UNIVERSITÉ D'OTTAWA ÉCOLE DES GRADUÉS

# INVENTORY INVESTMENT IN CANADA (1958-1965): AN ANALYSIS OF THE DURABLE MANUFACTURING SECTOR

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# TABLE OF CONTENTS

# INTRODUCTION

During the past two decades, studies of various aspects of inventory behavior have appeared with increasing frequency in the literature. During this time, interest in this field has proceeded principally along two lines. The rise of operations research and mathematical programming to legitimate sub-disciplines of applied mathematics have provided considerable impetus to this tendency. Interest in inventory behavior from this sector, however, has tended to concentrate on problems of inventory management and queueing. A second source of interest has arisen from an increasing awareness of the role of inventories in generating fluctuations in economic activity. Despite these developments, little empirical work has been done to explain inventory behaviour per se, or to determine the processes by which inventory investment is determined.

Aside from providing a very inviting area for research, the potential investigator finds himself dealing with a data rich situation in many respects. Certain data series, however, do not exist or cannot be transformed into forms that are directly comparable to the inventory series being used. This poses the practical problem of choosing the proper basis for disaggregation, and moreover limits the degree of sophistication that can be accommodated in an econometric investigation of inventory investment.

# INTRODUCTION



This particular study deals with the durable manufacturing sector, which according to the Standard Industrial Classification, consists of the wood, furniture and fixture, metal fabricating, machinery, transportation equipment, electrical products and non-metallic mineral products industries. Each of these broad aggregates is, in turn, composed of many specialized industries.

Throughout the analysis presented in the following chapters, the discussion is carried out almost exclusively in terms of the available data. Thus the presentation lacks much of the detail that might have been attempted in a purely theoretical work. The model developed, then, is necessarily a modest one, and the results obtained are, no doubt, an oversimplification of what, in fact, really occurs. Nonetheless, it is felt that the basic processes, whereby inventory change in the durable manufacturing sector is generated, are accounted for.

The procedure consists in estimating the parameters of a system reducible to a single equation, by the method of least-squares. The basis for disaggregation in this study is the conventional one, - by stage of fabrication. Despite the fact that a much deeper insight into inventory behavior could be gained by carrying disaggregation further, it is submitted that there is considerable knowledge to be derived even at the level of aggregation chosen in this study.

In this analysis, then, an effort is made to explain how each of the inventory components in the durable manufacturing sector is generated, and to provide an assessment of the contributions of the relevant variables to its behavior. Finally, an expression explaining aggregate inventory investment will be derived, defining a functional relationship between this variable and its determinants.

It is to be noted that the processes described in the subsequent pages seek to define a closed system, i.e., inventory change is explained in terms of the factors that immediately generate it. No attempt is made to establish interrelationships between inventory investment and other economic magnitudes or to explain the implications of the findings submitted in other areas of economic study.

# CHAPTER I

## THE NATURE AND ECONOMIC ROLE OF INVENTORIES

Materials held by manufacturers for further processing, or for shipment, constitute their inventory. Inventories consist of raw materials (which may be unprocessed, partially processed or even fully manufactured), materials actually being processed and finished goods either awaiting sale or shipment. Manufacturers' inventories occur of necessity (because of the existence of procurement and manufacturing lead-times), as a matter of choice, i.e., because it is in manufacturers' interests to hold stocks, and as a result of exogenous factors, many of which are beyond the control of manufacturers.

Although the reasons for holding inventories are diverse, it is useful to consider them in two categories: those reasons arising from manufacturers' consideration of costs, and those arising from uncertainty about future business conditions.

Consider the common business practice of offering quantity discounts to would-be purchasers. If the unit cost of procurement of manufacturers' material requirements is a decreasing function of the number of units purchased at any given time, there exists a compelling reason for purchasing such materials in large quantities and at less frequent intervals. However, in planning the appropriate level of stocks to be carried, the advantages of bulk procurement are not to be considered alone. Even though substantial economies may be incurred from large-scale purchasing of raw materials, beyond a certain point, the reduced cost per unit will be outweighed by increasing insurance and storage costs.

The cost of holding inventories will be met from manufacturers' own financial resources or through borrowing. Whatever the method of financing, a rational inventory policy will require an examination of investment in inventories as well as other investment alternatives. Thus the opportunity cost of holding inventories will be an important consideration when formulating inventory objectives.

In addition to those costs incurred by manufacturers in the normal conduct of their operations, there is another element of cost which, if minimized, will contribute to the accumulation of inventories. This is explained by the familiar "production smoothing" contention. It is argued that costs of production tend to be an increasing function of variations in the rate of production. In an effort to minimize these fluctuations, manufacturers may be constrained to tolerate larger inventories of in-process and finished goods than the immediate conditions of demand might warrant during so-called slack periods, with a view to liquidating these stocks at a later date. Indeed, it may be that certain manufacturers could only satisfy the requirements of periods of peak demand for their products by accumulating sizable inventories during periods of low or moderate demand.

Outlined above are a few of manufacturers' cost reasons for holding inventories. It is noteworthy that these factors are based solely on considerations of costs, and would still be valid even if the future conditions of demand were known. There are, however, several factors that are basically related to the uncertainty surrounding the future state of business affairs, that also make the holding of inventories both desirable and necessary.

Inventories fulfil an important function by contributing to the sustained performance of the production process. The full production cycle tends to be inherently discontinuous. Long lapses of time may occur between the order and receipt of industrial raw materials. Also, the transformation of raw materials into finished products is time consuming and of variable duration. Finally, orders received by manufacturers cannot be shipped immediately, for a certain amount of time will be required for orders to be processed, the goods packed, and transportation for these arranged. The holding of inventories of goods in various stages of fabrication therefore provides an important element of continuity in manufacturers' activities.

Manufacturers' attempts to accurately assess future conditions of supply and demand are subject to considerable uncertainty. Business decisions must be formulated on the basis of anticipated changes in the economic climate. The structure of costs and the availability of manufacturers' material requirements must be estimated in view of anticipated conditions of demand for their finished goods. In addition, inventory policies must be instituted that will hopefully satisfy the demand for manufacturers' output, for failing this, manufacturers risk loss of potential profits, loss of customers' goodwill and interruptions in the production process.

In formulating their inventory objectives, manufacturers will seek to anticipate those factors that determine the conditions of demand for their output. However, to minimize the danger of possible run-outs, they may choose to carry stocks over and above that estimated as adequate. These reserves are known as "buffer stocks".[1] Buffer stocks, like intended inventory levels, are not measurable, yet this fact does not preclude the usefulness of the term. Several writers, and in particular Michael Lovell, have

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1 M.C. Lovell, "Buffer Stocks, Sales Expectations, and Stability: A multicycle Analysis of the Inventory Cycle", Econometrica, April 1962, p. 267.

meaningfully incorporated the concept of buffer stocks into their analyses of finished inventory behavior.

Another inventory variable often encountered in the discussion of inventory behavior is that known as an "equilibrium" level of stocks. This hypothetical "quantity" can be considered to be that level of stocks toward which actual stocks would gravitate if the determinants of the level of inventories were to be constant for a sufficiently long period of time. This definition can be modified to allow for a moving equilibrium. In this case, the determinants of a particular inventory level would be permitted to change, but only in such a way that the contribution of each factor to the level of stocks remains unchanged in relation to the contributions of the other determinants.

Manufacturers' activities are conditioned by their estimation of the expected behavior of those variables that normally affect them. In particular, manufacturers will attempt to achieve certain inventory objectives, i.e., they try to maintain inventory levels that are most appropriate in the light of the circumstances that are expected to prevail during the forecast period. In view of this, one can speak of "desired" or "intended" levels of stocks. These are, in general, unmeasurable. Desired and actual inventory will rarely coincide; the discrepancy is the result of the interaction of various factors, many of which cannot be regulated by manufacturers.

Similarly, reference can be made to "desired" and "actual" inventory change. Inventory change (the difference between inventory levels at the end of one period and the levels existing at the end of the previous period) is also referred to as inventory investment and can assume either a positive or a negative value.

The extent and direction of errors in forecasting may constitute powerful determinants of the inventory objectives of manufacturers in the subsequent period(s). The nature of the response, by manufacturers, to their inability to achieve their inventory objectives, or to the prior realization of ill-conceived inventory objectives will vary, depending upon the extent of the error, the rigidity of the production process and the current and anticipated economic climate.

Manufacturers face, to a greater or lesser extent, an element of risk in all of their undertakings. The holding of stocks can provide a buffer against uncertainty regarding manufacturers' sources of supply as well as against unanticipated increases in the demand for industrial output. Yet the holding of stocks in various forms involves, in itself, an element of risk, i.e., the danger of incurring both real and financial losses.

The aggregate referred to as "total inventories" consists of raw materials, goods-in-process and finished goods. Each of these differs in nature and in origin. Moreover, each is generated differently and perhaps uniquely, responds differently to common stimuli, and contributes in varying amount to overall inventory behavior.

It is suggested that these individual components will fail to behave uniformly from industry to industry. This contention can be explained, in part, by the extent to which an industry produces "to order" or "for stock". It is suggested that the role and behavior of aggregate inventories and their components will differ essentially between pure production-to-order and production-for-stock industries. However, pure production-to-order or production-for-stock industries do not actually exist therefore a measure of the extent to which a given industry belongs to either of these categories must be derived if this thesis is to be empirically investigated. Without specific data relating to the operations of the industries in question, it is doubtful whether a truly satisfactory measure can be found. Thus the value of the production-to-order/production-for-stock distinction will probably never, in a highly aggregative study, be conclusively established.[2]

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2 The usefulness of the production-to-order/production-for-stock distinction was demonstrated in a preliminary

Theoretically, the effects of the extent to which an industry is for-stock or to-order oriented would be most pronounced with respect to finished inventory behavior. For pure production-to-order industries stocks of finished goods would be non-existent, since only on the receipt of an order for finished manufactures would the actual production of these be initiated. New orders could not be filled immediately but would be equal to sales (shipments) at some future date depending on the length of the production process, i.e., at the time of their receipt, new orders would simply be added to the unfilled-order backlog.

Most of the pure production-to-order industry's stocks would be held in the form of raw materials and goods-in-process and the quantity of the latter would depend on the

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study (unpublished) undertaken by T.J. Courchene, in which the inventory behavior of thirteen industry groups (comprising the entire manufacturing sector) was examined. These industry groups were ordered in a stock-order spectrum employing a technique suggested by Victor Zarnowitz in a National Bureau of Economic Research publication entitled "Unfilled Orders, Price Changes, and Business Fluctuations". The ranking of the industry groups was accomplished by forming, for each of these sectors, the ratio $H_t^f/U_t$, i.e., the ratio of a measure of finished stocks to a measure of the backlog of unfilled orders at any given time. For a pure production-to-order industry, this ratio would be numerically equal to zero, whereas for a pure production-to-stock industry, the ratio would become infinitely large. This ratio will, in general, lie between these two extreme values. The smaller the ratio, the closer that particular sector is to the production-to-order end of the spectrum, whereas a larger value of the ratio described above implies that the sector is production-to-stock oriented.

volume of unfilled orders as well as the characteristics of the production process. Such a firm may also hold quantities of standardized components and/or semi-finished goods. The prevailing competitive conditions would undoubtedly influence this practice. In addition, the need to minimize the time lag between receipt of an order and its delivery would probably compel manufacturers to carry substantial stocks of raw materials to avoid possible run-outs.

Manufacturers producing "for stock" would face a somewhat different situation with respect to their inventories. If production is carried out largely in anticipation of demand, sizable stocks of finished goods would normally be held and new orders would be filled immediately from stock, so a backlog of unfilled orders would not exist. Moreover, new orders would be identical to shipments made during the same period.

The effects of the production-for-stock/production-to-order distinction are less evident when considering inventories in the form of goods-in-process or raw materials, as behavior of stocks of goods-in-process are mainly determined by the characteristics of the production process and the nature of the commodity in question. Stocks of raw materials, whether owned by production-to-order or production-for-stock industries tend to fulfil the same functions, and in much the same way.

# CHAPTER II

## DATA AND METHODOLOGY

### 1. Sources of Data

The historical series used in this study were obtained from four principal sources. Price data were taken from "Prices and Price Indexes", published by the Dominion Bureau of Statistics. Financial series were obtained from the "Bank of Canada Statistical Summary". The D.B.S. publication, "Inventories, Shipments and Orders in Manufacturing Industries", yielded the data on inventories (total and by component), sales (shipments), unfilled orders and new orders. Finally, the Canadian Statistical Review was the source of miscellaneous series that were occasionally used.

Series indicating estimated values of inventories, shipments, unfilled orders and new orders, compiled according to an "Economic Use" classification, were available for the ten year period 1952-62. These series, however, were discontinued in 1962. The desire to incorporate more recent data into this study prompted the choice of a second data series covering a somewhat shorter period, but based on the Standard Industrial Classification currently in use by most government agencies.

## 2. Treatment of Data

Modern statistical methods deal substantially with random phenomena and random samples. Statistical estimates, tests of hypotheses and tests of significance rely on an essentially random character in data series. Statistical time series, i.e., items of data that are ordered in time are, in general, not mutually independent or random, and as such, violate one of the most crucial assumptions required in the application of probability theory.

In general, functions can be fitted for variates, whether the latter are random or not. In either case, the application of the least-squares principle will yield an expression in which the sum of the squares of the deviations between the fitted and observed values of the dependent variable are minimized. If these errors are not random, however, it may be impossible to give a statistical or probability meaning to the results obtained.

In order to minimize the incidence of multicollinearity, certain nonrandom components were eliminated.from the various data series used in this analysis. Toward this end, all series used were adjusted for seasonality using a procedure outlined in Appendix I. Next, using a non-parametric test attributed to H.B. Mann and described by Gerhard Tintner, the series were examined for trend (see

Appendix I).[1] Wherever a strong or even moderate trend was indicated, this component was removed from the data. Since evidence of trend was present in differing amounts in most of the series that were examined, all series used in the subsequent analysis are both trend free and seasonally adjusted.

No attempt was made to eliminate the cyclical component, the one remaining element that is conventionally said to comprise the nonrandom part of economic time series, because no evidence of any cycle of regular duration was observed in the data during the subject period.

## 3. The Nature and Dating of the Variables

Two types of variables are encountered in the ensuing analysis. Stock variables are those which represent some measurable characteristic of an item at a particular point in time. The subscript t, associated with this type of variable, represents its value at the end of period t. Thus the value of stocks of raw materials, Hr, at the end of period t, for example, would be represented by $Hr_t$.

Other variables, however, represent flows, i.e., the behavior over time of a particular characteristic of an

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1 Gerhard Tintner, Econometrics, New York, John Wiley and Sons, Inc., 1952, p. 212.

item, New orders, sales and changes in the value of stocks are of this type. The subscript t, used in this connection, represents the behavior of some attribute of an item during the interval (t-1,t), e.g., inventory investment in raw materials that occurred during period t is defined by $\Delta Hr_t = Hr_t - Hr_{t-1}$. Similarly, new orders received during the interval (t-1,t) are dated with the subscript t.

All data used in this analysis, represent quarterly observations. The period covered by this study extends from the fourth quarter of 1958 to the third quarter of 1965 inclusive.

## 4. Methodology

The format of the following four chapters, in which an attempt is made to explain inventory investment in raw materials, goods-in-process, finished durables and aggregate stocks, each in turn, is essentially the same. It consists first of postulating a linear relationship between inventory investment and those factors that are theoretically expected to generate it. This hypothetical relationship is not derived from the data but rather from considerations arising in economic theory. The theoretical model, once formulated, is then investigated on the basis of a finite sample (the available data) drawn from an unknown infinite population of all possible economic relationships of the form postulated in the hypothesis. On the basis of the sample, certain inferences regarding the nature of the population can be made. Finally, measures of the credibility that can be attached to the derived estimates, are given.

The estimating procedure employed in this study is based on the least-squares principle. The mathematics of least-squares estimation, following closely the presentation of J. Johnston, is presented in Appendix II.[2] The application of this procedure will yield an expression (regression equation) having the property that the squares of the deviations of the observed dependent variable from its fitted value are minimized.

The regression equation will not, as a rule, express an exact relationship between the dependent variable and the explanatory variables, thus errors will occur. These disturbances could be due to errors in measurement, however, since there exists no a priori information that would permit an assessment of the direction or magnitude of possible errors of measurement, the data are assumed to be error-free. While this assumption is undoubtedly violated in fact, it is

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2 J. Johnston, <u>Econometric Methods</u>, Toronto, McGraw-Hill Book Co., Inc., 1960, p. 106.

likely that deviations between observed and fitted values of the dependent variable are due mainly to the failure to include in the regression all the variables that influence the behavior of the regressand. This omission may be due to the fact that no information pertaining to these variables exists, that the existence of these variables is not even suspected, or that there are too many and the influence of a single one is neglegible. As long as the disturbances contain no large and systematic component, their existence in no way adversely affects the satisfactory performance of a least-squares procedure. Under certain assumptions regarding these errors, the method of least-squares, applied to a single equation, will yield the best unbiased estimates of the regression coefficients existing in the population.

The satisfactory performance of the least-squares principle requires that the errors be serially independent. The assumption of serial independence must be satisfied if the estimates obtained in the regression are to hold, and a correct interpretation of these values is to be given. The procedure used in this paper is one developed by H. Thiel and A.L. Nagar and is, like the Durbin-Watson test, based on the Von Neumann ratio of the least-squares estimated disturbances.[3]

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3 H. Theil and A.L. Nagar, "Testing the Independence of Regression Disturbances". Journal of the American Statistical Association, Vol. 56, No. 296, p. 793-806.

The authors of this test have provided tables containing one and five percent significance points of the statistic Q for testing the null hypothesis of residual independence against the alternative hypothesis that successive disturbances are positively correlated. A description of the test statistic and the method for locating the critical point for this test are given in Appendix II.

The regression, once completed, will yield numerical values for the regression constant and regression coefficients. It then becomes necessary to apply certain tests of significance to these values. If the assumption of independence of the residuals is satisfied, a quantity, which is useful for testing the significance of, and establishing confidence limits for, the intercept term and the regression coefficients, can be computed (see Appendix II). The testing of a particular coefficient for significance is accomplished by forming the null hypothesis that, in the population, this regression coefficient is zero. This will be the case if there is no linear relationship between the dependent variable and the particular explanatory variable in the population. The distribution of t, for different degrees of freedom, is tabulated. If, from the point of view of the given level of significance, the null hypothesis is rejected, then it is concluded that the empirical regression coefficient is significant, i.e., it is significantly different from zero.

If the null hypothesis is accepted, then the empirical coefficient is considered not to be significant. In the latter case one could conclude that there exists, in all probability, no linear relationship between the dependent variable and the independent variable in the population. A similar test is used to test the significance of the intercept term.

A measure of the strength of the relationship between the dependent variable and its determining variables is provided by computing the coefficient of determination which is conventionally denoted by $R^2$. This value represents the fraction of the total variation in the dependent variable that is accounted for by the variables included in the regression equation. This coefficient will always lie in the interval (-1.1). If all points are close to the line, the coefficient will have a value close to unity; but as the scatter becomes greater, the coefficient of determination will become smaller. Since the coefficient of determination, $R^2$, is the fraction of the total variation in the dependent variable accounted for by the regression, the quantity, $1-R^2$, is the fraction of the variation in the dependent variable that is unaccounted for, i.e., unexplained.

# CHAPTER III

## INVENTORY INVESTMENT IN RAW MATERIALS

Raw materials constitute that portion of total stocks held by manufacturers that have not undergone any form of processing by the firms that hold them. It is noteworthy that these stocks need not be totally unprocessed as suggested by their name, for often the inputs of one industry are, at the same time, the finished products of another.

Raw materials are, in general, the largest component of total inventories in the durable manufacturing sector. An inspection of the raw-material inventory data provided by the Dominion Bureau of Statistics[1] yields the fact that in the wood, furniture and fixture and primary metal industries, over 50 per cent of total stocks are normally held in this form. In the remaining industry groups that comprise the durable manufacturing sector, inventories of raw materials rarely account for less than one-third of total stocks at any given time.

An examination of the published data during the subject period shows that in every year except one, invent-

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1 Dominion Bureau of Statistics, Inventories, Shipments and Orders in Manufacturing Industries, Catalogue No. 31-001, Ottawa, Queen's Printer, March 1966, Table 3, p.5.

ories of raw materials reached their maximum levels during the fourth quarter. Minimum inventory levels did not occur consistently, yet the existence of a strong seasonal element was indicated.

The seasonally adjusted data showed a moderate rising trend throughout most of the raw-material inventory series. This tendency was undoubtedly conditioned by the requirements of an expanding volume of industrial output that occurred during the period reviewed in this study. A generally rising trend in prices, moreover, served to strengthen this tendency, but in such a way as to obscure the real changes that took place. The seasonally adjusted and trend-free inventory series demonstrated considerable irregularity. In particular, the series representing inventory change, like that representing inventory investment in goods-in-process, was extremely irregular but did not demonstrate the extreme violatility that characterized the corresponding finished-inventory variable.

As suggested earlier, it is because of the existence of procurement lead-time that raw material inventories do, and must, exist. Any measures that manufacturers take to compress the procurement lead-time will result in a corresponding reduction in these inventory levels. The effects of improvements in communications, transportation and methods for processing and filling orders for manufacturers' raw materials, in terms of reduced lead-time, would not be expected to perceptibly influence inventory levels (and indirectly inventory investment) in the short run.

While the existence of procurement lead-time explains, the existence of inventories of raw materials, it does not yield any insight into how inventory levels are determined or how variations in the level these stocks are generated.

It is possible to construct a highly simplified model that will provide some understanding of the processes whereby raw-material inventory behavior is determined; a theoretical "structure" that will be empirically tested later in this chapter. The analysis that underlies the theoretical model is based on the presupposition that the durable manufacturing sector is, for the most part, "order-oriented".

In general, the level of current and future production is determined mainly by manufacturers' estimation of the prevailing and anticipated conditions of demand for their output. Firms producing "to order" are able to forecast the demand for their finished products more accurately than those producing "for stock". Indeed, where a firm produces purely "to order", the demand for its output can be specified completely in terms of the orders for finished manufactures already received by that firm. In effect, this hypothetical firm would be producing in response to demand rather than in anticipation of demand. In view of this consideration, it is likely that the volume of new orders and variations in the unfilled-order backlog will be particularly important factors in explaining raw-material inventory behavior.

Ceteris paribus, the extent of the current and planned output of a particular industry will suggest a level of stocks of raw materials sufficient to meet these production requirements. As new orders for finished durables are placed, manufacturers will review their inventory position in the light of these changed circumstances. Thus new orders placed for finished goods in one period will result in orders for raw materials being subsequently placed by manufacturers. Receipt of these materials will occur, depending on delivery times, somewhat later.

An accurate representation of the process whereby new orders placed with manufacturers for their products are ultimately translated into receipts, by manufacturers, of their production requirements would have to take into account detailed information regarding replenishment procedures, lot sizes, the frequency with which orders are placed as well as information about order-delivery lags. Unfortunately no data are available that would permit an assessment of the influence exerted by these variables on raw-material inventory behavior. Thus while their influence can be theoretically justified, their importance, in fact, remains untested.

Stocks of raw materials would be expected to be positively related to the backlog of unfilled orders, inasmuch as these (unfilled orders) usually represent a firm commitment that must be met within a given period of time. Thus when the backlog of unfilled orders is increasing, manufacturers would attempt to carry larger stocks in order to avoid possible shortages in the event that a subsequent expansion of output is required.

Apart from the role ascribed to the holding of stocks of raw materials of providing a continuous source of materials sufficient to meet the requirements of production, there exist several factors that will, in part, determine the inventory level at any particular time. Presumably savings will be incurred by manufacturers purchasing their materials in bulk. The benefits of quantity purchasing will be partly offset by increasing storage costs etc., and indeed be limited by existing or procurable storage facilities. The net effect of these considerations is unknown, for the lack of data in this area prohibits empirical investigation.

Certain other factors, although beyond the control of manufacturers, are relevant in determining the actual level of stocks of raw materials on hand and should be considered. For example, the availability and accessibility of sources of raw materials will influence inventory behavior. The reliability and efficiency of transportation facilities will affect inventories similarly. In addition, the lapsed time between the order and delivery of raw materials will influence the level of stocks, and hence the inventory investment considered appropriate for a given set of circumstances. Thus when sources of industrial raw materials are readily accessible and delivery times are short, firms would be less likely to hold as large stocks as would be required if the situation were otherwise. Owing to a lack of data, one can only indicate the direction of the influence that these factors are expected to exert on the level of stocks at any time. No estimate of their actual (or relative) importance can be made from the information that is currently available.

Any discussion of possible determinants of inventory behavior with respect to raw materials would be incomplete without examining the impact of variations in the terms and availability of credit. The financing of inventories may be accomplished internally. Alternatively, manufacturers will seek to borrow the necessary funds. Whatever the course of action adopted, variations in the cost of money, or the availability of funds, will affect the level of inventories that manufacturers will hold through the opportunity cost of holding stocks. Theoretically, an expansion in holdings of inventories could be accommodated more easily during periods of low or decreasing interest rates. Conversely one would expect that inventory accumulation would be restricted somewhat by relatively high or increasing interest rates. In the latter case, purchases of raw materials that are not essential would probably be deferred until interest rates return to a more favourable level. The question arises as to whether it is more appropriate, in the context of the problem being examined, to consider the behavior of the short-term rate of interest or the long-term bond rate. In view of the relatively short periods required for even fairly substantial changes in inventory levels to occur, one might assume the condition of the short-term market to be the more appropriate.

One other factor should be considered in the context of the problem posed, namely, whether there exists, in fact, a basis for the supposition that manufacturers systematically adjust their holdings of raw materials in anticipation of changes in the prices of these goods. It is a fairly widely accepted view that this is not likely to be the case, for raw materials are probably furnished to manufacturers under long term agreements in which the price is known and stipulated. Moreover the temporarily improved profit position of firms would, in all probability, be moderated by increased costs of accommodating these purchases. This view might not hold if the price change were expected to be substantial or discriminatory. Experience has shown, however, that price changes tend to occur quite regularly and be moderate in amount, and moreover affect the whole range of raw materials to more or less the same extent.

Again, if a price change were expected to be short lived, it is doubtful whether manufacturers would significantly alter their inventory practices with respect to raw materials. Anticipated price changes that are expected to be permanent in effect and duration likewise would not be expected to induce any systematic change in the holding of stocks of raw materials. In this case, the price change would, in large measure, affect all phases of manufacturing. The added element of cost for subsequently purchased raw materials would presumably be absorbed in the selling price of the finished goods and no lasting adverse effects on sales would be expected to occur. In conclusion then, while it is conceded that certain firms may occasionally anticipate price changes and adjust their holdings of raw materials accordingly, it is doubtful whether this practice occurs widely in the durable manufacturing sector.

The buffer motive was cited as being an important consideration in explaining raw-material inventory behavior. In general, the size of that portion of stocks of raw materials designated as a buffer against contingencies will be roughly proportional to the uncertainty facing firms with respect to their sources of supplies as well as with respect to satisfying production requirements. Where firms produce under firm orders, the danger of miscalculation with respect to the latter is minimized. Manufacturers will find it necessary to consider the characteristics of their sources of raw materials in formulating their raw-material inventory policies. Ideally, where raw materials are readily available and replenishment periods are short, there will be little reason to hold stocks of raw materials in quantities in excess of their immediate needs. However where sources of supply are less reliable, the "buffer motive" assumes greater importance. It is likely, then, that any anticipated disruption in the normal flow of raw materials from primary producers will cause manufacturers to revise their inventory position accordingly.

The explanation proposed in this study, of the process by which durable manufacturing inventory investment in raw materials is generated, is developed within the context of the flexible-accelerator model proposed by Richard Goodwin[2].

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2 Richard M. Goodwin, "Secular and Cyclical Aspects of the Multiplier and Accelerator", Income, Employment and Public Policy: Essays in Honor of Alvin H. Hansen, New York, Norton and Co., 1948, p. 108-132.

This procedure is based on the assumption that manufacturers attempt to achieve a partial adjustment of their raw-material stocks to their equilibrium level during any given period. This mode of behavior can be given the following mathematical representation:

(1.1) $\Delta Hr_t = b(Hr_t^e - Hr_{t-1}) + e_{1t}, \quad o \leq b \leq 1,$

where $Hr_t^e$ denotes the end-of-period equilibrium level (unmeasurable) of stocks of raw materials, $Hr_{t-1}$ denotes the actual beginning-of-period level of these stocks, and $\Delta Hr_t$, inventory investment in raw materials, is defined as follows:

(1.2) $\Delta Hr_t = Hr_t - Hr_{t-1}.$

The quantity $e_{1t}$ in equation (1.1) is an error term and is an unknown quantity. The coefficient b in expression (1.1) is known as the speed-of-adjustment coefficient, and provides a measure of the extent to which the hypothesized adjustment toward equilibrium is accomplished. A value of b equal to unity implies that total adjustment to the equilibrium level occurred within the period, whereas a zero value for this coefficient suggests that no attempt was made to adjust stocks to their equilibrium levels during the period.

Expression (1.1), using definition (1.2), can be written

(1.3) $Hr_t - Hr_{t-1} = b(Hr_t^e - Hr_{t-1}) + e_{1t}$

or equivalently,

(1.4) $Hr_t = bHr_t^e + (1-b)Hr_{t-1} + e_{1t}.$

Taking first differences in expression (1.4) yields

(1.5) $\Delta Hr_t = b\Delta Hr_t^e + (1-b)\,\Delta\, Hr_{t-1} + e_{2t}$,

where all of the variables except $\Delta Hr_t^e$, the equilibrium inventory change during the interval (t-1, t), are observable.

On the basis of some of the theoretical considerations discussed earlier, an expression designed to explain changes in the equilibrium level of stocks was derived. As a first approximation, $\Delta Hr_t^e$ was assumed to be positively and linearly related to new orders placed in earlier periods. This supposition was subsequently examined (empirically), the results indicating that new orders did not directly effect raw-material inventory behavior. It is likely that new orders would only indirectly influence inventory investment in raw materials as long as a substantial unfilled-order backlog existed.

Another variable that could be significant in determining the direction and magnitude of inventory change is the anticipated behavior of prices, i.e., inventory change might be expected to be positively related to anticipated price changes. The data used in examining this contention was a composite index reflecting movements in prices of thirty basic industrial raw materials.[3]

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3 Dominion Bureau of Statistics, Prices and Price Indexes, Catalogue No. 62-002, Ottawa, Queen's Printer, June 1966, Table I, p.l.

Being unable to derive an expression that would satisfactorily explain how price anticipations are generated, it was assumed that manufacturers were able to correctly anticipate price changes, i.e., price expectations were assumed to be equal to the actual price changes that occurred. Proceeding on this basis, it was found that the coefficient of the price expectations variable was not significant at the specified level of significance (90%), i.e., no evidence was found to substantiate the contention that manufacturers of durable commodities, on the whole, systematically adjust their holdings of raw materials in the light of expected price changes. This does not preclude the possibility that manufacturers are consistently unable to correctly anticipate changing prices (in which case the basic assumption of this test would be violated). It is unlikely that this is so however; it is more probable that any benefits that might be derived from adjusting raw-material stock levels as a result of expected price changes,are outweighed by the disadvantages of adopting such a course of action.

An attempt was made to establish empirically that manufacturers tend to revise their inventories of raw materials in anticipation of changes in the physical conditions of supply of their material inputs. According to this supposition, manufacturers would attempt to offset shortages in raw materials caused by work stoppages in either the primary producing or transportation industries, by accumulating additional stocks before these bottlenecks occurred. To test this hypothesis, a procedure suggested by Maurice Liebenberg and colleagues was employed, whereby a dummy series was constructed in which the entry during a major strike quarter was set equal to -1, quarters before and after strike quarters were designated by +1, and other periods were represented by 0.[4] Using data provided by the Department of Labour and reported in the Canadian Statistical Review, the possible effects of work stoppages in both transportation and industrial raw-material industries were examined and found not to influence raw-material inventory investment to a significant extent.

The final expression explaining equilibrium inventory change contained four variables. Equilibrium inventory change was assumed to be determined mainly by manufacturers' immediate and future requirements for raw materials, and modified by the opportunity cost of holding inventories as well as the actual size of beginning-of-period stocks of raw materials.

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4 M Liebenberg, A.A. Hirsch, and J. Popkin, "A Quarterly Econometric Model of the United States: A Progress Report", Survey of Current Business, U.S. Department of Commerce, Vol. 46, No. 5, May 1966, p. 31.

The final expression explaining equilibrium inventory change, $\Delta Hr_t^e$, was assumed to be

(1.6) $\Delta Hr_t^e = a_1 \Delta U_{t-2} + a_2 U_{t-2} + a_3 R_{t-1} + a_4 Hr_{t-1}$,

where the coefficients $a_1$ and $a_2$ were expected to be positive and the coefficients $a_3$ and $a_4$ were expected to be negatively signed. Thus equilibrium inventory investment was assumed to be positively and linearly related to the change in unfilled orders that occurred two periods earlier, $\Delta U_{t-2}$, and the volume of unfilled orders lagged two periods, $U_{t-2}$. It was further assumed that equilibrium inventory change was linearly but negatively related to a measure of the tightness of the money market (as approximated by the prevailing short-term treasury bill rate at the beginning of the period) and the volume of stocks of raw materials on hand at that time. Substituting expression (1.6) into (1.5) yielded an expression of the form:

(1.7) $\Delta Hr_t = C_o + C_1 \Delta U_{t-2} + C_2 U_{t-2} + C_3 R_{t-1} + C_4 Hr_{t-1} + C_5 \Delta Hr_{t-1} + e_{3t}$.

Expression (1.7) was fitted by the method of least-squares and the following numerical results were obtained, covering the period extending from the fourth quarter of 1958 to the third quarter of 1965 inclusive:

(1.8) $\Delta Hr_t = 1.57 + .33 \Delta U_{t-2} + 3.29 U_{t-2} - 4.57 Hr_{t-1}$

(3.70) (5.28) (6.70) (4.49)

$$- .66R_{t-1} + .22\Delta Hr_{t-1} \qquad R^2 = .72$$
$$(1.87) \quad (1.79) \qquad Q = 2.03$$

where the values in parentheses are the computed t-values for the associated coefficients. All of the coefficients were signed as expected and were significant at the 90% level.

No attempt was made to incorporate into the regression factors which, however relevant theoretically, could not be quantified or for which suitable surrogates could not be found. Thus the analysis is admittedly an oversimplification of the processes that did, in fact, occur. While considerable insight into the processes, by which inventory investment is determined, is undoubtedly denied us because of the inadequacy of the analysis or the nonexistence of relevant data, there would seem to be little profit in offering explanations which, however plausible theoretically, cannot be verified empirically and remain at best conjecture.

Of the variables appearing in equation (1.8), that which contributed most to explaining variations in inventory investment in raw materials was the change in the unfilled-order backlog that occurred two quarters earlier. The value of unfilled orders at any given time was also shown to significantly affect inventory investment in raw materials two periods later. This lends considerable weight to the supposition that durable manufacturing sector is, to a large extent, "production-to-order" oriented.

Beginning-of-period stocks of raw materials were also shown to be significant in determining inventory investment during the ensuing period. As expected on theoretical grounds, the influence was a negative one.

A term representing the opportunity cost of tying up funds in stocks of raw materials was found to be statistically significant and appears in expression (1.8). This variable was represented by the short-term treasury bill rate of interest that prevailed at the beginning of the period.[5] The relationship between inventory investment and the interest-rate variable conformed to a priori expectations, i.e., inventory investment in raw materials was shown to be inversely related to the opportunity cost of tying up funds in this way.

Finally, inventory investment in raw materials during any period was shown to be related to this same variable, lagged one period. The latter quantity was the least significant of the explanatory variables considered. This demonstrated inertial effect suggests that while orders for raw materials are placed by manufacturers for their various requirements as stocks of these items are being used up, these orders will be filled somewhat later, after delivery times

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5 Bank of Canada, Statistical Summary, Ottawa, Queen's Printer, May 1966, Table entitled "Money Market Statistics", p. 302.

that will probably vary for different classes of raw materials. This will result in a relatively stable flow of deliveries of raw materials to manufacturers over time; the rate of flow being roughly proportional to the rate at which raw materials are being absorbed into production, assuming that no bottlenecks or shortages of raw materials occur.

# CHAPTER IV

## INVENTORY INVESTMENT IN GOODS-IN-PROCESS

Manufacturers must always hold some portion of their stocks in the form of goods-in-process. The proportion of total inventories that is held in this form will vary widely from one industry or industry group to another. For example, in the non-durable manufacturing sector, goods-in-process rarely exceed fifteen per cent of total stocks at any time whereas in durable manufacturing industries, this same inventory component will usually account for between thirty and forty per cent of the value of total stocks held by manufacturers.

This observation is consistent with a priori expectations, considering the nature of durable goods in general, and the production methods required to manufacture them. Durables are, in general, structurally more complex than non-durables, thus their manufacture will require more sophisticated equipment and possibly a higher calibre (in terms of specialized training) of workmanship. Certainly, durable commodities will be in process of manufacture for longer periods of time than goods of simpler construction.

It is likely that goods-in-process exist in far smaller quantities than those of raw materials held by manufacturers. Yet in some industries, the values of goods-in-process approach the magnitudes of raw-material holdings. This indicates that given values of in-process stocks contain, in many cases, a substantial "value added" component. In fact, the behavior of goods-in-process is probably dominated by this latter quantity.

Since a "value added" series was not available on a quarterly basis for the durable manufacturing sector, this quantity was assumed to be proportional to the total wage-bill (salaried employees and wage-earners) of this sector. The wage-bill was found by multiplying average quarterly earnings[1] by the number of people employed in durable manufacturing, for each quarter of the 1958-65 period. Some difficulty was encountered at the very outset in attempting to establish a relationship between goods-in-process inventories and the total wage-bill of the durable manufacturing sector, because the definitions of the "durable manufacturing sector" did not coincide in each case. Despite promising beginnings, variations in goods-in-process could not be explained in terms of variations in the durable manufacturing

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1 Dominion Bureau of Statistics, Earnings and Hours of Work in Manufacturing, Catalogue No. 72-204, Ottawa, Queen's Printer, January 1966, Table A, p.7. The data given in this source represent annual quantities. The corresponding quarterly figures (unpublished) were obtained from the Dominion Bureau of Statistics. The quarterly employment figures used in calculating the durable manufacturing wage-bill were provided by the Department of Labour. These too were unpublished data, and were a by-product of the Labour Force Survey.

wage-bill, and the latter variable does not appear in the final regression equation.

Stocks of goods-in-process are closely linked with the production process, and as such will be affected by a wide range of technical factors that determine its character. Therefore, inventory investment in this component will probably be affected by such factors as the duration (manufacturing lend-time) and sophistication of the production process, economic batches and set-up time, costs of production, capacity restraints, production losses and the availability of raw materials.[2] Owing to insufficient data, the precise nature of the relationships that exist among these variables cannot be determined empirically, and the impact of each of these variables on in-process inventory behavior is difficult to assess.

Assuming that manufacturers of durable goods produce mainly in response to demand for their products, i.e., "to order", the value of goods-in-process in any period will, to a great extent, be determined by new orders placed for their products in earlier periods. The difference in the dating of these two variables will depend on the time lapse between the placing of orders with manufacturers and such

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2 National Industrial Conference Board, Inventory Management in Industry, Studies on Business Policy No. 88., New York, 1958, p. 21-22.

times as these goods are actually being processed. This lag will depend upon the size of the unfilled-order backlog and the rate of production.

While this relationship between new orders and goods-in-process is generally acknowledged and is expected to be an important one, a direct measure of the impact of new-order receipts on subsequent production would be difficult to achieve, for the effect of new orders will be somewhat dissipated as these are added to the backlog of unfilled orders. Thus variations in new orders may have little perceptible effect on the value of goods-in-process, particularly if a substantial backlog of unfilled orders exists. Only when the unfilled-order backlog becomes small in relation to new-order receipts would the volume of goods-in-process be expected to become directly sensitive to new-order receipts.

The existence of a backlog of unfilled orders provides an element of stability in the production process by insulating manufacturers' operations from short-term fluctuations in the demand for their products. Manufacturers will attempt to maintain an even flow of production, for variations in the rate of production usually involve an element of cost. This tendency will, however, be partly offset by competitive conditions that will require that orders be filled as quickly as possible. On balance then, it is expected that output will be positively related to the backlog of unfilled orders. Production schedules, however, cannot be altered spontaneously, therefore variations in unfilled orders will tend to lead changes in the rate of production, and hence changes in the value of goods-in-process.

If the contention that costs of production are positively related to variations in the rate of production is a valid one, then the smoothing of production will be an important objective of manufacturers. Thus manufacturers will strive to maintain production at a fairly stable level, and thereby insulate their operations as much as possible from short-term variations in the factors that would normally be expected to affect them, in the interest of achieving long-run stability in their operations. If manufacturers are successful in achieving this end, then it would be expected that the rate of production in any period would bear some fairly stable relation to that of the previous period(s), and changes in the value of goods-in-process during any period would be positively related to inventory investment in goods-in-process during the previous period.

On theoretical grounds, it is expected that the level of goods-in-process would be related to the extent of capacity utilization at that time. An absolute measure of this variable was not available, however this quantity was approximated by taking the ratio of current output to the previous high level of output. This procedure yielded a relative measure of capacity utilization, and variations in this quantity would be expected to positively affect inventory change in goods-in-process.

The value of in-process stocks at any time will tend to be positively related to capacity utilization at that time. If an increase in the value of goods-in-process occurs during one period, then this implies that productive capacity has been used to a greater extent. It follows then, assuming that goods are "in process" for more than one period, that this greater utilization will restrict the amount of new production that can be accommodated in the following period. Thus it is suggested that inventory investment in goods-in-process in any period will be negatively related to the level of these stocks at the beginning of that production period.

Holdings of goods-in-process represent large disbursements of funds by manufacturers. These funds will not be so invested without regard for alternative forms of investment. The availability of funds will affect holdings of goods-in-process similarly. Inventory investment in goods-in-process, under this assumption, would be inversely related to the tightness of the money market and the return on funds otherwise invested. Both of these effects were approximated, in this study, by the short-term treasury bill yield that prevailed at the beginning of the period.

The relationship between inventory investment in goods-in-process and its determinants was developed in terms of the flexible-accelerator model, i.e.,

(2.1) $\Delta Hg_t = c(Hg_t^e - Hg_{t-1}) + e_{1t}, \quad 0 \leq c \leq 1,$

where $\Delta Hg_t$ denotes inventory investment in goods-in-process $Hg_t^e$ represents the equilibrium end-of-period level of in-process stocks and the variable $Hg_{t-1}$, actual beginning-of-period stocks. The coefficient c provides some measure of the extent to which an adjustment toward equilibrium can (or will) be accomplished during any given period. It is, in effect, a measure of the flexibility of the production process, a low value of this coefficient indicating that the production process was, by nature or design, fairly inflexible.

Employing the procedure used in the previous chapter, an expression in terms of inventory change in goods-in-process can be given the following representation:

(2.2) $\Delta Hg_t = c\Delta Hg_t^e + (1-c)\Delta Hg_{t-1} + e_{2t}.$

On the basis of the theoretical considerations presented earlier, equilibrium in-process inventory investment was assumed to be positively related to the behavior of unfilled orders and/or new orders placed in earlier periods, capacity utilization during the period in question, goods-in-process inventory change lagged one period and the change in the wage-bill that occurred during the quarter. Equilibrium inventory change was also assumed to be negatively related to beginning-of-period stocks of goods-in-process and the short-term treasury bill yield at the beginning of the period.

The dating of the unfilled-order and new-order terms was subsequently determined by trial and error, yielding finally the following expression for equilibrium inventory change in goods-in-process:

$$(2.3) \quad \Delta Hg^e_t = d_o + d_1 \Delta U_{t-2} + d_2 N_{t-3} + d_3 Utl_t + d_4 Hg_{t-1} + d_5 R_{t-1} + d_6 \Delta W_t$$

where theoretically,

$d1, d2, d3, d6, > 0$ and $d4, d5, < 0$.

Equation (2.3), when substituted into (2.2), yielded an expression in which all of the variables were measurable. The results obtained from the regression are:

$$(2.4) \quad \Delta Hg_t = -\underset{(2.34)}{1.36} + \underset{(3.63)}{.34} \Delta U_{t-2} + \underset{(1.86)}{.92} N_{t-3} + \underset{(2.07)}{.36} \Delta Hg_{t-1}$$

$$- \underset{(2.35)}{1.26} Hg_{t-1} + \underset{(1.70)}{2.03} Utl. - \underset{(1.89)}{.09} R_{t-1} \qquad R^2 = .75 \qquad Q = 2.28$$

A few summary remarks are in order regarding the results shown above and the nature of the analysis that gave rise to expression (2.4). It is seen that the variables contained in this expression are signed as expected on theoretical grounds. The fit, however, is not particularly good. This no doubt follows from the author's inability to take into account all of the relevant variables. It is to be expected, however, that at this level of aggregation, individual characteristics of various production processes would be lost. Moreover certain variables would have defied measurement regardless of the level of aggregation.

The regression findings indicated that the coefficient of flexibility c, in equation (2.1) was numerically equal to .64. Thus, in any period, manufacturers effected an adjustment in their stocks of goods-in-process equal to approximately two-thirds of the discrepancy between end-of-period equilibrium stocks and the actual beginning-of-period stocks.

Of the explanatory variables included in equation (2.4), that which contributed most to explaining inventory investment in goods-in-process was the term representing changes in unfilled orders, lagged two periods. The term representing new orders, lagged three periods, acquired a significant coefficient at the 90% confidence level, but contributed somewhat less to explaining inventory change in goods-in-process.

The extent of capacity utilization was shown to be a relevant factor in explaining inventory investment in goods-in-process. The contribution of this variable was a significant one, yet its coefficient acquired only a nearly-significant t-value at the 90% confidence level. Inventory investment in goods-in-process was shown to be determined, in part, by this same variable lagged one period, although the effect of this latter variable was comparatively slight.

Finally, two negative influences were ascertained to be statistically significant, at the 90% confidence level, in explaining how in-process inventory investment, during the subject period was generated; the beginning-of-period short-term interest rate, reflecting the opportunity cost of holding inventories in this form and the beginning-of-period level of in-process stocks.

## CHAPTER V

## INVENTORY INVESTMENT IN FINISHED DURABLES

The assumption that the durable manufacturing sector is order-oriented has particular implications when applied to stocks of finished goods. In the limiting case where production is carried out entirely "to order", any discussion of finished stocks as well as inventory investment in finished manufactures would be inappropriate, for theoretically these quantities would not exist.

However, stocks of finished durables do exist and this is undoubtedly so by design. It is precisely because of this fact, and the extent to which manufacturers designate some portion of their output, however small, as production "for stock", that an analysis of inventory investment in finished goods can be undertaken.

An examination of published inventory data shows that throughout the durable manufacturing sector, only a relatively small portion of total stocks exist in the form of finished goods. For most industry groups, finished durables account for less than one quarter of the value of total stocks. This stands in marked contrast to non-durable manufactures where stocks of finished goods are often the largest inventory component.

As in the case of goods-in-process, the very nature of the industry and the product will determine, and possibly limit, that portion of total stocks held in finished form. Finished inventory behavior will be influenced by the interaction of many factors that will affect all industries that comprise the durable manufacturing sector, but in varying amounts. Despite the fact that many of these factors cannot be quantified, certain of these, albeit implicitly, would be considered by manufacturers when formulating finished-inventory objectives. Among the more important of these factors are: customer ordering practices, the unit value of the product, manufacturing lead-time, the sales history of the item and the danger of obsolescence.

One of the practices most frequently cited in connection with inventory management involves manufacturers' deliberate adjustment of finished-inventory levels in the light of anticipated price changes. This mode of behavior was examined as a possible factor affecting inventory investment in raw materials and found, in that context, not to be significant. Unfortunately the possible effects of anticipated price changes on inventory investment in finished durables could not be examined directly in this study, for no price data on a basis comparable to the other series being used, was available. There does, however, exist strong support, on both theoretical and empirical grounds, for the view that anticipated price changes do not, in fact, induce any systematic response in finished-inventory behavior.

While the practice of increasing inventories in anticipation of rising prices and decreasing stocks in view of expected price declines is expected to be a significant factor in explaining trade inventory behavior, various writers have submitted that manufacturers are likely to avoid price speculation on an extensive scale. Michael Lovell, for example, on the basis of his studies of United States manufacturers' inventories, concluded that "no empirical evidence was found for the hypothesis that manufacturers speculate in inventories, adjusting their holdings of stocks in response to anticipated price changes."[1]

This view was also substantiated by Professor Clarence Barber who conducted an extensive inquiry into manufacturing activities in Canada. He explained his position as follows:

> Under the most widely used methods of inventory accounting, it is customary to calculate profits by charging the earliest purchases still on hand, rather than the materials that have been purchased most recently, to cost of goods sold. The effect of this practice, is to inflate profits in periods

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1 Michael Lovell, "Buffer Stocks, Sales Expectations, and Stability: A Multi-Sector Analysis of the Inventory Cycle", Econometrica, Vol. 30, No. 2, April 1962, p. 269.

of rising prices and deflate them when prices are falling. This bit of self-deception results in business firms feeling more optimistic in periods of rising prices, paying out more money as dividends and spending more for capital expansion. The reverse is true in periods of falling prices. Thus it can be argued that the profits which tempt business firms to anticipate their purchases in a period of rising prices are mainly paper profits, at least for any firm that is in business on a continuing basis.[2]

Levels of stocks and changing price levels are not, however, unrelated. In fact it has been suggested that it is precisely inventory changes that account, in large measure, for short-term fluctuations in prices.

Effective inventory policy will compel manufacturers to formulate some rule that will define, in view of the circumstances that are expected to prevail, what the appropriate level of their finished inventories should be. In some cases, the decision rule may be very elementary while in others, manufacturers may base their inventory policy on extremely elaborate formulations. Whatever its form, the inventory decision rule will seek to establish a relation between inventories and expected future requirements.

Firms producing entirely "to order" would have little difficulty in this respect, for the demand for their products is completely specified, and their entire output, barring

2 C.L. Barber, Inventories and the Business Cycle with Special Reference to Canada, Toronto, University of Toronto Press, 1958, p.7.

cancellations of orders, is committed to filling orders already received. But where conditions of demand are less certain, manufacturers will be compelled by competitive conditions to produce in excess of an amount just sufficient to meet firm orders already placed with them. This, for the manufacturer, poses the practical problem of forecasting sales, and for the investigator of inventory behavior, the yet more difficult task of deducing the inventory strategy that was realized.

In attempting to explain the complex process that gave rise to the extremely irregular pattern of finished-inventory investment that occurred in the 1958-65 period, a procedure suggested by Franco Modigliani was used as a first approximation.

> While the immediate goal of decisions affecting the size of stock is usually not that of maintaining the stock of any given item in a certain desirable relation with sales, yet, for the purpose of aggregative analysis it may not be a bad approximation to assume, as has been done in recent inventory models, that firms endeavour to establish and maintain such a relation [...] . While this relation may not be desired per se, it performs the same role as if it were desired.[3]

The constant inventory-sales ratio would be expected to explain only the basic tendency in the behavior of stocks of

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3 Franco Modigliani, "Business Reasons for Holding Inventories and their Macro-economic Implications", NBER studies in Income and Wealth, Volume 19, Princeton, Princeton University Press, 1957, p.503.

finished durables. The influence of other variables would, of course, modify this behavior pattern.

As in the preceding two chapters, the flexible-accelerator model provided the basis for the analysis of finished-inventory investment that is proposed in the following paragraphs, i.e.,

(3.1) $\Delta Hf_t = c(Hf_t^e - Hf_{t-1}) + c_{1t}$

which after a suitable transformation, becomes

(3.2) $\Delta Hf_t = d\,\Delta Hf_t^e + (1-d)\Delta Hf_{t-1} + c_{2t}$,

where actual finished-durable inventory change during the period is denoted by $\Delta Hf_t$, and $Hf_{t-1}$ represents beginning-of-period stocks of finished goods. Equilibrium inventory investment that occurred during the interval (t-1,t) is designated by $\Delta Hf_t^e$. The coefficient c in equation (3.1) is the speed of adjustment coefficient and provides a measure of the extent to which manufacturers adjust finished inventories to their equilibrium levels during any particular quarter.

Equilibrium inventory investment during the interval (t-1,t) was assumed to be inversely and linearly related to beginning-of-period stocks of finished durables, $Hf_{t-1}$, and positively related to changes in the inflow into the finished goods category resulting from new production. This latter quantity, since a suitable measure of durable manufacturing output by quarter could not be found, was assumed to be proportional to the change in stocks of goods-in-process that occurred during the previous quarter, $\Delta Hg_{t-1}$.

It was assumed, moreover, that equilibrium change in stocks of finished durables was negatively related to the opportunity cost of holding these stocks, as represented by the prevailing beginning-of-period treasury bill rate of interest, negatively related to the difference between the current period's shipments and those of the previous quarter, $\Delta St$, and likewise negatively related to shipments made during the current quarter, $S_t$.

Finally, if the hypothesis that the durable manufacturing sector is order-oriented is basically correct, then stocks on hand at any given time would be already sold and be simply awaiting shipment. Any curtailment of normal transportation facilities, whatever the reason, would be expected to result in the accumulation of stocks of finished manufactured goods. In order to examine the possible effects of strikes and work stoppages in the transportation industry on finished-durable inventory investment, a dummy series, denoted by $D_t$, similar to that employed in the analysis of changes in stocks of raw materials, was used in which a value +1 was assigned to major strike quarters, i.e., where time lost exceeded, say, twenty thousand man-working days, -1 to quarters immediately preceding or following major strike quarters, and a zero value was assigned to the remaining periods.

Equilibrium inventory investment in finished durables, in view of the above, can be given the following symbolic representation:

(3.3) $\Delta Hf_t^e = do + d_1Hf_{t-1} + d_2S_t + d_3\Delta S_t + d_4D_t + d_5\Delta Hg_{t-1}$,

where $d_1, d_2, d_3, < 0$ and $d_4$ and $d_5 > 0$.

Expression (3.3) was combined with equation (3.2) and submitted for testing. The following results were obtained:

(3.4) $\Delta Hf_t = 14.75 - 10.69Hf_{t-1} + .272\Delta S_t - 4.03S_t$
(16.88) (5.45) (1.90) (1.85)

$+ .17\Delta Hg_{t-1}$
(1.12)

$R^2 = .53$

$Q = 1.93$

In terms of fit, expression (3.4) is disappointing. Moreover, one observes that the coefficient of the variable representing the change in the value of shipments is wrongly signed, and that the t-values for most of the coefficients are quite low.

Of the variables omitted from equation (3.4) but included in equations (3.2) and (3.3), the variable representing finished inventory change, lagged one period, was found to be least significant. The dummy variable reflecting disruptions in the transportation industry and the term representing the opportunity cost of holding finished stocks, were likewise shown to have coefficients that were statistically insignificant. All of these variables had coefficients whose t-values were considerably less than unity.

The results obtained, however, do indicate that the supposition that the durable manufacturing sector is order-oriented is not entirely correct, for in a pure production "to order" situation, inventory investment in finished durables would be expected, on theoretical grounds, to be a random variable. Some of the variation in finished inventory investment can be explained in terms of "other" variables, thus it must be concluded that durable manufacturers designated some portion of their output as production "for stock" (since the concepts "to order" and "for stock" are mutually exhaustive).

Apart from the fact that equation (3.4) performs poorly in terms of fit, there is yet another factor that limits the predictive ability of this expression. In the final equations explaining inventory investment in both raw-materials and goods-in-process, the explanatory variables are, almost without exception, predetermined. In the corresponding final-inventory equation, two of the four explanatory variables are currently determined and one of these is wrongly signed.

Finally, the analysis of finished-inventory behavior is seriously impaired by the omission, from the regression, of factors that may have been most significant in explaining inventory investment in finished durables during the 1958-65 period. The most important of these is probably the current and forecast economic climate (in a business cycle sense). The effects of this factor might have been approximated, for example, given a series representing new-order concellations. In addition, the occurrence (and extent) of errors in forecasting finished-inventory requirements in any quarter was, in all probability, a significant factor in determining subsequent finished-inventory investment.

It would be inappropriate to terminate this chapter without examining, however briefly, the results obtained by some of the more prominent investigators of finished-inventory behavior. Although none of these studies deal with the durable manufacturing sector alone, the results obtained are nonetheless relevant inasmuch these afford a background against which to view the results already established in this chapter.

Paul Darling[4], whose continuing work in the field in recent years has provided considerable insight into manufacturers' inventory behavior, fitted an expression explaining

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4 Paul G. Darling, "Manufacturers' Inventory Investment, 1947-1958: An Application of Acceleration Analysis", *American Economic Review*, December 1959, p. 952.

total manufacturing inventory investment, using quarterly data (book values) extending from the third quarter of 1947 through the third quarter of 1958. On the basis of his investigations, Darling concluded that total manufacturing inventory change was positively and linearly related to the sales of the previous period, the change in unfilled orders lagged one period and negatively related to end-of-period stocks lagged two periods.

(3.5) $\Delta H_t = -.387 + .415S_{t-1} - .212H_{t-2} + .324\,\Delta U_{t-1} + e_t, \quad R^2 = .89$

Using deflated nonfarm inventory data for the United States covering a period extending from 1947 to 1959, Michael Lovell[5] submitted a regression in which aggregate nonfarm inventory investment was found to be positively and linearly related to current sales and the end-of-period backlog of unfilled orders. Lovell's research also indicated a linear but inverse relationship between inventory investment and beginning-of-period stocks as well as changes in sales.

(3.6) $\Delta H_t = 2.49 + .328S_t - .407H_{t-1} - .137\,\Delta S_t + .043U_t + e_t, \quad R^2 = .74$

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5 Michael C. Lovell, "Determinants of Inventory Investment", Models of Income Determination, NBER Studies in Income and Wealth, Vol. 28, Princeton, Princeton University Press, 1964, p.186.

Finally, and most recently published, is a study submitted by Ta-Chung Liu who developed an inventory sub-model as part of a quarterly econometric model of the postwar United States economy. This study was undertaken in an attempt to show "that short-run changes in prices are mainly decided by considerations involving inventories".[6] The change in nonfarm business inventories, according to Liu, was explained by the following equation:

$$(3.7) \quad \Delta H_t = 22.35 + .122S_t - .302R_t + .525B_t + .166\Delta H_{t-1} + .246\Delta H_{t-2} + .460_{t-1} - .781H_{t-1} + 1.427W_t + e_t,$$

$$R^2 = .76$$

where $S_t$ denotes current sales, $R_t$ denotes the current real short-term rate of interest (defined as the short-term rate of interest less the rate of change of the price level during the preceding quarter), $B_t$ represents business liquid assets, $O_{t-1}$ represents output during period t-1 and $W_t$, the change in the wage rate during period t. End-of-period nonfarm business stocks are denoted by $H_t$ and changes in this variable, by $\Delta H_t$.

6 Ta-Chung Liu, "An Exploratory Quarterly Econometric Model of Effective Demand in the Postwar U.S. Economy", Econometrica, Vol. 31, No. 3, July 1963, p. 313.

# CHAPTER VI

## AGGREGATE INVENTORY INVESTMENT AND ITS DETERMINANTS

Having examined the behavior of the three inventory components individually, and relying on the results obtained in the process, it is proposed that an expression should be derived that would explain how aggregate durable manufacturing inventory investment in Canada, during the period extending from 1958 to 1965, was generated. This analysis of aggregate inventory investment will perforce be somewhat superficial inasmuch as it is not possible to explain precisely how the individual inventory components, which are being determined simultaneously, interact to produce the observed aggregate inventory behavior.

Studies devoted mainly to explaining aggregate inventory investment for various categories of manufactures have been conducted, and a number of these have been published in recent years. A cross section of the techniques employed and the results obtained by various writers in the field are summarized below, even though these may not be concerned with the durable manufacturing sector alone, and as such, be only indirectly relevant to this study.

Most of the published studies of aggregate inventory behavior have used models based on the accelerator principle, where in its simplest form it was assumed that end-of-period equilibrium stocks bear a stable relation to the sales of that period. It was further assumed that manufacturers were, in fact, able to adjust actual stocks to their equilibrium levels during the specified period. For purposes of estimation, actual stocks were assumed to be identical to equilibrium stocks which were, by supposition, linearly related to current sales. The simple accelerator model, when used to explain inventory change, would be modified by differencing the variables in the stock model, yielding an expression of the form:

(4.1) $\Delta H_t = a_o + a_1 \Delta S_t + e_t$

D.J. Smyth[1], who was interested primarily in calculating the inventory accelerator and not in explaining how inventory investment was determined, employed a variation of the model described above and found that the change in aggregate manufacturing inventories could, with some success, be expressed as a function of $\Delta \dot{Y}_t$, the change in the gross national product, and a variable representing the passage of time.

(4.2) $\Delta H_t = -.86 - .30 \Delta Y_t + 0.07_t \qquad R^2 = .87$

In this study, Smyth used annual deflated data for the United States covering the period 1948 to 1958. (While the result cited above is only incidentally relevant to this

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1 D.J. Smyth, "Inventory Investment and Fixed Capital Accelerators", Economic Record, August 1960, p. 163.

study, it does illustrate the simplest application of the accelerator model).

It is clear that the simple accelerator model could not satisfactorily be applied to the problem of explaining inventory behavior and for two principal reasons. First, the simultaneous-adjustment feature of the model ascribed to manufacturing activities a flexibility that was quite unrealistic. Secondly, the model did not provide the scope required to effectively establish the processes whereby inventory investment was generated.

Many of the shortcomings of the simple accelerator model were eliminated through the efforts of Richard Goodwin, who suggested a flexible-accelerator formulation that was the basis for many of the more recent econometric investigations of inventory behavior. It was founded on the somewhat more realistic assumption that producers were able to affect only some portion of the adjustment toward the equilibrium level of stocks during any single period.

The flexible-accelerator model provided the framework for an investigation begun some time ago, but hitherto unpublished, of aggregate (durable and non-durable combined) manufacturing inventories in Canada during the period extending from 1955 to 1962.[2]

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2 T.J. Courchene, An Econometric Analysis of Canadian Inventory Behavior 1955-1962, Mimeographed progress report

While attention was focused, in the analysis, on inter-industry comparisons of inventory behavior, an equation relating to total stocks was derived, and is given below:

$$(4.3) \quad \Delta H_t = 24.5 - .354 \Delta S_t + .233 S_t - 6.0 RL_{t-1} - .274 H_{t-1}$$

$$R = .75,$$

where all of the variables, except $RL_t$, which represents the long-term corporate bond rate of interest, are consistent with convention already established in this thesis.

Nestor Terleckyj[3] presented an explanation of inventory behavior in United States manufacturing and trade combined which was also based on the flexible-accelerator concept. The Terleckyj representation differed from more conventional formulations in several respects. In this regression, the inventory variable represented the percentage quarterly change in book value of stocks adjusted for revaluation of existing stocks. This variable was shown to be a linear function of the ratios, lagged one period, of inventory to sales, new orders to sales and unfilled orders to sales.

$$(4.4) \quad \frac{\Delta H_t}{H_t} = -14.59 - 11.26 \frac{H_{t-1}}{S_{t-1}} + 30.75 \frac{NO_{t-1}}{S_{t-1}} + 1.88 \frac{U_{t-1}}{S_{t-1}}$$

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prepared for the Econometric Workshop, Undated, p.3. The current status of this study is unknown.

3 Nestor Terleckyj, Measures of Inventory Conditions, New York, National Industrial Conference Board, 1960, p.26.

$+ e_t \qquad R^2 = .78.$

Finally, and perhaps best known, is the research conducted by Michael Lovell[4] in the field of manufacturing inventory behavior in the United States. Using durable manufacturing (quarterly) data extending from 1948 through 1960, Lovell derived the following regression equation:

$$(4.5) \quad \Delta H_t = -1.55 - .12H_{t-1} + .13S_t - .002\Delta S_t + .01U_t + .05\Delta U_t \qquad R^2 = .57$$

where $\Delta H_t$ denotes aggregate durable manufacturers' inventory investment during quarter t and the explanatory variables (in the order that they appear in the equation) are: the level of stocks at the beginning of the quarter, sales of the current quarter, current sales less the sales of the previous quarter, the end-of-quarter unfilled-order backlog and the difference between the level of end-of-quarter unfilled orders and the level that existed at the beginning of the quarter. It is noteworthy that in this regression, only one of the explanatory variables is predetermined.

The preceding few paragraphs do not presume to survey all of the work that has been done in the field to date, but rather are designed to indicate, in broad outline, the approach that researchers have tended to pursue in studying aggregate inventory behavior.

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4 Michael C. Lovell, "Factors Determining Manufacturing Inventory Investment", Inventory Fluctuations and

The basic model used in the examination of aggregate inventory change in the Canadian durable manufacturing sector was essentially the one in the preceding chapters, i.e.,

(4.6) $\Delta Ha_t = a_1 \Delta Ha^e_t + a_2 \Delta Ha_{t-1} + e_t$.

The problem of formulating an expression that would adequately explain equilibrium inventory change, $\Delta Ha^e_t$, was somewhat more difficult than describing this same variable for the individual inventory components. On the basis of information gained regarding the behavior of the various inventory components, it was submitted that equilibrium aggregate inventory change was positively and linearly related to unfilled orders lagged two periods, the change in unfilled orders lagged two periods, new orders lagged three periods and denoted $NO_{t-3}$, and negatively related to beginning-of-period aggregate stocks as well as the prevailing short-term rate of interest at the beginning of the period. All of these variables, except the rate-of-interest term were found to be significant at the 90% level of confidence.

The foregoing formulation was modified to allow for the production-for-stock aspect of durable manufacturing by including, in the equation representing equilibrium inventory change, a term representing current sales. Also included in

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Economic Stabilization, Washington, Joint Economic Committee, 87th Congress, 1st Session, Part II, December 1961, p. 129.

this equation was a term representing the difference between new orders received during the current period and those received during the previous quarter. The latter variable, although difficult to justify on theoretical grounds, substantially improved the fit of the final regression equation.

This modified equation was submitted for testing and the following results were obtained:

(4.7) $\Delta Ha_t = 8.16 + .363\Delta Ha_{t-1} - 8.48Ha_{t-1} + .257U_{t-2}$

(18.61) (2.28) (4.37 (2.85)

$+ .090\Delta U_{t-2} + 1.31NO_{t-3} + .145\Delta NO_t - .264S_t$

(2.72) (3.10) (3.23) (3.21)

$- .315R_{t-1}$ $R^2 = .77$

(1.51) $Q = 1.49$

At the 90% confidence level, all of the variables, except the beginning-of-period interest-rate variable, acquired statistically significant coefficients. All of the variables were, moreover, signed as expected. It is noteworthy too, that aggregation yielded a better fitting equation than was obtained for each of the inventory components. The value of the Q-statistic obtained for this regression was quite low, however it was not expected that this would invalidate the findings of this study as represented in equation (4.7).

# SUMMARY AND CONCLUSIONS

In the preceding four chapters, attention has been focused on examining the behavior of changes in aggregate inventories in the durable manufacturing sector as a whole, as well as in the three distinct classes of goods that comprise aggregate stocks, i.e., raw materials, goods-in-process and finished goods.

The stated objective of this thesis has been to explain how inventory investment, in each of the above-mentioned categories, is generated. The procedure, in each case, consisted of specifying a relationship between inventory change and its (postulated) determinants. Next, employing statistical procedures, the hypothetical model was tested on the basis of the observed (quarterly) behavior of the relevant variables over a period extending from the fourth quarter of 1958 to the third quarter of 1965 inclusive, yielding numerical estimates of the parameters of the hypothetical equations. Finally, a measure of the "quality" of these estimates was computed as well as an indicator of the overall performance of the model.

Of the equations explaining inventory change for each of the categories of stocks considered, the expression relating to aggregate inventory investment performed most satisfactorily in terms of fit. This equation considered alone, however, was relatively uninformative, for it represented the combined effects of movements in the three subcategories of stocks, which are themselves rooted in basically different processes, and are determined either by different variables or the same variables, but functioning in an essentially different way.

The inventory equation submitted in Chapter III demonstrated that inventory investment in raw materials, during the subject period, tended to be relatively stable as compared with finished-inventory investment, for example. This suggested that, while orders placed by manufacturers for raw materials may have fluctuated considerably both with respect to quantity and timing, the filling of these orders was nonetheless accomplished at a fairly uniform rate. It was suggested that firms would, in general, review their holdings of raw materials periodically and probably place orders for these requirements on a more or less regular basis. The alternative practice of only placing orders when the risk of depletion threatens, while no doubt pursued by certain producers, was not thought likely to characterize the durable manufacturing sector as a whole. Finally, the fact that stocks of raw materials were, in general, the largest single component of aggregate stocks suggested that manufacturers held substantial buffer reserves, and as a result, maintained only an imprecise relationship between their raw-material holdings and the anticipated need for them.

It was demonstrated that inventory investment in raw materials was inversely related to two factors. One of these was the level of beginning-of-period holdings of raw materials indicating that the larger the stocks on hand at any time, the less likely would a further outlay on this very item be forthcoming during the succeeding period. Again, while manufacturers' policy with respect to raw material inventories will focus on being able to meet even abnormal requirements, they would not stockpile purchased materials indiscriminantly. Rather, manufacturers would tend to allocate investment funds in such a way as to maximize the return on their investment; hence investment in raw materials would compete with alternative forms of investment. This view was examined empirically and it was shown that a consideration of opportunity cost seemed to be an important factor in determining raw-material inventory change during the period examined.

The variables that contributed most to explaining raw-material inventory investment were terms reflecting unfilled orders and changes in unfilled orders, both lagged two periods. It was indicated that the size of the backlog of unfilled orders and increases in this backlog during any quarter would result in increased inventory investment two periods later. Conversely, as the level of unfilled orders decreased from the previous quarter, raw-material inventory disinvestment would be induced two periods later, i.e., raw materials absorbed into the production process would not be fully replaced in view of the decreased demand for finished durables.

Unlike inventory investment in raw materials, which was basically determined by future production requirements, modified by certain considerations already discussed, goods-in-process inventory investment was influenced, to a great extent, by certain characteristics of the production process.

It has been argued, on theoretical grounds, that manufacturers will attempt to maintain production at a fairly stable level in the short run. The results obtained in Chapter IV suggested that this hypothetical mode of behavior was essentially correct, i.e., in-process inventory investment in any period tended to be positively related to this same variable, lagged one period. It was also shown that inventory investment in goods-in-process in any period was negatively related to beginning-of-period level of in-process stocks. This implied that the higher the value of in-process stocks at the beginning of the quarter, the less willing (or able) were manufacturers to accomodate increased production during the ensuing quarter; an observation that is also consistent with the production smoothing hypothesis. It was demonstrated too, that inventory investment in goods-in-process during any period was positively and linearly related to the utilization of productive capacity at that time.

Production is carried out in the light of the anticipated demand for manufacturers' output. Thus it was assumed, in this study, that the demand for durable manufactures was given, i.e., production would, in general, reflect new orders placed in earlier periods. This view was substantiated by the fact that both new orders, lagged three periods and the change in unfilled orders, lagged two periods, were shown to exert considerable influence in determining in-process inventory investment.

It was shown that manufacturers, during the period reviewed, adjusted the extent of their in-process holdings as variations in the returns from alternative forms of investment occurred. The yield from the alternative employment of funds, for the purposes of this study, was taken to be the short-term (90 day) treasury bill rate of interest, which was assumed to be an indicator of the state of the market for short-term paper in general. The inverse relationship between investment in goods-in-process and the state of the short-term money market, as given in Chapter IV, indicated that in-process stocks, as a rule, were expanded when the short-term rate of interest was relatively low. Similarly, manufacturers who required short-term financing of their in-process stocks would, in all probability, defer expansion of output during periods of high or rising interest rates until funds could be obtained on more favourable terms.

Inventory investment in finished durables was found to be the most volatile of any of the inventory components examined. This was suggested by the fact that no inertial effect was observed during the period considered. The behavior of finished-inventory change did, however, demonstrate a tendency common to both raw materials and goods-in-process; it varied inversely with beginning-of-period stocks of finished durables.

It was moreover shown that inventory change in finished durables was positively related to changes in the inflow into the finished goods category, but attempts to establish that an inverse relationship existed between inventory investment in finished durables and changes in the outflow (shipments), were unsuccessful. Finally, it was demonstrated that finished-inventory investment, during any period, tended to be inversely related to shipments made during that period.

The equation representing aggregate inventory change reflected, in general, the influences of the individual inventory components. In fact, only one variable, namely, the change in new orders, $\Delta NO_t$, appeared in this equation but did not appear in the equations representing the change in the individual inventory components. Aggregate inventory investment was shown to exhibit a moderate inertial effect and, moreover, indicated a strong sensitivity to beginning-of-period aggregate stocks. The positive influences of unfilled orders lagged two periods, changes in unfilled orders, lagged two periods and new orders, lagged three periods, suggested that aggregate inventory investment tended to be dominated by the raw material and goods-in-process sectors.

Aggregate inventory investment during any period, finally, was shown to be inversely related to shipments made during that same period and the opportunity cost consideration, that was shown to be prominent in determining raw-material and in-process inventory change, was shown to exhibit only a mild influence when related to changes in aggregate stocks.

While this particular study may have made some small contribution to an understanding of the processes whereby manufacturers' inventory investment, in Canada, during the years 1958 through 1965, was determined, the fact remains that in certain areas, more questions were asked than were answered, and at times, more problems were raised than were solved. It is possible that more satisfactory results could have been obtained by using a bolder and less conventional approach, but this would have made demands of the data that could not have always been met. The analysis was often impaired by lack of data and at times data series could not be used because they were not derived from a common universe.

Before manufacturing inventory behavior can satisfactorily be explained, much research has yet to be done in the field. This will require the resolving of many specific issues. Of these, the task of explaining how business expectations are determined and how errors in forecasting various economic magnitudes affect manufacturers' subsequent activities would be among the more compelling, and would, once achieved, be very substantial contributions indeed.

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# APPENDIX I

## The Adjustment of the Data for Seasonality

The method used to adjust the data for seasonality follows essentially the procedure used by the Dominion Bureau of Statistics that is described, in considerable detail, in Chapter 5 of the publication entitled, "Seasonally Adjusted Economic Indicators", Catalogue No. 61-503.

Two types of data series were encountered in this study; one in which each element of the series was positively signed and another in which the series contained both positive and negative values, the latter type arising whenever the differencing of variables was required. Each of these cases called for a somewhat different approach. The variant employed, in each case, is sketched below.

### (a) The Case of Series in which the Elements are Positively Signed

1. The data (quarterly observations) are arrayed in chronological order.
2. The four quarter moving total of the original data is calculated.
3. The two quarter moving total of the four month moving total is then computed.
4. Each element of the series obtained from step 3 is divided by 8 to give a centered four quarter moving average.

5. The original data are divided by the corresponding element of the centered four quarter moving average; these are the ratios-to-moving average, and are expressed as percentages.

6. The average percentage for each of the quarters during the subject period is calculated (where extreme values of the percentages obtained in step 5 are obtained, the medians are used instead).

7. Whatever the alternative used in step 6, the seasonal factors, when summed should equal four hundred. If this requirement is not met (at least approximately), the percentages obtained in step 6 are adjusted accordingly, yielding the final seasonal indexes.

8. The original data are divided by the seasonal indexes to give a seasonally adjusted series. This series, when summed, should be approximately equal to the sum of the original series.

(b) The Case of Series Containing Positive and Negative Elements

1-4. These steps are identical with the procedure outlined in part (a).

5. The centered four quarter moving average is subtracted from the original data.

6-7. These steps are the same as the corresponding items described in part (a) of this section.

8. The seasonally adjusted series is obtained by subtracting the final seasonal indexes (as found in step 7) from the original data. This series, like that obtained by employing the procedure described in the first part of this section, will contain only trend, cyclical and irregular components, and will be expressed in the same units as the original series.

## Testing for Trend

The method employed in testing the data series for trend is formally attributed to H.B. Mann[1], although it is based on material published earlier by M.G. Kendall. The method, briefly stated, is examined below.

Let the data (T. observations), in chronological order, be represented by the series: $X_1, X_2, \ldots . X_T$. From this data set, a new series is formed in which the values of the observed series are replaced by their ranks, i.e., the new series consists of the integers 1,2,.....T, which represent the position each element in the original series would occupy if this series were to be rearranged in ascending order of magnitude.

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1 G. Tinter, Econometrics, New York, John Wiley and Sons, 1952, P.211-215. This reference is a secondary source. The primary source for this material, a paper by H.B. Mann entitled "Non-parametric tests Against Trends", and published in Vol. 13 of Econometrica could not be obtained.

APPENDIX I



Let $r_1$ denote the rank of the first element of the new series. Let $n_1$ be the number of ranks of this series, and following $r_1$ in the set, that are numerically larger than $r_1$. Next, consider $r_2$, the second element of the ranked series, and call $n_2$, the number of ranks, following $r_2$ in the series, that are numerically larger than $r_2$. In general for any $r_i$ $(i=1,2,\ldots\ldots,T-1)$, find $n_i$, the number of ranks (elements) of the set $r_{i+1}, r_{i+2},\ldots\ldots,r_T$, that are numerically larger than $r_i$. This procedure is continued until a quantity $n_{T-1}$ is calculated.

Next, a quantity P, called the number of positive scores, is formed where $P = n_1 + n_2 + \ldots\ldots + n_{T-1}$.

Given P, the total score S is computed where

$$S = 2P - \frac{T(T - 1)}{2}.$$

Finally, a coefficient of disarray C is calculated. It is defined as:

$$C = \frac{2S}{N(N - 1)}, \quad -1 \leq C \leq 1.$$

A value of C = 1 implies a perfect positive trend whereas C = -1 indicates a (perfect) trend that is negatively sloped. C = 0 would suggest the absence of trend from a series.

APPENDIX I



## The Elimination of Trend from the Data

It is noteworthy that the test for trend, described in the preceding section requires no assumptions about the form of trend. In order to eliminate trend from a data series, however, it is necessary that the form of the trend be specified. It was assumed that the trend underlying the series used in this study was, in every case, linear.

The procedure consists of fitting the data (already adjusted for seasonality) to a linear function, determining the appropriate trend values and removing the trend from the data, yielding what is known as a stationary time series. The trend line was fitted by the method of least-squares[2]. The prescribed procedure is set out below.

1. Array the data (T quarterly observations) in chronological order. Call this data set Y.
2. Corresponding to the data set Y, form a second data set X, consisting of an ordered sequence of T integers that is symmetrical about zero. If T is odd, this sequence will be of the form: ...-3,-2,-1,0,1,2,.....; whereas if T is even, the sequence will of the form: ...5,-3,-1,1,3,5,...
3. The function to be fitted is of the form Y = a + bX, where $a = \bar{Y}$ and $b = \frac{\sum XY}{\sum X^2}$

2 Taro Yamane, Statistics, An Introductory Analysis, New York, Harper and Row, 1964, p.339-349.

4. Trend values, at the appropriate intervals, are calculated from the trend equation derived in the previous step.

5. Each element of the seasonally adjusted data set is divided by its corresponding trend value, leaving in the data only cyclical and random components. As a result of this process, the original units are lost. The seasonally adjusted and trend-free series is expressed in terms of relative deviations from trend.

# APPENDIX II

## The Mathematics of Least-Squares Estimation

Assume that, in the population, a variable Y is associated with a set of k-1 other variables, $X_2$, $X_3$,....., $X_k$, and a vector of order N, $X_1$ = (1,1,.....,1), by a relationship of the form

(1) $Y = B_1X_1 + B_2X_{2i} + B_3X_{3i} + \ldots\ldots B_kX_{ki} + U_i$

$(i = 1,2,\ldots\ldots,N)$

or, in matrix notation,

(2) $Y = XB + u,$

where the disturbance term u arises because the relationship between the dependent variable and the explanatory variables is not exact. The u's reflect the influence of many variables which have not, or cannot (because the influence of a single one is negligible) be explicitly incorporated into the system, as well as an element of randomness. Certain assumptions are required regarding the nature of the disturbance terms. It is required that these be independently distributed with zero mean and constant variance $\sigma^2$. It is moreover required that no explanatory variable of system (1) should be a linear combination of any other(s). Symbolically, in a notation consistent with representation (2) these assumptions are:

$E(u) = 0,$

$$E(uu') = \sigma^2 I$$

$$E(X'u) = 0$$

and

The rank of X = k, $k < N$.

Expressions (1) or (2) represent a relationship between the dependent variable Y and its explanatory variables X in an (hypothetical) population. The parameters of this relationship are unknown; the problem, therefore, is to obtain estimates of these quantities.

Proceeding on the basis of the given data (T observations on each variable), we form a system of T linear equations which can be represented:

(3) $Y_i = B_1{*}X_{1i} + B_2{*}X_{2i} + \ldots\ldots + B_k{*}X_{ki} + e_i$ $(i = 1, 2, \ldots\ldots, T)$

or equivalently, in matrix notation,

(4) $Y = XB^* + e$ where

Y is a column vector of order T of observations on the dependent variable.

X is a T X k matrix.

B* is a column vector of order k of the B* coefficients (not as yet determined).

e is a column vector of order T of residuals.

By using the method of least-squares, the data are fitted to a function (linear in this case) in which the sum of the squares of the residuals is minimized.

The sum of the squared residuals is denoted e'e, and from expression (4) we have

$$e'e = (Y-XB^*)'(Y-XB^*)$$

i.e.,

$$e'e = Y'Y - 2B^{*\prime}X'Y + B^{*\prime}X'XB^*$$

To find the value of B* which minimizes the sum of the squared residuals, differentiate expression (5) with respect to B* and obtain

(6) $$\frac{\partial}{\partial B^*}(e'e) = -2X'Y + 2X'XB^*$$

Setting (6) equal to zero gives

(7) $$X'XB^* = X'Y$$

whereupon

(8) $$B^* = (X'X)^{-1}X'Y,$$

where the column vector B* is the least-squares estimator of B.

To calculate the mean of B*, substitute expression (2) into equation (8), giving

$$B^* = (X'X)^{-1}X'(XB + u)$$

$$= (X'X)^{-1}X'XB + (X'X)^{-1}X'u$$

$$= IB + (X'X)^{-1}X'u \quad , \quad \text{since } (X'X)^{-1}X'X = I$$

or,

(9) $$B^* = B + (X'X)^{-1}X'u$$

Taking expected values of both sides of expression (9), we have

$$E(B^*) = B + E\,((X'X)^{-1}X'u)$$

$$= B + (X'X)^{-1}X'E(u)$$

$$= B + 0 \quad , \text{ since } E(u) = 0 \text{ and } E(X'u) = 0$$

(10) $$= B$$

Since $E(B^*) = B$, $B^*$ is an unbiased estimator of B, the population constant and coefficients.

To find the variance of $B^*$, $Var(B^*)$, consider the definition:

(11) $$Var(B^*) = E(B^* - E(B^*))^2$$

which, using result (10), is equivalent to

(12) $$Var(B^*) = E(B^* - B)^2 = E\ ((B^*-B)(B^*-B)')$$

But from equation (9),

(13) $$B^* - B = (X'X)^{-1}X'u$$

Using the equality given in (12) and the relationship established in (13)

$$Var(B^*) = E\ ((X'X)^{-1}X'uu'X(X'X)^{-1})$$

$$= (X'X)^{-1}X'E(uu')X(X'X)^{-1}$$

But $E(uu') = \sigma^2 I$ since $E(u_i u_j) = 0$ for $i \neq j$

$$Var(B^*) = (X'X)^{-1}X'\sigma^2 IX(X'X)^{-1}$$

$$= \sigma^2 I(X'X)^{-1}X'X(X'X)^{-1}$$

$$= \sigma^2 I(X'X)^{-1}I \quad , \text{ since } X'X\ (X'X)^{-1} = I$$

$$= \sigma^2 I(X'X)^{-1}$$

$$= \sigma^2 (X'X)^{-1}$$

The variance of any of the $B^*$'s is given by multiplying the variance of the u's, $\sigma^2$, by the appropriate element of the principal diagonal of the matrix $(X'X)^{-1}$. Therefore $Var(B_i^*)$

equals $\sigma^2 a_{ii}$ where $a_{ii}$ is the ith diagonal element of the matrix $(X'X)^{-1}$.

## Significance Tests for the Regression Coefficients ($B_i$*'s)

The statistic

(1)
$$\frac{B_i^* - B_i}{\sum_{i=1}^{T} \sqrt{\frac{e_i^2}{(T-k)}} \cdot \sqrt{\frac{1}{a_{ii}}}}$$
, where $a_{ii}$ is the ith diagonal element of $(X'X)^{-1}$

has a "t" distribution with T-k degrees of freedom.

In order to test the significance of a regression coefficient $B_i^*$, proceed as follows:

Form the null hypothesis that, in the population, the regression coefficient $B_i$ equals zero

i.e,, $H_0 : B_i = 0$

The alternative hypothesis, then, is

$$H_1 : B_i \neq 0$$

Choose the level of significance of the test = a.

The test statistic, in view of the null hypothesis, becomes

$$t = \frac{B_i^* - 0}{\sqrt{\frac{\sum e_i^2}{T-k}} \cdot \sqrt{\frac{1}{a_{ii}}}} = t_i \text{ say}$$

Determine the critical points for the test. These are:

$t_{\frac{a}{2}}(T-k)$ at the lower end and $t_{1-\frac{a}{2}}(T-k)$ at the upper end.

The acceptance region of the null hypothesis lies between these two values.

If, at the given level of significance a, $t_i$ lies in the critical region, ($t_i < t_{\frac{a}{2}}(T-k)$ or $t_i > t_{1-\frac{a}{2}}(T-k)$, whichever is appropriate) the null hypothesis would be rejected, and one would conclude that, in the population, $B_i \neq 0$, i.e., in all probability, the variable $X_i$ does have a linear influence on Y.

Testing the Independence of the Regression Disturbances

The test, used in this study, to determine if the crucial assumption that the regression disturbances are serially independent is satisfied, is founded on a procedure based on the Von Neumann ratio of least-squares estimated disturbances:

$$Q = \frac{\sum (u_t^* - u_{t-1})^2}{\sum u_t^{*2}} = \frac{\sum \Delta u_t^{*2}}{\sum u_t^{*2}} ,$$

where the u*'s are the least-squares estimators of the u's, the population disturbances.

The authors of this test[1] have provided tables indicating the significance points for this test at the one and five per cent significance levels. For a given level of

1 H. Theil and A.L. Nagar, "Testing the Independence of Regression Disturbances", Journal of the American Statistical Association, December 1961, p. 793-806.

significance, the null hypothesis to be tested maintains that the residuals are independently distributed. The alternative hypothesis, then, asserts that the successive disturbances (population) are positively correlated.

This test is one-sided. The null hypothesis would be rejected if the test statistic (defined above and computed using sample values) is less than the appropriate critical value that is obtained from the tables. If the test statistic is numerically larger than, or equal to, the critical value of Q (as given in the tables), one would normally accept the null hypothesis and conclude that at the chosen level of significance, the population residuals are, in all probability, serially independent.

DEPENDENT VARIABLE DRO     CRITERION CONTROL 1     STOP CONTROL 1

| P-NO. | P-VALUE | P-VALUE | T-VALUE | CONTRIBUTION | VAR. NAME |
|---|---|---|---|---|---|
| 1 | 0.32826 | 0.32825770D 00 | 5.280 | 0.283 | DU2 |
| 2 | 3.29110 | 0.32911017D 01 | 6.702 | 0.256 | U2 |
| 3 | -4.57030 | -0.45702976D 01 | -4.491 | 0.208 | R1 |
| 4 | -0.05979 | -0.59788353D-01 | -1.886 | 0.044 | R-1 |
| 5 | 0.22027 | 0.22027023D 00 | 1.794 | 0.037 | DR1 |
| 0 | 1.56064 | 0.15606441E 01 | 3.701 | | |

CV = 3.34540     S = 0.10780     S-SQ = 0.01162     R-SQ = 0.71829

THEIL NAGAR Q = 2.03274

AVERAGE ABSOLUTE ERROR = 4.38839

TOTAL EXPLAINED SUM OF SQUARES     0.82844

TOTAL     SUM OF SQUARES     1.07247

DEPENDENT VARIABLE DGO CRITERION CONTROL 1 STOP CONTROL 1

| P-NO. | P-VALUE | P-VALUE | T-VALUE | CONTRIBUTION | VAR. NAME |
|---|---|---|---|---|---|
| 1 | 0.33772 | 0.33771593D 00 | 3.617 | 0.958 | DU2 |
| 2 | -0.08735 | -0.87351567D-01 | -1.893 | 0.290 | R-1 |
| 3 | 2.03682 | 0.20368184D 01 | 1.733 | 0.271 | UTL |
| 4 | -1.25340 | -0.12533977D 01 | -2.367 | 0.026 | HG |
| 5 | 0.37045 | 0.37045492D 00 | 2.101 | 0.038 | DG1 |
| 6 | 0.90210 | 0.90209807D 00 | 1.841 | 0.065 | N-3 |
| 0 | -1.37097 | -0.13709679E 01 | -2.387 | | |

CV = -6.67255 S = 0.13839 S-SQ = 0.01915 R-SQ = 0.75474

THEIL NAGAR Q = 2.27930

AVERAGE ABSOLUTE ERROR = 6.44316

TOTAL EXPLAINED SUM OF SQUARES 1.64733

TOTAL SUM OF SQUARES 2.03039

DEPENDENT VARIABLE DFO    CRITERION CONTROL 1    STOP CONTROL 1

| P-NO. | P-VALUE | P-VALUE | T-VALUE | CONTRIBUTION | VAR. NAME |
|---|---|---|---|---|---|
| 1 | -10.68285 | -0.10682847D 02 | -5.448 | 7.267 | F-1 |
| 2 | 0.27178 | 0.27177619D 00 | 1.898 | 0.681 | DST |
| 3 | -4.03071 | -0.40307057D 01 | -1.854 | 0.586 | STO |
| 4 | 0.17151 | 0.17150669D 00 | 1.122 | 0.338 | DG1 |
| 0 | 14.73641 | 0.14736415E 02 | 16.884 | | |

CV = 18.41962    S = 0.51848    S-SQ = 0.26882    R-SQ = 0.52731

THEIL NAGAR Q = 1.92841

AVERAGE ABSOLUTE ERROR = 20.43184

TOTAL EXPLAINED SUM OF SQUARES 8.87217

TOTAL SUM OF SQUARES 14.78621

DEPENDENT VARIABLE DAO    CRITERION CONTROL 1    STOP CONTROL 1

| P-NO. | P-VALUE | P-VALUE | T-VALUE | CONTRIBUTION | VAR. NAME |
|---|---|---|---|---|---|
| 1 | -0.31594 | -0.31594256D 00 | -1.513 | 0.398 | R-1 |
| 2 | 1.30639 | 0.13063874D 01 | 3.095 | 0.069 | N-3 |
| 3 | 0.14457 | 0.14457318D 00 | 3.227 | 0.097 | DMO |
| 4 | -8.47582 | -0.84758208D 01 | -4.367 | 0.051 | HA1 |
| 5 | 0.36340 | 0.36340215D 00 | 2.278 | 0.020 | DA1 |
| 6 | -0.26423 | -0.26423150D 00 | -3.214 | 0.022 | STO |
| 7 | 0.25659 | 0.25658861D 00 | 2.842 | 0.032 | U-2 |
| 8 | 0.09014 | 0.90144460D-01 | 2.745 | 0.059 | DU2 |
| 0 | 8.15689 | 0.81568871E 01 | 18.606 | | |

CV = 5.81940    S = 0.08837    S-SQ = 0.00781    R-SQ = 0.77204

THEIL NAGAR Q =- 1.48545

AVERAGE ABSOLUTE ERROR = 3.50213

TOTAL EXPLAINED SUM OF SQUARES 0.75011

TOTAL SUM OF SQUARES 0.89067