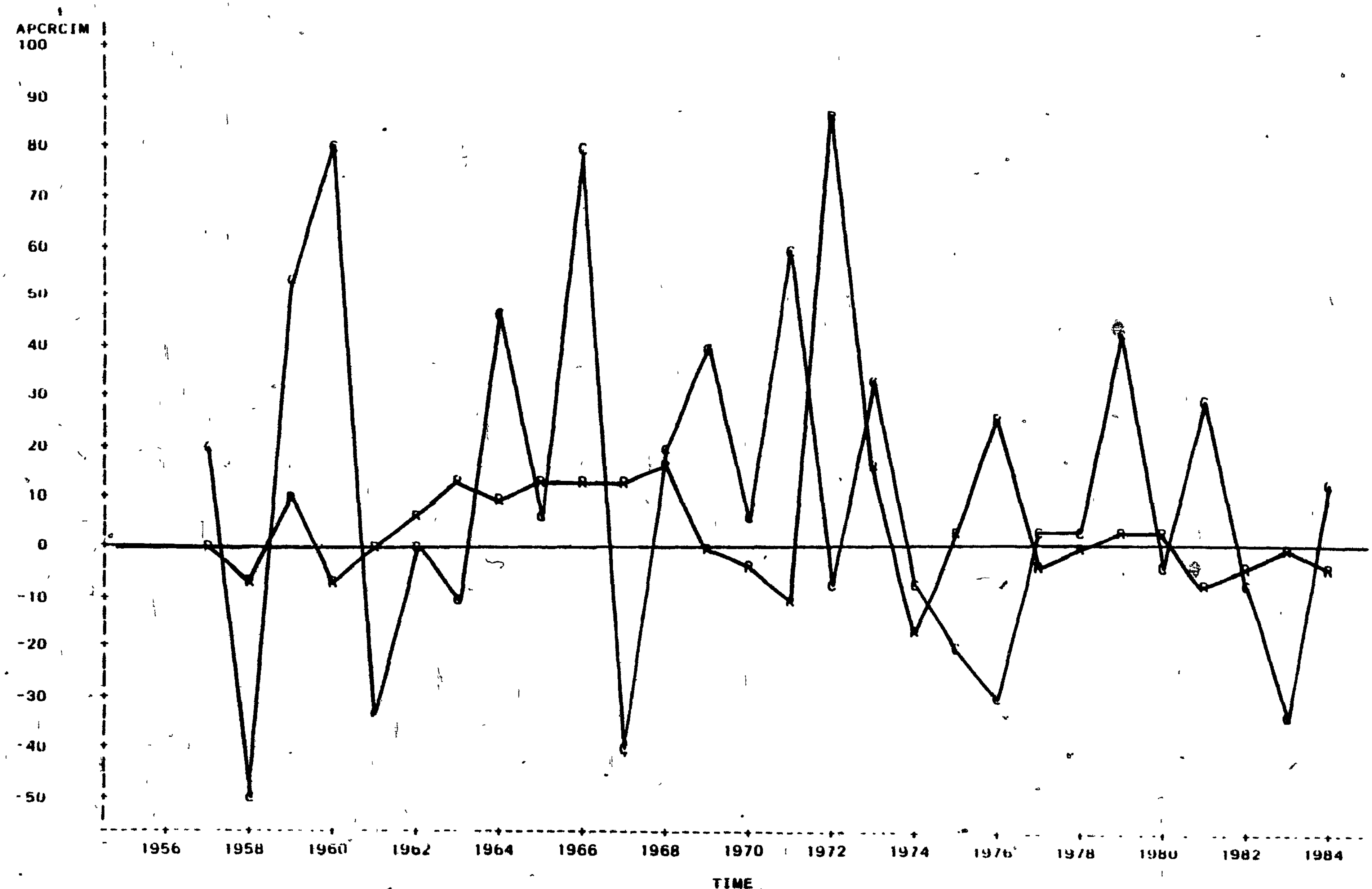


ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=TOBACCO



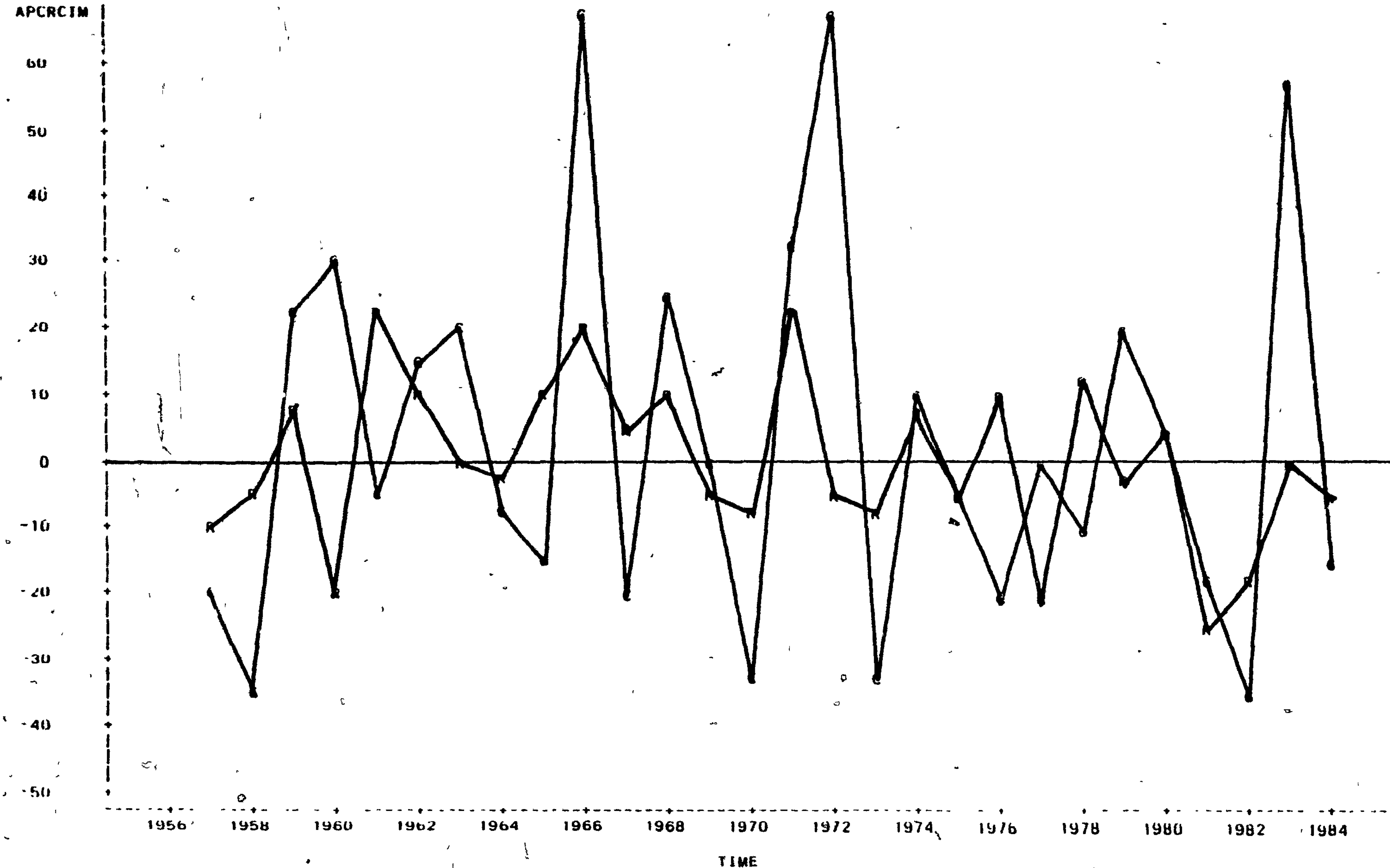
NOTE: 2 OBS HAD MISSING VALUES

ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=RUBBER

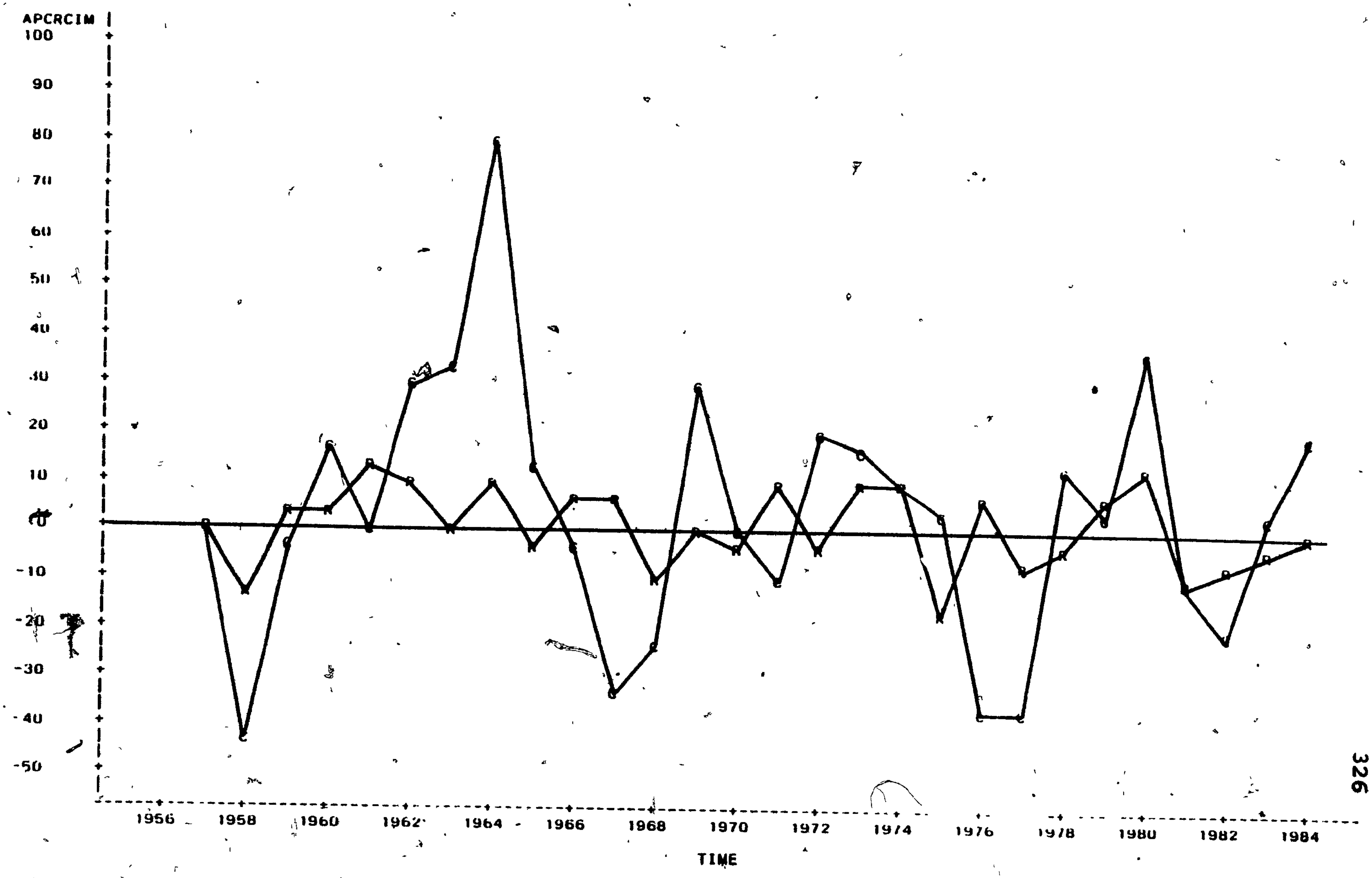


ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=LEATHER

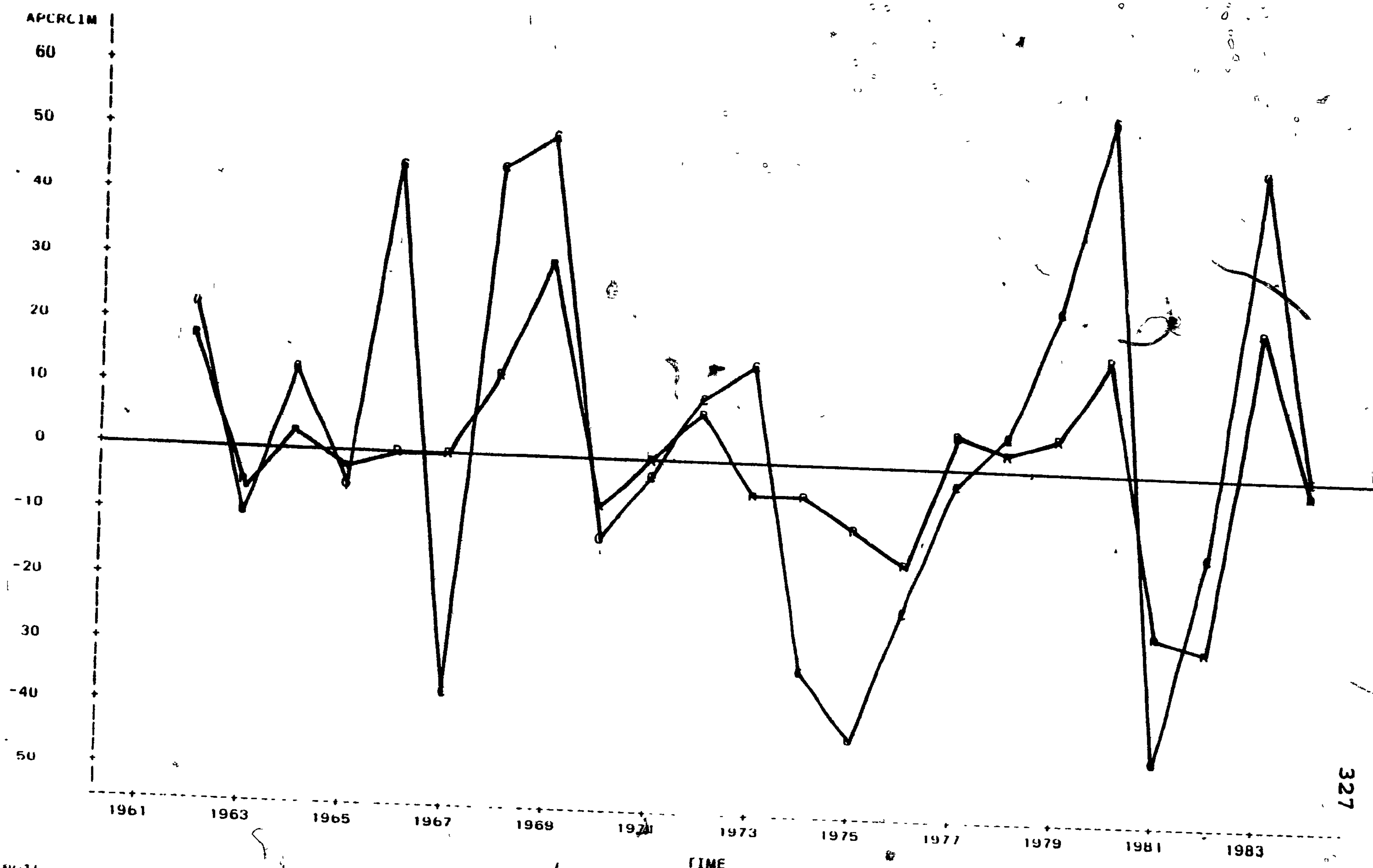
PLOT OF APCRCIM*TIME   SYMBOL USED IS C
PLOT OF APCRRIM*TIME   SYMBOL USED IS R



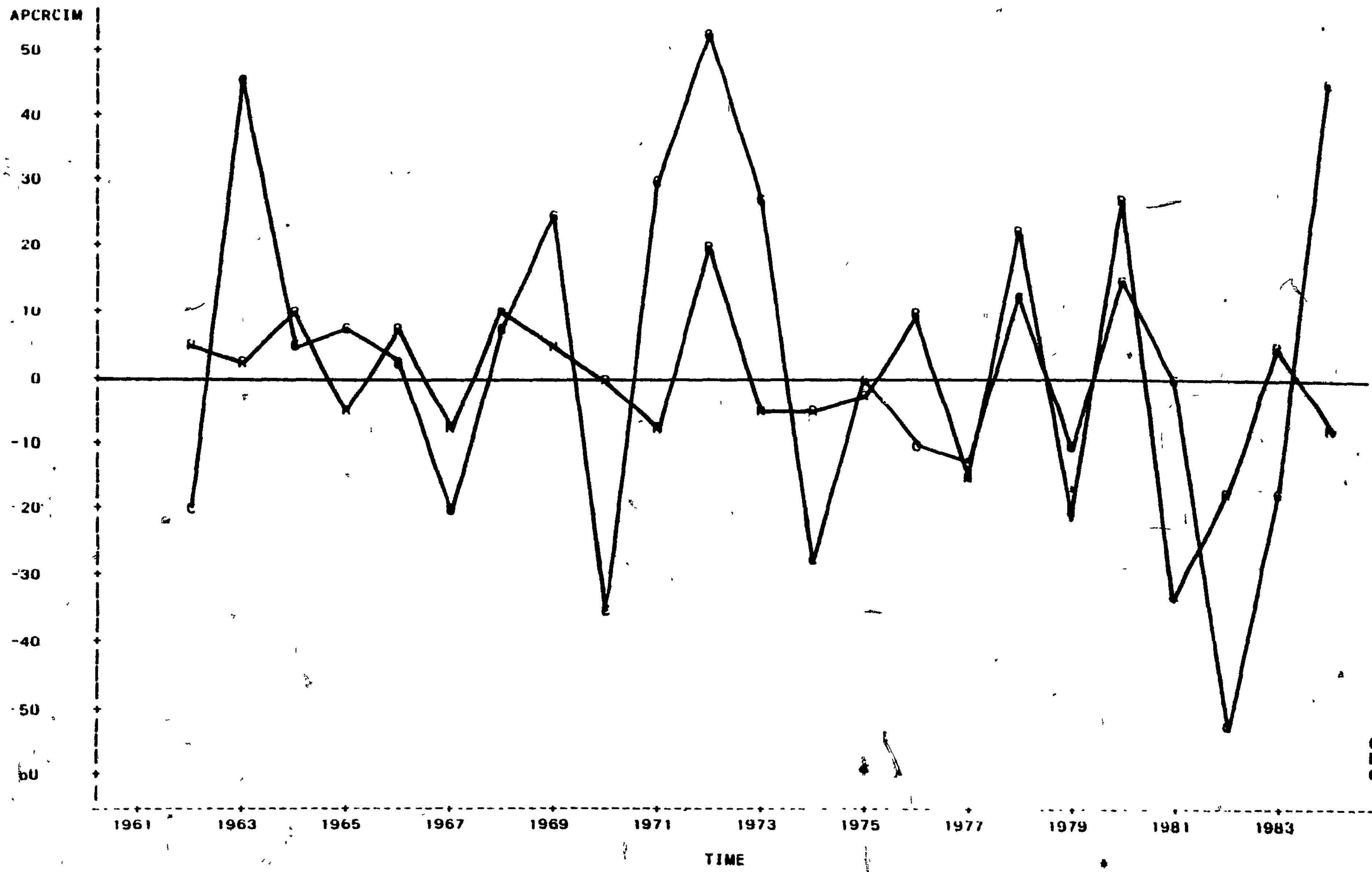
ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=TEXTILES

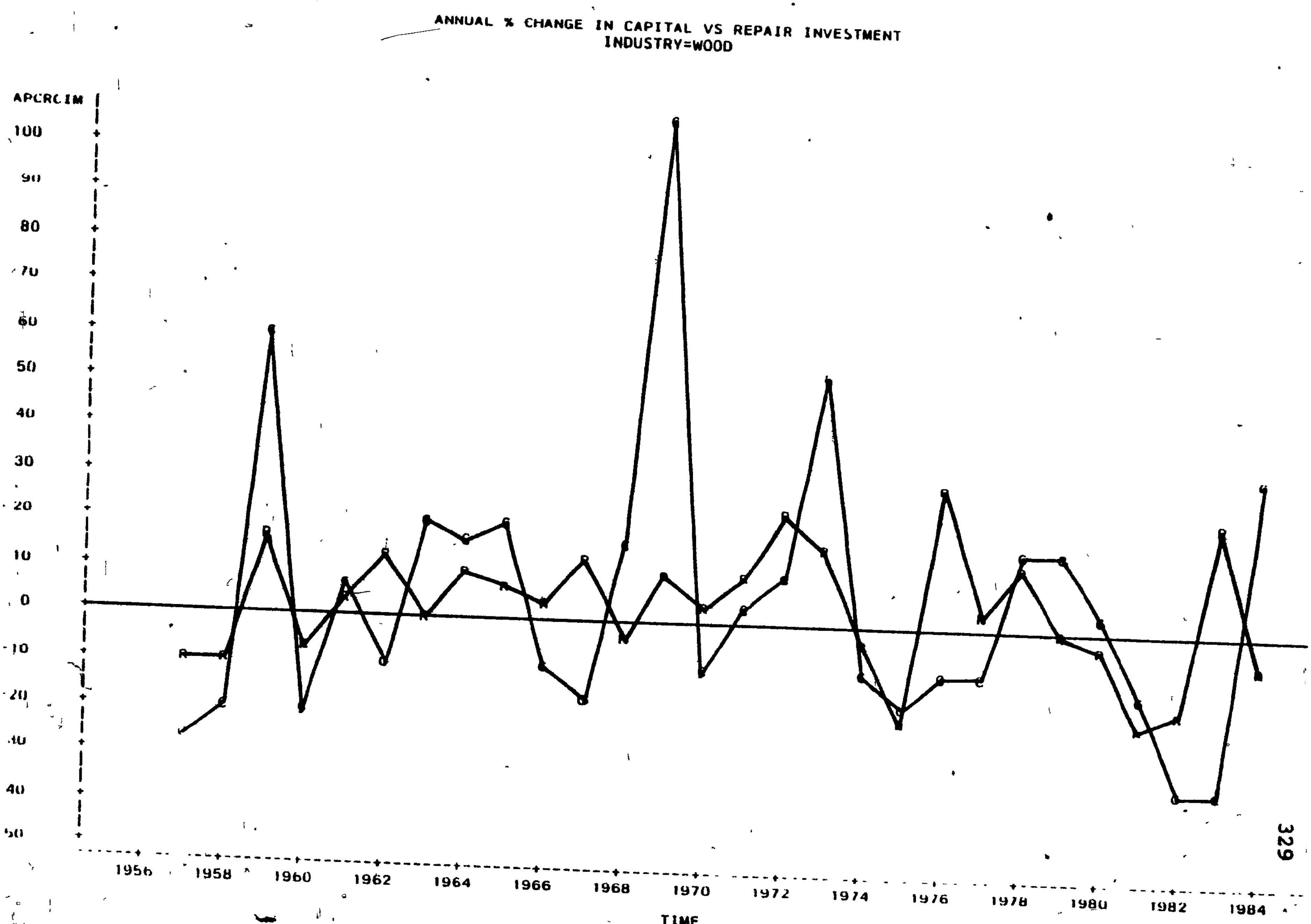


ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=KNITTING MILLS

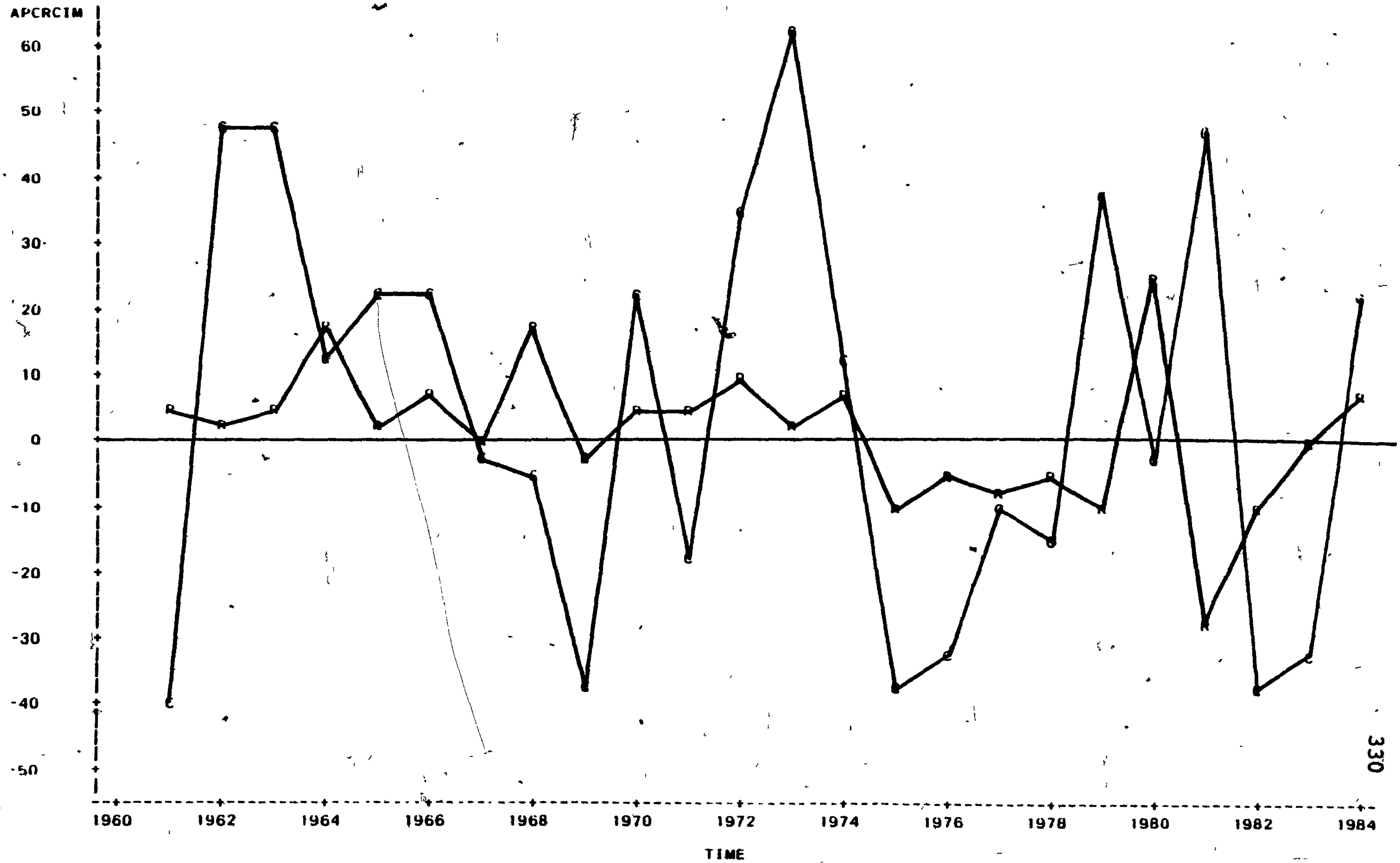


ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=CLOTHING



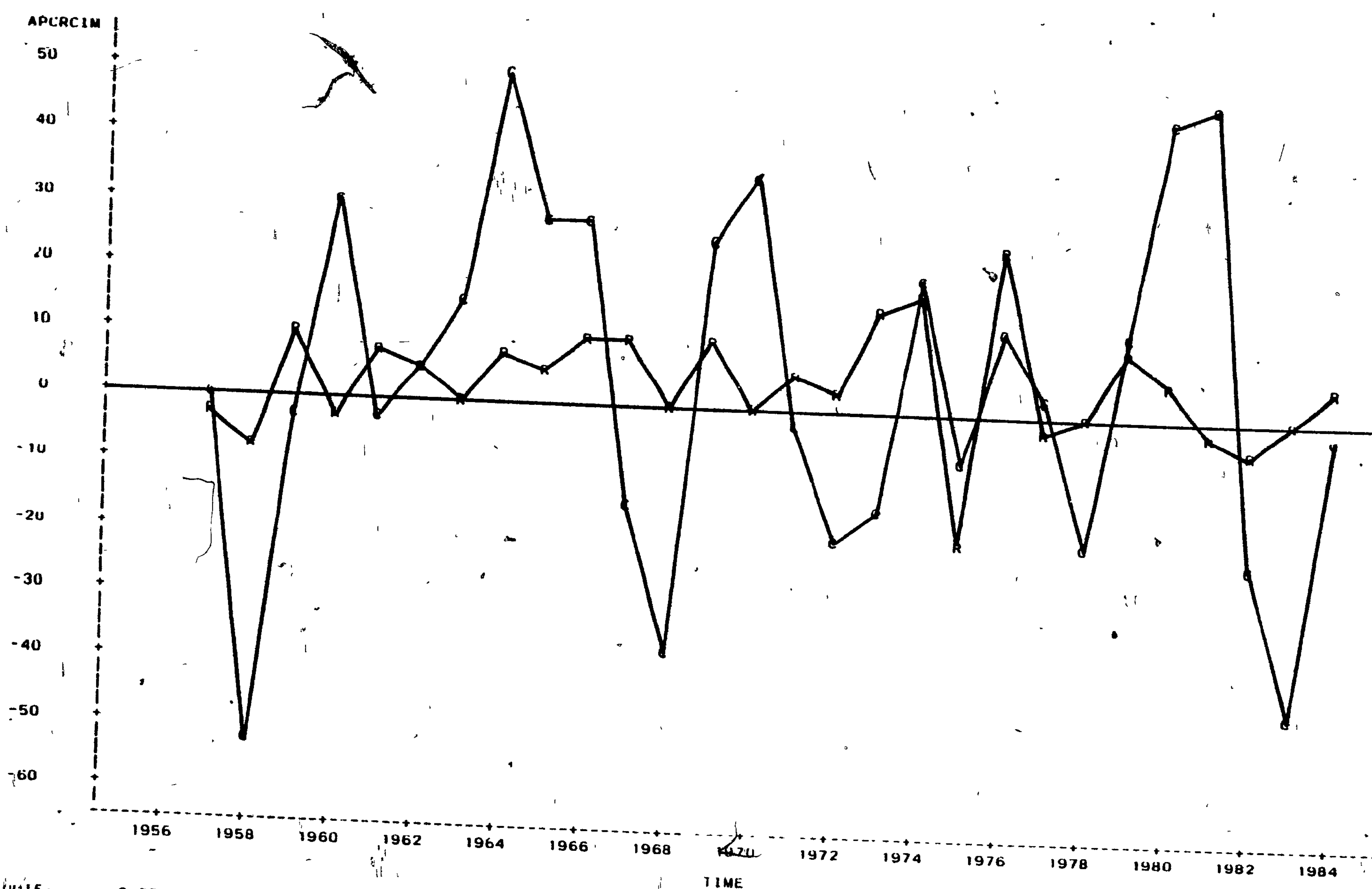

ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=WOOD
APCRCIM
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
TIME

ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=FURNITURE

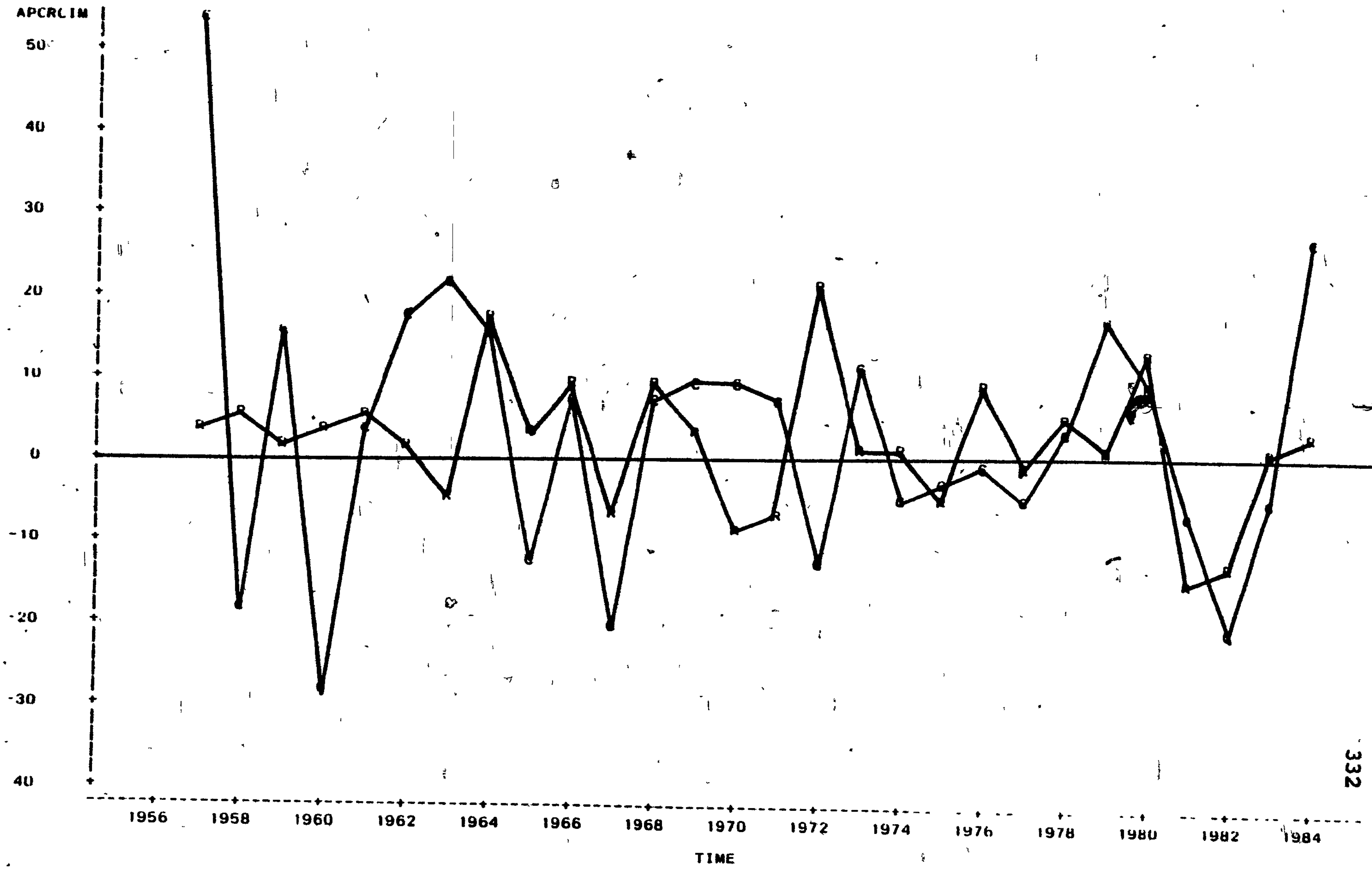


10

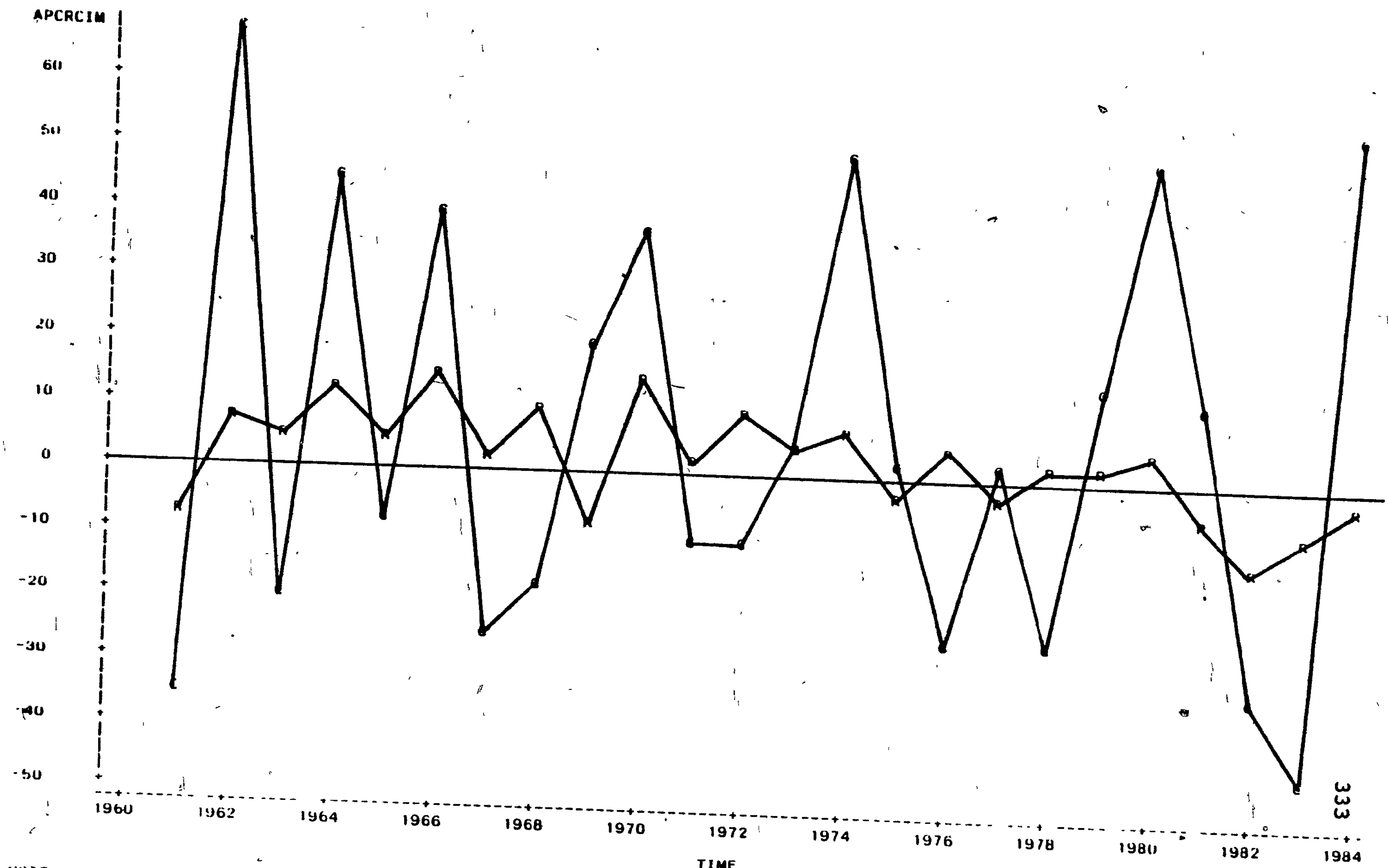
ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=PAPER



ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=PRINTING

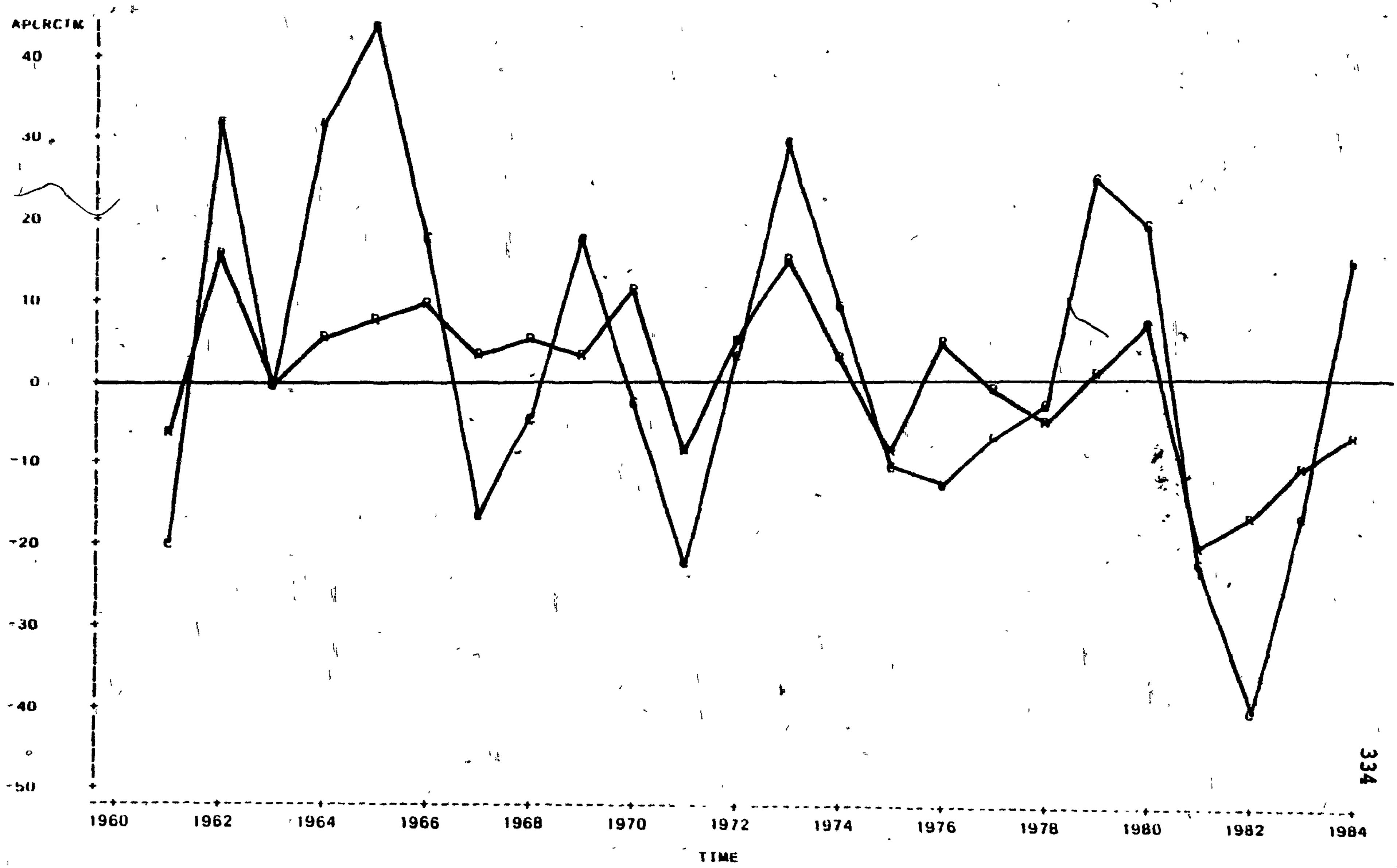


ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=PRIMARY METALS



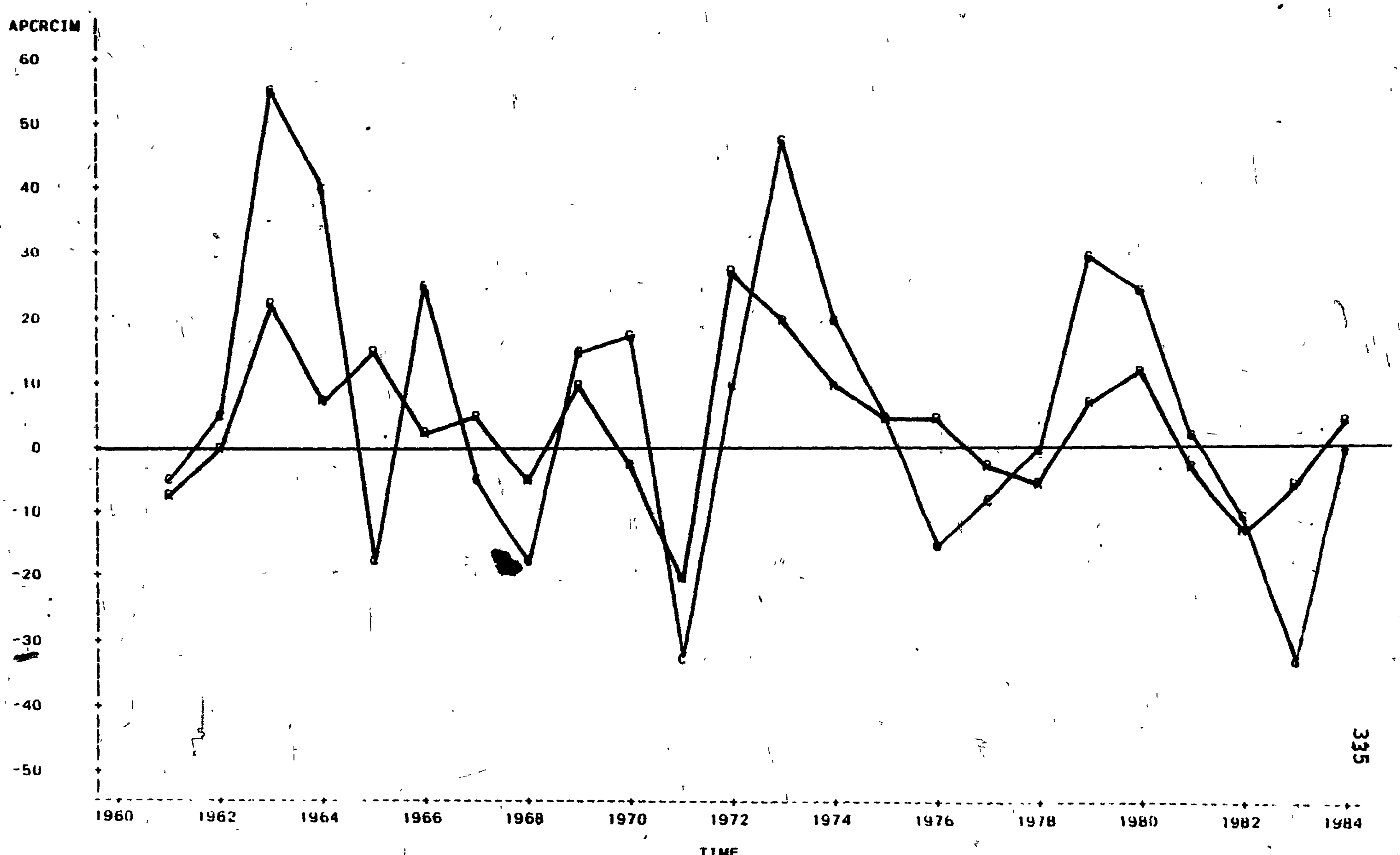
NOTE: 2 OBS HAD MISSING VALUES

ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=METAL FABRICATING

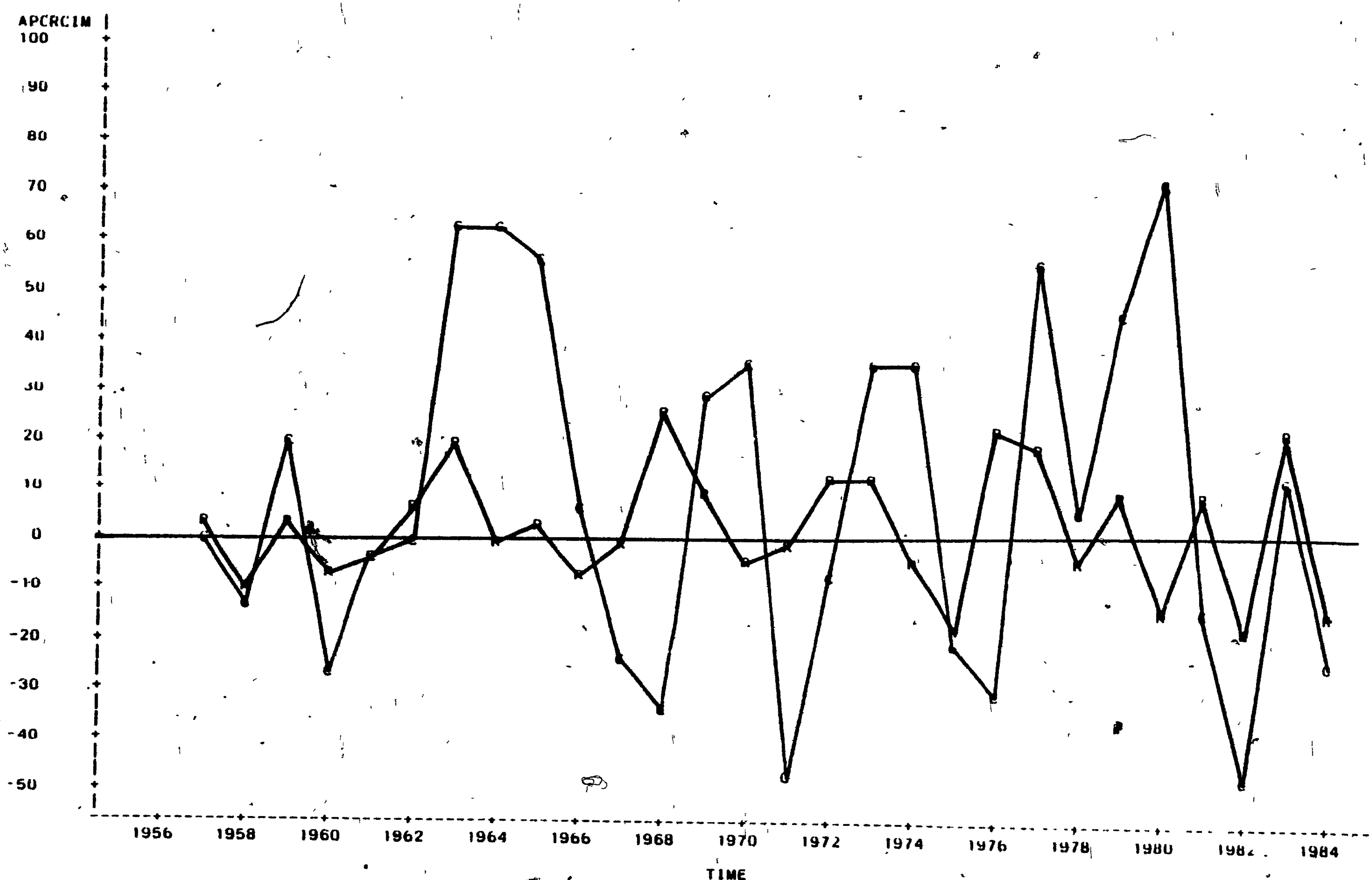


NOTE: 2 OBS HAD MISSING VALUES

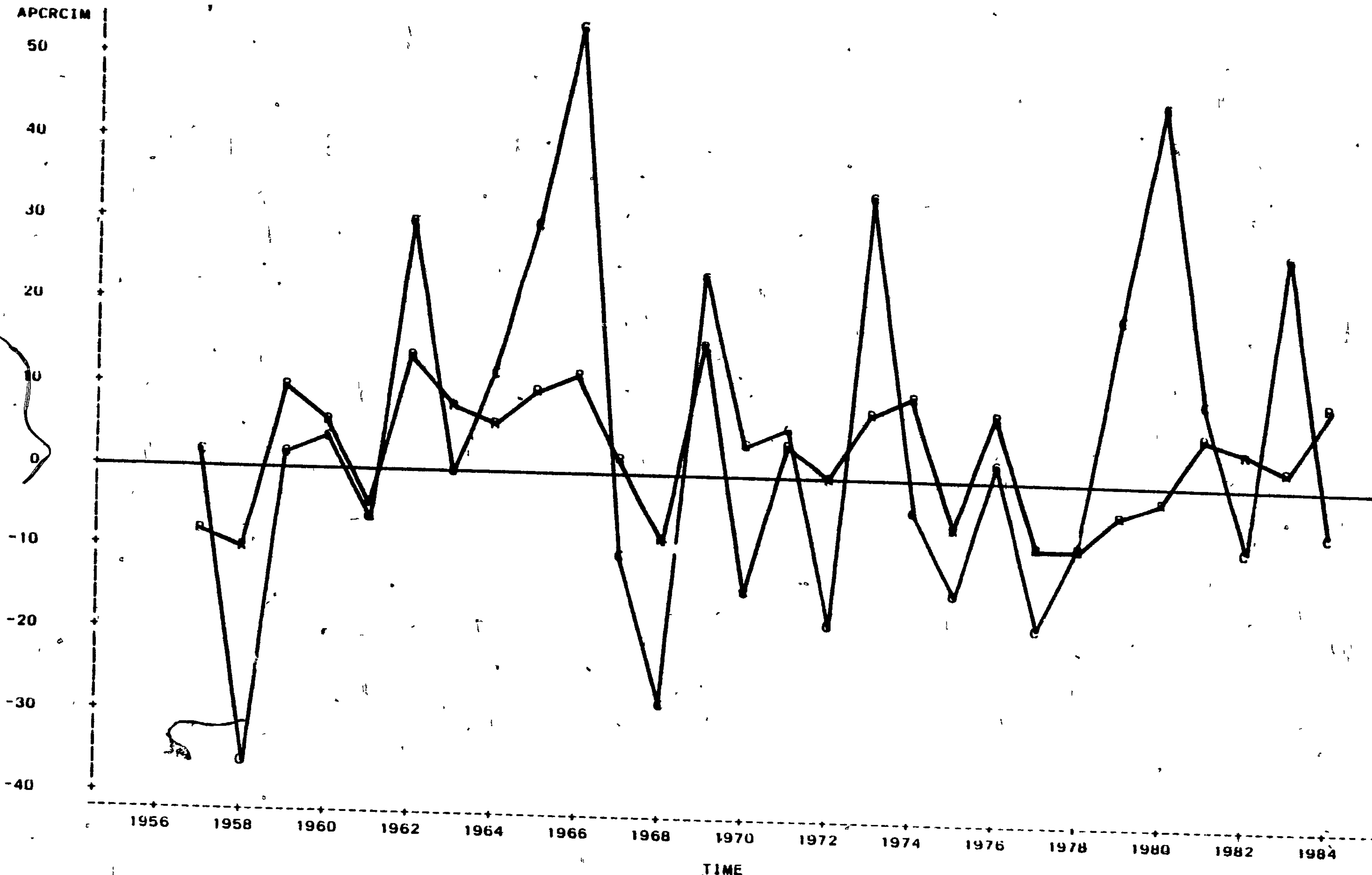
ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=MACHINERY



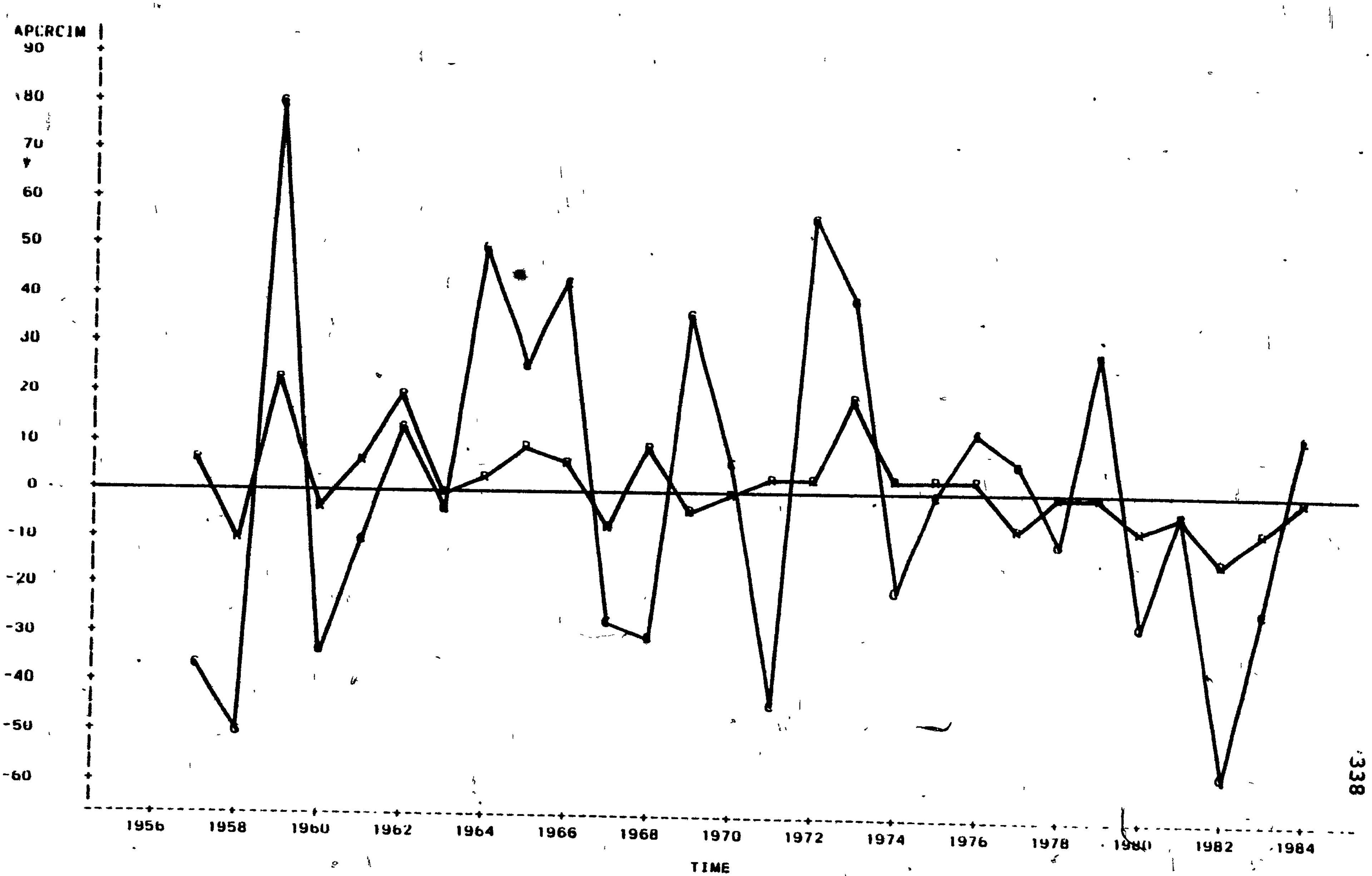
ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=TRANSPORT EQUIPMENT

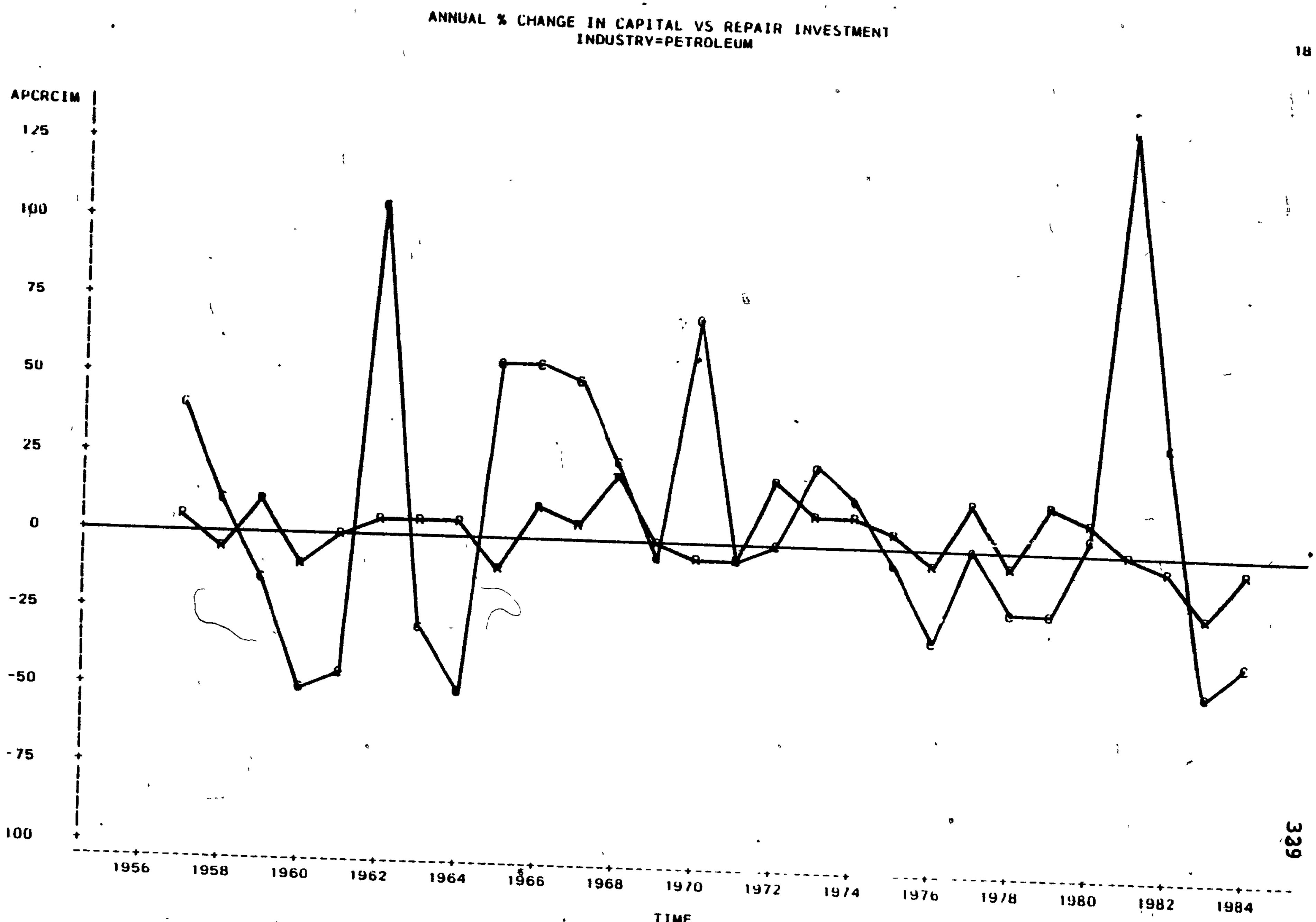


ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=ELECTRICAL



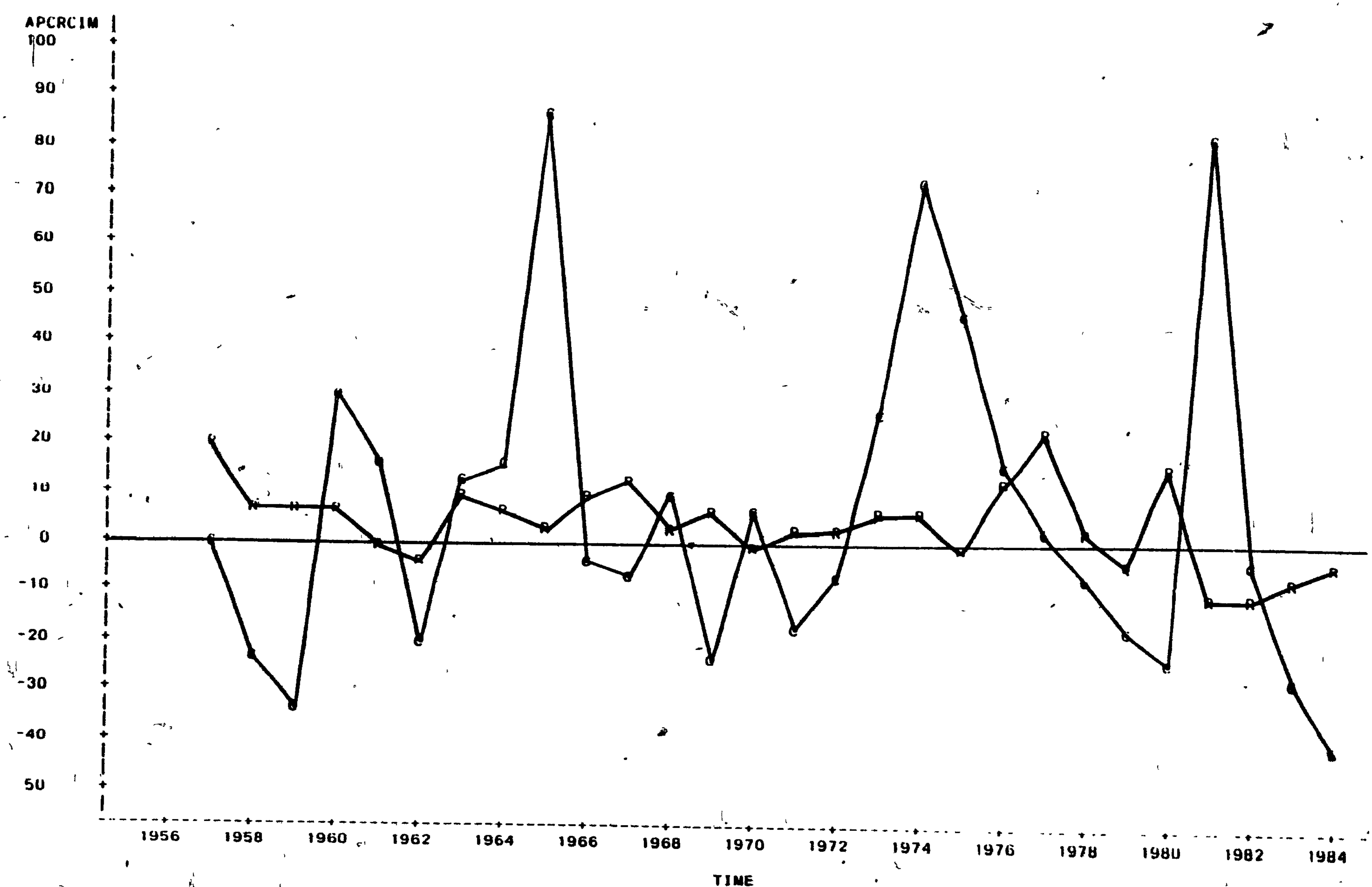
ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=NON-METALLIC MINERAL



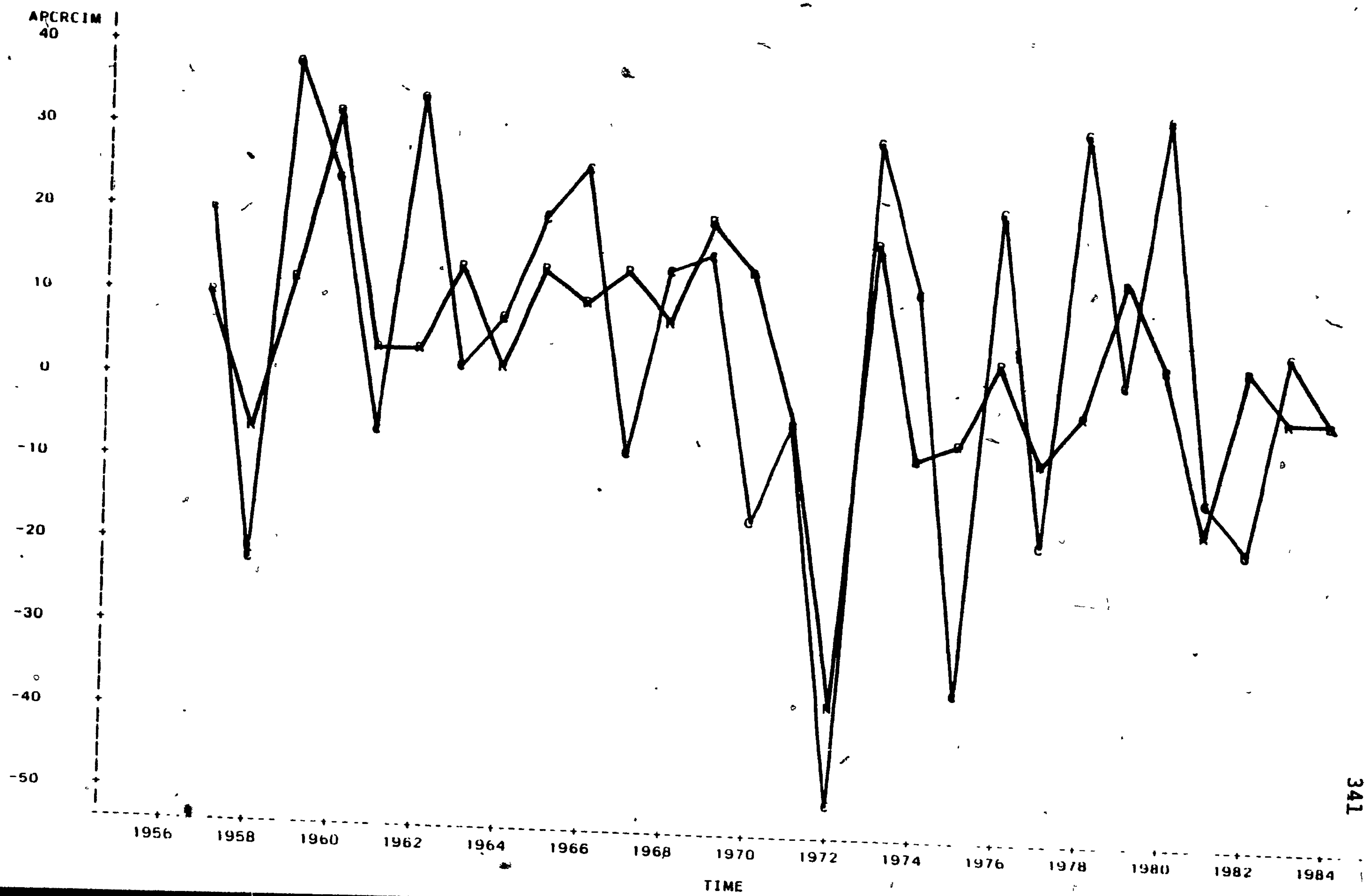

ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=PETROLEUM
APCRCIM
125
100
75
50
25
0
-25
-50
-75
100
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
TIME

19.

ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=CHEMICAL



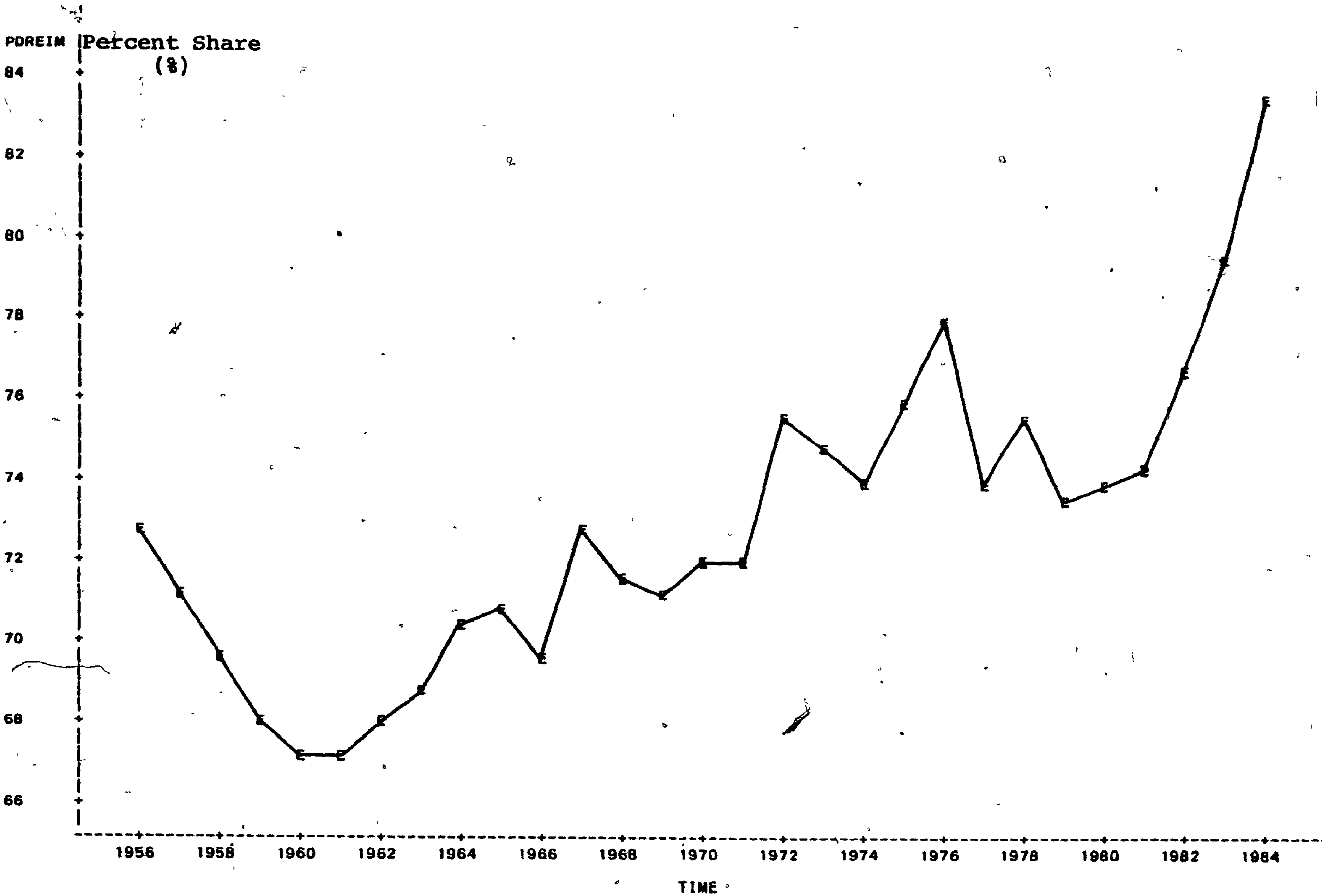
ANNUAL % CHANGE IN CAPITAL VS REPAIR INVESTMENT
INDUSTRY=MISCELLANEOUS



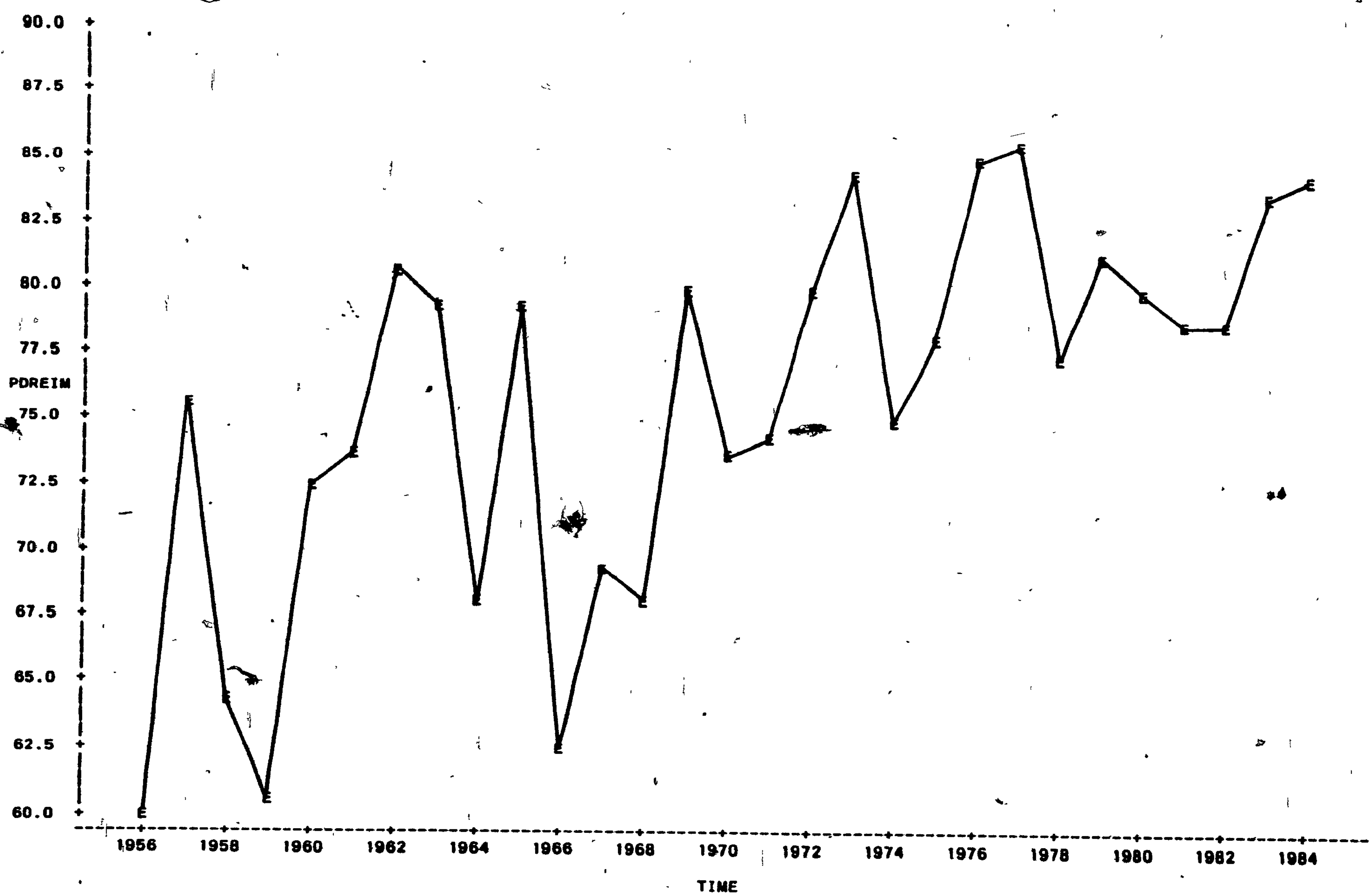
APPENDIX E

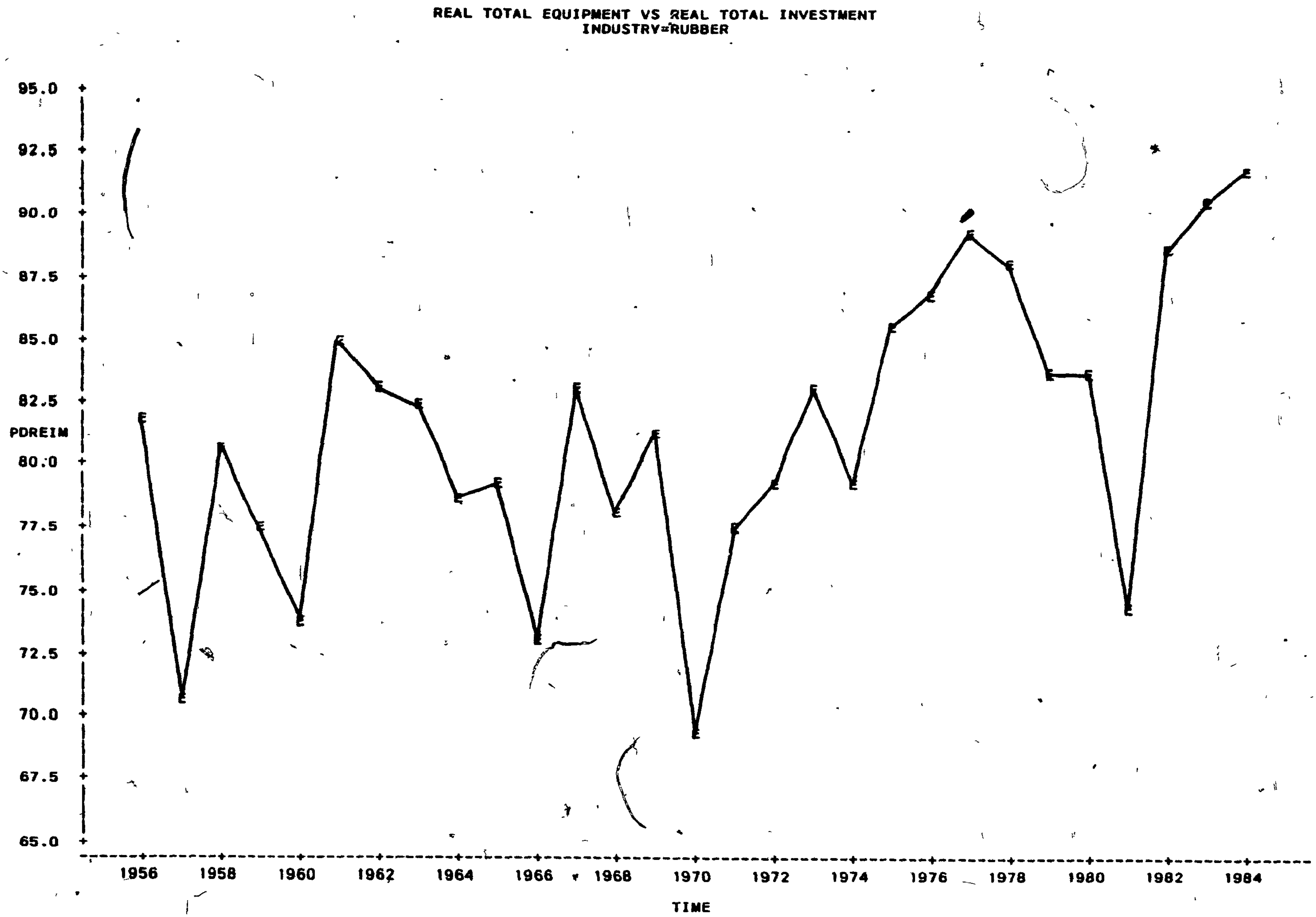
MACHINERY & EQUIPMENT EXPENDITURES AS A SHARE OF TOTAL MANUFACTURING INVESTMENT, BY TWO-DIGIT SIC INDUSTRIES: 1956-1984

REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=FOOD

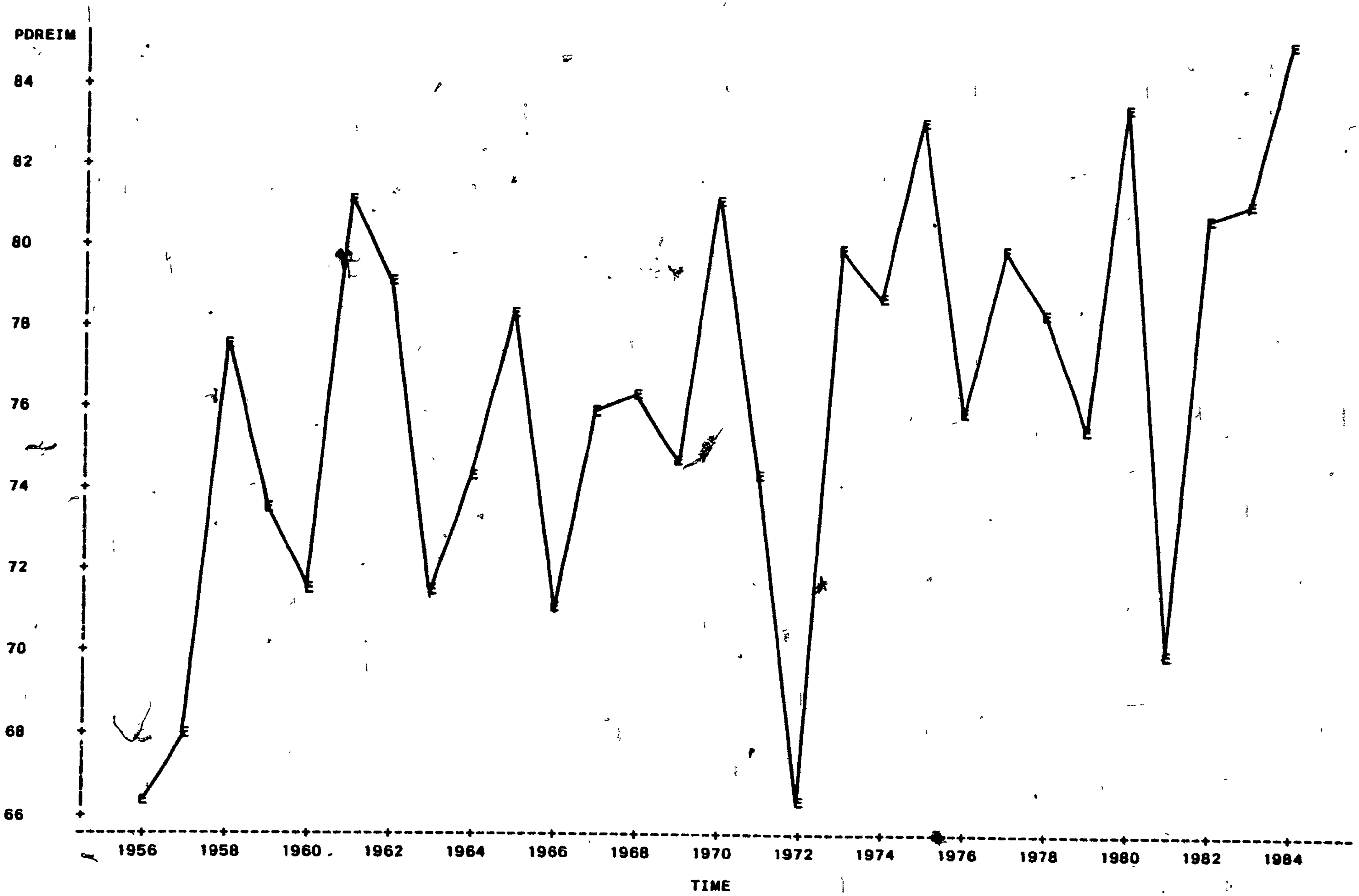


REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=TOBACCO

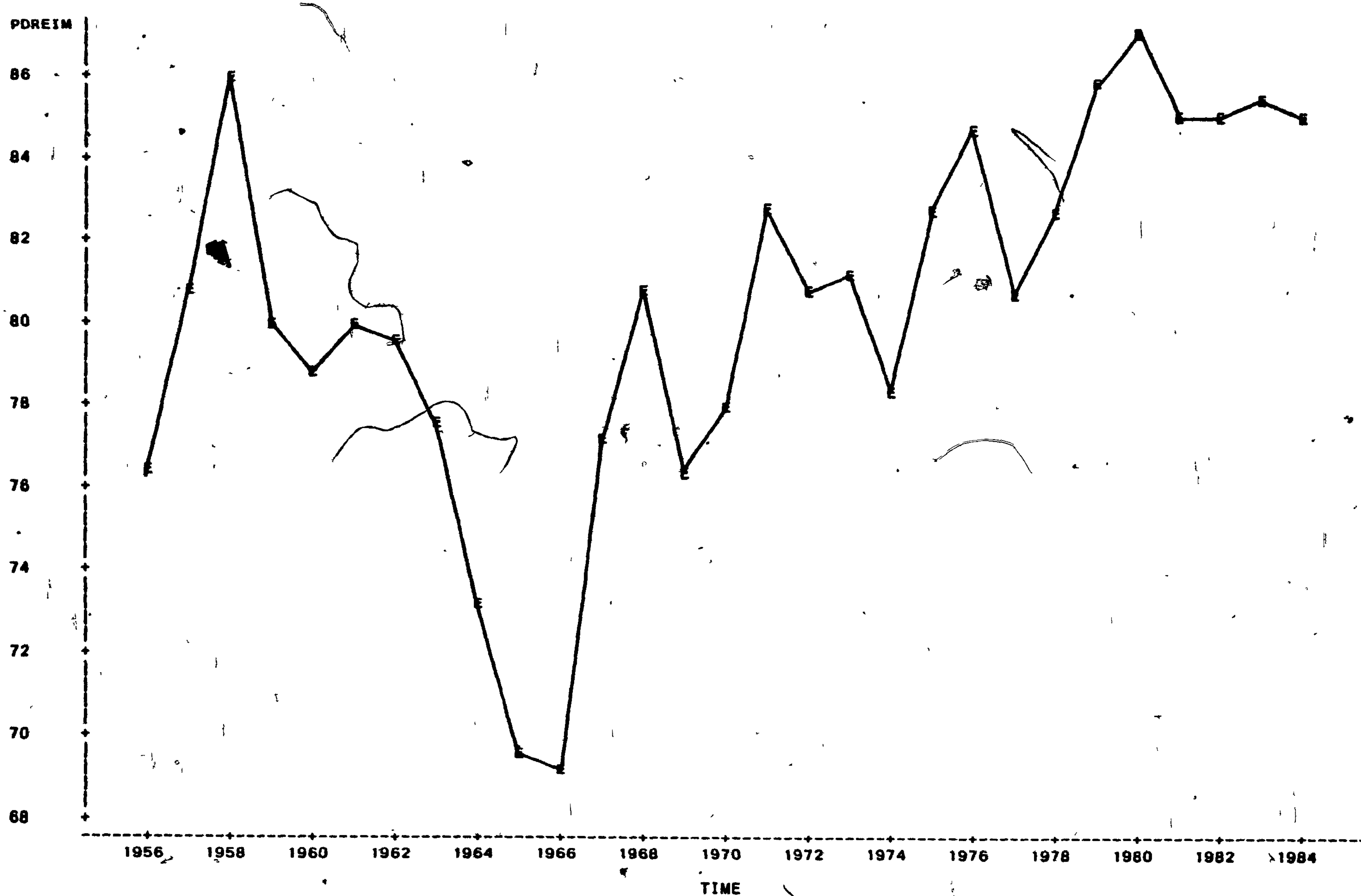



REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=RUBBER
PDREIM
95.0
92.5
90.0
87.5
85.0
82.5
80.0
77.5
75.0
72.5
70.0
67.5
65.0
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
TIME

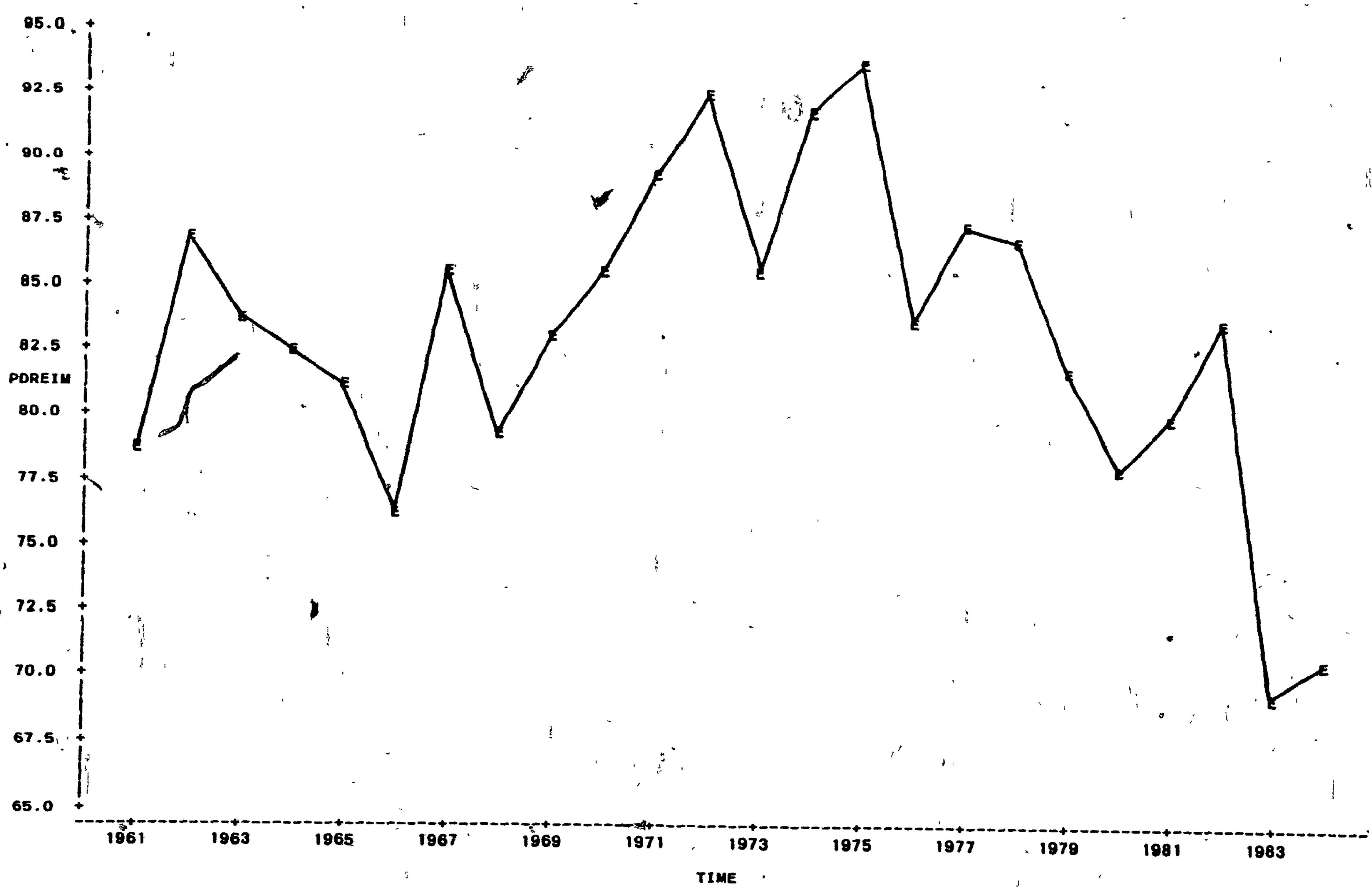
REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=LEATHER



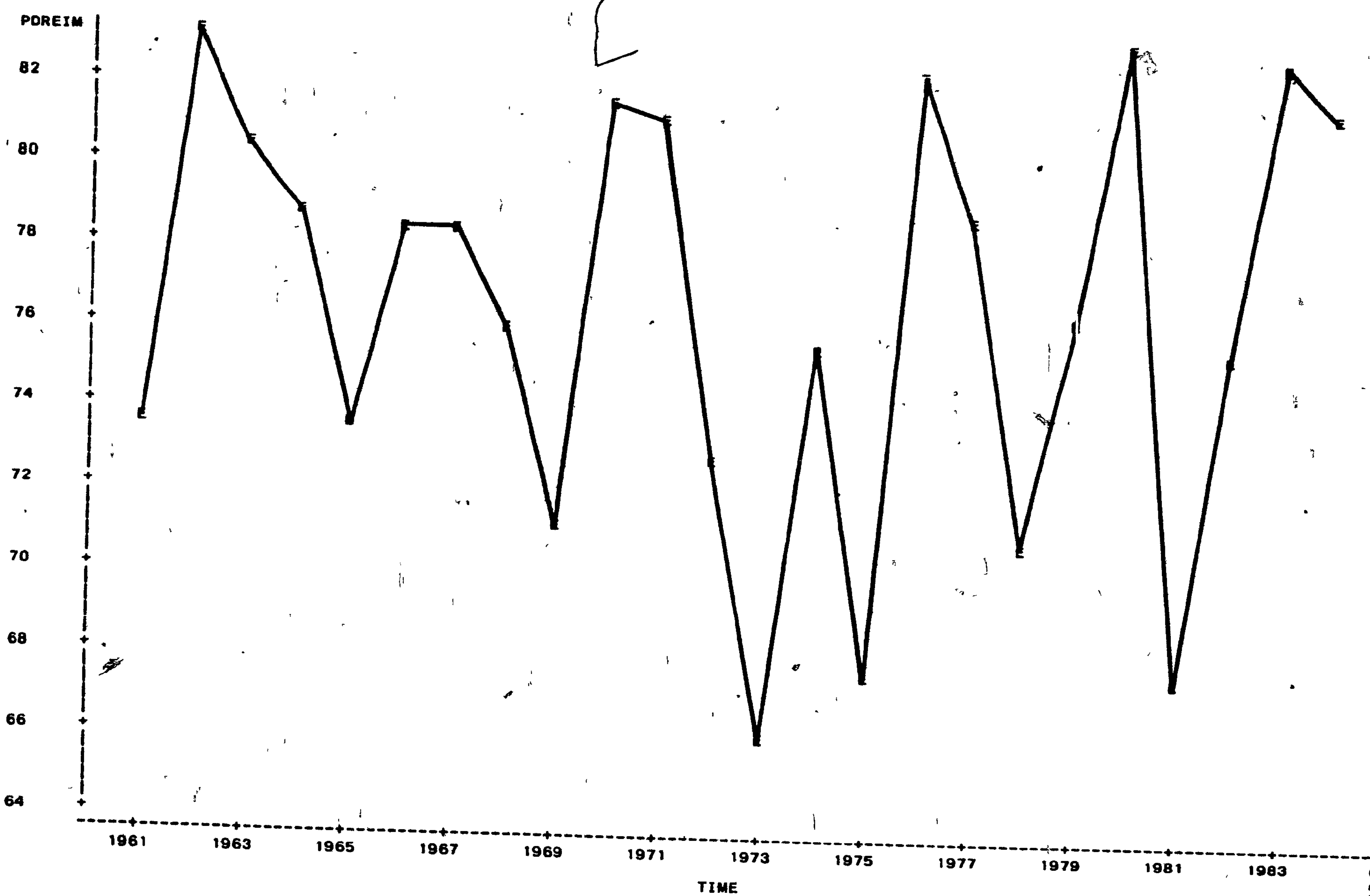
REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=TEXTILES



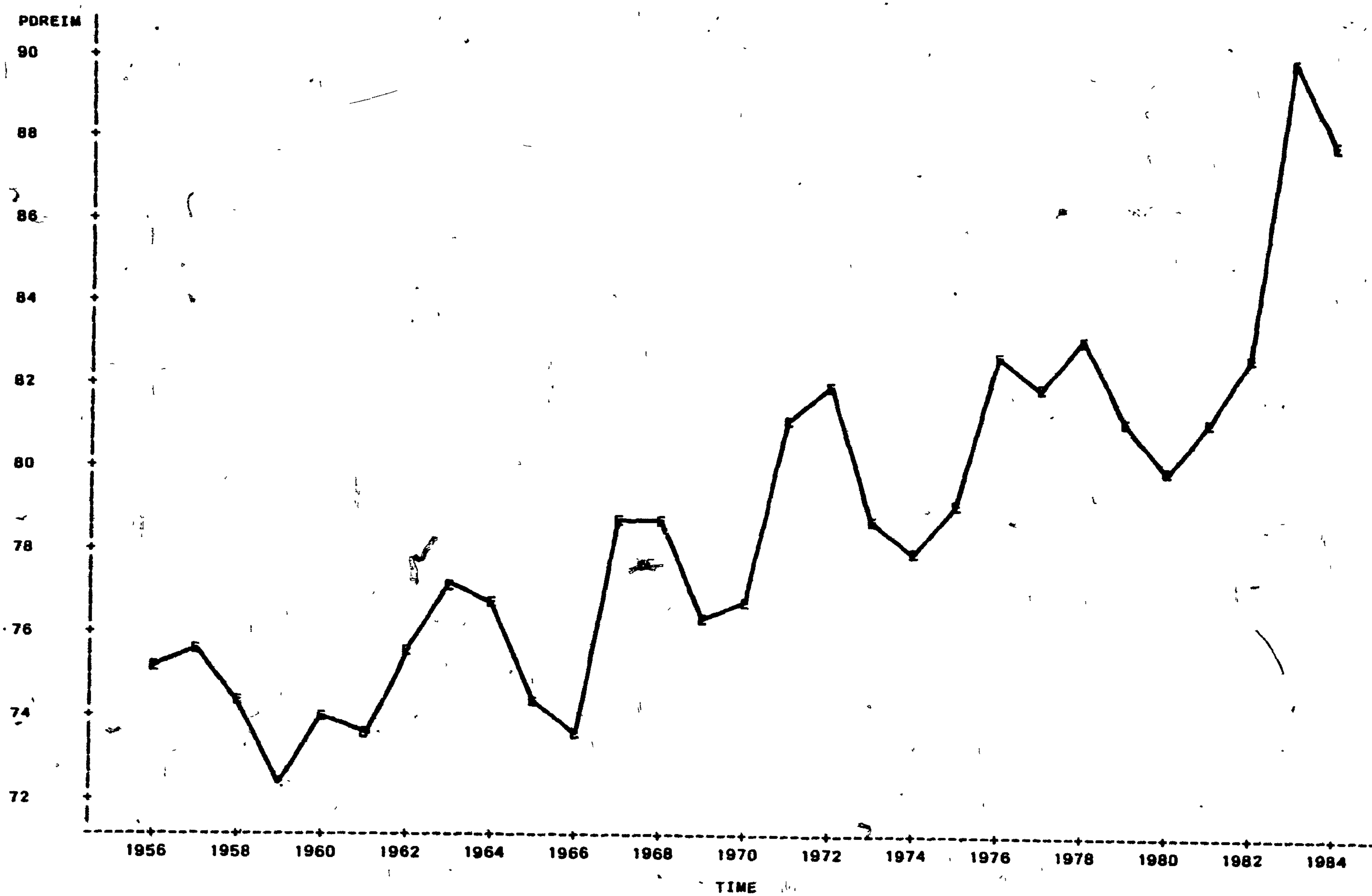
REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=KNITTING MILLS



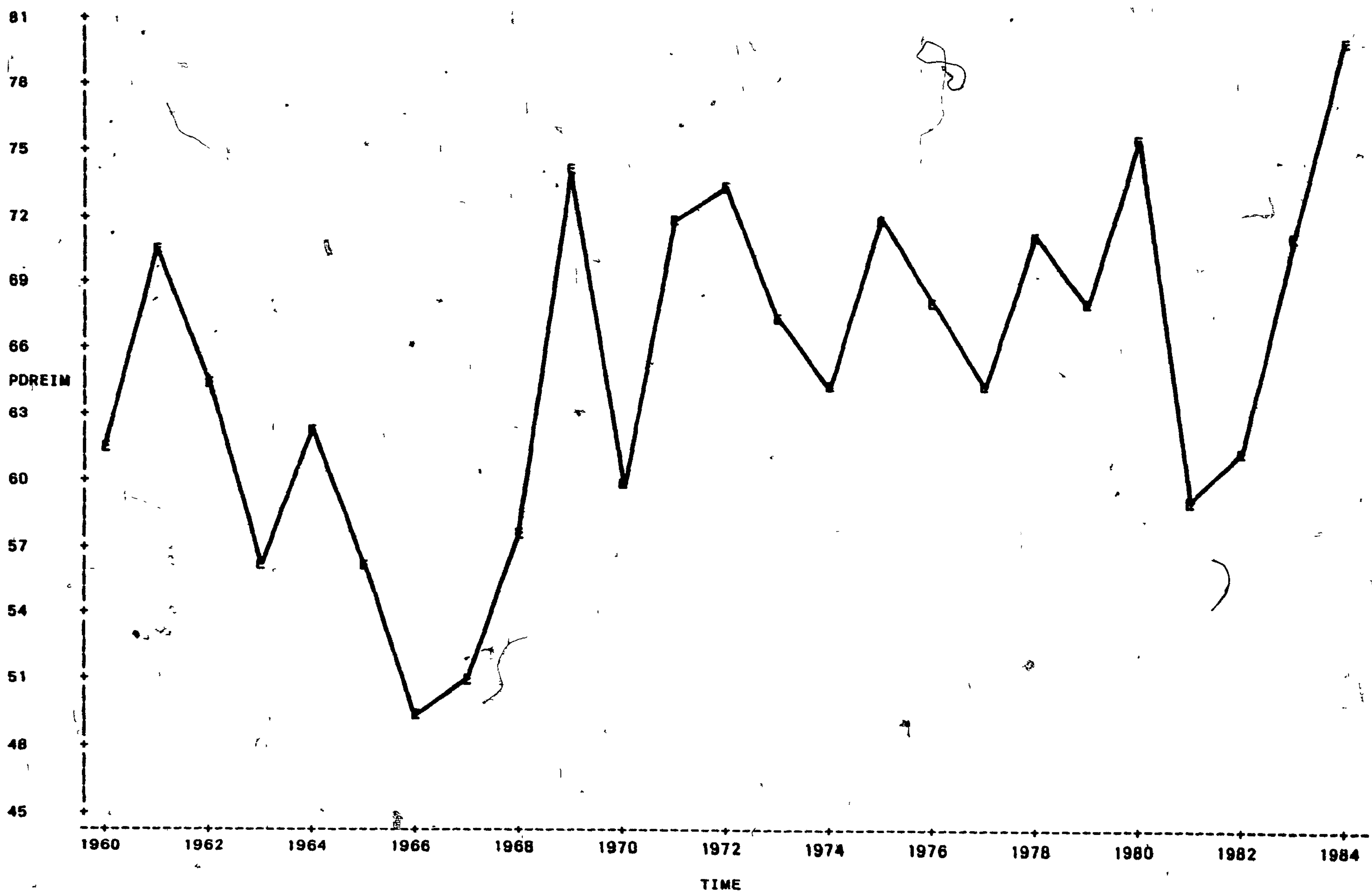
REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=CLOTHING



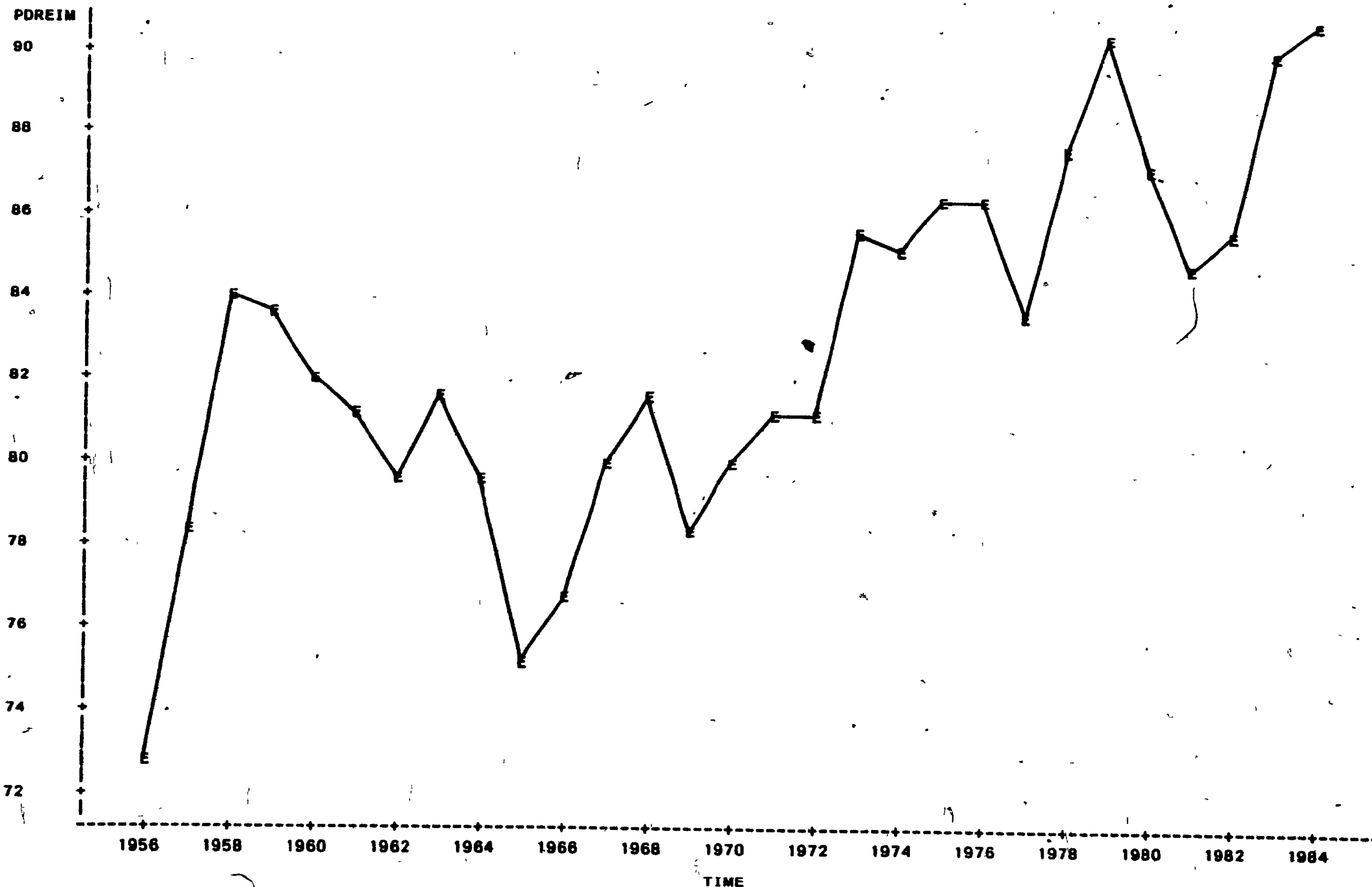
REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=WOOD

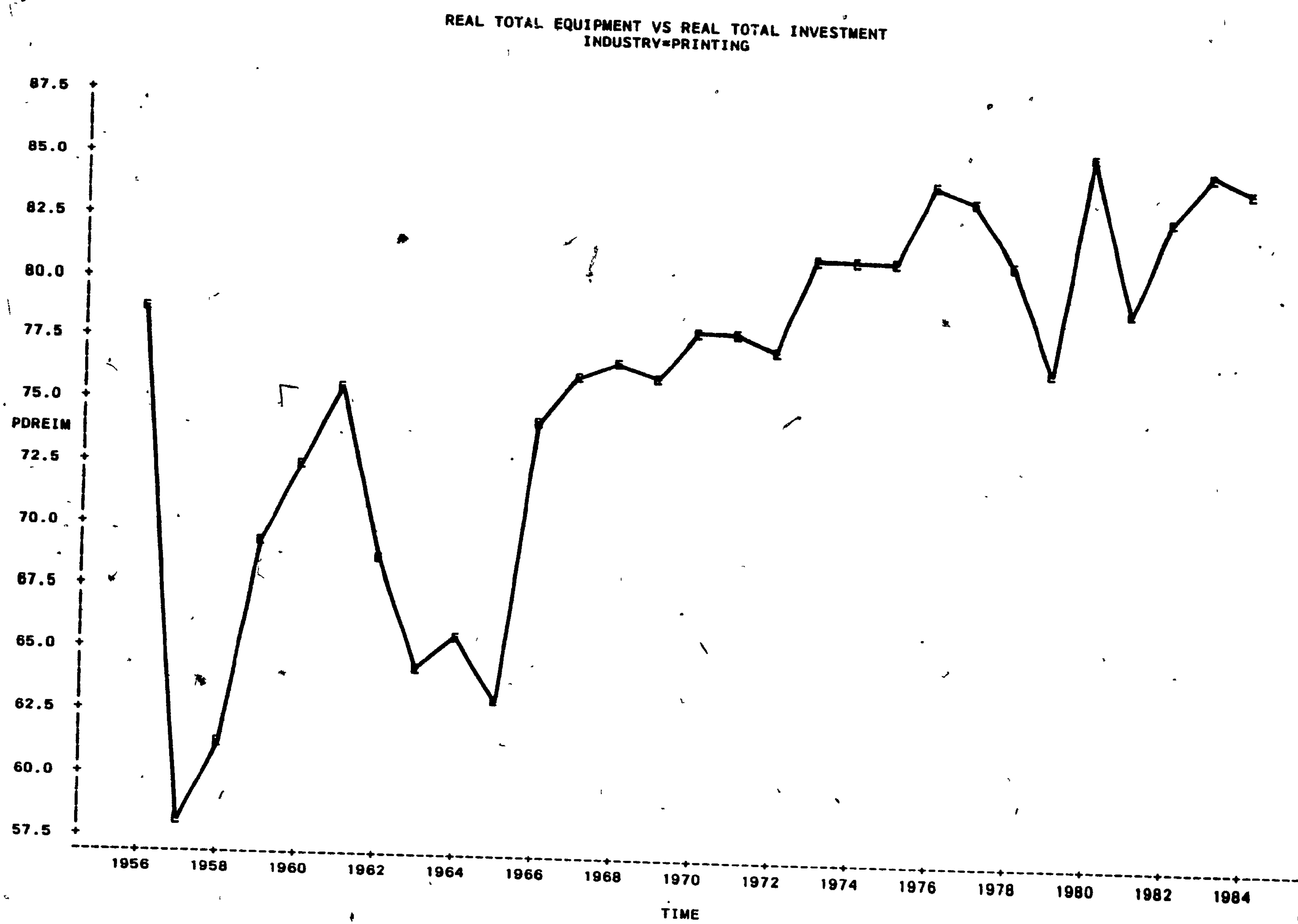


REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=FURNITURE

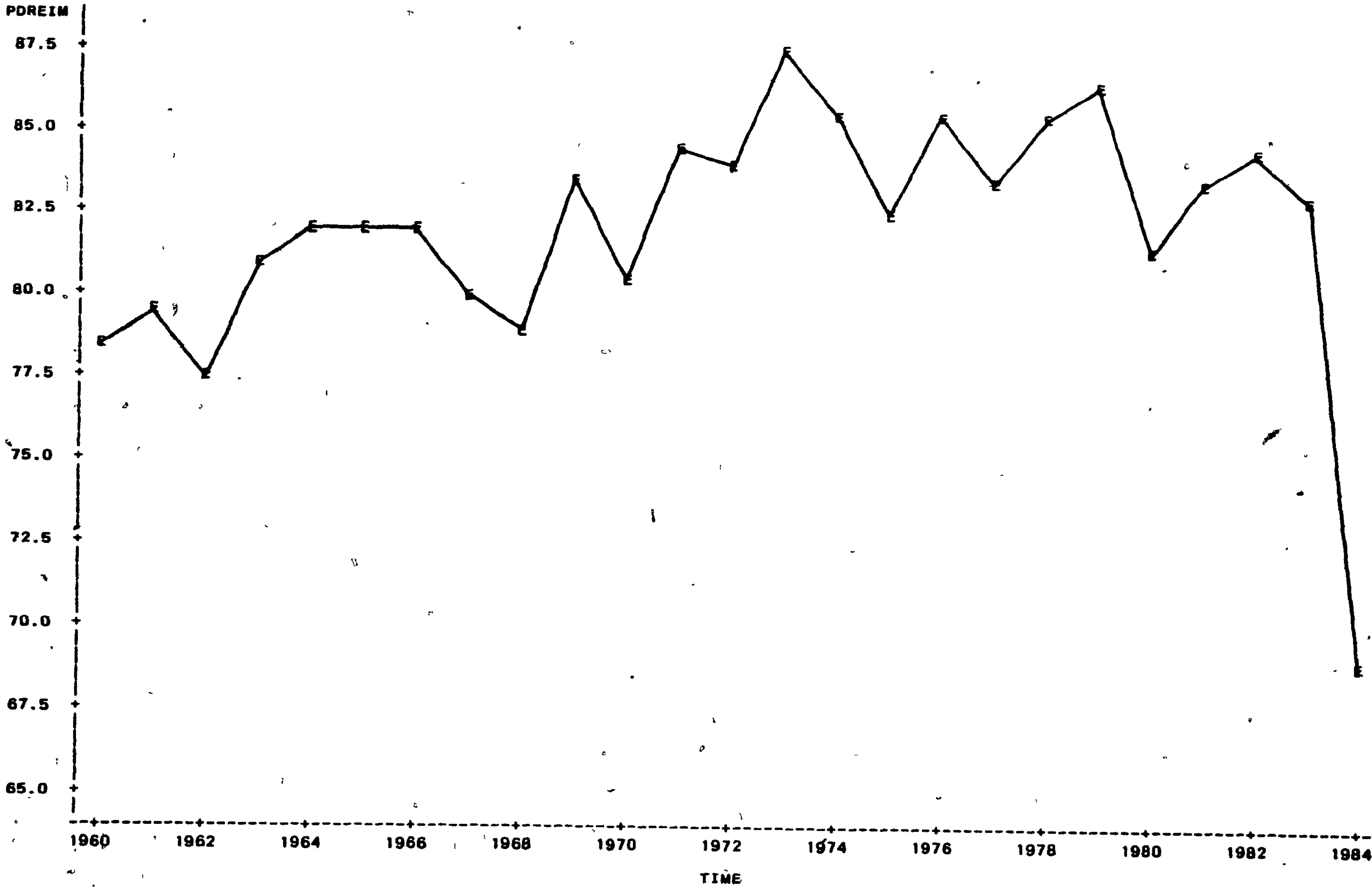


REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=PAPER

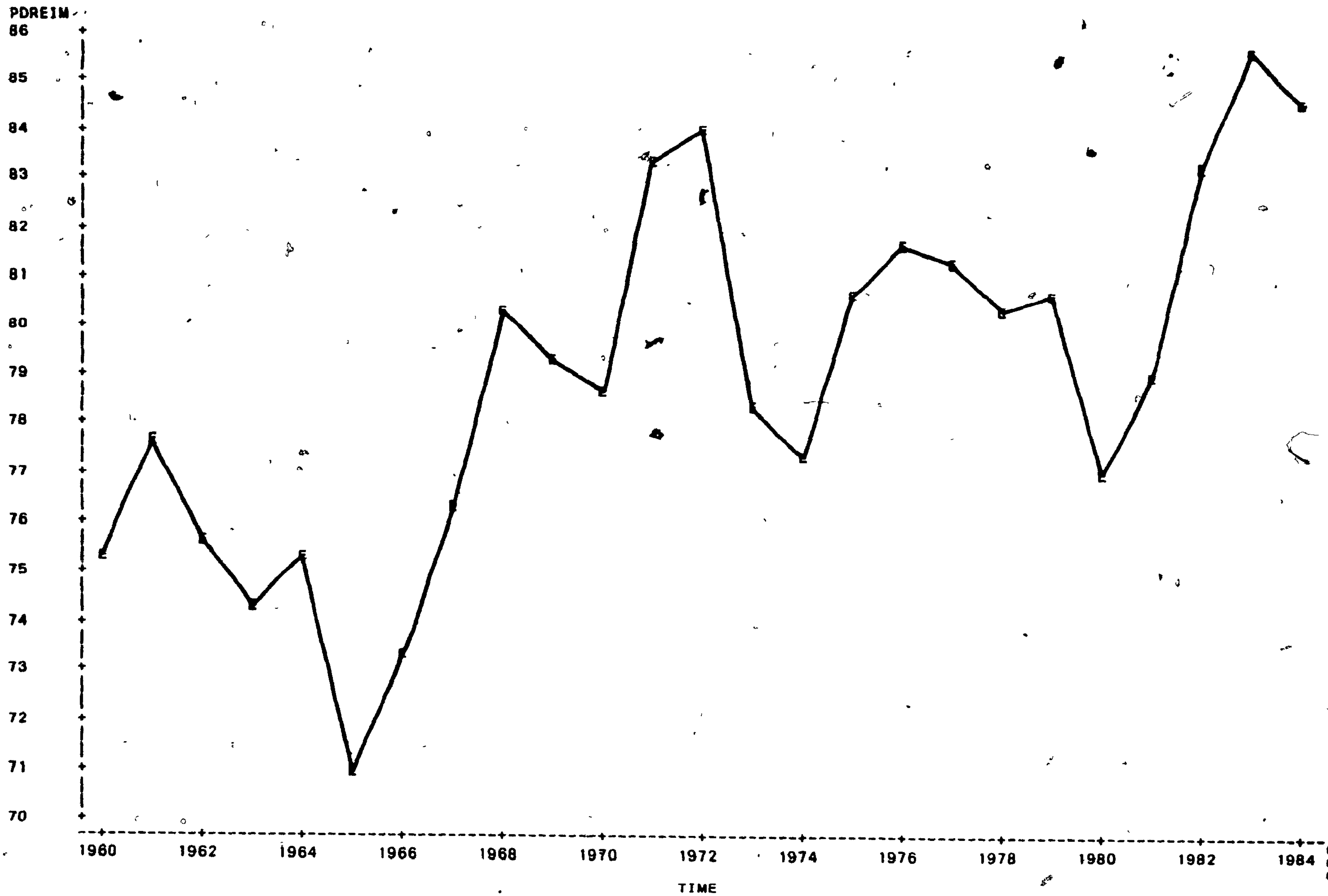



REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=PRINTING
87.5
85.0
82.5
80.0
77.5
75.0
PDREIM
72.5
70.0
67.5
65.0
62.5
60.0
57.5
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
TIME

REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=PRIMARY METALS

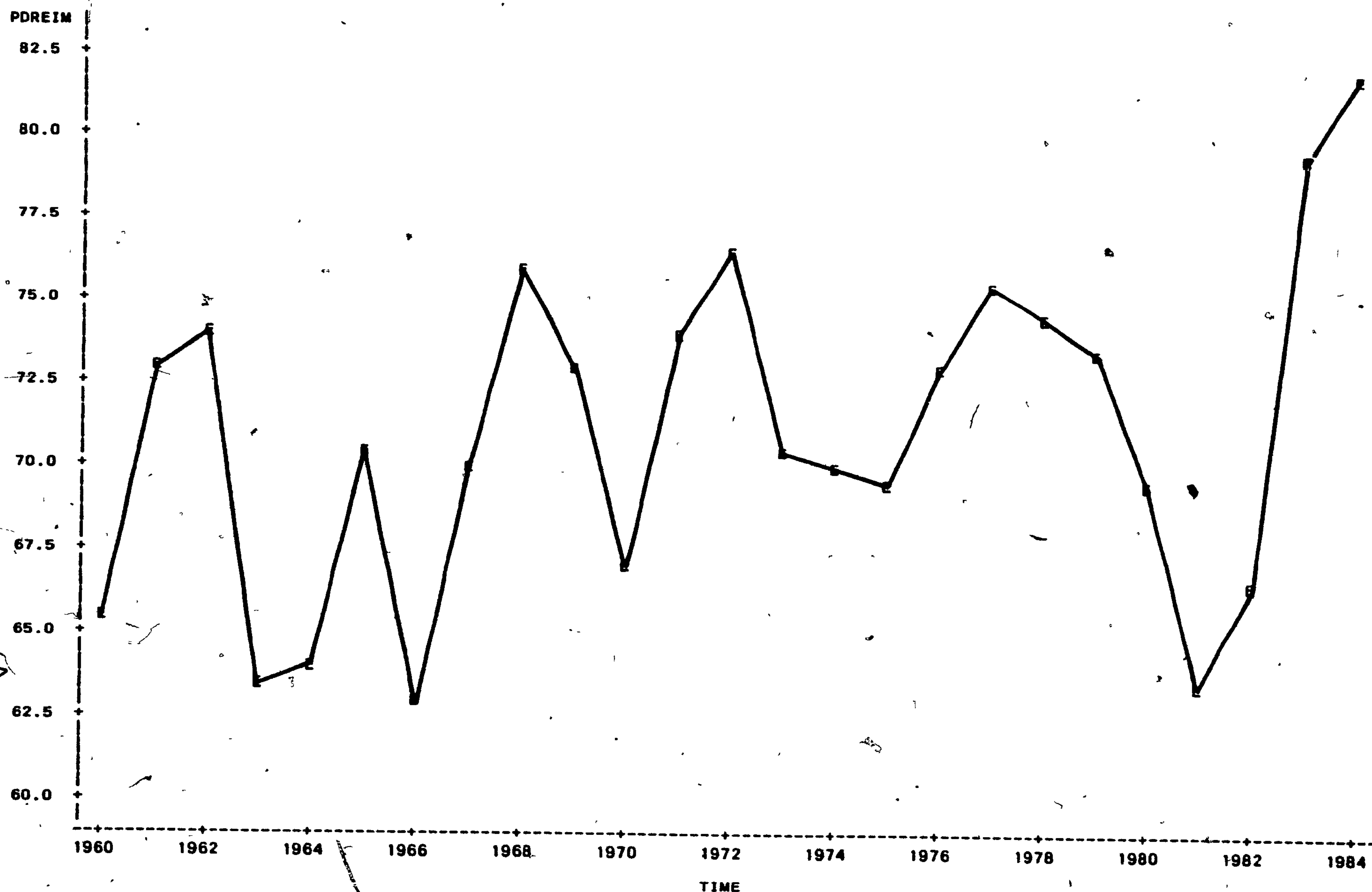


REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=METAL FABRICATING

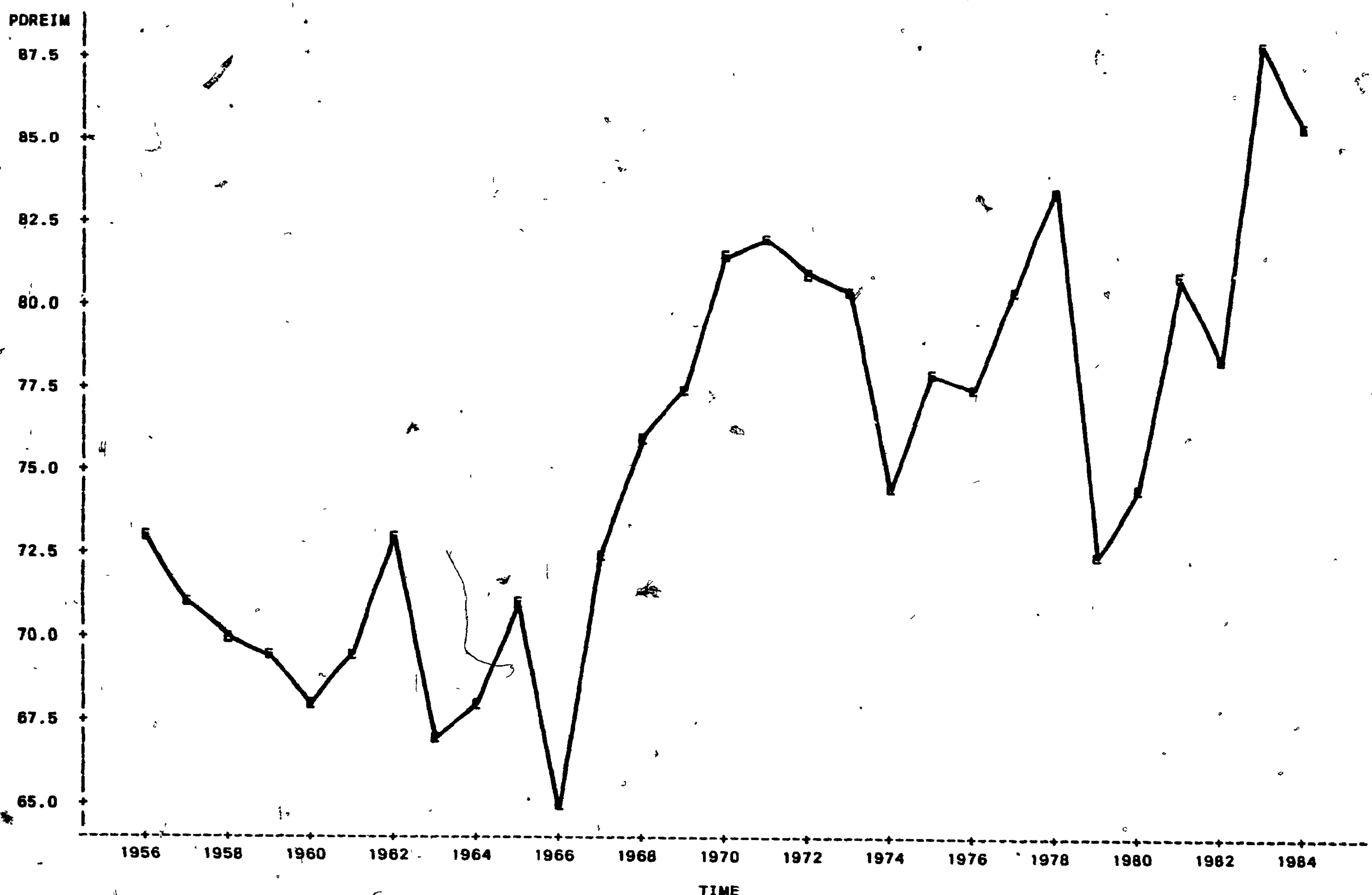


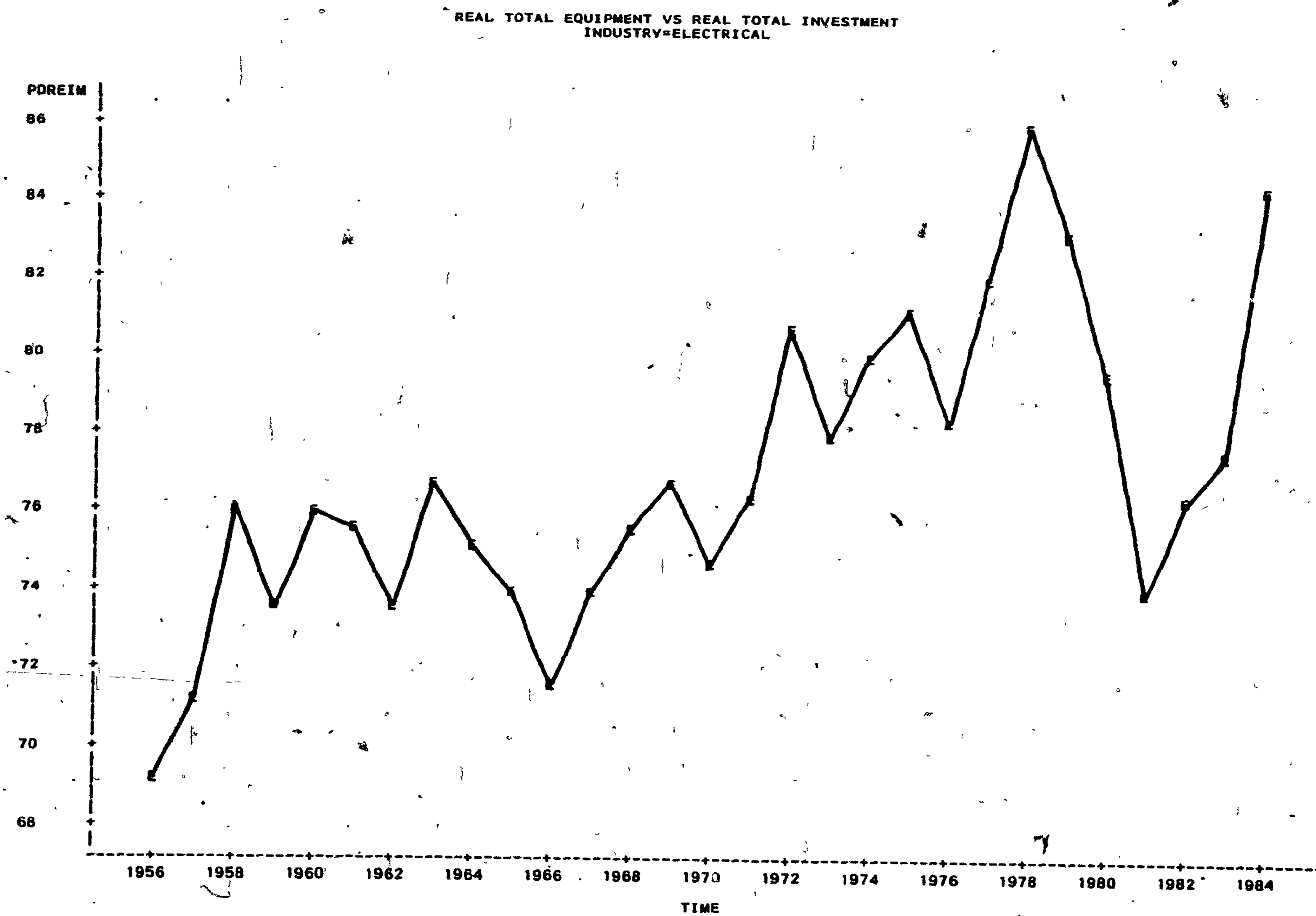
355

REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=MACHINERY

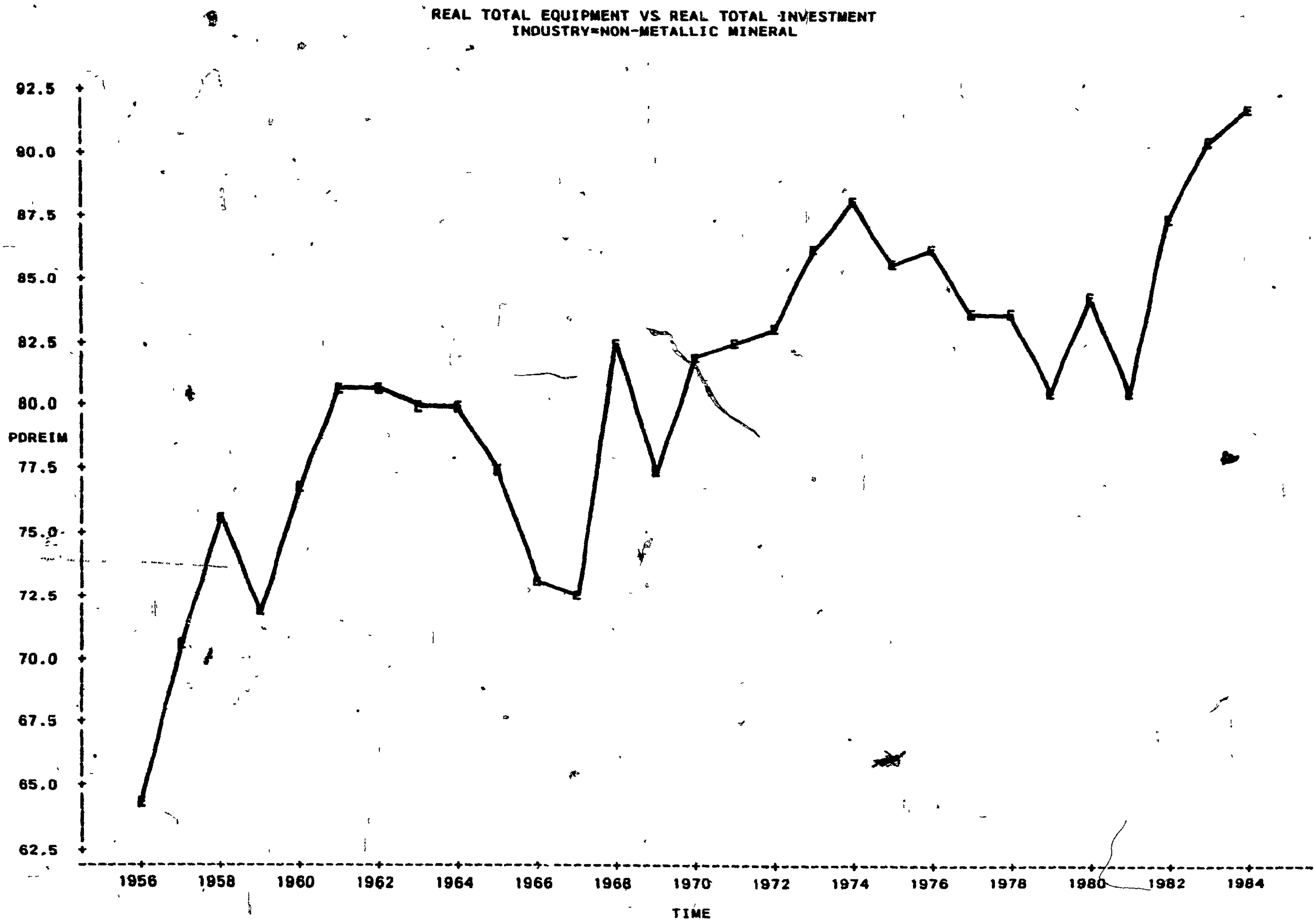


REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=TRANSPORT EQUIPMENT



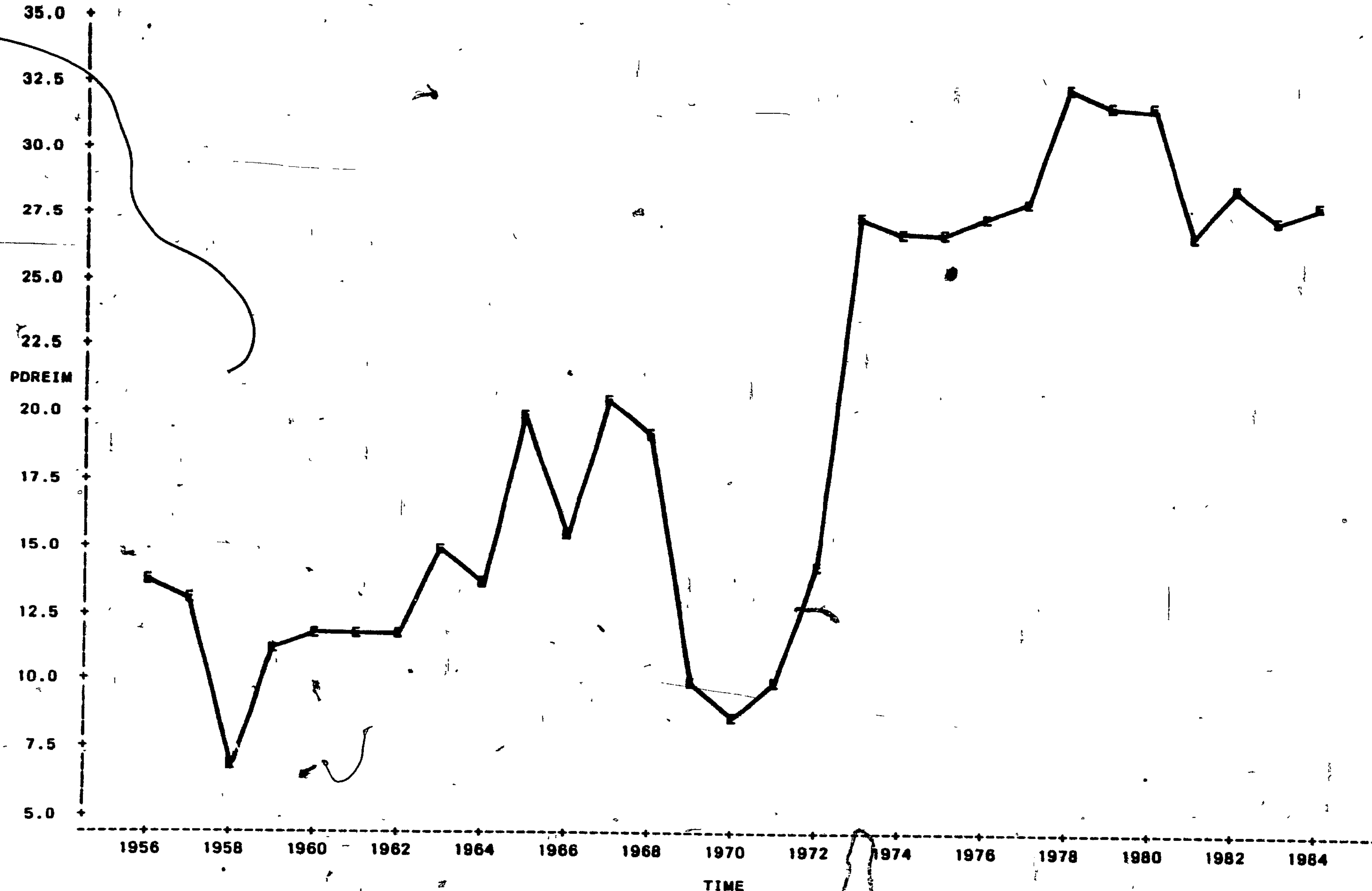

REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=ELECTRICAL
PDREIM
86
84
82
80
78
76
74
72
70
68
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
TIME

358

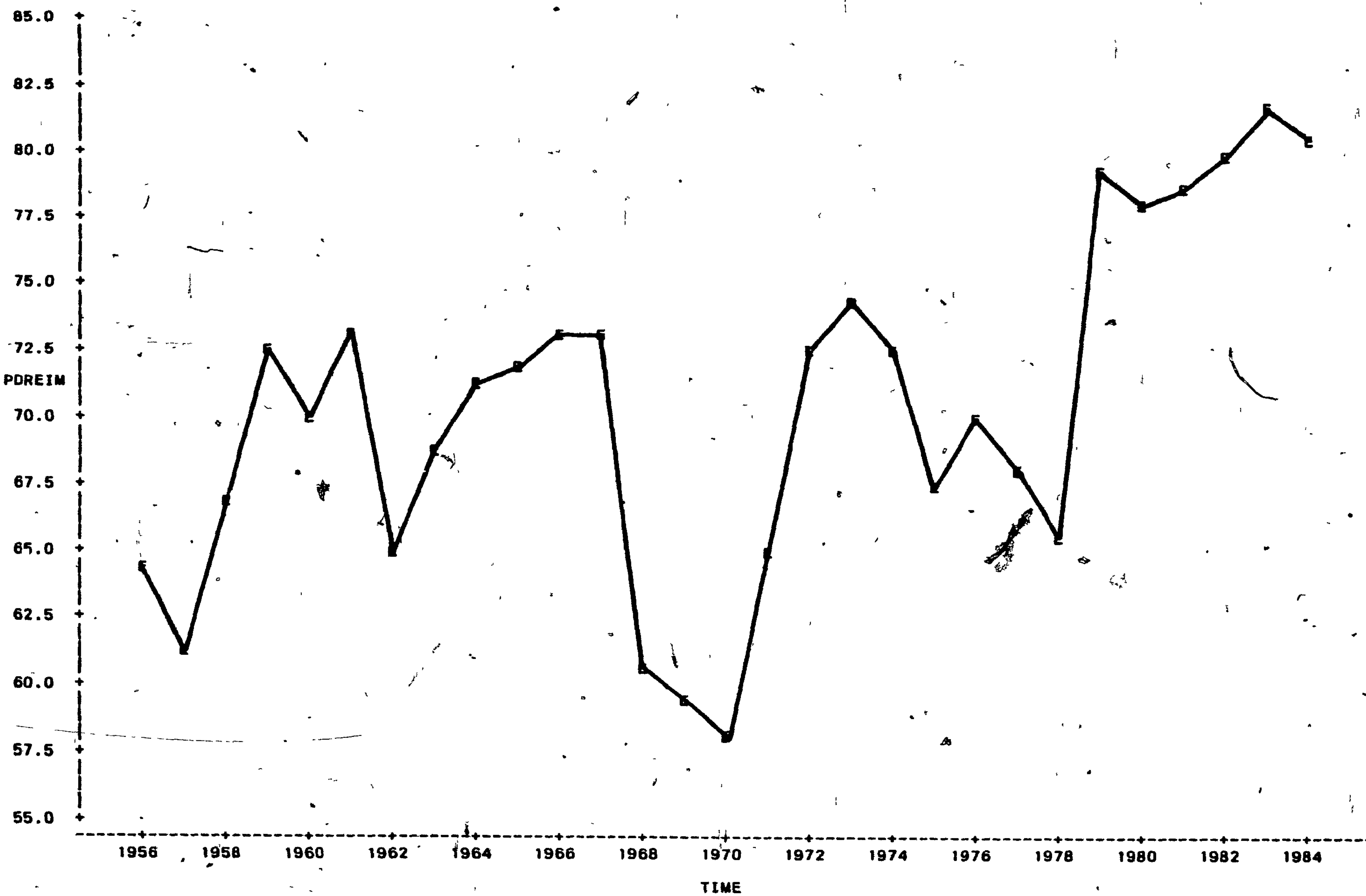


REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=NON-METALLIC MINERAL
92.5
90.0
87.5
85.0
82.5
80.0
PDREIM
77.5
75.0
72.5
70.0
67.5
65.0
62.5
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
TIME

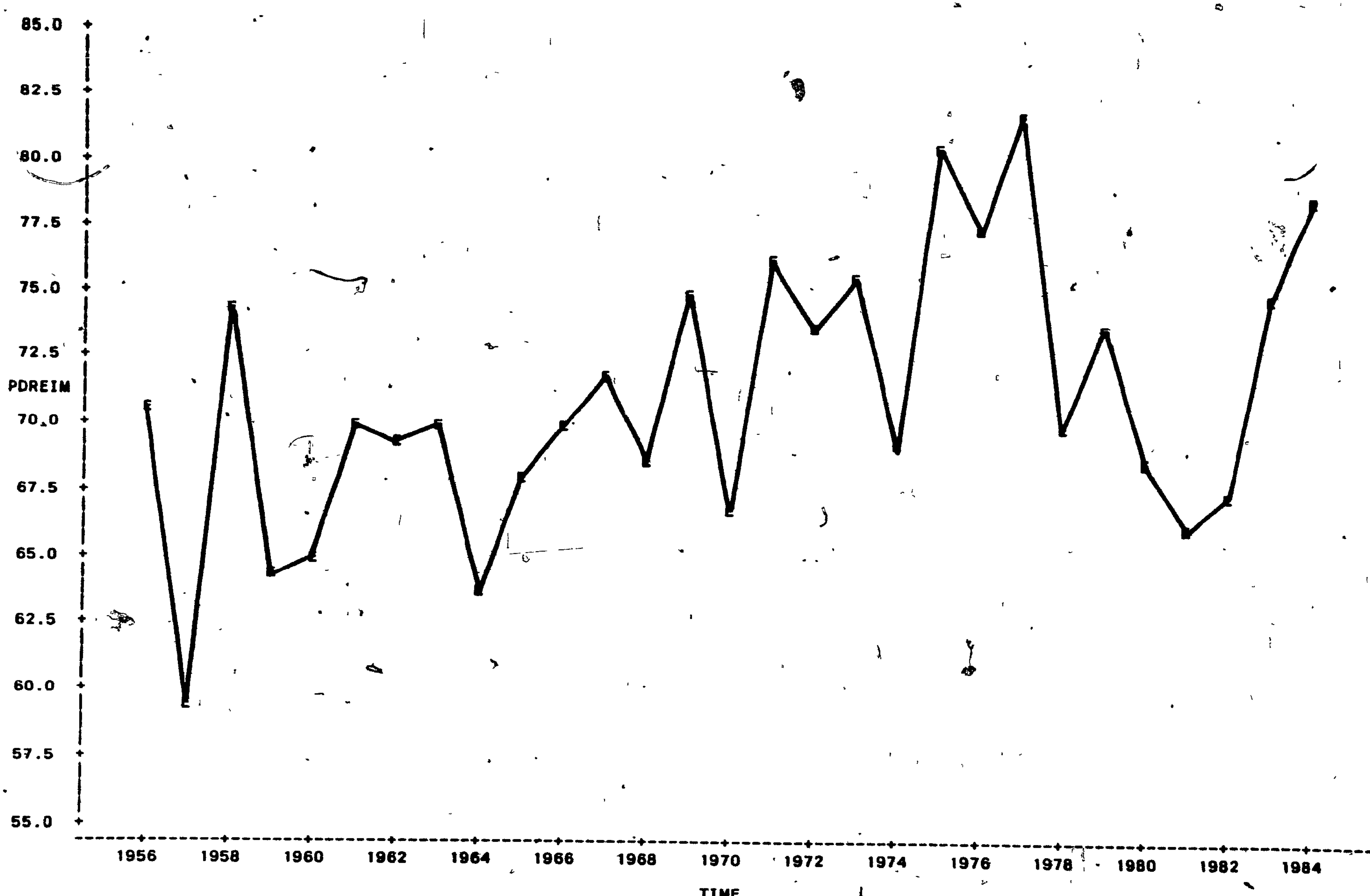
REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=PETROLEUM



REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=CHEMICAL



REAL TOTAL EQUIPMENT VS REAL TOTAL INVESTMENT
INDUSTRY=MISCELLANEOUS



APPENDIX F

JAPANESE CAPITAL STOCK SURVEY

Source: Koumanakos, Lapointe, O'Reilly, Patterson (1984)

Type of Assets

Other than machinery and equipment

classification code	Type of asset	Classification code	Type of asset
A.	Tangidle fixed Assets	136	Arcade and sun-shading device
1	Buildings and building attachments	137	Simplified shop arrangement
11	Residentiel	138	Others
110	Steel-frame reinforced concrete buildings	13V	Unclassifiable
111	Reinforced concrete buildings	14	Unclassifiable building
112	Brick buildings	1V	Unclassifiadle buildings and building attachments
113	Stone buildings		
114	Block buildings	2	Construction other than buildings
115	Metal buildings	21	Transportation equipment
116	Wooden buildings	210	Railway equipment
117	Mortared wooden buildings	211	Paved road
118	Simplified buildings	219	Others
11V	Unclassifiable	21V	Unclassifiable
12	Non-residential	22	Water control and supply facilities
120	Steel-frame reinforced concrete buildings	220	Sewage disposing equipment
		229	Others
121	Reinforced concrete buildings	22V	Unclassifiadle
122	Brick buildings	29	Other construction other than buildings
123	Stone buildings		
124	Block buildings	290	Power generation, transmission and distribution equipment
125	Metal buildings		
126	Wooden buildings	291	Broadcasting and cammunication epuipment
127	Mortared wooden buildings		
128	Simplified buildings	292	Smoke disposing equipment
12V	Unclassifiable	293	Advertising equipment
13	Building attachments	294	Equipment for stadium, ground recreation ground and schools
130	Electricity and lighting equipment		
131	Water supply, sewage, hygiene, gas equipment	295	Garden
		299	Others
132	Heating, cooling ventilation and boiler equipment	29V	Unclassifiable
		2V	Unclassifiable
133	Lift equipment	4	Vessels
134	Fire fighting and disaster informing device	41	Stell vessels
		42	Wooden vessels
135	Air curtain and automatic door device	49	Others
		4V	Unclassifiable

Kind of Economic Activity Used in the 1970 National Wealth Survey and the Correspondence to the Standard Industrial Classificaton of Japan

Classification code	Kind of economic activity	Standard industrial classification
A	Agriculture	A
B	Forestry and Hunting	B
C	Fisheries and Aquaculture	C
D	Mining	D
E	Construction	E
F	Manufacturing	F
F01	Food and beverage manufacturing	F18~19 (except F193)
F02	Textile and its product manufacturing	F20, 21
F03	Wood and wood product, furniture and fixture manufacturing	F22, 23
F04	Fabricated metal, non-ferrous metal, iron and steel material and product manufacturing	F31~33
F05	Machinery and equipment manufacturing	F34~37
F06	Other manufacturing	F24~30, 39
G	Wholesale and retail trade	G
G07	Wholesale trade, including agents and brokers	G40~41, 42
G08	Retail trade, including restaurant, cafe and other drinking places	G43~49
H, I	Finance, insurance and real estate	H, I
J	Transport and communication	J
L	Services	L
L09	Hotels, boarding houses and other lodging places	L75
L10	Laundries, barber and beauty shops and bath houses	L77
L11	Other personal services	L78~80
L12	Medical and other health services	L88
[illegible]3	Other services	L82~87 89~95

Classification code	Type of assets	Classification code	Type of assets
5	Vehicles and transport tools		and measuring apparatus
51	Rolling stock	624	Optical instruments and camera
52	Aircraft	625	Medical instruments
53	Motor cars , excluding tricycles and motor-cycles	626	Equipment for amusement , sport , public entertainment, barber's shop and beauty parlor
530	Passenger cars	627	Vending machines
539	Others	629	Others
53V	Unclassifiable	62V	Unclassifiable
59	Other vehicles and transport tools	6V	Unclassifiable
590	Tricycles and motorcycles	7	Big animals and plants
591	bicycle and rearcar	710	Animals
599	Others	720	Plants
59V	Unclassifiable	79V	Unclassifiable
5V	Unclassifiable	8	Construction in process
6	Tools and implements	9	Land formation and improvements
61	Tools	B	Inventory assets
62	Implements	1	Finished goods and merchandise
620	Electric computor	2	Semi-processed goods
621	Business and communication machinery	3	Raw materials
622	Furniture , electrical and gas machinery	4	Goods in stock
		V	Unclassifiable
623	Timepieces , testing machines		

2 Machinery and equiqment

a Type of assets used in the statistical tables and the correspondence to the list "b"

Assets (division) code used in the statistical tables	Type of assets	correspondence code of the list ("b")
3	Machinery and equipment	3
31	Construction machinery and equipment	303
32	Equipment for food, beverge and tobaco manufacture and processing	304
33	Equipment for textile and its product manufacture	305
34	Equipment for lumber and wooden product manufacture	306
35	Epuipment for fabricated metal , non-ferrous metal , Iron and steel material and product manufacture	318—320

Assets (division) code used in the statistical tables	Type of assets	correspondence code of the list "b"
36	Equipment for machinery and instrument manufacture	321~324
37	Epuipment for other product manufacture	307~317 325
38	Equipment for services	329
39	Machinery and epuipment, not elsewhere classified	301~302 326~388 330, 399

b Fundamental list of type of assets

Classification code	Type of assets
3	Machinery and equipment
301	Agriculture, forestry and fishery equipment
30101	Machinery and equipment for livestock production
30102	Machinery and equipment for horticulture
30103	Other agricultural machinery and eqiupment
30104	Equipment for afforestation, felling and lumber collection
30105	Equipment for aquaculture
302	Mining equipment
30201	Metal mining equipment
30202	Coal mining equipment
30203	Petroleum and natural gas mining equipment
30204	Equipment for press-processing of natural gas
30205	Equipment for gravel mining, quarrying rock and rubble
30206	Other non-metal mining equipment
303	Construction epuipment
30301	Bulldozer, power shovel and other. (Self -moving machinery)
30309	Others
304	Equipment for food and tobacco manufacture and processing
30401	Equipment for livestock product manufacture and processing
30402	Epuipment for sea food product manufacture and processing
30403	Equipment for fruit, vegetable and agricultural preserved food manufacture and processing
30404	Equipment for seasoning manufacture
30405	Equipment for polished grain and enriched rice manufacture
30406	Equipment for wheat flour manufacture
30407	Equipment for sugar manufacture and refining, millet honey, glucose and caramel manafacture

Classification code	Type of assets
30408	Equipment for bread and cake manufacture
30409	Equipment for soft drink manufacture
30410	Equipment for other drink manufacture
30411	Equipment for feed manufacture
30412	Equipment for fat and oil, margarine and linter manufacture
30413	Equipment for edible yeast and malt manufacture
30414	Equipment for tea manufacture
30415	Equipment for starch manufacture
30416	Equipment for noodles manufacture
30417	Equipment for bean curd, "konnyaku" and "edible Fu" manufacture and other beans processing
30418	Equipment for freezing, ice manufacture and cold storage business
30419	Equipment for other food manufacture
30420	Equipment for tobacco manufucture
305	Equipment for textile product manufacture
30501	Equipment for silk reeling, spinning, twisting yearn and other thread playing
30502	Equipment for woven good manufacture
30503	Equipment for knitted good manufacture
30504	Equipment for adjusting dyeing and hand-dyeing of textile
30505	Equipment for sewed good manufacture
30509	Others
306	Equipment for lumber and wooden product manufacture
30601	Equipment for sawing and lumber chip manufacture
30602	Equipment for plank and veneer board manufacture
30603	Equipment for wooden product manufacture
30604	Equipment for wood antisepsis
307	Equipment for pulp, paper and paper product manufacture
30701	Equipment for pulp manufacture
30702	Equipment for paper manufacture
30703	Equipment for processed paper, paper product and paper container manufacture
308	Equipment for publishing, printing and allied industries
30801	Printing equipment
30802	Bookbinding equipment
30803	Equipment for phototype processing and other printing allied industries
309	Equipment for fertilizer manufacture
30901	Equipment for ammonia manufacture
30902	Equipment for sulphuric acid and nitric acid manufacture
30903	Equipment for soluble phosphor fertilizer manufacture

Classification code	Type of assets
30904	Equipment for other chemical fertilizer manufacture
30905	Equipment for compound fertilizer and other fertilizer manufacture
310	Equipment for inorganic industrial chemicals manufacture
31001	Equipment for soda ash, caustic soda, metallic soda, ammonium chloride and caustic potash manufacture
31002	Equipment for sodium sulfide and its hydrate, sodium sulfate, sodium cyanide and sodium peroxide manufacture
31003	Equipment for other chloride manufacture of soda and potash, excluding assets listed in the classification code 31013 and 31014
31004	Equipment for ammonium salt manufacture, excluding ammoniun sulphate and ammonium chloride
31005	Equipment for carbide, phosphoric acid, phosphorus and phosphoric compound manufacture
31006	Equipment for light carbonate of lime manufacture
31007	Equipment for bengala, minium, litharge and zinc oxide manufacture
31008	Equipment for titanous oxide, lithopone and barium salt manufacture
31009	Equipment for carbon black manufacture
31010	Equipment for oxgen, hydrogen, carbon dioxide and soluble acetylene manufacture
31011	Equipment for salts manufacture
31012	Equipment for sulphate of iron, other sulphates and sulphite manufacture
31013	Equipment for manufacture of bromine, iodine and compounds of bromine, iodine, chlorine and fluorine
31014	Equipment for anpydrou chromate and other chromate compound manufacture
31015	Equipment for carbon disulphide manufacture
31016	Equipment for active carbon manufacture
31019	Others
311	Equipment for organic industrial chemicals manufacture
31101	Equipment for ethylene, propilene, putylene, putagien and acetylene manufacture made from petroleum and natural gas
31112	Equipment for acetaldehydo and acetic acid manufacture
31103	Equipment for ethanol, methanol and their derivatives manufacture
31104	Equipment for other alchols and ketone manufacture
31105	Equipment for aliphatic intermediate manufacture, excluding those listed otherwise
31106	Equipment for chlolide, bromide and fluoride manufacture of hydrocarbon
31107	Equipment for formic acid, oxalic acid lactic acid, tartaric acid succinic acid, citric acid, tannic acid and gallic acid manufacture
	Equipment for separating and refinning of coal gas, oil gas, aromatic

Classification code	Type of assets
	compounds made from petroleum and other compounds
31109	Equipment for dyes and pigments manufacture, not listed otherwise
31110	Equipment for cyclic intermediate manufacture, excluding those listed otherwise
31111	Equipment for plastic and synthetic rubber manufacture
31112	Equipment for plasticizer manufacture for synthetic resins
31119	Others
312	Equipment for synthetic fiber manufacture
31201	Equipment for rayon and acetate fiber manufacture
31202	Equipment for synthetic fibers manufacture
313	Equipment for manufacture of oil and fat products, detergents, surface active agents and paints
31301	Equipment for hydrogented oil, fatty acid and glycerin manufacture
31302	Equipment for soap, synthetic detergent and surface-active agent manufacture
31303	Equipment for paint and printing ink manufacture
31304	Equipment for polishing materials, griding oil emalsified oil manufacture
31305	Equipment for candle manufacture
314	Equipment for medical drug manufacture
31401	Equipment for medical drug manufacture
31402	Equipment for manufacture of sterilizers, insecticides, rat poisons, herbicides and other preparations for animals and plants
31403	Equipment for reagent manufacture
315	Equipment for other chemical industrial product manufacture
31501	Equipment for explosive manufacture
31502	Equipment for manufacture of organic rubbur chemicals, photo chemicals and artificial perfume
31503	Equipment for toiletries manufacture
31504	Equipment for glne, gelatin and glue manufacture
31505	Equipment for photo film and other sensitive materials manufacture
31506	Equipment for magnetized tape manufacture
31507	Equipment for natural resin and lumber chemical product manufacture
31508	Equipment for processed starch manufacture
31509	Equipment for active kaolin and silicagel manufacture
31510	Equipment for electric insulating material manufacture
31511	Equipment for writing and stamp ink manufacture
31519	Others
316	Equipment for petroleum and coal product manufacture
31601	Equipment for petroleum refining and reproduction of waste oil, and

Classification code	Type of assets
	for lubricating oil and grease manufacture
31602	Equipment for briquette, briquette ball and carbon powder manufacture
31603	Equipment for asphalt emulsion and other asphalt products manufacture
31609	Others
317	Equipment for ceramic, stone and clay product manufacture
31701	Equipment for grass and its product manufacture
31702	Equipment for cement manufacture
31703	Equipment for ready-mixed concrete manufacture
31704	Equipment for cement product manufacture
31705	Equipment for seramic ware, clay product , fire-proof material and diatomaceous earth product manufacture
31706	Equipment for carbon product manufacture
31707	Equipment for abrasive grain and its product manufacture
31708	Equipment for flyash mining and for stone product and pseudo-stone manufacture
31709	Equipment for asbestos product , asbestos cement product , rock wool and its product manufacture
31710	Equipment for lime and magnesium lime manufacture
31719	Others
318	Equipment for iron and steel materials and product manufacture
31801	Equipment for pig iron manufacture
31802	Equipment for pure iron and ferro-alloys manufacture
31803	Equipment for steel manufacture
31804	Equipment for steel manufacture by continuous casting process
31805	Equipment for hot rolling
31806	Equipment for cold rolling and cold forming
31807	Equipment for steel pipe and tube manufacture
31808	Equipment for wire drawing , drawing, steel re-rolling and shearing industries
31809	Equipment for iron and steel forging
31810	Equipment for steel and pig iron casting manufacture
31819	Equipment for other iron and steel industries
319	Equipment for non-ferrous metal material and product manufacture
31901	Equipment for copper, lead and zinc smelting
31902	Equipment for aluminium smelting
31903	Equipment for other non-ferrous metal smelting
31904	Equipment for rolling, extruding and wire drawing of non-ferrous metals
31905	Equipment for casting manufacture of non-ferrous metals
31906	Equipment for electric wire and cable manufacture

Classification code	Type of assets
31909	Others
320	Equipment for fabricated metal product manufacture
32001	Equipment for metal can, and metal container manufacture
32002	Equipment for metal western style tableware, cutlery, hand tool and agricultural tool manufacture
32003	Equipment for steel structure manufacture
32004	Equipment for metal furniture, fixture and construction ironware manufacture
32005	Equipment for punched, pressed and, other fabricated metal product manufacture
32006	Equipment for metal painting, plating, engraving and aluminium foil processing
32007	Equipment for fabricated wire product, screw, rivet and bolt manufacture
32009	Others
321	Equipment for general machinery and attachment manufacture
32101	Equipment for boilers, engines and turbines manufacture
32102	Equipment for agricultural machinery manufacture
32103	Equipment for construction and mining machinery and vehicle with prime mover manufacture, not elseware classified
32104	Equipment for metal machine tool manufacture
32105	Equipment for metal working, foundry, synthetic regin processing and wood working machinery manufacture
32106	Equipment for machinists precision tool, mold and die and jig manufacture
32107	Equipment for sawing machines, textile machinery and their parts and accessories manufacture
32108	Equipment for wind and water power equipment, oil hydraulic equipment, metallic valve, refrigerator and centrifugal separator manufacture
32109	Equipment for ball and roller bearing and their parts manufacture
32110	Equipment for gear and other power transmission equipment manufacturing
32111	Equipment for food preparation, heating, household and survice industrial appliance manufacture
32112	Equipment for other industrial machinery, parts and accessories manufacture
32113	Equipment for office machine manufacture

Classification code	Type of assets
32114	Equipment for machine, parts and accesories manufacture, not elsewhere classified
322	Equipment for electrical machinery and supplies manufacture
32201	Equipment for industrial and household electric apparantus manufacture
32202	Equipment for electric lump, electron tube and electric discharge lump manufacture
32203	Equipment for electric measuring instrument, comunication equipment, applied electronic equipment and their parts manufacture
32204	Equipment for railway signal and safety appliance manufacture
32205	Equipment for semi-conductor element manufacture
32206	Equipment for integrated circuit manufacture
32207	Equipment for resistor and static condenser manufacture
32208	Equipment for battery manufacture
32209	Equipment for electric apparatus parts manufacture
323	Equipment for transportation machinery and instrument manufacture
32301	Equipment for motor car manufacture
32302	Equipment for motor car body manufacture and setting
32303	Equipment for engine and parts manufacture for vehicles
32304	Equipment for rolling stock and parts manufacture
32305	Equipment for bicycle and parts manufacture
32306	Equipment for steel vessel building and repairing
32307	Equipment for wooden vessel building and repairing
32308	Equipment for aircraft and parts manufacturing or repairing
32309	Others
324	Equipment for precision machinery and instrument manufacture
32401	Equipment for testing machines and measuring instrument manufacture
32402	Equipment for dental material manufacture
32403	Equipment for medical, physical and chemical apparatus and instrument manufacture
32404	Equipment for lense, optical apparatus and their parts manufacture
32405	Equipment for time keeper and its parts, photograph shutter, mechanism of musical box and film sprol manufacture
325	Equipment for other products manufacture
32501	Equipment for small arms and artillery bullet, shell, exploding article, fuse and other gun use parts and accessories manufacture
32502	Equipment for musical instrument and phonograph record manufacture

Classification code	Type of asets
32503	Equipment for toys, fishing rod and their accessories manufacture
32504	Equipment for fountain pen, boll-point pen, lead pencile, painting material and india ink manufacture
32505	Equipment for personal adornment, brush, button and slide-fastener manufacture
32506	Equipment for plastic product manufacture and manufacturing industries
32507	Equipment for "tatami" (Japanese mat), matting and other strawgoods manufacture
32508	Equipment for match manufacture
32509	Epuipment for linoleum, linotile, asphalt tile manufacture
32510	Equipment for textile wall material manufacture
32511	Equipment for tyers and tubes manufacture
32512	Equipment for other rubber products and reproduced rubber manufacture
32523	Equipment for leather tanning and finishing manufacture
32514	Equipment for leather product manufacture
32515	Others
326	Equipment for wholesale and retail trade
32601	Equipment for stevedoring and warehousing for wholesale and retail trade
32602	Equipment for wholesale trade of petroleun and liquified gas
32603	Equipment for waste paper packing
32604	Equipment for iron scrap disposing
32605	Equipment for dinning use, etc. in restaurants and hotels
32606	Equipment for gasoline and liquified petroleum gas stand and car washing industries
327	Equipment for transportation and communication
32701	Equipment for cable railways and rope-ways
32702	Equipment for stevedoring and warehousing industries
32703	Equipment for measured result certificates issuing industries
32704	Equipment for rescuring wrecked ship and salvaging
32705	Equipment for international telephone and telegraph
32706	Other communication equipment
328	Equipment for electricity, gas and water works
32801	Equipment for hydro power generation
32802	Other power generation equipment
32803	Equipment for electrical transmission, transformation and distribution

Classification code	Type of assets
	(electrical transformation equipment are for electricity, railway and tramway enterprises, and electrical distribution equipment are for electricity enterprises)
32804	Equipment for storage battery power supply
32805	Equipment for electric news letters
32806	Equipment for coal gas, petroleum gas and coke manufacture and gas refining
32807	Equipment for gas works
32808	Equipment for water supply and drainage systems
329	Equipment for services
32901	Laundries equipment
32902	Public bath houses equipment
32903	Cremation equipment
32904	Equipment for developing and printing color film
32905	Equipment for other film development and print
32906	Equipment for motion pictures productiom
32907	Equipment for motion pictures and drama running
32908	Equipment for recreation at amusement parks
32909	Bowling alleys equipment
32910	Equipment for broadcasting TV and radio
32911	Equipment for automobile breakingup and repair services
32912	Copying equipment
32913	Surveying equipment
32914	Equipment for lease industries
330	Equipment to be used for repair shops in non-machinery industry sewage disposal, research and other purposes
33001	Equipment to be used for repair shops and workshops in non-machinery industry
33002	Equipment for sewage disposal
33003	Equipment for smoke disposal
33004	Equipment for development research
399	Other equipment, not elsewhere listed

APPENDIX G

STRUCTURAL CHANGES IN OUTPUT SHARES, CANADA: 1951-1984

TABLE G-1

STRUCTURAL CHANGES IN GROSS DOMESTIC PRODUCT SHARES, CANADA: 1951-1984

	GOODS		SERVICES			
Year	Goods Producing Sector	Manufacturing	Transport. Communic. Utilities	Public Administ.	Trade Finance Services	Total Services
1951	23.9	29.5	11.6	5.4	29.6	46.6
1952	22.3	29.6	11.3	5.5	31.3	48.1
1953	20.4	29.9	11.7	5.9	32.1	49.7
1954	18.3	29.2	11.8	6.6	34.1	52.5
1955	18.7	28.5	12.1	6.4	34.3	52.8
1956	19.2	28.6	12.4	5.8	34.0	52.2
1957	17.7	28.0	12.4	6.5	35.4	54.3
1958	17.4	26.8	12.1	6.8	36.9	55.8
1959	16.8	26.9	12.5	6.8	37.0	56.3
1960	16.5	26.4	12.4	6.9	37.8	57.1
1961	15.4	26.0	12.6	7.1	38.9	58.6
1962	16.4	26.1	12.1	7.0	38.4	57.5
1963	16.4	26.2	12.1	6.8	38.5	57.4
1964	15.9	26.6	12.1	6.7	38.7	57.5
1965	16.5	26.1	11.9	6.6	38.9	57.4
1966	17.2	25.6	11.7	6.8	38.7	57.2
1967	15.8	25.0	11.9	6.9	40.4	59.4
1968	15.4	24.8	11.7	7.0	41.1	59.8
1969	14.9	24.4	11.6	7.2	41.9	60.7
1970	14.6	23.4	11.8	7.3	42.9	62.0
1971	15.0	22.9	12.1	6.7	43.3	62.1
1972	14.2	23.3	12.4	7.3	42.8	62.5
1973	14.1	23.9	12.5	7.1	42.4	62.0
1974	13.4	23.7	12.7	7.0	43.2	62.9
1975	13.5	22.0	12.7	7.4	44.4	64.5
1976	13.5	22.3	12.8	7.2	44.2	64.2
1977	13.3	22.1	13.1	7.2	44.3	64.6
1978	12.4	22.5	13.3	7.1	44.7	65.1
1979	12.2	22.9	13.7	6.8	44.5	65.0
1980	12.3	21.9	13.9	6.8	45.1	65.8
1981	12.3	21.5	13.9	6.8	45.5	66.2
1982	11.9	19.9	10.5	10.7	47.0	68.2
1983	11.7	20.6	13.8	7.1	46.8	67.7
1984	11.2	21.3	14.1	6.9	46.5	67.5

Source: Urquhart, M.C. (1983) Historical Statistics of Canada, 2 ed., Statistics Canada, Ottawa.
Department of Finance (1985), Economic Review, Ottawa.

TABLE G-2

STRUCTURAL CHANGE IN SERVICE GDP SHARES, CANADA: 1951-1984

Year	Wholesale & Retail Trade	Finance Insurance & Real Est.	Community Business Personal Services	Total
1951	10.9	8.9	9.7	29.6
1952	12.5	9.1	9.7	31.3
1953	12.1	9.7	10.2	32.1
1954	12.4	10.8	10.9	34.1
1955	12.5	11.0	10.8	34.3
1956	12.5	10.1	11.0	34.0
1957	12.8	11.0	11.5	35.4
1958	12.8	11.9	12.2	36.9
1959	12.9	11.5	12.6	37.0
1960	12.8	11.6	13.5	37.8
1961	12.7	11.8	14.4	38.9
1962	12.5	11.5	14.4	38.4
1963	12.4	11.4	14.7	38.5
1964	12.5	11.2	15.0	38.7
1965	12.1	11.5	15.4	38.9
1966	12.0	10.8	15.9	38.7
1967	12.2	11.0	17.2	40.4
1968	12.2	11.5	19.9	41.1
1969	12.1	11.4	18.4	41.9
1970	12.4	11.3	19.2	42.9
1971	11.8	11.5	19.3	43.3
1972	12.2	11.5	19.1	42.8
1973	12.4	11.5	18.5	42.4
1974	12.8	11.7	18.7	43.2
1975	12.9	12.0	19.4	44.4
1976	12.9	12.0	19.3	44.2
1977	12.8	12.4	19.1	44.3
1978	12.9	12.7	19.1	44.7
1979	12.9	12.7	18.9	44.5
1980	12.8	13.0	19.3	45.1
1981	12.6	13.2	19.7	45.5
1982	12.2	13.9	20.8	47.0
1983	12.4	13.8	20.6	46.8
1984	12.5	13.5	20.5	46.5

TABLE G-3

INDUSTRIAL PRODUCTION INDEXES IN CANADIAN MANUFACTURING: 1951-1985

Two Digit SIC	Manufacturing Industry	1951	1961	1966	1971	1976	1981	1985
5:01	Food & Beverage Products	42.4	64.3	82.4	100.0	113.5	122.6	125.5
5:02	Tobacco Products	33.0	73.0	87.5	100.0	112.9	114.6	105.3
5:03	Rubber & Plastic Products	32.8	38.9	70.8	100.0	138.0	162.3	195.0
5:04	Leather Products	63.6	90.0	99.3	100.0	106.3	110.3	100.6
5:05	Textile Products	38.7	51.9	73.3	100.0	114.0	136.0	135.5
5:06	Knitting Mill Products	29.5	49.4	68.2	100.0	105.6	116.4	112.7*
5:07	Clothing Products	57.0	74.1	90.9	100.0	126.3	123.4	123.8*
5:08	Wood Products	51.5	64.2	84.9	100.0	134.8	145.6	166.6
5:09	Furniture & Fixtures	37.1	58.4	92.6	100.0	124.3	140.6	134.9
5:10	Paper & Allied Products	49.1	63.4	87.0	100.0	112.0	125.4	133.1
5:11	Printing & Publishing	44.3	69.8	85.3	100.0	137.7	173.3	192.0
5:12	Primary Metal Products	-	59.2	87.9	100.0	104.1	119.0	124.5
5:13	Fabricated Metal Products	-	54.2	89.9	100.0	120.2	131.0	114.3
5:14	Non-Electrical Machinery	-	45.7	83.7	100.0	140.5	206.8	190.2
5:15	Transportation Equipment	32.2	32.0	65.1	100.0	149.0	137.5	186.9
5:16	Electrical Products	27.5	47.9	87.3	100.0	118.7	140.0	139.0
5:17	Non-Metallic Mineral Products	33.0	59.3	85.9	100.0	121.0	119.9	119.9
5:18	Petroleum & Coal Products	28.5	62.0	79.3	100.0	126.3	141.3	120.8
5:19	Chemicals & Chemical Products	23.6	48.8	76.8	100.0	125.0	156.2	173.1
5:20	Miscellaneous Products	28.3	57.6	82.5	100.0	124.8	132.9	122.2

* Index of Industrial Production is for 1984.

Source: Urquhart, M.C. (1983) Historical Statistics of Canada, 2nd Edition, Statistics Canada, Ottawa
Statistics Canada (1983) Gross Domestic Product by Industry, Catalogue 61-213, Annual, Ottawa