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A STUDY OF THE EFFECTS OF CHANGING RAW MATERIAL PRICES AND VARYING INTEREST RATES ON THE STOCKHOLDING DECISIONS OF A SMALL MANUFACTURING COMPANY

by

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CONTENTS

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A study is made of the inventory control procedures in a manufacturing company with an annual turnover of around £5M. The study is made at a time of fluctuating prices and varying interest rates in order to determine both their effect on, and ways of improving, the control procedures. The study concentrates on one of the many stock items carried, peppermint oil, it being fairly typical. The study lists the main costs of establishing and growing peppermint in Washington State. The study reveals the importance of price forecasting in the determination of timing and quantity of purchases. Various price forecasting methods including that due to Box and Jenkins are tested and found wanting for one reason or another. The ordinary economic order quantity formula is modified to take account of fluctuating prices and varying interest rates. It is then tested with an assumption of perfect price forecasts against the performance of the firm's buyer over the years 1971-1978. The results indicate that the buyer possesses faculties which cannot yet, if ever, be emulated by machine based formulas. Normally economic models are devised with the assumption that the purchaser is at least risk-neutral if not risk-averse. This study reveals a pronounced bias in the opposite direction, namely risk-preference, in the case of essential oil traders. The study, in examining the market structure, also shows that there are peppermint farmers in the western United States who are both willing and able to make direct contracts with importers in the United Kingdom in order to eliminate the risks associated with dealing through second and third parties. The absence of a formal controlled market for the particular oil studied is noted together with the buyer's inability to 'hedge' except with purchases of other equally risky oils. It is recommended that the possibility of such a market being organised be further investigated.

CHAPTER I

A SEARCH FOR THE DOOR TO RESEARCH

1.1 Introduction

The direction taken by the research reported in this thesis and the perspectives from which the inter-related problems have been examined have, very naturally, been influenced by the writer's experiences in the period over which the material was being gathered. It is not inappropriate, therefore, to preface the work with a brief personal note which may serve to orient both the reader and the researcher himself.

A Personal Note

In the autumn of 1974, after some six months' search, I found a manufacturing company willing to allow me to investigate their stock control procedures. The company was interested in my examining their stock control, initially for three months, because they felt that my computer experience might help guide their undoubted need for a more efficient system. They did not at first appreciate the complications surrounding any changeover to a computer aided system and they did not realise the extent to which changes would be necessary in order to achieve their aims. They put a certain amount of trust in my ability and in return I promised not to disclose any confidential material in future publications. As a consequence, throughout this thesis no names are given to the growers, dealers, manufacturers or end users. However, those in the trade who should chance to read this thesis may be able to recognise themselves, their fellows and competitors in some of what follows.

The company investigated imported essential oils and consequently this thesis is concerned with essential oils. It will be explained that this is not an eccentric choice. It has been most useful to concentrate my attention on just one oil out of the many essential oils imported into this country. It seemed strange at first that I could not look at the stock control procedure as an entity and try to produce plans to improve it. It seemed likely that the experiences of other workers in this field might provide valuable hints. The reality seems to have been more complex. A great deal of information is available on the topic of stock (or inventory) control. The way in which people use this information in their practice of stock control has not been examined in much depth. At one time I found myself questioning the point of trying to penetrate further into this area where so much is obscure, intangible and unquantifiable.

I cannot claim that any solutions have been found because, in my opinion, the problems that seem to trouble one individual are not problems to everyone and hence only partial solutions exist to be found. The 'problem' that I have concentrated on for the sake of this thesis has proved to be an aid to me. It has been something at which to aim my attention and as one aspect of the situation is illuminated, new shadows are cast and the nature of the problem seems to change. The process of concentration on an object produced by the mind is no less real than that of concentrating on a physical object, but concentration on neither the object nor its shadow will reveal the source of light which alone makes observation possible. In the same way with our stock control problem it is all too easy to be engrossed in the tangible physical detail of records and prices or in the morass of man's motivations and expectancies, but at the end of the study we shall have missed seeing the day to day way in which people cope with the 'problem'. That is to say that the overall picture will have been distorted by continual swings of concentration from one aspect to another of the problem. The foresight and judgement exhibited by many of those with whom I have been in contact over the last three years can only be described as uncanny. No amount of formulating on my part can ever hope to describe from whence their decisions came. I can only sit back in wonder at the abilities of these men and hope to describe their talents to you, whilst isolating one or two practices that might profitably be structured in algorithms. There will be equations for the mathematically minded to peruse and there will be learned references for those interested in the history of the debate. There will be descriptions of my visits to a peppermint grower, to two competing buyers and to two blenders and manufacturers.

1.2 Peppermint Oil: The Subject of the Study

The distinctive aroma and flavour of peppermint are familiar but hard to define or describe. This flavour is derived from a blended oil which may come from one or many sources but is always from the soil in the first instance. Mint flavoured toothpaste, chewing gum and toffees contain mint oil which has been extracted from peppermint or spearmint plants nurtured by the farmer in fields all over the world. The way in which mint flavouring reaches us from the mint fields is considered in detail in Chapter 3.

To return to the subject of why only one oil is considered, let me add that there is no reason why what is attempted here should not be repeated for each of the many hundreds of essential oils used in the industry. However, it will soon become apparent that in a limited time it would not be feasible to attempt to examine oils grown under widely differing conditions. I propose therefore to concentrate on peppermint oil and hope that the conclusions I have drawn in Chapter Eight will be applicable to other oils and commodities. Certainly the price forecasting methods discussed in Chapter Four, with modifications, will be suitable for most oils and indeed the expert may see ways to adapt them to iron ore buying or wheat exchange dealings. It seems to me, though, that these methods are endowed with a certain numinosity by the operator of the methods. I contend that the same method can give different results depending on the user. It may be permissible for the writer to claim some skill in forecasting the price of peppermint oil after only three years of working on the subject, but I could not hope to do the same with Eucalyptus Oil or Almond Oil unless more time was spent examining them and gaining experience of their peculiar characteristics. Experience plays a great part in the process of price forecasting but there is something more, which it is not appropriate to discuss here, that provides the forecaster with his intuitive feeling for future events. This I hope to discuss more fully in Chapter Six where a game is played to illustrate the strategy developed.

I have written little so far about the dealers who buy oil from the grower and sell it again to the manufacturer. They play a vital part in closing the circle which will be discussed in some depth in Chapter Five. Suffice it to say at this stage that without them the industry could not have reached its present stage of development.

1.3 Background to the Study

This chapter will continue with a general background to the subject covering the period from Roman times to the present, followed by a more detailed background covering the last twenty or so years. A summary of the chapter can be found just before the references at the end.

From written records it is possible to imagine the early examples of inventory control. The Roman legions as they spread the Empire, East, South, West and North, had a second army of clerks, cooks, baggage-minders and armourers following in their wake. Caesar's writings[1] show us the care with which records were kept of arms and other spoils captured in this process. It is not hard to recognise the methodical mind at work nor the obvious efficiency with which those legions operated. An army marches on its stomach and immediately the need for provisions arises. Lines of communication were set up with staging posts and depots as they are today by large international companies. War and peace are little different in this respect. The so called Barbarians also had their stores, but Caesar does not help us much here. Archeological remains show us that some form of rudimentary control must have existed. An organisation that can bring together Stonehenge is not to be despised. Yet, when writing about stores control in those times, I cannot overlook the fact that the price of goods was not a large factor. The small holder who wanted to retain his cow was simply put to the sword whilst the iron for forging the swords was taken by territorial gains. Money was used by the more enlightened generals, particularly those with astute political sense.

In Roman times, and earlier, the huntsman was a prominent figure bringing home fresh meat for the family; whilst at home the householders would fetch fuel for fires and grow other foods to supplement the meat. How can one ensure a steady supply of vegetables to the table? Grow your own vegetables and you should encounter at first hand the stock controller's problems. Have you ever found yourself with a glut of gooseberries and a dislike of frozen foodstuffs? The most careful planting of lettuce cannot stop those planted to mature in two months time arriving two weeks late and those planted to mature in three months time arriving two weeks early. Soil conditions, weather and other factors play their part in determining the supply available at any given time. We all, naturally, either go without, on certain days, or supplement our store from the market place. Similarly with the fuel for heating. Wet weather means wet wood and hence the need for a wood store.

A biblical example of stores control is provided by Noah. In the best modern tradition he prepared a store that could brave all the elements, the ark. He gathered in pairs of every species available to ensure a future supply of those species. He did all of this before the elements struck; in three words he was prepared. To live up to the motto "Je suis prêt" or "I am ready" is the first requirement for a good stock controller. The floods of former times can be compared with events like the crude fuel oil price increase in 1973. Presumably the writing was on the wall since the time of Suez for those who could see it; but how easy it is to be wise after the event. In what follows we shall see how the price of peppermint oil soared with just about every other commodity. Very few were ready; that is history.

In January 1976, just before I left the United Kingdom to visit a peppermint grower in the Yakima Valley of the Cascade mountains in Washington state, the department under the auspices of which I gathered the material for this work requested me to give a talk about my research up until that time. It was clear to my colleagues that the data presented on peppermint oil prices were far from adequate. They had a number of suggestions to help me with my task. One asked me to examine import and export figures for the commodity in order to obtain a usage figure. This apparently sensible and practical suggestion is typical of many that have been urged on the researcher. Countless hours have been spent talking to customs officials and perusing trade figures. The suggestions have all been food for thought but there are many difficulties in carrying out logical procedures where specific markets are involved.

Peppermint oil is imported to this country by ship in bulk and by air in small, usually sample, lots. It is exported untouched or blended with other oils. Here a technicality must be considered. The peppermint oil with which we are concerned is derived from the plant <u>mentha piperita</u>. This is largely produced in the United States of America. There is another plant, <u>mentha arvensis</u>, produced largely in Brasil and China which yields a different grade of oil and has little to do with this study. However, the oil from mentha arvensis is much less expensive and consequently is often used to dilute or blend with oil from mentha piperita to produce a hybrid oil. The point here is that blended or diluted oil is not recorded in the export figures under peppermint oil (piperita). It is lost under a different blanket category of manufactured goods and so the suggestion to obtain a usage figure cannot, even if it were desirable to do so, be persued. While it would no doubt be convenient to have more concise figures, it would, perhaps, be more appropriate to ask whether the detailed figures are really necessary for the study. A conventional reply would be that usage figures are needed in order to determine demand. Demand, however, will consist not only of manufacturer's demand for current production but also of his demand for stock and this, in turn, is likely to be related to expectations concerning supply. In any case, the overall demand in the United Kingdom (UK) and British Isles is limited by the fact that only so much gum is chewed and so many sets of teeth cleaned. In the literature this is called a 'derived' demand. Sweet eaters account for only a few per cent of the total oil used. The true annual usage is therefore a figure proportional to the population with some percentage added each year for growth. This leaves us with the difficult question of exports. Naturally overseas demand fluctuates with the world economy as does the price of the raw oil. In no time at all we find ourselves back with supply, in the price of oil. Demand, supply and price are closely inter-related; in our investigation of the supply of peppermint oil, we understand more of the nature of the demand for it, and in considering demand we discover the nature of supply. No doubt this could be taken as a commonsense instance of the 'paradox of identification'.

The price of the oil is the key to gaining an overall picture. Since price reflects both supply and demand, it may be possible to begin by considering price movements directly.

Anyone who has tried to guess the price of oranges next January or July will realise immediately the nature of the price forecaster's dilemma. An abundant crop usually means lower prices but what if everyone decided apples or ascorbic acid tablets were better? There is another element. When you and I go to buy oranges we are faced with the stallholder, be he enemy or friend. He has brought from the central market in competition with the other stallholders. The central market, in turn, has purchased from the individual grower. It is at the grower's level that weather, crop health and similar factors become of some importance. Let us leave aside for the time being the latter considerations and stay with the central market.

The elementary models of economic theory provide a basis for analysis, but give little insight into the dynamic processes involved in the formation of price. In the present context a simply analogy is offered.

Price may be considered as being formed in the way that a raindrop collects. The atmosphere becomes dense as activity begins. The moisture thickens into droplets which condense into globules of water which, becoming too heavy for their supporting medium, fall. A commodity is produced and the buyers move into a ring. One offer is matched with another to be supplanted by a third. The bids flow around the ring (the atmosphere thickens) until is formed a final bid (the globule). This holds and is taken from the ring (the supporting medium). This is today's price and will hold until the ring is filled again to fix a new price. Each purchaser can now go forth with his holding and become a supplier to the next ring in which is fixed the second level price. The number of levels will depend on the market and in the case of 'piperita' is sometimes three and sometimes four. The grower to the dealer is the first level. The dealer to the wholesaler is the second level. The wholesaler to the blender is the third level. The blender to the manufacturer is the fourth level. In Chapter Three will be given a full description of each of these stages detailing the function of each person concerned. At this stage it has been my intention to outline the way in which the oil acquires a price as it moves along from producer to customer. Supply and demand are ever present faces on the Janus of price.

It is clear that there is no infallible method by which price can be forecast. A method, if it existed, could not be kept secret for long; once common knowledge then surely everyone would be attempting to make their fortune out of commodity dealing or playing the currency exchange markets. The very success of the method would make it invalid since speculation depends, for its success, on superior knowledge or a superior intuition about market conditions. I am envisaging here the perfect market with perfect competition, which means perfect information for all dealing in the market. This would need all relevant factors to be quantifiable. Can the grains of sand on a beach be divided and counted? Enclose the sand in a six faced box and the answer is yes; but the beach is open to the influence of wind and tide so how can we talk of a quantifiable world. Change is ever present in life and so with the factors affecting price. One day it may be the lack of water, caused by low snow pack in the mountains, that causes concern to the farmer. The next day it may be the prevalence of weeds, caused by a rainy growing season. This may appear unduly pessimistic to the embryo price forecaster, but it is not intended so. Prices are forecast daily by industrial buyers but not by the way of division and counting. Later it will be seen why I am leading away from the quantifiable world of theoretical economics, and I hope that this gentle introduction will provide a cushion from the impact of the more awesome picture that the industrial buyer presents when in full regalia.

In presenting this general background I have written hardly a word about the end users, you and me. When we brush our teeth tonight there will be a little piperita in the squeeze of paste. Without us the industry would not exist. We have brought it into being with our demand for gum to chew and with our love of peppermint sweets. This is neither good nor bad but a simple truth hardly worth mentioning except to bring us that bit closer to the earth, mother to the plant.

1.4 The Problem and its Context

The inventory problem, if it is a problem, is only one aspect, isolated artificially, of a very complex situation involving natural forces, human decision and a variety of events, some controllable but most not so. The writer is aware of a conflict between the rational and irrational forces at work and must emphasise that a severely rational approach to the inventory problem can only secure a harbour, as it were, at the mouth of a turbulent ocean, but this harbour is the point of departure into the real situation. At a later section of the work, random walks and their application to forecasting are discussed. Perhaps, following the analogy above, these are the rope tying the ship to the wharf; they are the last point at which a strictly logical approach or assumptions of rationality, can constrain the problem. Beyond this point is the world which we do not eagerly explore for our rational mind can gain no footing and the lifetime's habitual mode of thought is challenged. Now is not the time to dip too far into these waters for the discussion begins on terra firma, we hope, by considering the strictly rational approach to the inventory decision.

1.5 The Rational Basis for Inventory Decisions

Inventory control is the science based art of controlling the amount of stock held, in various forms, within a business to meet economically the demands placed upon that business. The stocks are held in such a way as to meet the management criteria for profitability and capital investment as will be seen later in this chapter. Inventory control becomes an art when judgement has to be exercised on the various facts and figures provided, very often in probabilistic terms, by scientific methods. The decision on how much to purchase of a certain commodity and when to purchase it will depend in part on uncertainties. The estimate of future prices may be affected by past prices, about which there is no uncertainty, but a probablistic element has to be introduced. There will also be available data on storage space, spoilage rate and all the various costs associated with acquiring and holding stocks of the commodity. The art is in applying a stock controller's experience together with an element of informed guesswork to the data available and thereby hopefully arriving at a best solution.

In an ideal world, where the demand upon a business is known exactly and well in advance and where suppliers keep to their delivery dates, there would be little need to hold any form of inventory other than a limited amount of work-in-progress stocks which are caused naturally by the manufacturing process. The only problem in this situation would be one of scheduling which, although possibly complicated, would be completely deterministic because all the problem parameters would be exactly defined. In practice, however, demand is not known in advance and suppliers will often be late, seldom early, in delivering. In this practical situation, stocks can act as a buffer between the vagaries of supply and demand.

1.5.1 Principal Reasons for Holding Stocks

The principal reasons for holding stocks are as follows. Firstly to act as an insurance against a higher than expected demand. This helps to ensure that customer demand will more often than not be met, resulting in satisfied customers and consequently continued demand. Secondly to act as an insurance against longer than expect supplier delivery times, this usually being termed in the literature as 'leadtime'. Customers reordering their usual amount of goods are unlikely to be impressed by the excuse that one's supplier is late in delivery, especially if they can obtain the same goods elsewhere. Thirdly to take advantage of quantity discounts. It may be advantageous to purchase more supplies than are immediately required and to incur the slightly higher holding and storage costs if these increases in costs are more than offset by the reduction in an item's unit cost as a result of the large quantity purchased. Fourthly to take advantage of seasonal and other price fluctuations. The consumer who buys coal during the summer months calculates that the consequent saving in material costs more than outweighs the small increased storage and investment costs. On the side of the coal supplier this seasonal price reduction stimulates demand in an otherwise slack period and so reduces production costs by levelling demand over the year. The type of stocks referred to in the first reason are finished goods whilst in the other cases it is raw materials. The fifth reason for holding stocks refers to work-in-progress stocks. These are held to minimise delay in production caused by lack of parts. With products comprising many components and subassemblies, it is administratively nearly impossible to ensure that one of each of all these parts arrive simultaneously at a final assembly point. In this situation, stocks of components and subassemblies at assembly points act as a buffer within the production system to absorb the demand that the system exerts on itself.

1.5.2 Categories of Stocks

Inventory is usually broadly classified into three categories of raw material, work-in- progress and finished goods.

1.5.2.1 Raw Materials

By holding stocks of raw material a business creates a buffer between its primary production sections and the raw material supplier. This allows primary production to be initiated in a shorter period of time than the raw material supplier's delivery time, a facility always required for urgent items some of which tend to occur in most production programmes. Where the price of a raw material fluctuates considerably such as in the case of tin, a speculative purchasing policy can, to a limited extent, insulate an organisation from these price changes. The holding of raw material stocks also allows bulk purchases to be made and the consequent discounts to be obtained. Raw materials represent about thirty-five per cent of UK investment in stock.

1.5.2.2 Work-in-Progress

The holding of both raw material stocks and finished goods is generally a planned activity, in so far as such stocks should not exist unless they are planned for. Work-in-progress stocks however, are likely to exist in any manufacturing organisation whether or not they are planned for. This is because the function provided by this category of inventory is to buffer the demand of a later stage in the production process from the supply of an earlier stage, a function essential for any production process. As an example, a final assembly section, requiring three sub-assemblies from three stages occurring earlier in the production process, must have available in-progress stocks from all three sub-assembly sections if the assembly section is not to be invariably held up by a shortage of one or other of these sub-assemblies. Also the sub-assembly sections require a buffer between themselves and final assembly, not only so that they can continue production when sub-assemblies are not immediately required by final assembly but also so that all three sub-assembly sections need not operate synchronously with one another.

It is evident, therefore, that production systems can rarely function without work-in-progress stocks. These stocks, because they are essential tend to be a by-product of any production process; but as such it is important that they are closely controlled in order to prevent proliferation. Work-in-progress represents about thirty-eight per cent of UK investment in stock.

1.5.2.3 <u>Finished Goods</u>

The stocking of finished goods provides a buffer between the customer demand and the manufacturer's supply. In many cases the size of the customer's order is smaller than can be supplied by the manufacturer and a wholesaler can act as an intermediary between the two. When this happens a larger proportion of finished goods may be held by the wholesalers than by the manufacturers. Finished goods represent about twenty-seven per cent of UK investment in stock.

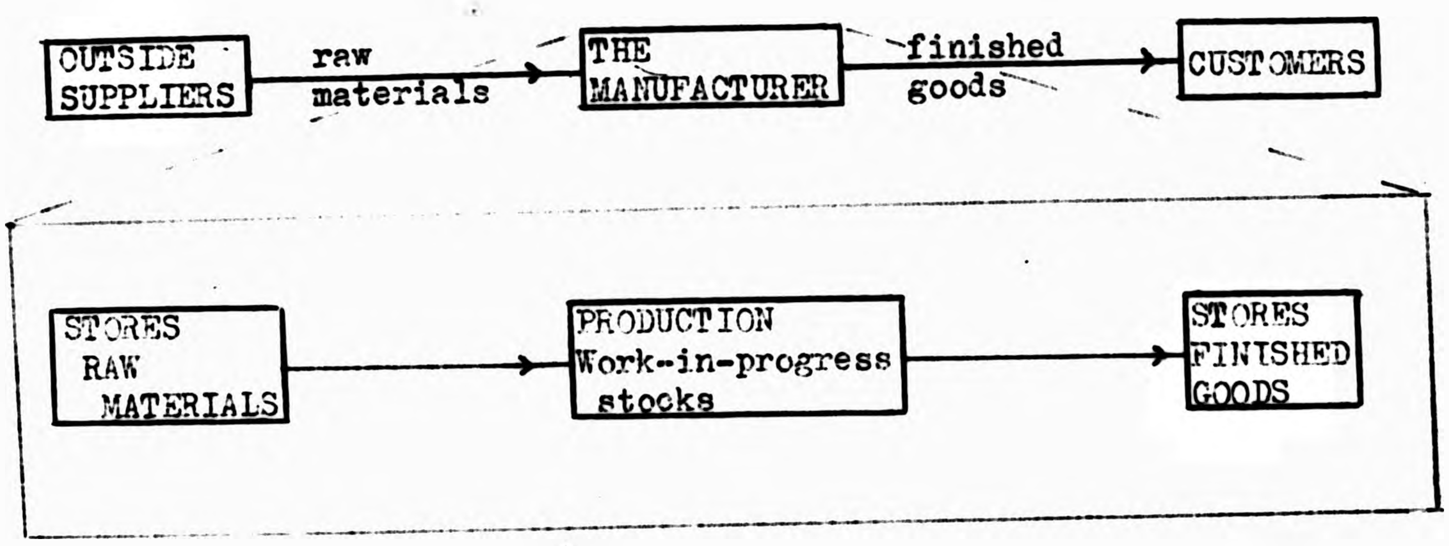

Fig.1.5.1 Stocks and flows in manufacturing industry

1.5.3 The Inventory Decision as Compromise

The amount of inventory or stock a business plans to hold should be a compromise between several conflicting interests, consequently it is essential that the management decides at the highest level what the overall objective of the business's stockholding policy should be. This statement of the stockholding policy should then be communicated to all interested parties to prevent any one particular interest overriding the others. For instance, if the overall policy is to offer a high level of service, this can only be achieved by holding large stocks. Hence the firm's accounting interest, although in general desiring a low level of stockholding and thus a minimum of invested capital, knowing the policy of high levels of customer service should accept and understand the reasons for the inevitably large stockholding incurred. Alternatively, should the firm have a specific short-term policy of releasing invested capital, then informed of this the production interest should appreciate the need for the resultant irregularity and disruption to their production schedules caused by a reduced stockholding. There are disadvantages both in holding too little or too much stock and some of these are now listed. Some disadvantages of holding low stock levels are:-

1. Customer demand can often not be satisfied. This can lead to an immediate loss of business and to a loss of repeat orders due to customer dissatisfaction.
2. Often, as a result of trying to satisfy the customer, costly emergency procedures such as special production runs and upset schedules are resorted to in an attempt to maintain customer goodwill.
3. In order to maintain a reasonable service it will be necessary to place replenishment orders more frequently than in the case where higher stock levels are kept. Thus higher replenishment ordering costs are incurred.

Of these three disadvantages the first is probably the most serious. The disadvantages associated with high stock levels are:-

1. High storage costs are incurred. These costs cover buildings, labour, heating and similar things and they also contain an element to cover deterioration and spoilage.

2. High amounts of capital are tied up in stock. This capital might have been used elsewhere in the business or it might have been invested outside to earn interest.
3. Where the stored product becomes obsolete, a large stock holding of that item could, in the worst case, represent a large capital investment in an unsaleable product that has to be written off at scrap value.
4. When a high stock level of raw material is held at a time of fluctuating prices a sudden drop in the going market price of the materials represents a cash loss to the business for having bought at the higher price previously existing. (A cash benefit is derived in the converse case). As a general rule it is better to hold higher stocks in a period of general inflation than in a period of deflation.

The subject of speculation is treated elsewhere at some length in this work. Here it is worth noting that the decision to speculate in any commodity is separate from the inventory decision but, once made, it can be used to the advantage of the everday stock control. This is because lower stocks of that commodity can be held for day to day use in the knowledge that an emergency stock is close at hand in the case of a stock out.

1.5.4 Stock and Trading Fluctuations

Both the economy as a whole and most sectors of industry are affected by trade cycles. Periods of low activity are followed by periods of increasing activity then periods of great activity and so on until the period of low activity is reached again. Clearly stock levels have to be adjusted to the changing trading circumstances of the firm. The extent of the changes will be partially governed as before by the expected future demand. The future demand will depend on the position within the trade cycle which the firm judges itself to hold. Thus in the transition from low to high activity stocks reach their peak, whilst in the transition from high to low activity stocks reach their lowest level. Apart from the trade cycles there are also seasonal factors to be taken into account. For example, a manufacturer of overcoats probably has his highest stocks in the summer in preparation to fill orders from retailers in the autumn. The relationship between stock levels and the economic situation in the country as a whole is examined in the next chapter.

1.5.5 Conflicts in Managerial Attitudes

It was mentioned earlier that the amount of stock held must be a compromise between several conflicting interests. Inventory management specifically affects the operations of numerous areas of a business. By looking at these relationships and seeing the different objectives of each area we obtain a better understanding of the role of inventory management.

There is a relationship between product design and inventory management. For example, if a product design change is contemplated, the leadtime for its implementation should consider the stocks of the item that is to be made obsolete. The design itself might help to reduce inventories by efforts to design products with standard parts and components.

The marketing management is usually concerned that the customer is kept satisfied, and this inevitably means pursuing a policy of high finished goods inventories. The cost of customer dissatisfaction is easily measured when he goes to a competitor for the unsupplied service and is simply the profit that would have resulted from the unfilled order. However when the customer becomes so dissatisfied as to never return with future orders the cost becomes more difficult to assess. The question of costs will be extent of the changes will be partially governed as before by the expected future demand. The future demand will depend on the position within the trade cycle which the firm judges itself to hold. Thus in the transition from low to high activity stocks reach their peak, whilst in the transition from high to low activity stocks reach their lowest level. Apart from the trade cycles there are also seasonal factors to be taken into account. For example, a manufacturer of overcoats probably has his highest stocks in the summer in preparation to fill orders from retailers in the autumn. The relationship between stock levels and the economic situation in the country as a whole is examined in the next chapter.

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The manufacturing management prefer to have raw material inventories at a high level. A production department can conduct its operations most efficiently, and at lowest cost, by planning lengthy production runs, which build up substantial inventories. Set-up charges for new production runs are reduced and higher quality work produced. The operations of the manufacturing area can be predicted on the plans developed by the inventory control system. The labour requirements, and the plant and machine loading for each period, can be a result of the inventory plan.

Purchasing management is similar to manufacturing management in that the achievement of purchasing objectives also tends to increase inventory levels. In order to minimise the expenses of purchasing, a few large orders of materials are preferable to frequent orders of small amounts. There are three main classes of expense which will be incurred in the purchasing area if inventory levels must be kept at less than desirable levels. Savings are foregone if quantity discounts cannot be realised; with a high number of orders for materials, salaries for additional purchasing staff will be incurred; and when stockouts occur extra-ordinary transport costs and employee time are needed.

Physical storage facilities can limit ordering quantities just as special storage requirements influence inventory policy. The expense of storing goods is usually proportional to the inventory level. The warehouse, in order to minimise their expenses, would like to see general inventory levels reduced. When high stock levels or perishable items are held, there is the risk of obsolescence charges increasing. Labour relations are at their best when the company's employment level remains steady. The only way to achieve this in the face of the usual fluctuating demand is by manufacturing for inventory. This, of course, increases inventory levels.

The financial management's function is to create a control system aimed at providing the greatest possible return on assets invested. A major element of any company's assets is usually represented by inventory. The return generated from that asset is a dual function, composed first of the amount of capital invested in inventories and its related turnover and, second, of the measure of profitability. That is, a better return is generated from £X of capital turned over eight times making 15p on each £1 of capital than on the same capital turned over four times making 25p on each £1 of capital. Financial management need to recognise that, while a low inventory will raise the return on the investment carried, this is true only if profit levels are considered to be unaffected no matter how low the inventory level is set. This assumption tends to be incorrect, because profitability of operations is materially affected by the respective expenses of acquiring versus carrying inventories. In a sense the finance department has to act as an arbitrator between the conflicting objectives of the various departments. They do this by evaluating the relationships and quantifying the objectives of each department, as they are affected by inventories, so that a 'best economic balance' is created. The creation of this balance is the purpose of inventory planning and control systems.

In the next chapter we shall examine the history of inventory control in economics and trace the gradual introduction of risk and uncertainty into the subject.

1.6 Perspectives

The writer of this study has been much concerned that the foregoing discussion has been conducted as if the problem existed only at the level of the single firm. Not only is this a partial analysis, many of the aspects of the problem being suppressed in the interest of simplicity, but in considering only the delimiters of the essential, that is to say the detail, the nature of the whole disappears. In attempting to show how the standpoint taken affects the perception of the whole, the writer intends to end this chapter by reverting to a personal note once again.

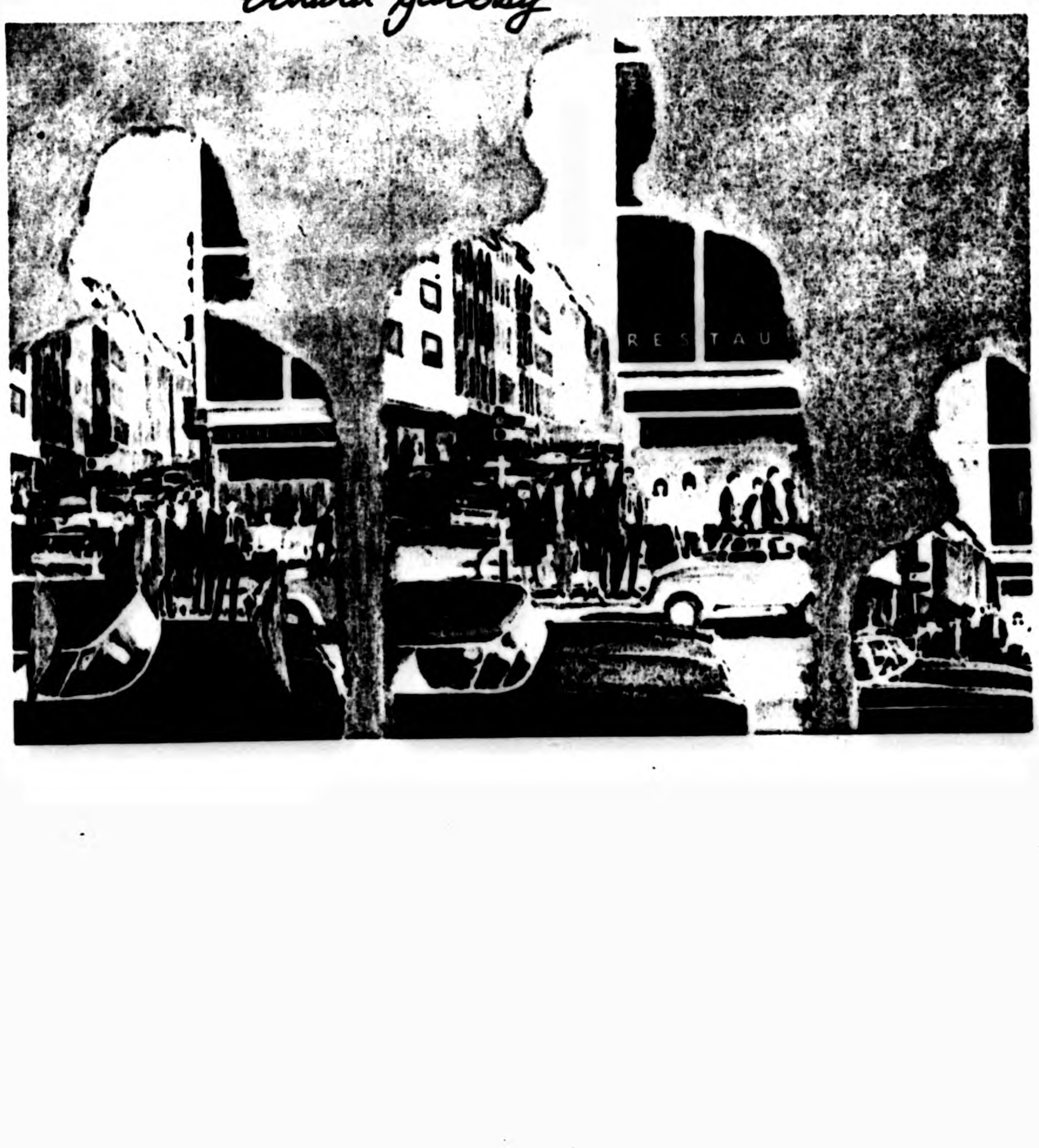
An art critic might declare that a portrait can only be described by reference to its various features and I might agree with him if I were a scientist interested in reproducing the portrait brush stroke by brush stroke. No polite artist would condemn outright such an aim, but most would laugh into their sleeves at the foolishness of such an endeavour. What of the numinous intensity poured into the canvas by the artist as he strives hour after hour to capture the soul of his subject? How will this be reproduced? The point I keep repeating is that no amount of analysis will ever capture the beauty of a scene. No amount of analysis will ever capture the experiences that go into giving a craftsman the feel for his tools. No amount of analysis will capture the art of price forecasting.

In this thesis I do not aim to show the essence of the inventory problem because to do so would be merely an expression of personal beliefs about human behaviour which would not be easy to support without much philosophical argument. However some discussion on these lines is made in Chapter Six after the game is played out, and in Chapter Seven. For the time being I shall circle around the essence with facts and figures which will all be open to dispute because of the nature of such things. This is not to decry them for the circle can only be drawn with their aid. The essence would be indistinguishable from all else without such delimiters.

The distinction has been made between the rational and irrational parts of the mind. This is of course an artificial division because the two parts are inseperable, together making up the whole which is ourselves. However the distinction is necessary in order to make a completely human understanding of any situation. To support this view I shall relate an occurrence in my own life. I was standing on a small wooden footbridge spanning a highland river. The water tumbled across the rocks catching the sunlight as it swept on. Every pebble was visible on the bed of the river and the sun brought each colour and shade into a glorious medley of motion and stillness. My companion was caught for a moment in the spell of that beauty, then began to analyse some of the parts of the scene. I was called upon to look at a particular rock or an area of shade where a trout may have lingered. The switch of attention from the whole scene to a part thereof caused a dulling of the senses as the rational mind exerted a control on the information reaching me through eyes, ears, nose, mouth and touch. The sixth sense whereby the five senses unite into a whole was overcome and I was left looking at this or listening to that. The magical beauty fled the scene. What I am calling here a sixth sense cannot be defined except by the sort of example above. It is not unusual to feel the presence of this sense in our daily lives. It is that which senses the gaze of someone across a busy room, that makes the hair prickle at the base of the skull or

This painting (by Erhard Jacoby) illustrates the fact that each of us, perceiving the world through an individual psyche, perceives it in a slightly different way from others. The man, woman, and child are looking at the same scene ; but, for each, different details become clear or obscured. Only by means of our conscious perception does the world exist "outside" : We are surrounded by something completely unknown and unknowable (here represented by the painting's grey background).

Erhard Jacoby



that causes us to predict successfully the toss of a coin. I shall refer again to this sixth sense later.

There is one other aspect of perception that I wish to mention before the close. I have often taken a photograph of a scene and then wondered why I did not obtain a picture of what I had seen. Recently I came across a reproduction of a painting by Erhard Jacoby[2]. The canvas has a grey background outlined against which are visible a woman, a man and a child. Where the flesh of the people should be is a street scene so that in effect one is looking through each of the three people at the same scene. The painting depicts the scene differently in the case of each person. A camera would have recorded a car in the foreground and a group of people, waiting to cross the street, on the other side beside a traffic signal. Behind them are some pedestrians strolling past a shop window which has the letters GOLDEN written above it. On the window above the shop is the lettering RESTAURANT. Seen through the woman the 'golden' is clearly visible but only RES and T are dimly seen. The car in the foreground is dark and the people on the other side central in her view. Through the man RESTA and U are clearly visible but the 'golden' is only dimly visible. The car in the foreground is a lighter shade and a way round it to the right is visible. More of the strolling pedestrians are in view whilst a second small car on the other side of the street is glimpsed to the right. Seen through the child all the foreground is blocked by the car whose chromework is highlighted. None of the writing over the shop is visible whilst the people on the other side of the street seem small.

To this one scene therefore there are four views, one through each of the people and a fourth through the photograph. In the solution of any apparent problem there must first be agreement amongst the interested parties as to what the statement of the problem means. Each individual will inevitably see it in a different light and a common ground needs to be found. Even this common ground will not be a whole answer to the question 'what is the problem'; nor would agreement between the three watchers in Jacoby's painting as to what they could see be a complete answer to the question 'what is there'. Alongside the reproduction of the painting referred to above are the following words by von Franz, a colleague of Jung:

> 'this painting illustrates the fact that each of us, perceiving the world through an individual psyche, perceives it in a slightly different way from others. The man, woman and child are looking at the same view; but, for each, different details become clear or obscured. Only by means of our concious perception does the world exist 'outside'. We are surrounded by something completely unknown and unknowable (here represented by the painting's grey background).'

I do not like the idea that the something by which I am surrounded is completely unknowable. I would like to see added to that last sentence the words '... with the five senses'. The grey area is also perhaps a representation of my ocean of the irrational mind mentioned above. The mind's Eye will be needed to see into the greyness, to steer the ship and to chart a course. Each individual will choose a different course though our destination is the same. This is why I have written of no methods existing in the problem of price forecasting. Any method I care to examine here has an element in it that depends on the judgment of the individual concerned in using the method. The judgment of the individual will depend on how he 'sees' the problem. As I have emphasised above, each individual 'sees' the problem differently and so necessarily his method will more often than not be different from that of the next man.

In conclusion let me reaffirm my lack of pessimism when faced with a price forecasting problem. The problem is as large or small as I care to make it, a mountain or a molehill. The solution that holds for me today will hopefully be the best solution for those affected by it including myself. That my solution will differ from that of someone else is an inevitable fact of life and should encourage rather than depress me. The question of who is right and who is wrong simply does not arise.

1.7 Summary

The Chapter opens with some remarks on the approach taken by this researcher to the proposed research topic. The topic is then presented in outline and a general background to the field of inventory control is given, without any detail, ranging from Caesar to the present day. Indications are given as to which of the future Chapters will contain more detail on any subject which I consider worth more attention. A more detailed background of the inventory control methods generally in use throughout industry follows the opening remarks. The way in which stock is generally divided in different areas of a plant, together with the divisions in the management that control the flow of materials, is described. The Chapter concludes with some more general comments on the way in which an individual approaches a problem and how a solution, satisfactory to one individual, can differ from that produced by someone else without there being cause for conflict.

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CHAPTER II

A REVIEW OF THE LITERATURE

2.1 Introduction

The purpose of this chapter is to provide a path for the reader through the maze of literature that exists on the subject under consideration. A bibliography is provided at the end of the chapter. Any criticisms made necessarily reflect a personal appraisal of the works concerned, for the field is a complex one and it is seldom possible to take an absolute position. The mathematics involved belongs to the field of Operations Research whilst economists have been writing since the early seventeenth century on related topics. This century much work has been done by both mathematicians and economists on the subject, with concern tending to narrow to increasingly detailed points of the so-called 'inventory problem'. Frequently the mathematical methods employed have seemed disproportionate, in both power and complexity, with the problem to be solved and the solutions produced have lacked applicability in practical situations.

The formal literature on inventory control begins, as is so often the case, with Adam Smith. An earlier approach at the beginning of the seventeenth century was attempted by Thomas Mun. A director of the East India Company, writing from a 'mercantilist' position, he tended to be concerned with acquisition rather than with use. There are many layers of meaning in what a man writes. For example, when Mun writes of 'bringing treasure into England, a country which has no mines of its own'does he refer solely to the jewels and precious metals from the East? He looks to the East, the source of so much of our Western civilisation for treasure and while, physically, he brings home gold and accumulated wealth this may symbolise, for Mun and the men of his time, a renewal and reinforcement, from the Orient, of cultural and spiritual values.

2.2 The Earlier Literature

The East India Company was flourishing when Thomas Mun[1] became a director. He was born in 1571 and, during a lifetime of seventy years, wrote much that is today classified under the heading 'Economics'. He, together with the other writers of his time, is classified as a mercantilist. He writes about wealth a portion of which generally takes the form of money. This portion he suggests should be employed as 'stock'; that is in such a way as to yield a surplus. The method typical of the age, and the man, was that of foreign trade. Stock, Mun argues, is wisely employed in foreign trade when it secures a favourable balance; this is the only way of bringing treasure into England, a country which has no mines of its own. We next hear of stock from Sir Dudley North[2]. He seems to have been the first economist to have had a clear idea of capital, which he called stock. He made the lending of stock-in-trade, by those who lack the ability to use it or avoided the trouble of doing so, equivalent to the letting of land. The interest which lenders received was a rent of money akin to the rent of land. Landlords and 'stocklords' were in effect the same. North preserved no traces of the mercantilist love for treasure. He echoed the parable of the buried talents in condemning those who did not employ their wealth. Only those whose possessions were bearing fruit all the time by either being lent out or employed in trade increased their wealth.

Adam Smith[3], born in the strife torn times of 1723 and living sixty-seven years, develops the same theme telling us how 'in that rude state of society in which there is no division of labour stock is unnecessary'. Once, however, that the division of labour has occurred a man can produce only a part of what he needs for himself. The greater part of his needs is satisfied by other men's produce which he purchases with the price of his own produce. First, however, a stock of goods must be built up sufficient to maintain him and to supply him with the materials and tools of his work. Smith tells us how the accumulation of stock and the division of labour advance together; also how the accumulation of stock causes the same quantity of industry to produce more. He goes on to show how a man's stock consists of two parts, namely that part from which he expects to derive a revenue, called his capital, and that part which supplies his immediate needs. He then specifies two different ways in which capital can be used to yield a revenue, namely circulating capital and fixed capital. The first is employed in raising, manufacturing or purchasing goods and selling them again with a profit.

> 'The capital employed in this manner yields no revenue or profit to its employer, while it either remains in his possession, or continues in the same shape. The goods of the merchant yield him no revenue or profit till he sells them for money, and the money yields him as little till it is exchanged for goods. His capital is continually going from him in one shape, and returning to him in another, and it is only by means of such circulation, or successive exchanges, that it can yield him any profit.'

After defining fixed capital he goes on to show how different occupations require different proportions between the fixed and circulating capitals employed in them.

In all of this we can see contained the so called 'inventory problem' without its ever actually being specifically mentioned. 'The stock of goods....stored up....to supply him with the materials and tools of his work' embraces the inventory with which we are concerned, whilst the remarks about the proportions of fixed and circulating capital in different trades might have been developed to a discussion of how these proportions can be changed in a particular trade through inventory control. This type of detail is not entered into by Adam Smith, nor indeed does it receive significant attention from any of the classical writers.

2.3 Precursors of Modern Thought

The neo-classical school of economists added nothing of great significance. Marshall (1842-1924) writes only in general terms of the stock of capital. In one example on wages and profits he mentions stocks in the sense in which we wish to use the word, but the subject of stock, or inventory, control is never examined. He writes that 'managers and dealers, knowing that larger supplies than before are being made, will not hesitate to sell freely from their stocks'. It is not really until the work of J.M. Keynes[4] in the 1930's that we find an awareness of the problems of stock control in the mundane sense. In his 'A Treatise on Money' he devotes a chapter to fluctuations in the rate of investment which deals with liquid capital and the uses to which it is put in the trade cycle. Here for the first time we see mention of carrying costs of stocks.

The costs he describes in four ways:

> '1. Allowance for deterioration in quality or in suitability (through the unpredictability of the precise specifications which will be required when demand recovers).

2. Warehouse and insurance charges

3. Interest charges

4. Remuneration against the risk of changes in the money value of the commodity during the time through which it has to be carried by means of borrowed money.'

The discussion is about how our present economic system makes no normal provision for looking after surplus liquid capital which he equates with stocks. In the event that such stocks do come into existence then:

> 'the price of the goods continues to fall until either consumption increases or production falls off sufficiently to absorb them. In no case can surplus stocks exist alongside of normal production. Recovery - broadly speaking - cannot begin until stocks have been absorbed, with the result that the process of recovery cannot be much facilitated by the existence of stocks.'

The conclusion that he comes to is that the economic system is hostile to surplus stocks and as soon as they appear strong forces come into action to absorbe them. In a slump the efforts to get rid of surplus stock aggravate the slump and the success of these efforts retard the eventual recovery. Thus a factor of instability is introduced into the economic system.

> 'Industry is extraordinarily sensitive to any excess or deficiency, even a slight one, in the flow of available output ready to be fed back into the productive process. If there is a deficiency, full employment is impossible at the existing level of real wages; if there is an excess, equally, though for quite a different reason, full employment is impossible at the existing level of real wages. In the event of a deficiency the means for full employment is lacking; in the event of an excess the incentive is lacking.' 5

All of this is a discussion on the grand scale of the economics of a country but a parallel can be seen between this and the level of the individual firm which we are going to be examining.

A highly relevant description of the trade cycle, which can bear repeated study, is given by R.G. Hawtrey[6] in his 'A Century of Bank Rate' in which he explains the role of Bank rate in the economic system. He writes:

> 'A rise of Bank rate is expressly intended to restrain activity. It does so by making traders less willing to hold stocks of goods with borrowed money. When traders become less disposed to buy and more disposed to sell, manufacturers receive less orders, pay less wages and make less profits. There is a shrinkage of incomes which is reflected in a shrinkage of demand. Sales fall off and the retailers and wholesalers find that after all their stocks resist reduction. The decrease of their purchases has failed to attain its full effect in that direction because it has been followed by a decrease in sales. But just because their stocks have not fallen off they will cut down their orders to manufacturers still more.
>
> Similarly a reduction of Bank rates makes traders more willing to hold stocks of goods with borrowed money, and more disposed to buy. Manufacturers receive more orders, pay more wages and make more profits. The consequent expansion of incomes and of demand results in increased sales, and dealers find that their increased orders have failed to produce the desired increase in stocks. And because of the increased sales they aim at a great increase in stocks than before.'

Anticipating a little the later sections in this work, it is instructive here to see how he goes on.

> 'When activity has taken hold, an apparently high Bank rate may fail to check it. To be successful, the rate must be high enough to counteract this intensified desire to increase stocks. And when demand outstrips productive capacity, there

will be an accumulation of forward orders, which will keep producers busy even after the demand has begun to fall off. When the demand for the product of a particular industry increases to such an extent that the industry's productive capacity is strained, the first sympton of strain is delay in the delivery of the goods ordered. When producers find that they cannot keep pace with orders, they raise their prices, and, if they are satisfied that the increase in demand is not merely temporary, they take steps to expand the capacity of the industry.

At a time of expansion of general demand all industries, or nearly all, find themselves in this position. They cannot all extend capacity at the same time except to the very limited extent that the productive resources of the producers of capital goods will allow. Therefore they have to rely on raising their prices to keep demand within limits, but the rise of prices always lags some time behind demand. When the expansion of demand is progressive, so that a succession of price rises is called for, the majority of industries are likely at any given time to be working through an accumulation of past orders. If pressure is then applied through a rise in Bank rate, and traders wish to hold smaller stocks of commodities, the effect will be felt first only in a reduced volume of forward orders, and the activity of producers will be little if at all diminished. The consumer's income will be sustained and with it general demand. There may therefore be a considerable interval before the corner is really turned and the spiral of inflation broken.'

Hawtrey also has quite a lot to say on the effect of prices on stock holdings, or at least on forward quotations and on the cost of holding stocks of goods in addition to the effects of changes in Bank interest rate on stock holdings. All of these topics are considered in more detail at a later stage in this work.

2.4 More Recent Analysis

Metzler[7], writing in 1941, discusses the effect on the trade cycle of different policies towards inventory. He finds that an economy in which businessmen attempt to recoup inventory losses will always be likely to undergo cyclical fluctuations when equilibrium is disturbed. His interest is, however, in broad general effects on the economy rather than the specific effects on the individual firm of different inventory policies.

Lutz and Lutz[8] in their seminal work on the investment decision (1950) consider investment in raw material inventory:

> 'The motives for holding raw material inventory are similar to those for holding finished goods inventory: (a) the lack of perfect coincidence between purchases (or deliveries) of raw materials and inputs of raw materials into the productive process, and (b) expected increases in raw material prices.
>
> The case of speculative raw material inventory is simpler to analyse than the case of speculative finished goods inventory. If rising raw material prices are expected, the entrepreneur will profit by buying in advance up to the point where the present value of the future selling price (or marginal revenue) just covers the present buying price (or marginal buying cost) plus the present value of (marginal) storage charges.
>
> The volume of raw materials purchased for inventory (or sold from inventory) in any period will depend, then, on the relationship between interest (and storage) charges and expected price changes. In times of rising prices the firms scale of buying may be limited by one or all of three factors: (1) rising storage costs, (2) imperfect competition in the raw material market causing the current price to rise as the firm buys more (and the expected future selling price to fall), (3) a rising interest rate as the firm borrows increasing amounts.
>
> The buying of raw materials to hold is a separate source of profit which is independent of the entrepreneur's productive operations. The fact that he has bought ahead will not affect

> the optimum output of any future short period; for in order to maximize his total profits, he must always charge the raw materials to current operations at their current market price (or the discounted value of the expected future market price if that is higher than the current price), since the raw materials have an alternative outlet in the market.
>
> In times of rising raw material prices, if the materials are valued at original cost instead of market price, the cost curve of the current period will be set too low, and production will be in excess of that which would maximise profits. In other words, the entrepreneur will realize for some of his raw materials less than he could have obtained for them by selling them in the market.
>
> In times when raw material prices are falling and are expected to go on falling, it will pay the entrepreneur to sell out the whole of his raw material inventory in excess of what he needs immediately for current operations. What he takes for current operations should, of course, be valued in the cost curve at the present market value even though that value is below the original cost: for otherwise he will be setting the cost curve too high, and production will be below the optimum level.'

While Lutz and Lutz may have made a clear theoretical analysis, there will be many practical situations in which their essentially neo-classical approach is not helpful. The advice which they give is sound provided that the entrepreneur knows which of the two situations he is in; namely one of rising or of falling prices. It is the absence of this information which renders both the neo-classical approach to economic decision making, which was discussed earlier in this chapter, and the conventional inventory decision-algorithms which are referred to later, of very limited practical use.

Bridge[9] (1971), a commentator on econometric studies, considers that inventories are particularly difficult to handle in economic theory. He points out that one of the reasons for the existence of inventories stems from the presence of uncertainty, a factor to which attention has already been drawn in this study. Firms are not sure when their goods will be required and hence hold stocks in order to satisfy demand as it occurs. Similarly, firms may hold stock of raw materials because supplies are not certain. Although some stochastic theory is available uncertainty is more often allowed for by ad hoc devices because the theory is difficult to put into practice. One device which has been extensively used in inventory analysis is the concept of 'the desired level of stocks'. This is assumed to be proportionate to the expected level of sales or output. In this, however, we have an inventory-output ratio which plays the same role in inventory studies as the capital-output ratio does in investment studies. The traditional accelerator theory was used in early econometric studies because inventories are easily run down. Later work introduces more variables, such as prices, the rate of interest and the level of unfilled orders; but, almost without exception, these models depend upon probability theory and contain factors which must be 'set' to obtain a result.

Many of the econometric studies are concerned with inventories at the level of the national economy or that of an industry taken 'en bloc'. Some disaggregation would appear to be desirable. Inventories are usually thought of as three types: finished goods, work-in-progress and raw materials. Bridge comments:

> 'We would expect each of these to be determined by different factors and this provides a possible form of disaggregation. One might think that it is an easy matter to determine which goods are raw materials and which are finished goods from published statistics. This is not so, for all intermediate goods can be thought to be either a finished good or a raw material depending on who owns them. For example, a piece of sheet steel may be the finished good of the steel industry or a raw material of the motor industry'.

There is a further important distinction concerning the role of unfilled orders. This is the essential dissimilarity of inventory behaviour between firms which produce to order and those which produce to stock. Bridge holds that disaggregation to a level which will allow this distinction to become apparent is important in inventory studies. Also, he writes it is important to emphasise that aggregation through time of an inventory function, because of the possibility of negative inventory change, is rather different from that of a demand or investment function whether dealing with monthly, quarterly or annual data.

> 'That is to say inventory fluctuations are essentially short run phenomena which may not be recorded in data pertaining to long periods. In the short run therefore we can only expect partial adjustment to equilibrium and this is an essential element of the study of inventories.'

2.5 Practical Approaches to the Inventory Decision

A discussion of the literature, such as this chapter, may further the readers understanding of the subject, but the problem of providing practical advice for the decision-maker remains. The work so far reviewed does include studies intended to discover and outline conditions under which optimum inventory decisions might be made, but much of the discussion is in general rather than in operational terms. Many of the more effective 'normative' models lie not within the literature of mainstream economics but in the specialist literature of management and operational research. The earliest type of economic lot size equation was developed in 1915 by F.W. Harris. This expression aimed to minimise the sum of inventory carrying and set-up costs in the case of known invariant demand. By 1925 articles on the subject had begun to appear in business journals including articles on the economy of placing larger requisitions by R.C. Davis[10], G.F. Mellen[11] and H.S. Owen[12]. The conjecture has been raised that the costly inventory liquidations resulting from the depression of 1921 were responsible for stimulating this interest. The following decade saw numerous publications including work by R.H. Wilson[13] and W.A. Mueller[14] and H.N. McGill[15]. The period from 1935 to 1950 witnessed a gradually increasing interest on the part of economists, statisticians, mathematicians, and students of management, in the problems of the firm.

The problem of optimal safety allowances under conditions of uncertainty was reconsidered by writers such as T.C. Fry[16] and C. Eisenhart[17]. Eisenhart reasoned along similar lines to those of Edgeworth's but considered a Poisson distribution for demand rather than a Normal one as in the case of Edgeworth. E. Schneider and B. Jessen[18] strived to reach a higher level of generality, and showed their awareness of the concepts of over-all versus sub-optimisation. The problem considered was a manufacturer's sales forecast as a function of time, initial inventory, productive capacity constraints, carrying charges and production costs; the optimal production schedule was to be determined so that the combined cost of production and storage needed to meet sales requirements would be minimised. This work was not carried out to complete optimisation although this limitation was explicitly stated. A graphical method was used to find the cumulative production curve bounded by the sales curve on the one side and plant capacity on the other.

In providing a framework for discussing the more recent literature and the principal results produced by workers since the Second World War, it may be useful to return to two basic questions. These are 'How much to buy?' and 'When to buy it?'. The amount bought is termed the lot size and the amount still in stock when the new order is placed is called the safety stock(s). The (s,S) policy, described and used by most writers on this topic, prescribes ordering (S-x) if $x < s$ and not ordering if $x \geq s$ where x is the current inventory level and S is the maximum stock level.

A great deal has been written on the optimal inventory policy since 1950 notably by Arrow, Harris and Marschak[19], Dvoretsky, Kiefer and Wolfowitz.[20] A good summary of their work is contained in a book by Hadley and Whittin[21] (1963). Arrow et al.(1951) and Dvoretzky et al.(1952 and 1953) considered the interdependence of demand in the various time periods, as well as cases where the probability distribution of demand is not completely known, plus simultaneous demands for several items. The continuous dynamic approach was a fresh contribution in the case of both groups. The second group even included probabilistic replenishment cycles and serially-correlated demand in their elaborate equations. Users of these probabilistic models will find much sympathy with the following comments from Clyne:[22]

> 'Other things being equal, the argument goes, random events tend to occur in a distinct and well studied pattern. If there are enough of them they increasingly approach this pattern and their likelihood can be forecast mathematically with increasing precision. This forecast can be used to calculate the reorder points which will give a one-in-ten, one-in-a-hundred or one-in-a-thousand or indeed any other probability of running out. That is as long as the events continue to follow this random pattern. The mathematics are quite well known and short cuts have been published to simplify the labour of the routine calculations, which anyway a computer can take in its stride.
>
> The argument is correct but the dangers lie in the basic assumption that the

> incidence of demand orders is genuinely random. It rarely is or at least it takes a lot of searching to find a situation that comes usefully and reliably close to it. More often than not external events like the Budget, a sunny Bank Holiday, a competitor closing down or a new product entering the market produce distinct distortions - 'assignable causes of deviation' - which breach the basic assumption of random pattern. Detailed reordering formulae based on probability have been published and are available to all. The use of these is unwise especially in the hands of the semi-skilled. Also the potential benefits from using them are relatively small since the main costs of stock keeping arise not from the minimum stock but from the average stock level, which is controlled not from the reorder point but by the reorder quantity.'

The adjective random is used as in the Penguin English Dictionary, i.e. "made or done without calculation or method; left to chance." What Clyne is trying to say here is actually anticipated by some of the writers mentioned earlier because they hedge their solutions about with restrictions on use in such a way that one might as well toss a coin to decide the next step. To understand the type of activity that relies on guesses, which are rationalised as 'probabilities', it is best to leave the twentieth century and return to one of the governors of the Bank of England. Mr. Edgeworth[23] (1888) was interested in the 'problem' of safety allowances (cautious banker) in the face of uncertainty with respect to the determination of reserve ratios for banks. He uses the example of catering for a club. The manager does not know each night how many members will turn out for dinner and the methods he employs are parallel with those of a banker in meeting the uncertain demand. Bankers, catering managers, shopkeepers and race-course bookmakers are all in effect conducting the same business. The successful are those who manage to keep their customers satisfied. A personal story illustrates the point. The other day I needed a bearing for one of my motor van's wheels. I found myself at a small village garage which was run by the owner who lived on the opposite side of the road. This garage might have been expected to carry a few fan belts, the odd tyre and a selection of nuts and bolts. He had the bearing for my van. I asked him how this came about and he told how he always liked to have 'a few odd things in stock for they are sure to come in handy.'. A professional stock controller should throw up his hands in horror at such a principle being applied to his stocks and with good reason; but reason, it will be recalled, is only half of the story. I need only say that I am now most favourably disposed towards that garage owner and my custom comes his way on every occasion. One last thought crosses my mind regarding this incident. There are two garages in this village. What took me to the one that had the spare part? The other garage is a large busy place with an apparently better hope of finding my spare. However, subsequent investigation discovered they had stopped carrying spares for that model owing to its age.

Work on inventory problems was carried on at many different levels during the sixties. At one extreme a considerable amount of work was concerned strictly with practical applications while, at the other extreme, work was done on the abstract mathematical properties of inventory models without regard to immediate practical applications. A comprehensive survey of the literature on reordering stock items was produced by Leonard Fortuin[24] in 1977. His paper deals with Material Requirements Planning (MRP) and Statistical Inventory Control (SIC) techniques both of which are used in industry. However, these techniques are only useful in periods of price stability and are usually used in industries where no elements of speculation are present in the stocks held.

2.6 A Categorisation of Systems

A.B. Thomas[25] outlines the main systems in practical use. They fall into one of two categories:-

1) Fixed order quantity systems (Table 2.6.1)

2) Periodic review system (Table 2.6.2)

- though there are some special systems which must be considered separately as not falling conveniently into either of these.

2.6.1 Fixed Order Quantity Systems

One basic characteristic of the first category of systems is that the stock level is monitored continuously, (or each time a withdrawal from stock takes place), against a preset reorder level, and when the stock falls to or below this reorder level an order is placed. The reorder level is usually made up of two parts:-

a. The quantity expected to be used in the period which lies between the time when the stock falls below the reorder level and the time when the replenishment quantity is received into stores, the 'lead-time usage'.

b. An extra quantity in case the lead-time usage should exceed the estimate, either because the rate of usage increases or because the delivery is late. This quantity is 'the safety stock'.

When an order is placed, the order is for a pre-determined quantity

Table 2.6.1 Fixed Order Quantity Systems

	LAST BAG	SIMPLE STOCK CARD	RESERVATION STOCK CARD
OUTLINE OF SYSTEM	Estimate usage. Set safety stock. Reorder level = Lead-time usage + safety stock. Put reorder level in one (or two) 'bags'. Place replenishment order when reorder bag is opened. Expedite if third bag opened.	Estimate usage. Stock card shows all movements. 'Stock-plus-on-order' tested against reorder level at each posting. Replenishment order (EOQ or similar) placed if level is below reorder level. Expedite if below 'danger level', if this exists.	Stock card carries all movements and future reservations. Usage is based on these. Reorder level as for simple stock card unless reserved period uniform. Replenishment as for simple stock card:
SUGGESTED FIELD OF APPLICATION	Low usage-value items individually cheap, used fairly regularly	Low or medium usuage-value items used fairly regularly.	Items of high or medium usage-value with known forward-programme.
LIMITING CONDITIONS	Usage must be fairly regular. Items must be cheap. Lead-time must be less than time corresponding to the order quantity.	Usage must be fairly regular. Needs continuous monitoring of balance.	Forward programme must be known far enough ahead for explosion to give advance warning of lead-time away. Issues must be identifiable with reservations.
ORDERING COSTS V WORKING INVENTORY	Balanced	Balanced	Balanced

Continued....

	LAST BAG	SIMPLE STOCK CARD	RESERVATION STOCK CARD
SAFETY STOCKS	Depends on variation of both usage and lead-time. Typically 3 to 6 month's usage.	Depends on variation of both usage and lead-time. Typically 1 to 3 month's usage.	Depends on accuracy, reliability and horizon of forward programme as well as lead-time variation. Typically 3 to 6 months.
EFFECT ON OVERALL MANUFACTURING CYCLE	Order-to-delivery cycle need not include procurement time.	Order-to-delivery cycle need not include procurement time.	Order-to-delivery cycle may have to include procurement time, typically 3 to 6 months.

Table 2.6.1 (concluded).

Table 2.6.2 Periodic Review Systems

	TOPPING-UP	MIN-MAX (s,S)	BASE STOCKS	PLANNED ORDERING
OUTLINE OF SYSTEM	Establish review period and average usage. Set 'Max' level = usage x (lead-time + review period) + safety stock. At each review, order enough to restore actual level to Max.	Establish review period and average usage. Set 'Min' = usage x (lead-time + review period) + safety stock. Set 'Max' = Min + ½ EOQ + ½ (usage in a review period). Order if 'stock plus on order' is below Min. Order enough to restore 'stock plus on order' to Max.	List all sequential stages with lead-times. Select base stage. Use Min-Max at all times with overall lead-time at base stage, but only inter-stage lead-times at other stages.	Establish review period. Explode programme to give requirements. Aggregate requirements as necessary. Order when not covered by 'stock plus on order'. Order one-for-one or modified EOQ. Safety margin is in time, not quantity.
SUGGESTED FIELD OF APPLICATION	Warehousing replenishment from main stock many items from same supplier on regular basis. Often used with blanket orders and 'call off'.	Items of moderate usage and value, where cost of reviewing each item every time is justified. Often used with blanket orders and 'call-off'.	Multi-stage items.	Items of moderate or high usage value with known forward programme.
LIMITING CONDITIONS	Usage must be fairly regular lead-time must be short. Preferably many items from same supplier.	Usage must be reasonably regular.	Stocks of related parts must be considered together.	Forward programme must be known far enough ahead to cover lead-times for low-level items.

Continued....

	TOPPING-UP	MIN-MAX (s,S)	BASE STOCKS	PLANNED ORDERING
ORDERING COSTS V WORKING INVENTORY	Ordering costs can be high.	Balanced	Each case needs separate consideration.	Ordering costs can be high.
SAFETY STOCKS	Depends on usage variation and review period. Typically 2 to 8 week's usage.	Depends on review period and on variation of usage and lead-time. Typically 1 to 4 month's usage.	Base stock high, typically 1 to 6 month's usage. Other stocks low, typically 1 to 2 week's usage.	Low. Depends on accuracy, stability and horizon of forward programme as well as delivery reliability. Typically 1 to 4 weeks.
EFFECT ON OVERALL MANUFACTURING CYCLE	Order-to-delivery cycle need not include procurement time.	Order-to-delivery cycle need not include procurement time.	As for system used for the base stock.	Order-to-delivery cycle must include procurement time, in general, typically 3 to 6 months.

<u>Tables summarising the leading features of the main stock control systems in practical use.</u>

calculated by an appropriate method.

It is here worth recording, before proceeding to the second category of systems outlined by Thomas, a commonly used method of classifying stock items. It is possible to divide stock items into three classes A, B and C such that:

A items are the top 10% of the items and account for 60% of the usage-value

B items are the next 30% of the items and account for 30% of the usage-value

C items are the remaining 60% of the items and account for only 10% of the usage-value

2.6.2 Periodic Review Systems

Periodic review systems are usually one of three types.

a. Regular reviews. In these systems, the position of each item (stock, outstanding orders and requirements if any) is reviewed at regular intervals of time- weekly, fortnightly, monthly or even less frequently, depending on the classification of the item. Most computer based stock control systems, at the present time, come under this heading.

b. Review periods by classification of items. The determination of the most appropriate review period for each class of item is a basic step in designing and installing a system but in general it will be found that A items tend to be reviewed fairly frequently (perhaps weekly), B items less frequently, and C items at infrequent intervals some months apart.

c. Variable Order quantity. It is characteristic of this type of system that the order quantity varies from period to period and is not predetermined.

Consider computer stock control systems. Usually they are arranged so that the user intervenes at various stages to supply information. He decides what information to give the next program when he has studied the results of a previous program. The suite of computer programs usually:

1. Reviews all safety stocks and levels affected by them (e.g. reorder levels).
2. Explodes the forward program one level giving requirements, period by period, for all parts and sub-assemblies needed for the final assembly stage.
3. Adds any requirements for direct sales, spares and so on of parts at this level.
4. Compares the total requirements, period by period, with current stocks and due deliveries from orders already placed, taking into account any safety margins specified.

5. Identifies any shortages or potential shortages.

6. Calculates any necessary order quantities.

7. Explodes these into their requirements for parts at the next level down period by period and so on.

Various computer systems have different conditions calling for action, and different possible actions. These can be drawn up as 'logic diagrams' or as 'decision tables'. A separate run through the stock record file may be used for analysis purposes:

1. To produce an ABC breakdown.

2. To report any dangerously imminent shortages.

3. To identify any slow moving or obsolescent parts.

4. To identify any excess stocks of current parts.

or 5. To evaluate the inventory periodically.

To conclude this section on stock control systems I should mention that a computer can be used to simulate a manual stock control system in order to test, modify and improve it and to determine what kind of control it is going to give. Unless done on a very small scale, however, simulation can be very expensive and unreliable.

2.7 Price Fluctuation and Interest Rate Changes in the Literature

In recent years, as in the post-Great War period, it has been increasingly necessary to take inflation into account when making economic decisions. By inflation I shall mean a general and persistent rise in price levels. An inflationary situation is chacterised by a rise in most prices and by a tendency towards continuation of increases. Not all prices go up at the same rate, and the differences between the increases in several sectors of the economy and in the different components of costs are of some importance in a study of the effects of inflation on inventory management; similar factors must be taken into account at times of a general and persistent fall in prices. To be precise let $p(t)$ be a suitable measure of prices taken over that sector of the economy in which we are interested. An inflationary situation is said to pertain at epoch $t \in (0, \infty)$ if, and only if, $\frac{dp}{dt} > 0$. On the other hand a deflationary situation is said to pertain at epoch $t \in (0, \infty)$ if, and only if, $\frac{dp}{dt} < 0$. The rate at t in either situation expressed as a percentage per time unit is $\left| 100(\frac{dp}{dt}/p) \right|$. The interest rate also affects this discussion because it is a large component of the holding cost of inventories.

2.7.1 Real and Apparent Interest Rates

An amount of currency C_o will, at the beginning of a period of n years, have the same purchasing power as the amount $C = C_o(1 + d/100)^n$, at the end of the period, if an inflation rate of d per cent per year is anticipated. Therefore before even considering the return on money lent, an increase of d per cent of the amount loaned would have to be asked by a lender after one year just in order to maintain the purchasing power of his capital.

Irving Fisher[26] held that, in times of inflation, it is necessary to distinguish between the real interest rate, corrected for inflation, and the apparent interest rate, which is the nominal or stated interest rate. The lender, if he were able to anticipate the inflation rate d exactly and if the real interest rate were i, would have to charge the apparent interest rate r, such that

$$r = i + d \quad \text{........................(A)}$$

in order to protect himself against the erosion of the currency's purchasing power.

In a period of inflation, the lenders will charge more than the real interest rate i, but it is not sure that they will be able to forecast perfectly the inflation d and charge, in consequence, the theorectical apparent interest rate r as in A above. As the desired real interest rate of the lenders, i, is also not known, it cannot be 'proved' that the formula A holds in the real world. But it can be observed that, in general, in an economy, the nominal interest rate r and the inflation rate d are positively correlated in the long run, although they display lags in the short run, (see fig.2.1, pg.63).

Milton Friedman[27] uses Fisher's idea, outlined above, that the nominal or money rate of interest (the current market interest rate) depends on the real rate of interest and the expected change in the price level. He combines Fisher's idea with that of Keynes that the current market interest rate is largely determined by the rate that is expected to prevail over a longer period in order to develop the quantity theory of money. He contrasted monetarist and Keynsian views in a paper at the Sheffield money seminar (1970) and was followed by two discussion papers and a general discussion. In his discussion paper Sir Roy Harrod pointed out that Keynes held that, although there were special occasions when the rate of interest was determined by the views of asset holders about the future, it was in general determined by the money supply and demand for liquidity. Harrod supported Keynes in denying Fisher's view that prospective inflation is added to what would otherwise be the money rate of interest. In the general discussion that followed it was argued by most of the discussants that both Keynes and Harrod were wrong on this issue.

With appropriate modifications equation A above applies also to rates of return, both before and after income tax. The stated rate of return, before or after taxes, should a 10% real rate of return be desired and if the foreseen inflation rate be 20%, should be 30%.
Even in a non-inflationary economy, a difficult and unsolved problem is the choice of the proper rate to be selected as the financial component of the cost of holding inventories. The general consensus of opinion by virtue of being the most often used method is that the lowest limit of a possible range of candidate figures is the effective bank rate (after the effect of compensating balances) charged to the firm for its short term loans. This is actually the rate which most companies adopt; it has the advantage of being a very concrete datum. Theoretically, however, a case could be made in favour of some opportunity cost such as the rate of return (before taxes) that the best alternative investment would yield. This solution might be conceptually superior from an economic standpoint but requires making a subjective decision and so is open to serious criticism by the practical manager. Other possibilities would be last year's rate of return on investment, the last five years' rate of return, some arbitrary rate of return or the industry's average rate of return.
In times of inflation, it is not the real interest rate i that should be used in computing inventory holding costs, but, instead, the apparent interest rate as in A. Assume that the firm borrows from a bank in order to finance its inventory. The bank, careful to protect the purchasing power of its principal, charges the apparent interest rate. After completion of the manufacturing cycle, the goods leave the production department. The holding costs to be debited to the

operations department are the interest charges incurred during the manufacturing cycle. This is an out-of-pocket expenditure. It could be argued that, if the firm were able to readjust its sale prices during the period, the sum received compensates for the sum paid as inflated interest. But the loan is contracted at a time that the firm ignores its ability to readjust its prices. From a conservative viewpoint, and especially in periods in which the firm has no certainty of being able to readjust its own prices and 'pass the increase to the customer', the apparent interest rate is, therefore, the proper cost of money to be adopted.

Fisher's work was reviewed and restated by J. Hirshleifer[28] in order to illuminate two competing rules of behaviour proposed by economists to guide business investment decisions, namely the present-value rule and the internal-rate-of-return rule. He develops the case where borrowing and lending rates diverge to find that there is more support for the use of the present-value rule than the internal-rate-of-return as an investment criterion. This theoretical work has a basic assumption that the costs and returns of alternative individual investments are known with certainty, the problem being to select the scale and the mix of investments to be undertaken.

During an inflationary period, it becomes even more difficult than in non-inflationary times to decide what specific opportunity cost to attribute to holding inventories. This cost arises because money tied up in stocks might have been producing interest elsewhere. The effect of the inflation on the firm's opportunity profits becomes a new factor with which to reckon. The opportunity costs debited to inventory should not be modified if the forecasted inflation will not affect business profits. This rule of thumb must, in Britain, be balanced with tax allowances made on stock profits. The apparent interest rate, if inflation hurts profits to the extent that the rate of return drops below the apparent interest rate, or some reasonable desired rate of return should be used, whichever is higher. In periods of rising costs, the relative increases in materials, labour and other prices and in the interest rates chargeable to inventories play a decisive role in the determination of the inventory policy of the firm.

2.7.2 Price Increases and Inventory Accumulation

It seems likely that, if interest rate changes are ignored, an anticipated increase in prices will favour an increase in inventories. The economic literature has provided some evidence to this effect. An early reference to the topic was made by John M. Clark[29].

> 'One other factor which may make merchants more willing to invest in considerable stocks is that a time of growing demand for some one commodity, or a time of general increase in activity, are both times of rising prices for the intermediate products called for in the business affected. This makes these commodities a profitable investment so long as credit can be had on easy terms with which to enlarge one's holdings. Merchants tend to assure their future supplies by buying either outright or for future delivery.'

Fisher[30] gave two reasons for purchasing more in periods of rising prices: flight from money and the appreciation of inventories. As he puts it:

> 'We all hasten to get rid of any commodity which, like ripe fruit, is spoiling on our hands. Money is no exception; when it is depreciated, holders will get rid of it as fast as possible. As they view it, their motive is to buy goods which appreciate in terms of money in order to profit by the rise in their value.'

Hawtrey[31] presents two simultaneous reasons for the accumulation of stock, growing productive activity and the rise of prices:

> 'If .... the purchasing traders are led by the growing activity of the producers to expect a rise of price, they will give further orders, in excess of their current requirements, in order to take advantage of the market while the price is still low. In effect the traders will be acquiring an additional stock by way of speculation'.

During the two years that followed the First World War the following events occurred:

> 'In every trade people anticipated a further expansion of demand and a furthur rise of price. And traders proceeded accordingly to order additional supplies of goods with a view to adding to their stocks before the rise of price materialised..... The vicious circle of inflation revolved merrily. Prices were rising at the rate of 3 to 4 per cent a month. The forward buyer or the trader who bought commodities with borrowed money made an extra profit at that rate. It appeared to be worth while to borrow at any rate of interest not exceeding the expected rate of the rise of prices.' [32]

Rotwein's[33](1945) description of the same period might well be applied to the 1973-1975 years.

> 'Inventory hoarding and speculation were rife. Dealers, expecting further price increases, were ordering vast quantitites of goods far in advance. Acting as a stimulus to production, this resulted in a great increase of output, most of which ended up in storage, where it was held by speculators. Artificial shortages were created and prices boosted still higher'.

Chronic inflation exists in many economies including some of the less developed countries. Many observers believe that a constant rise of prices favours inventory accumulation but empirical evidence is lacking.

At the conference on inflation and economic growth in Latin America [34] held in Rio de Janeiro in 1963, some members of the panel

> 'felt that the distorting effects (in price rises) should cause increases in inventories ..... Other panel members indicated that, in some countries, this type of distortion has not taken place despite considerable inflation.'

Dorrance's paper[35] presented at the same conference suggests that

> 'In Brazil, when the rate of inflation rose, inventories were increased sharply. Thereafter, even though inflation might be rapid, the rate of inventory investment reverted to a more normal level; when the rate of inflation was reduced, there was a temporary decline in the rate of inventory investment.'

These quotations would seem to indicate that inflation causes an increase in stockholdings so long as buyers anticipate a rate of increase in price greater than the increase in their borrowing charges. However, the experience of Brazil does seem to indicate a limit beyond which the industrial buyer will curtail his speculative activities. Perhaps the limit is governed by storage capacity or factors associated with obsolescence. Another reason may be senior management decisions on a strategic level overriding short term considerations of speculative profit. Later in this work I shall show that the price of an individual commodity, namely peppermint oil, is not the only factor in decisions on whether or not to speculate in the commodity. Interest rates have been mentioned in connection with inventory holding costs. We now consider the influence of interest rates on inventory accumulation more fully.

2.7.3 Interest Rate and Inventory Accumulations

It was generally held in the literature of economics that, prior to the slump of the 1930's, variations in the rate of interest exerted great influence on the responsiveness of all forms of borrowing including inventories. Hawtrey[36] declares that changes in the rate of interest govern the fluctuations of business activity to a considerable extent:

> '...When a trader borrows from his bank in order to purchase goods, either for resale or use in manufacture, his outstanding indebtedness will depend on the quantity he chooses to be delivered at a time. He will not let his stock fall below the minimum which he judges necessary to guard against its being depleted by unexpected demands, but when the minimum is reached, and he has to replenish the stock, he is free to buy a week's supply or a month's or three month's. If he suddenly finds that he is charged 8 per cent for an overdraft instead of 4, he can reduce the amount he has to pay in interest at very little cost of inconvenience by obtaining the goods at shorter intervals and in smaller quantities. That does not necessarily mean buying smaller supplies; he can order the goods far ahead, if he thinks the moment favourable for a forward purchase, and can nevertheless stipulate for a series of deliveries at short intervals, so that at no time during the period over which his order extends will his stock be inconveniently large.'

Hawtrey[37] continues:

> 'A rise of Bank rate makes traders less disposed to buy and more disposed to sell and a fall has the contrary effect...... The merchant can regard each purchase of goods as a seperate venture; practically the whole capital involved is working capital, the cost of the goods themselves. And by postponing his purchases he can reduce the amount of capital employed without curtailing the scale of his operation at all. The additional charge imposed on him by a rise in the rate of discount affects him like a tax on the holding of goods. The tax may be a light one, but the subject of the tax, the amount of goods held in stock, can be varied so easily that it will be responsive even to a light tax.'

Keynes[38], contrary to Hawtrey, believes that the borrower for the purchase of commodities is insensitive to the short term rate of interest that he has to pay for holding goods in stock. Keynes[39] considers the fluctuations in interest rate to be insignificant in comparison with other costs of carrying stocks, namely, obsolescence risks, warehouse and insurance charges, and price-level fluctuations:

> '... it is evident that a fluctuation of 1 or 2 per cent in bank-rate will represent so small a part of the total carrying charges that it is not reasonable to assign to the <u>expense</u> of high bank-rate a preponderating influence on the minds of dealers in stocks. In so far as low and high bank-rates are regarded by dealers as <u>symptons</u> of impending rising or falling prices, it is another matter.'

In this we have a Keynsian blessing for some of the data-based prediction methods considered in Chapter IV.

Keynes does not look upon interest-rate fluctuations as the fundemental cause of changes in the level of business activity, except so far as capital equipment is concerned through investment and the multiplier effect. A similar position is taken by Evans[40] who contends that:

> 'other possible influences on inventory investment... are the possible cost and availability of funds as measured by interest rates and cash flow. Only a few studies have examined the importance of these variables on inventory investment; most of these show no significant relationships. There are several theoretical reasons for this. As is well known, a large percentage of the total cost of fixed business investment may represent interest payments; this is almost never true for inventories. The internal risk factor on fixed investment is virtually absent for inventory investment, because firms are not committed to any long-term debt service. There is more of a short-term technical relationship between inventories and sales than between fixed business investment and production. A firm may work existing plant and equipment

overtime or add additional man-hours in the short run; however it often cannot produce its product without closely specified proportions of raw materials and goods in process. For all these reasons, it is not surprising that the interest rate and cash flow are not relevant determinants of inventory investment.'

Other economists do not believe that the influence of monetary factors on inventory investment can be dismissed. Dernburg and McDougall[41], for example, write:

'The demand for money is but one aspect of the general inventory problem. Weighed against the desirability of holding inventories is the cost of holding inventories ... a cost that is partly dependent on the rate of interest. A high rate of interest raises carrying costs and is apt to lead merchants to try to get by on a smaller margin of inventory, while a low interest rate will have the opposite effect. It is in the relationship between inventory costs and interest rates that Hawtrey found the source of industrial fluctuations.'

Gottfried Haberler[42] reviews Hawtrey's position at length and concludes:

'Mr. Hawtrey is aware of the objection, which has been raised very frequently, that a reduction of 1 to 2% in the interest on bank advances is too unimportant an item in the profit-and-loss account of the average businessman to induce him to expand his business and to borrow more. His answer to this objection is that there exits one class of business-men which is very sensitive even to small changes of the rate of interest ... namely, the merchants. The merchant buys and sells large quantities of goods compared with his own capital, and he adds to what he buys the relatively small value which represents the dealer's profit. To him, a change in interest charges of 1 to 2% is not negligable, as it perhaps is to the manufacturer.'

Whitin[43] summarises Hawtrey's theory in the following way:

'Hawtrey, although addressing himself principally to business cycle theory, wrote much that is pertinent to the theory of the firm. ...... How much effect interest rate variations actually have on inventories is an empirical question. Enough data have not yet been compiled to provide an answer which will either prove or disprove Hawtrey's theory.... Changes in the interest rate should influence the rational entrepreneur to change his lot size, but two factors are present that help reduce the effects of changes in the interest rate. The first of these is the economic purchase quantity and the second is the set of components other than interest included in the carrying charge. In order to avoid this difficulty Hawtrey assumed that carrying charges other than interest were small and constant, an assumption that is ordinarily not realistic.'

Two surveys were conducted for the Radcliffe Committee in 1957[44] and 1958[45], which indicate that interest rates may not effect the majority of businesses or the full amount of many loans, but they will affect some borrowers and the amounts involved in some loans. Forward inventory commitments and later the actual purchases may be curbed. A clear awareness prevails among some authors that the influence of interest rate is ultimately a question of degree, depending on the situation of the economy, the particular firm analysed, and the size of the interest rate charges.

2.7.4 <u>The Lag in Interest Rate Changes</u>

The literature reviewed here seems to indicate that the changes in interest rate tend to lag behind the changes in price level. The collected historical evidence confirming the existence of such a lag is considerable. According to Brown[46], writing of China over the period of the Second World War, it appeared that it required four years or more of price increases amounting to a doubling or trebling of prices each year to make the conviction that this process would continue so strong as to be fully reflected in interest rates. He goes on:

> 'In Hungary, also, it required much experience of price inflation to raise interest rates abnormally.... The rate for day-to-day money rose to 5 or 6 per cent a day by early April 1946. At that time the cost of living index was rising at some 10 per cent a day. By mid-July, ... this interest rate was 35-40 per cent a day, but cost of living was then rising at about 140 per cent a day...... In Greece the commercial banks during 1945 .... lent at an effective rate (including commission) of only 15-20 per cent, while prices were rising at some 900 per cent per annum.'

Hawtrey[47] writes of Britain in the period 1919-1920:

> 'Bank rate was put up to 6 per cent in November, 1919, and to 7 in April 1920. The predominant rate for advances and overdrafts was perhaps 1 per cent higher. Even 8 per cent seems moderate in comparison with the rate at which prices had been rising.'

Summarising his extensive studies regarding the connection between interest rates and price changes, Fisher[48] reaches the following conclusions based on data from 1820 - 1924:

1. The rate of interest tends to be <u>high</u> during a <u>rising</u> price level and <u>low</u> during a <u>falling</u> price level.
2. The rate of interest lags behind the rate of price change, so that often the relationship

   Apparent interest rate = Real interest rate + Rate of price change

   is obscured when direct comparison is made.

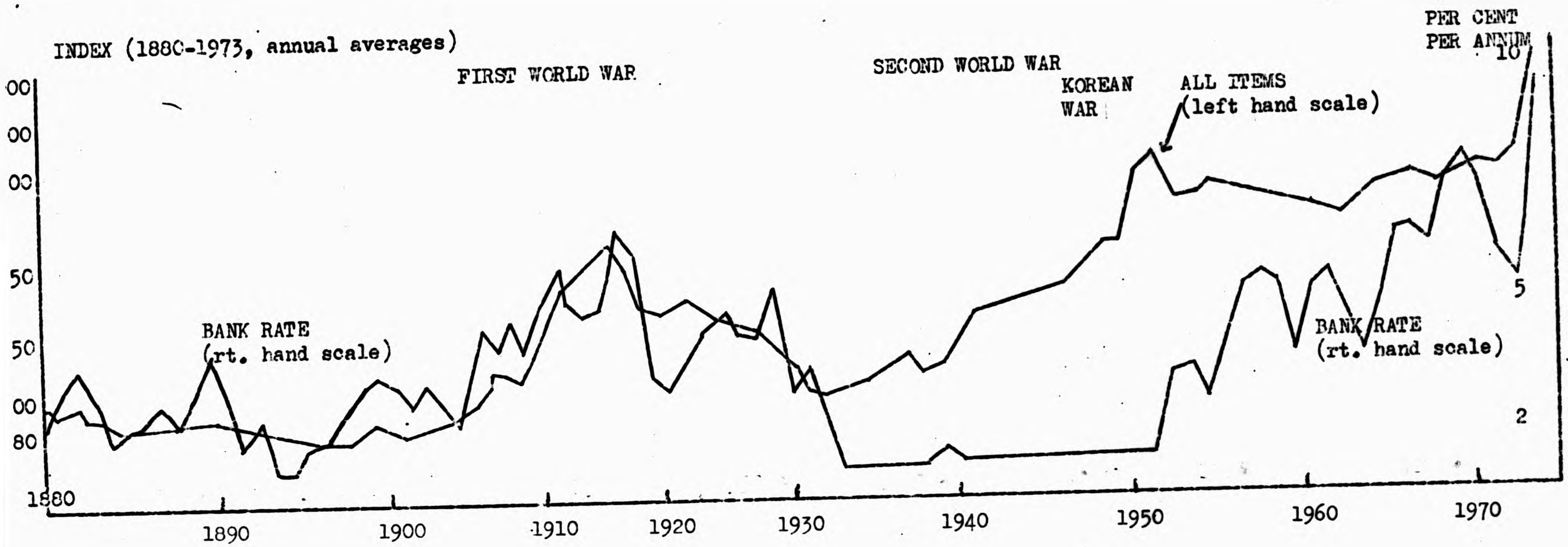

Fig. 2.1 Diagram showing relationship between changes in interest rate and commodity prices

3. The rate of interest correlates very markedly with a weighted average of successive rates of price changes, representing the distributed effect of lag.

He also observes that the computed real rate is exceedingly erratic during a serious inflation or deflation and that men are unable or unwilling to adjust accurately and promptly the money interest rates to changed price levels. He concludes:[49]

> 'These results and other evidence, indicate that, over long periods at least, interest rates follow price movements'.

The relevance of these latter passages to our study of peppermint oil will be shown at a later stage. It suffices to comment at this stage that the prices of individual commodities can sometimes lead and sometimes lag the general level of commodity price changes. Therefore lags in interest rate are sometimes of no consequence; but, when a particular commodity leads the rise in prices the lag in interest rate becomes a factor of great importance to the buyer.

2.7.5 More Recent Literature

Popkin[50] (1974) notes that the surge in raw material prices was a worldwide phenomenon that deserves careful investigation to sort out the roles of various nations and of international trade and monetary relationships. An ambitious investigation indeed. Hathaway[51] (1974) refering to the Russian grain purchases writes

> '...the key elements were the obsession of the developed country exporters with the high carrying costs and market-depressing effects of major reserve stocks; and the failures to recognize the steadily growing world demand for grains, to reevaluate the stocks necessary to absorb shocks in world output, and to consider the potential price implications of inadequate stocks'.

Cooper[52] (1975) gives a general account of th 1972-1974 commodity boom with much of the work based on the metal price index which is heavily influenced by the price of copper. Where explanations are required 'speculation' is invoked but no evidence produced in support from primary sources. Cargill[53] (1975) considers that commodity market behaviour is not explained accurately by random walk whilst Schmalensee[54] (1976) highlights the turning point periods in price series as ones of doubt. Clark[55] (1973) however holds to the view that the distribution of price change is subordinate to a normal distribution. Parikh[56] (1974), looking at the coffee market, has developed a simultaneous equation model which he claims gives better forecasts than naive methods over the short term. More fundamentally Leuthold[57] (1972) postulates two basic approaches to forecasting and warns that conclusions drawn from an investigation based on only one should be viewed with suspicion. Labys[58] (1975) gives a timely warning that little is known about how futures markets might contribute to international commodity stabilization. McCallun[59] (1974) reminds us that it would be wrong to base sweeping conclusions on results from only one industry.

For the more practically minded Kingsman[60] (1973) presents an interesting well illustrated account of a practical nature for stock controllers. He emphasizes the need for good price forecasting. Mandelbrot[61] (1972) corrects an error made in his paper of 1963. Contrary to Cargill he suggests that if markets are inefficient then perhaps random walk is the true explanation for price movements.

Taylor et al.[62] (1978) apply the Box and Jenkins approach to a sequence of prices. Both the application and its result are equally instructive. The authors do not feel that their adopted approach is helpful owing to the changes in the trends in their price data. This writer would only remark that there is a fine line between a frequently changing trend and no trend at all.

Driehuis[63] (1976) edits a collection of ten forecasting applications to primary commodities none of which give over encouraging results. Foote[64] (1972), forecasting the price of pigs bellies (i.e. bacon), comes to the conclusion that there is a correlation between the consumption of bacon and that of eggs.

Cromarty[65] (1975) advises the researcher to be prepared to make subjective judgements about the probable impact of information not included or accounted for in the model this being a continuous task. Crowder[66] (1972) had stated earlier that proper use of models requires a realistic recognition of the assumptions made, a knowledge of the market involved, and some evaluation of those factors not included in the model. Labys[67] (197) ascribes speculative and futures market activity, which normally increase during periods of economic uncertainty, as cause for much of that uncertainty.
Kingsman[68] (1969) concludes this review with his dynamic programming model developed to assist buyers of commodities in fluctuating price markets. The buyer still has to make his own forecasts, yet the method appears to have some merit.

2.8 Summary

The reasons for holding stocks have been traced through the early literature from Adam Smith.We have seen how the accumulation of stock and the division of labour advanced together. Further stock is seen to consist of two parts:one part from which is derived revenue, called capital, and one part which supplies immediate needs. The way in which capital is employed to produce revenue is discussed. This discussion is led towards a consideration of price and interest rate changes and the remainder of the chapter concentrates on these subjects in the literature. The consensus of opinion is that price changes lead to variations in inventories. The effect of interest rate changes is more vague. Some writers, notable amongst them being Hawtrey, say that interest rate, rather than any other economic factor, is the key to understanding the business cycle of industry. Others, such as Keynes, think that interest rates are of minor significance when buying inventories. However there is no real contradiction because, when viewing a cycle of events from a distance, it is clear that in the long term it does not matter whether changes in prices lead to changes in interest rates or vice versa. The logical sequence A→B→C→A can be interpreted to read either A→B or B→A depending on the point one wishes to make. In the short term however it is very important for a buyer to be aware of the place he is occupying in the current cycle. This awareness implies anticipation of the changes in direction of the price and interest rate trends and not simply an anticipation of the current trends. It is this point that interests the speculator and, in turn, us.

****

CHAPTER II

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CHAPTER III

ON THE TRACK OF PEPPERMINT OIL

3.1 Introduction

The mint flavour used in chewing gum, toothpaste and confectionary is not often associated with the plant grown in most kitchen gardens. The mint plant from which we pluck leaves to put in the pot with boiling potatoes is in fact a relative of the peppermint plant (Mentha Piperita) extensively cultivated in the USA. The mint family is noted for its richness in the aromatic orb. Spearmint is grown in two varieties, Scotch (Mentha Cardiaca) and common (Mentha Spicata) whilst a poorer relative cornmint (Mentha Arvensis) is grown in abundence in Brazil and China, largely for its menthol. This chapter is a record of the path travelled by US produced peppermint oil from the farmer to the consumer. It deals with the history of US mint production from the early settlers to the present day with notes on diseases and production costs. The important role of the dealer in determining both the price received by the farmer and that paid by the UK importer is emphasised. It is helpful to remember, however, that price is not determined wholly by farmer, dealer or importer but through a combination of the dealings of all three groups together with external factors not always in their control nor even always quantifiable. Any comments on price should be read with this in mind.

3.2 The Grower

Mint is a temperate zone crop needing long days of sunshine during the growing season. Therefore it is usually grown in latitudes around the fortieth parallel. The United States of America is the world's leading producer of menthol and peppermint oil from the plant mentha piperita.

Brazil is the world's leading producer of menthol and cornmint from the plant mentha arvensis. Cornmint is said to be a low-quality peppermint oil which provides little competition to the USA in export markets. This statement is open to question because US oil has been constantly rising in price in recent years much to the market advantage of cornmint. The US mint industry began in England, whence came the Mitcham strain of mentha piperita. It was taken to New England by the early settlers and gradually spread West through New York and Ohio to Michigan. The muck soils of Michigan proved fertile for mint farming which flourished until the turn of the twentieth century. At about this time Verticillium wilt disease seriously infected mint grown in the state causing farmers to move Northwest to disease-free sandy loams beginning around 1913. The states of Oregon and Washington now became the centre of US mint production. Peppermint (Mentha piperita) used to be grown commercially in two varieties, Mitcham and American. The former on account of its better yield of oil, is now the only commonly grown variety. The highest priced oil is still produced in the Midwest although most oil is produced in the Northwest. The major peppermint growing areas are the Yakima valley and Columbia basin of Washington State and the Willamette Valley and Madras Plateau of Oregon, see Appendix III for map.

3.2.1 A note on diseases

Verticillium wilt disease has been recorded here as the major reason for the westward movement of production. This fungus disease followed the farmers and is probably the major limiting factor in peppermint production in the Western states today. The disease was observed in the West nearly thirty years ago, but a severe strain was not reported until about twenty years ago. Wilt will remove a field from mint production within three to five years after it is first noticed. Since the fungus can survive in the soil for a very long time, infested fields will not be suitable for growing mint. The wilt is usually introduced into a new field by diseased roots or by soil and plant refuse from infected fields. Therefore it is important to use only roots certified to be disease-free. The strain of Verticillium albo-atrum attacking mint is specific for mint and will not cause wilt in other plants: similarly strains of Verticillium from other plants will, at the worse, cause only mild symptons in mint. Mint wilt can be successfully controlled only by using disease-free planting stock on disease-free ground. There are, as yet, no economical chemical methods of control. Crop rotations are ineffective. There are no Verticillium wilt-resistant varieties of mint commercially available, although common spearmint (Mentha spicata) is tolerant of the disease. Soil fumigation as a means of control is economical in Oregon but not under Washington conditions. A recent suggestion for controlling the disease has been to flame peppermint stubble with a propane field burner in order to destroy fungus in infected stems.[1] The fungus, if not destroyed, forms durable structures (called microsclerotia) that help it to survive in the soil without a host plant. Flaming is effective in meadow mint culture but is not effective in Washington mint producing areas. Since Washington mint is intensively cultivated, the microsclerotia are continually being brought into contact with rhizomes (underground stems), making it easy for the disease to develop.

Powdery mildew, caused by the fungus Erysiphe cichoracearum, is a disease rarely severe enough to warrant control measures and none has been developed for use on mint.

Rust disease, caused by the fungus Puccinia menthae affects spearmint and peppermint though the latter is not seriously affected in Washington. Peppermint rust has been controlled in some areas by killing the first shoots to come up in the Spring: both flaming and contact herbicides have been used. Killing the early shoots helps to eliminate the sources of infection as early in the season as possible.

Three parasitic nematodes are known to be potential pests of mint in Washington. Each one can cause a stunted unhealthy appearance in severely infected plants. The root knot nematode, meloidogyne hapla is probably the greatest threat to mint fields because of its wide range of hosts. The disease is easily recognised by the small swellings, or galls, on the roots of infected plants. Crop rotation helps to reduce the numbers of nematodes in the soil. Rotation is not the best means of control because of the wide variety of plants that can be attacked. Soil fumigation, although costly, is the best control method.

In some years mint plants in irrigated fields die a few days after rain has fallen due to 'salts'. This happens when irrigation water concentrates salts at the top of a mint bed. Rains move the salts back down in the ground and the heavy salt concentration kills the mint plants. It is therefore important that proper irrigation methods be used to lessen the chance of salt injury.

3.2.2 Washington Peppermint Oil

Peppermint is well suited to the soil and climatic conditions of central Washington. As a result the state is the national leader in levels of peppermint oil yields. The five year state average to 1970 was about

76 pounds per acre. First year yields of oil are generally ten to twenty pounds lower than yields from second and third year fields (known as 'stands'). One harvest per season is the most common practice but occasionally it is possible to harvest twice a year. The price of peppermint oil can fluctuate widely during a marketing season and from season to season. Prices until 1973 commonly ranged from about $3.50 per lb to over $5.00 per lb. Factors affecting oil prices are both the foreign and domestic demand and supply for oil, and the quality of each lot of oil. Oils low in weed oil and menthofuran and high in menthone generally sell for a higher price per pound. Maturity of peppermint at time of harvest is an important factor in determining mint oil quality.

Central Washington peppermint stands are commonly ploughed out after the fifth year. Nematodes, Verticilium wilt and frost damage reduce the quantity of oil from older stands. Heavy infestations of weeds reduce the oil's quality as well as providing plant competition. A grain or cereal crop is usually grown for one or two years after mint. Then a row crop, such as potatoes or sugar beets, is produced. A common practice is to rotate about one fifth of the acreage each year to maintain a continuous acreage of high productive mint.

3.2.3 Costs

A study made by Doran and Forster in 1969[2] determines the cost of establishing a peppermint stand in the Columbia Basin. It also determines the production costs for an established stand of peppermint. The data used in the study were compiled from information obtained from a selected group of Columbia Basin peppermint growers. The assembled data were reviewed by that committee, other growers, county agents, lenders and others familiar with peppermint production in the Basin area. It is helpful to examine in some detail the costs of establishing a mint stand since then we can isolate those most susceptible to outside influences. The following pages are best read with one eye on the tabulated data on pages 78-80.

3.2.3.1 First-year returns

The statewide average seasonal price for peppermint oil ranged from $2.65 to $5.95 per pound during the twenty years to 1969. It ranged from $4.40 to $4.65 per pound of oil for the years from 1965. Columbia Basin prices were near the average for the state. The growers' committee considered $4.50 per pound to be a reasonable price for the area. With good root stock and good management, first-year peppermint yields will range from sixty to eighty pounds of oil per acre. This is about ten to twenty pounds less than second and third year yields. Therefore, a yield of seventy pounds of oil per acre was considered typical for the establishment year.

3.2.3.2 Planting and growing expenses

For their study Doran and Forster considered the net establishment cost to be the amount remaining after the value of the first year crop was subtracted from the sum of the cash and non-cash costs for all preparation, planting, growing and harvest operations. Establishment costs do not include charges for storing or marketing the mint oil.

The farm studied had two hundred acres under peppermint. A farmer with this amount of peppermint would usually harvest and distil his own crop. However, due to the wide range in types of harvest equipment, and age and size of distilleries, the committee decided to charge harvest and distilling at current custom rates. The study was made on the cost of establishing forty acres of mint and cultivating the remaining acreage. It was considered best therefore to charge the planting operations on a custom basis. The study did not estimate the size of operation a farmer needs to justify hiring help and owning the equipment used for these operations.

Preparation consists of fertilising, ploughing, discing (an operation similar to harrowing), packing and ditch repair. Costs were estimated to be $38.65 per acre. The charges for buying, hauling and planting mint roots (stolons) were $99.72 per acre.

Weed control is a critical and expensive factor in producing high quality mint oil, particularly during the first year. Normal weed control practices include numerous trips across the field with a rotary hoe and a tine harrow. This is followed by hand weeding and pasturing by geese or sheep. Expected first year costs for rotary hoe, tine harrow and corrugating operations were $39.48 per acre. Hand weeding was estimated at $15.00 per acre. Costs for buying and feeding geese and maintaining a fence were $6.58 per acre. Thus the direct costs for weed control during the first year totalled $61.06 per acre. This amount does not include the annual non-cash interest and depreciation charges for the equipment and geese fence.

Pests common to peppermint in central Washington include Verticillum wilt, nematodes, aphids, mites, cutworms and loopers. Thus, a strict crop rotation and chemical control programme is necessary. From one to four chemical applications are made each year to control insects in established mint stands. Treatments include both ground and aerial chemical applications. Normal insect control for the first year was determined to consist of one ground application and one aerial treatment, at a cost of $21.02 per acre.

Fertiliser needs depend on the soil type, previous crops, and the farmer's irrigation management; the latter is most important. Phosphorous and potassium application rates are best determined by soil tests. An application of zinc during the first year is common for mint in the Columbia Basin particularly when following sugar beets. Nitrogen is usually applied three times during the year: before planting as a broadcast application; in the early summer as a sidedress application; and applied in the irrigation water in late summer. Total fertiliser costs were $52.25 per acre for the establishment year.

Labour charges were separated into operator's labour and hired labour. Operator's labour was entered as a non-cash expense whilst hired labour was a cash expense.

Harvest and autumn operations were charged at the 1968 custom rate of 85 cents per pound of oil. Mint slugs, that is the residue left after oil is extracted, are used for cattle feed, for bedding, or spread back on the fields. The method of disposing of mint slugs has considerable influence on the cost.

3.2.3.3 Cash overhead

A charge of five per cent of the cash costs was included as general overhead to cover such expenses as office, utilities, social security, insurance, assessments, travel etc. No charge was made for rent, but a charge was made for real estate (R.E.) and personal property (P.P.) taxes, and for interest on land.

The financial situation of the operator determines whether operating capital is a cash or non-cash expense. It is a cash expense when he borrows the money; it is a non-cash opportunity cost if he uses his own money to pay operating expenses.

The non-cash costs for the first year include charges for the operator's labour and investment overhead. Investment overhead consists of depreciation of needed equipment and buildings, and interest on investment in equipment, buildings and land. Again, charges for operator's labour are shown as a non-cash cost but hired labour as a cash cost.

Table 3.2.3.1 ESTIMATED PER ACRE COST OF ESTABLISHING PEPPERMINT COLUMBIA BASIN. WASHINGTON (1968)

	TOTAL HOURS PER ANNUM	LABOUR	MACHINERY FUEL AND REPAIRS	MATERIAL AND OTHER	TOTAL
RETURNS 70 lbs oil @ $4.50		$	$	$	$315.00
COSTS					
Pre-plant and Plant					
Fertiliser - broad-cast				2.00	2.00
100N, 60P, 50K, 10Zn				27.50	27.50
Plough	.75	1.31	2.29		3.60
Disc, pack, x2	.75	1.31	3.15		4.46
Corrugate - mark furrows	.5	.88	1.48		2.36
Planting - roots				33.00	33.00
- dig and haul roots				40.00	40.00
- hand planting				22.00	22.00
Corrugate, pack - cover plants	.5	.88	1.48		2.36
Ditch repair, cleanup	.1	.18	.16	.75	1.09
Growing					
Rotary hoe, x 4	2.5	4.38	6.50		10.88
Tine harrow, x 10	4.0	7.00	12.20		19.20
Corrugate, x 4	2.0	3.50	5.90		9.40
Irrigate, x 18	8.5	15.00			15.00
Fertiliser - side-dress				2.75	2.75
150N @ 10 c				15.00	15.00

Cont.

COSTS (cont)

Insect control - ground	.33	.58	1.04		1.62
- chemicals				8.00	8.00
- aerial				3.40	3.40
- chemicals				8.00	8.00
Weed control - geese (3 @ 2.00)				5.40	5.40
- fence repair, steralise fence rows				1.00	1.00
- geese feed				.18	.18
- hand weeding				15.00	15.00
Nitrogate, 50N @ 10c				5.00	5.00
Harvest and autumn Operations					
Harvest (70lbs @ $.85)				59.50	59.50
Spread Mint Slug (1.0 slug @ $3.50)				3.50	3.50
Cash overhead					
Taxes, R.E. & P.P.				10.00	10.00
Rent					
Water				12.00	12.00
General overhead (5% of cash costs)				17.00	17.00
Interest on Oper. Capital (6 mo. @ 7½%)				13.00	13.00
TOTAL CASH COSTS PER ACRE	32.50	34.20		303.98	370.68
Operator's Labour	2,52				2.52
Investment Overhead					
Depreciation				11.37	11.37
Interest on Investment				40.83	40.83
TOTAL NON-CASH COSTS PER ACRE	2.52			52.20	54.72

Cont.

COSTS (cont)

TOTAL COSTS PER ACRE	35.02	34.20	356.18	425.40
NET PER ACRE COST OF ESTABLISHING PEPPERMINT				110.40

The costs have been examined in full here because it is intended to establish an important point to be referred to later in this work, when discussing fluctuations in the price of peppermint oil. The costs under the heading Machinery, Fuel and Repairs amount to about eight per cent of the total costs per acre. Thus if fuel were the major item of these three and the cost of fuel trebled, then the cost of producing the oil would increase by only about one seventh or fifteen per cent. In later years when the mint is established, fewer tractor operations are necessary; consequently less fuel is used. It is recognised that oil costs will, after a lapse of time, also raise the other cost components. The effect will still be small in relation to the price rises considered.

3.2.4 Production and Yields

Cultural methods are important in determining yields because, if the mint plants are too thickly planted, yields will be lowered. Yields also will be low when there is cloudy, wet weather just before the harvest as this prevents the plant from properly developing its oil.

Mint oil is removed from the plant by passing steam through the partially-dried hay to vaporise the oil. The vapour is then condensed and the oil floats to the surface where it is separated from the water. A second distillation may be made if necessary to improve quality. The oil may be stored in a cool place for periods up to a year if free of water and packed in clean, air tight containers.

Production of peppermint oil has risen rapidly in the U.S. More irrigated land is becoming available where mint can be grown. In addition, wilt disease is becoming less important in mint production. U.S. peppermint oil average annual output almost doubled from a total of 2½ million pounds weight between 1957 and 1961 to 4½ million pounds in 1967 to 1971 period. The following table, 3.2.4.1 shows the yield per acre and the price per pound for the years indicated in both Washington

State and the United States of America. Also included are average inches of rainfall for the six months from October and average temperature for the three months from July each year. It is widely held that these are the critical periods.

Table 3.2.4.1 **A comparison of average prices and yields in Washington State with the remainder of the USA and with the rain- and temperature in the State for certain periods**

YEAR	1971	1972	1973	1974	1975
Yield, lbs/acre					
Washington	70	60	55	66	82
USA	58	53	54	54	60
Price, $/lb					
Washington	3.85	5.40	8.80	13.80	10.30
USA	4.10	5.25	6.99	12.70	12.40
Rainfall	Average total inches (Oct-Mar) = 306				
Inches	272	232	160	448	323
Temperature	Average temperature (Jul-Sep) = 15.6				
°C	15.4	15.1	16.0	15.5	14.4

The amount of snow that falls on the Cascade Mountains will determine the amount of water available in the Spring and Summer to feed the Yakima river. As the majority of districts in the Yakima valley take this river as the source of their irrigation the rainfall is important. In the winter of 1976 there was an exceptionally low rainfall in the area during these six months. The result has been strict rationing of water to the various irrigation systems. The temperature during the period from July through to September is also important when looking for quality and yields.

Thus rainfall and sunshine are both factors that affect the yield of oil. The farmer, depending on his financial position, is not obliged to sell his oil directly the harvest is complete. Peppermint oil, after distillation, will keep for a considerable length of time in the right conditions. The farmer, unless he has contracted to sell his crop for a fixed price regardless of yield, is able to await the price most favourable to him to sell his stock. This is the first point where stocks of peppermint may accumulate. It is necessary to leave the farmer here after mentioning only a few of his annual worries. On his shoulders rests the burden of producing the peppermint oil. Sometimes his labour is suitable rewarded, but far too often he is outmanoevoured by the more acute dealing fraternity.

3.3 The Dealer

The middleman in a business deal is the traditional villain of the piece. Consider the following trivial case. One person asks a second to buy a packet of biscuits and bring it back from the village shops. The second, on arrival in the village, is faced with a choice of seven shops that sell biscuits. At the second and fourth the brand is located, at the fifth purchased. On entering the seventh the brand is again noticed. The prices were as follows where the symbol + indicates no stock.

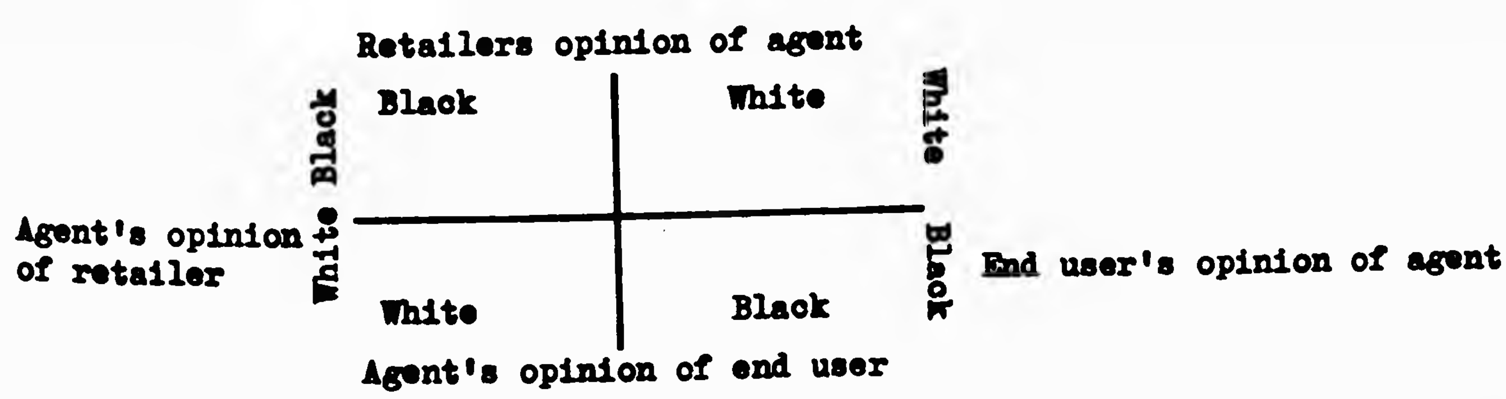
Table 3.3.1 Price of Biscuits

Shop	1	2	3	4	5	6	7
Price p. (per 7 oz.)	+	16	+	15½	14	+	15

The packet in shop five bore the legend '1½p. off'. It is assumed, in order to simplify the discussion, that shops two and seven did not like dealing in half pence. Shop number four sells its bisucits at the recommended retail price. The biscuit manufacturers had, a few weeks earlier, discovered in their storerooms ten boxfulls of the brand unopened and left over on account of a cancelled order. Under the suspicion that the biscuits may be deteriorating the lot is quickly distributed on 'special offer' with the price reduction printed on the packet. The scene is set, radiating innocence, when our purchaser buys the biscuits.

The dealer is this person who, having purchased the biscuits, takes them as an agent to the end user. This eater of the biscuits will round on the agent when the softness of the once crisp biscuit is discovered. The agent in his turn will look to the retailer for redress, only to meet with resistance from that quarter. There now arise within the agent two new sets of opinions engendered by the reaction of seller and end user. In turn they blame the retailer for selling soft biscuits and the end user for accepting the biscuits in the first instance. The middleman is now the holder of four sets of opinions which oscillate in their shade between black and white. The truly successful middleman can, at will, consider each opinion realising its two-fold nature whilst simultaneously manifesting its opposite and remaining aware of the other two quarters. A diagram here will serve to clarify the meaning.

FIG 3.3.1 <u>Illustration of shades in an agent's relationship with his customers</u>



Put in another way, the agent is very sensitive to the reactions of those he deals with and is aware that their opinion of him can oscillate between light and dark. He tones his own opinion of the one he is dealing with to meet the need of the other and keep in his favour.

The dealer in peppermint oil is doing what the agent in our simple example was doing. The dealer has many sources and many outlets, but each deal can be reduced to the simple situation when a bargain is struck. As outlined here, the dealer's position is unenviable; to bear the burden of conflicting opinions without taking one side or another. It is little wonder that the dealer is so much criticised.

The peppermint oil trader also deals in other commodities, but the true specialist in acting as a middleman is the broker. The dealers in this story are those who purchase oil from the farmer. The broker purchases from the dealer or; as in some cases, is a ramification of the dealer acting in a different guise. For the sake of brevity, I shall simply describe the dealer's actions. The customer is said to demand a consistent flavour in the mint trade. Consequently the importer in Great Britain will demand a sample of the oil he is expected to buy.

In order to maintain a constant supply of oil with consistent quality the dealer has apparatus with which to treat his oil. Each farmer produces an oil with a different chemical make up. The oil is <u>rectified</u>, to remove certain constituents, <u>distilled</u> to remove water content and <u>blended</u> with other batches of oil in order to maintain consistent quality.

It is normal practice for the dealer to test each drum of oil supplied by the farmer. A typical description of a Yakima oil is one with contents as follows:-

Table 3.3.2 Components of Peppermint Oil

COMPONENT	PER CENTUM	IMPORTANCE
Total Menthol	52.5	Taste
Menthylesters	8.5	Smoothness
Menthone	19.9	Bitterness
Menthofuran	8.6	Aroma Improved by Removal

The Yakima oil is said to have a clean flavour characteristic. The high menthol content in the oil is described as giving a cool taste. The more menthylesters contained in an oil the smoother it is, whilst it is desirable to have a low menthone content to lessen the risk of a harsh and bitter taste. It is considered an improvement to remove the menthofuran from the oil in order to improve the aroma. This is normally achieved by rectification after the oil leaves the farm.

Oils are classified usually by quality when received by the dealer from the farmer. The highest quality oils are usually set aside for the US chewing gum trade which prefers oil in its natural form. The other oils are usually blended. As a guide to export practices generally, Washington oil is used for the export market because of its unique quality. The quality is governed by the ratios of the constituents present in the oil as described above. Sometimes, however, oils from other areas are blended with Washington oil. Some of the blends are first redistilled or rectified, depending on customers' specifications. The tail fractions and sometimes even the middle fractions are removed by a fractioning column in the dealer's processing plant. The shrinkage can be as high as thirty per cent, resulting in a considerable disparity in prices quoted by the trade. Thus when comparing peppermint oil prices one must bear in mind these factors for further clarity.

3.3.1 The Dealer and the Farmer

It was mentioned earlier that some farmers contract to sell their oil at a given price to a dealer at the start of the growing season. The farmer bases his price on previous year's prices and on his expected costs in the forthcoming crop together with his expected yields. When the crop is harvested the dealer collects the stipulated quantity of oil and pays the agreed price. The farmer may lose, break even or profit on the arrangement. He will profit if his yield is higher than he expected or if his costs are lower than forecast. He will break even if his costs cover his receipts and no more. He will lose should his yield fall below his expectations or his costs be higher than forecast. The farmer can also lose in another sense if the price that he has fixed with the dealer turns out, at the end of the season, to be lower than that received by his less prudent colleagues who sell their oil only after the season's yield has been established. In the same way the farmer can gain over the others when the season's price is lower than his contract price.

The method of contract here described helps the farmer to face his task with a certain degree of financial confidence and security. It is however at a price because he has, until recently, only had four dealers whom he can approach with his product. In the last five years the farmers of the Yakima Valley have become resentful about the manner in which they are contained by this ring of dealers. The farmer sees the prices charged by the dealers in world markets and compares them with the price he has received.

In 1972 the farmers received an average $5.40 per lb. The dealers sold oil in 1973 for an average of $6.82. The dealers' mark-up was thus $1.42 per lb in 1973. The following table shows his mark-up in the years 1971-1975.

Table 3.3.3 <u>The difference between dealers selling and buying prices</u>

YEAR	1	2	3	4	5
MARK-UP $/lb	0.85	1.67	1.42	1.20	-1.14

In his negotiations for the 1973 crop the farmer was well aware of the high price that the dealers were obtaining in the world market. They thus determined to recoup some of the money which they considered had passed unfairly into the dealer's pockets. They obtained a price of $9.80 compared with the 1972 price of $5.40, a great increase. Notwithstanding, the dealers still managed to obtain $11.00 in the open market. Law suits under the anti-trust laws were threatened by certain farmers against certain dealers and the largest US industrial users of the oil. The result in 1974 was that the farmers received $12.90 for their crop whilst the average selling price obtained by the dealer was only $11.76.

At first reading, therefore, it seems that the farmer has succeeded in his struggle against the ring of dealers to whom he sells his crops. It is not possible to be sure of this, however, because, unless the dealers were to reveal it, we can never know how much stock the dealer manages to carry over from one year to the next. I have considered this aspect a little further later in this work. The purpose of this passage has been to demonstrate the relationship between dealer and farmer, which is not always amicable.

One might ask why the farmer does not deal direct with the foreign importer rather than use a middleman. Until 1975 direct sales from the farmer to European buyers accounted for only 2% of the quantity of oil purchased in Europe. Since 1973-74 many more farmers have been considering such arrangements and it may not be too long before a farmers' cooperative is seen marketing their produce. It is certainly the case that one UK buyer has set up his own purchasing organisation in the United States, evidently to avoid the monopoly power of the dealers. The dealers in the USA do hold an unusual amount of power over both farmer and buyer. The dealer can use his financial power, in the form of stockholdings, to force down the farmer's asking price while he can also use his monopoly position to force up the price to the buyer. Given this state of affairs it has hardly been surprising that those dealers with whom I have been in contact are most secretive about their business and most uncooperative in answering questions even of the most innocent nature.

Whilst in the US I also heard mention of the subject most vital to the Yakima Valley farmer's chances of success. That subject is water. Without irrigation the Yakima Valley project for turning a semi-desert into fertile farm land is helpless. In years of water shortage, such as 1976-1977, rationing is imposed by the water authorities. Allocations of water are made to the various sectors of the Valley on the basis of earliest settled, best served. It must be recognised however that allocations are arbitrarily determined without procedure for appeal and as a consequence of such allocations an individual or group of farmers could have their yields adversely affected. The allocation is controlled by the authorities who are, ultimately, at the mercy of the politicians who allocate cash for the irrigation project. It was suggested to me that a farmer who protested too loudly about the dealing ring might possibly find in future situations of drought that he might be 'unlucky' in his water allocation. I have no verification of this ever having arisen but it is conceivable that, where vast amounts of money are concerned and where politics and big business interests merge and entwine, the possibility is enough to frighten all but the hardiest individuals into silent concurrence with the status quo.

In concluding this section it is helpful to have an idea of the weight of oil exported to Great Britain each year. It is also interesting to note the disparity between the price offered by one large New York company of brokers and the average price paid by Great Britain's importers. The imports to this country account for between one quarter and one fifth of US exports.

FIG 3.3.4 <u>Imports to UK of peppermint oil together with average price paid and a broker's quoted price</u>

YEAR	1971	1972	1973	1974	1975
Imports (lbs)	520,531	505,096	561,286	389,180	247,513
Av. price $/lb.	4.65	5.52	6.82	11.00	11.76
Brokers price $/lb.	4.33	5.67	8.16	17.17	12.95

3.4 The manufacturer

Blended peppermint oil is imported into this country by companies of importer/blenders: these are the manufacturers. The oil is imported in drums containing forty-five gallons weighing about one hundred and eighty kilograms. We consumers are said to demand a certain characteristic flavour in the products containing mint that we purchase. This means that each buyer will ask for his own flavour to be repeated with each order, provided that the price has not increased excessively. In cases where the price is too high the buyer states the amount he is prepared to pay and the manufacturer blends to meet that demand. The oil might be blended with the much less expensive cornmint from the plant mentha arvensis and diluted with other compounds. The intricacies of the blender's art are for the initiated and are closely guarded secrets. The business depends partly on keeping the formula secret but also on the skill involved in the still rooms. It is due to the skills employed here that the manufacturer succeeds in producing to a price blended oil for the chewing gum, toothpaste and sweet manufacturers.

Stocks in the premises rise and fall according to the prevailing mood of the market. Our manufacturers only hold small stocks of finished goods for their customers as they produce to order. Work-in-progress stocks amount to little more than 1% of raw material stocks. The raw material stocks are approximately fifty per cent for manufacturing needs and fifty per cent for further trading purposes. The problem of controlling the stocks required for manufacturing in this sort of business under conditions of price stability and steady lending rates has been solved in theory. The solution is simply an application of the economic order quantity formula together with constant progress chasing of orders. The situation is easier for the business that has ready at hand reserves of stock which, although being stocked for another reason, can be called upon in emergency. The stock control problem that is of particular interest to us is how to control this stock held on a means that each buyer will ask for his own flavour to be repeated with each order, provided that the price has not increased excessively. In cases where the price is too high the buyer states the amount he is prepared to pay and the manufacturer blends to meet that demand. The oil might be blended with the much less expensive cornmint from the plant mentha arvensis and diluted with other compounds. The intricacies of the blender's art are for the initiated and are closely guarded secrets. The business depends partly on keeping the formula secret but also on the skill involved in the still rooms. It is due to the skills employed here that the manufacturer succeeds in producing to a price blended oil for the chewing gum, toothpaste and sweet manufacturers.

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3.5 The Consumer

The buyers of mint flavouring together with the wholesaler, retailers and ourselves are the consumers. The British Isles has shown a steady growing demand for peppermint oil over the last ten years with a particularly high figure in 1973 when fears of a shortage caused heavy buying compensated in the following years by a decline. More lower priced

Table 3.5.1 UK imports of peppermint oil 1966-1975 by weight

YEAR	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Weight 000's lbs	339	328	512	440	305	521	505	561	389	248

Brazilian oil was imported in the latter years which indicates either a shift in taste or a search for substitutes in a period of exceptionally high prices. The oil is used, as in most countries, for flavouring toothpaste and chewing gum but about fourteen per cent of oil is used in confectionary, food products and pharmaceuticals. Patty[3] gave an estimate of the price elasticity of demand for peppermint oil imported to Great Britain at near minus one. This means that if the price of oil drops one per cent, an increase of one per cent in the amount imported could be expected. This may have been true in 1970 but the last five years have changed the situation so that Patty's estimate no longer holds. No remarks need to be made on the futility of such an exercise in the light of the first chapter of this work. Demand from the consumer is reasonably constant being derived and tends to move in parallel to changes in the population. Demand is derived because people can only use a certain amount of toothpaste hence the demand is related to population changes. The import figures for the oil do not reflect demand in fact but rather some other factors such as price which will soon become apparent in the next chapter.

3.6 Summary

This chapter has been a simple description of the means by which the peppermint flavour in products we buy reaches the UK from the mint stands in Washington State. The most pertinent problems that face the farmer each year have been described. The costs involved in establishing a field of mint have been closely examined partly to further our general knowledge of the subject but mainly to establish one point. The fuel costs involved in establishing a first year growth of mint are higher than in the subsequent four years. In a situation where the price of fuel oil is trebled the cost of producing a first year stand of mint will be only increased by one seventh, other factors being equal. The 1973 and 1974 prices received by the farmer represent increases of 85% and 30% respectively. Even allowing for fertiliser price increases these leaps can in no way be attributed directly to the fuel oil price increase. The function of the dealer in ensuring a steady supply of even quality oil to this country's importers has been outlined. The manner in which the oil is then treated in this country before it reaches the consumer has been described pointing out the importance of the blending process in manufacturing to a given price. The demand exercised by the customer does not fluctuate violently and has little effect on the price of peppermint oil in its early forms.

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CHAPTER III

References

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CHAPTER IV

PROBLEMS OF FORECASTING PRICE: THE LIMITS OF RATIONALITY.

4.1 Introduction

In any discussion about the problems of forecasting price we are, whatever method is under examination, limited by our dependence on an incomplete understanding of the underlying processes, by our restriction to information about past occurrences and by the intrusion of 'shocks' which are unanticipated as part of any orderly process or continuation of past trends. These inadequacies in both information and understanding make the partial failure, at best, of any causally based forecasting approach inevitable. In our attempts to capture the skill of the price forecaster in mathematical models we can only succeed in describing the quantifiable factors used by the forecaster in making his predictions. In so doing we acknowledge that the intuitive side of forecasting is beyond the scope of modelling except in so far as the operator of the model is permitted to influence the model's result. This might be done in a model which produces intermediate results which are used as data for a later stage in the model. The operator might amend the intermediate results in accordance with his intuitive feel for the future. However it is evident that such an interaction with a model rather defeats the object of the exercise because it is being steered toward giving a solution already decided upon by the operator. While using models for prediction purposes the user should always bear in mind the limitation that his solution will be necessarily imperfect.

In this chapter I shall examine two types of model and a third which combines elements of the first two. The first, chosen partly because it is widely available in most computer libraries but also because it should be capable of reflecting true causative factors, is an equation obtained by multiple regression analysis on those factors thought to have the greatest influence on the price of peppermint oil. The second using an exponential smoothing method predicts prices on the basis of past history. It was chosen for the ease in supplying data. The first type is open to the criticism that the factors signif-icantly affecting price are not always the same from period to period. Further when the factors are the same the weight of influence from each factor can be changing. It was because of these shortcomings that the second type of model was examined where only the previous prices are considered. This type has the virtue of combining all the factors that influence price into one factor namely price itself. The future prices are then predicted from past prices. This type of model has a particular difficulty in predicting when a trend in price movements will change direction. This difficulty is one which can only be overcome if such changes in direction are correlated to factors other than price. This means returning to a model of the first sort with the hope of finding an indicator in the form of some factor other than price that leads price changes and to which price changes are firmly linked. In the case of peppermint oil it was possible to isolate one such factor for the period under considerat-ion in the form of an index of industrial production but its reliab-ility as an indicator turned out to be dubious as will be seen. The third model examined was developed using Box and Jenkin's[1] method.

One explanation of why the price of peppermint oil does not conform to trends in the price of other raw materials is to be found in the role of the dealer in determining price in the market. The changes in the price of peppermint oil sometimes lead the other materials and sometimes lag and sometimes bear no relation at all as from October 1974 to end of 1975 (see fig.4.3.1.2). Before reporting on my trials with the prediction methods mentioned above a further comment on the dealer is necessary.

4.2 Middlemen and Dealers

The traditional functions of the middleman include holding stocks in excess of those which traders closer to the eventual user would wish to carry; buying in advance of consumer's/manufacturer's demand; helping both 'ends' of the trade by providing finance, this last at a price by buying from growers in advance of production, thus providing liquidity, and by extending credit to importers and manufacturers. Other functions of the middleman include providing knowledge of sources of supply and outlets for produce that might not be available to the individual grower or the individual manufacturer and passing information of future needs or of criticisms of products to growers. The middleman will also help the grower with technical advice, where necessary, on the extraction and storage of the oil in the period before collection by the middleman.

The functions listed put the middleman in a position of great power. Where he extends credit to importers and manufacturers he has the opportunity to dictate trading terms. Similarly where he is the major source of funds for the grower he can impose terms otherwise the grower may find that he is illiquid. Again, because he must anticipate future demand and is a powerful buyer, he finds quite natural a speculative role; buying cheap, holding stocks and selling dear at a propitious time. Moreover, standing as he does at the 'information crossroads' of the trade, both sides of the market depend on him either to find outlets or to find customers. As has been already pointed out none of this makes him greatly loved.

In addition to the functions mentioned earlier, the middleman has other economic functions. As a buyer in bulk, both in anticipation of demand and as a speculator, his actions tend to regulate and stabilise market fluctuations since he will tend to buy when prices are low and quantities supplied are large. The quantity supplied is the quantity actually available on the market. Some larger growers of peppermint or groups of growers are able to afford to store their own surplus production and hold it off the market until prices improve. There will be an incentive to do this if expected gain (expected change in price x quantity offered in future period) exceeds the cost of holding which inter alia includes storage charges, insurance and loss of potential interest on proceeds of an immediate sale.

To some extent then the dealer is in danger of losing part of his function to the grower if the technical conditions are right, that is if storage is feasible and knowledge of preparation and storage processes is available, and if the dealers press the growers too hard.

Another function mentioned above is concerned with information and knowledge. The dealer has knowledge of sources of supply. The user or the home importer would have both to find and contract with growers in order to trade without the middleman. Finding growers that offer just the product required and discovering by bargaining, trial and error the best contract that could be negotiated would take time, money and possibly the employment of specialist staff. Similarly for the grower to find outlets for his product would require time and money. The dealer's specialist knowledge saves both sides of the market the time and resources which would otherwise be devoted to 'market search'.

In the orthodox market analysis the familiar demand and supply schedules are specified. In these 'supply' denotes quantities that would actually be offered on the markets at each price over the range whilst 'demand' denotes quantities that would actually be bought, and paid for, at each price over the range and the quantities relate to a specific time period. The intersection of the curves gives an equilibrium point to which prices and quantities would tend. However the elementary textbooks say (1) little or nothing about how the equilibrium (price and quantity) point is reached and (2) nothing about what happens if some people transact at non-equilibrium prices. In the second case the income of such people would be affected leaving them either better or worse off and so able, or obliged, to modify their buying or selling plans. One way of looking at the problem of how equilibrium is reached is to see the process as one of searching for the lowest price on the buyer's side or for the best price, or best price-quality mix, on the seller's side. Normally search continues until the expected gain is no greater than the marginal cost of search.[2]

The dealer's or middleman's activities stand in place of search by growers and importers or manufacturers. Whether the middleman's activities are seen by the rest of the trade as benign or not depends on how well he discharges the function and whether or not the reduction in profit by the rest of the trade (or the middleman's gain) is small compared with their own search costs. As has been described in some detail in the previous chapter not only price and quantity, but also quality are involved. The dealer's information and search, in the essential oil trade in particular, must extend to required qualities as their livelihood depends on the exactness of such knowledge. Failure here will also bring middlemen into disrepute.

The middleman's search function endows him with, to some extent, control over the market information flows. His physical possession of, or title to, stocks enables him to some extent to regulate supply. Also to some extent his buying power may enable him to represent himself to suppliers as regulating demand and if he can establish himself as monopsonist (in combination with other dealers) he will be able to enforce his claim at that level of the market. It has already been pointed out in an earlier chapter that until very recently this was the state of affairs in the United States peppermint market.

The traditional market analysis of the economist deals with plans and intentions; its schedules (demand and supply curves when they are represented graphically) are conditional whilst intentions to buy or sell are conditional on acceptable prices being asked or offered. Intentions and plans depend upon information. With the dealers to some extent controlling the market information flows and regulating, at some levels, the release of supplies or the take-up of supplies, the role of market forces in establishing an equilibrium can be frustrated. With the dealer, too, standing in place of the important market-search process, the movement towards equilibrium may, on occasion, be frustrated.

We might speak of the dealer's exploitation of his position as establishing a 'false equilibrium'. In any event we are able to see an unpredictable hand at work in the forces that govern the price of peppermint oil.

4.3 <u>The Prediction Methods Tested</u>

Three methods were tested to predict the price of peppermint oil. The first was based on multiple regression analysis and chosen for its general availability in most computer libraries. The second, chosen for its simple data requirements, is Brown's[3] exponential smoothing method. A more general class of models due to Box and Jenkins[1] is also considered and trials made.

4.3.1 Multiple Regression Analysis

It was decided to try correlating the price of peppermint oil with a number of a priori relevant and, at the same time, easily obtained statistics. The aim was to develop an equation of the following form and to evaluate the coefficients:-

$$Y(t) = b_1X_1(t) + b_2X_2(t) + \dots\dots\dots\dots + b_nX_n(t)$$

where b_1, b_2, ... b_n are regression coefficients and $X_1(t)$, $X_2(t)$, ... $X_n(t)$ are the independent variables in month t and Y(t) is the dependent variable (price) in month t. Eventually six factors were chosen. They were

1. Bank of England Minimum Lending Rate (MLR)
2. Financial Times Actuaries Index (FTA)
3. The OECD index of industrial production
4. Index of price of industrial raw materials
5. Yakima valley rainfall inches
6. Yakima valley sunshine hours.

The first two variables relate to financial influences. The MLR acts as a representative interest rate and is therefore indicative of the cost of acquiring and holding stocks of commodities, including peppermint oil. The FTA index gives an indication of the price of alternative, financial, assets. A high FTA would indicate a selling point for shares, but a low and rising FTA might indicate buying time for shares and so possibly an attractive alternative to purchasing commodities. The OECD index of industrial production would stand as a surrogate for the level of industrial activity (and perhaps of economic activity) and so might have some influence on demand for commodities. The price of raw materials would stand for commodity prices generally and might have various effects:-

(a) speculators might switch from one commodity to another e.g. if peppermint oil rises more quickly and in advance of other commodities it 'peaks' first and so the speculator sells peppermint and buys something else which is still rising,

(b) generally high commodity prices might induce switch to alternatives.

The last two factors were discarded at an early stage because they have no direct effect on price. These factors do play an important part in determining yields as has been described in the last chapter, but their importance is limited to certain times of the year; consequently they are of little value in the regression equation. Indirectly they can have a great effect on price because a low yield one year will usually be followed by higher prices although this effect can be modified by carrying over stocks from one season to the next.

A single equation model was used rather than a simultaneous equation model intended to represent the demand and supply sides of the market process for two reasons. First the activities of dealers blunts the effects of the supply variations and, it has been pointed out, variables 5 and 6 are in any case of limited significance. The second reason is that price forecasting is distinct from market analysis. All we are trying to do is to predict prices. The 'structural equations' which give the estimates of the coefficients for the supply and demand functions are of limited interest in this respect.

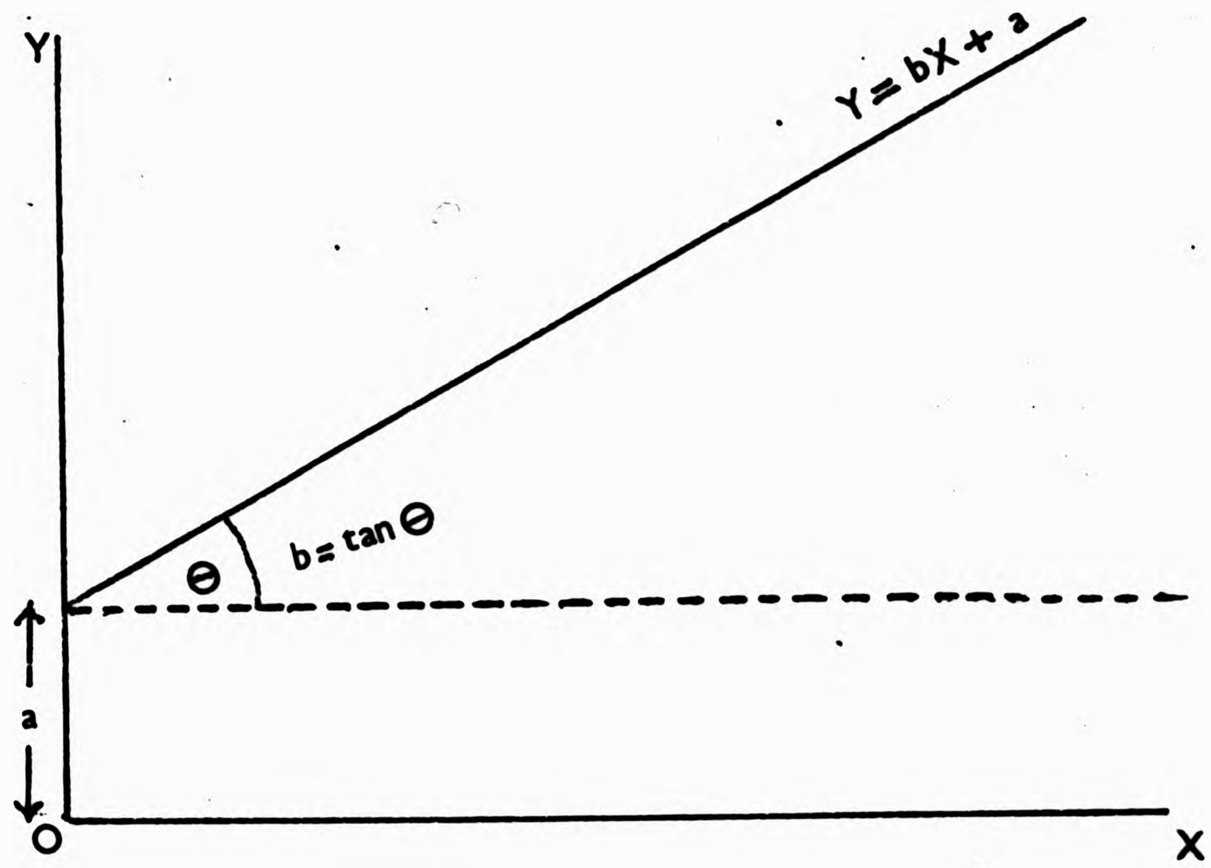

Figure 4.3.1.1

The remaining four factors were then correlated with the price over the five years, 1971-1975. A computer program was written to perform the task incorporating standard library programs for multiple regression analysis. While the techniques of linear regression are very well known, it is felt that a brief review of the method and the way in which it has been adapted in the solution of the present problem would not be out of place at this point. The computing approach followed can then be seen in perspective. For a more full description the reader is referred to Cooley and Lohnes[4] for practical computing aid and Ostle[5] for details of the theory.

The equation of a straight line in terms of its slope and intercept is

$Y=bX + a$ where b is the slope and a is the intercept of the line with the Y-axis. This is shown graphically in fig. 4.3.1.1. The equation involves coefficients specifying the location and direction of the line but no powers of X other than the first. Now the set of possible linear relations between X and Y is a small and manageable subset of the infinite number of other relationships that can exist between X and Y. The simplicity achieved by confining the discussion to linear relationships is the reason why they are often chosen by statisticians. The selection of an alternative to a linear model is never easy. When it is evident that some degree of curvature is present in the data, but no clear choice of a mathematical model (e.g. exponential) is possible, a reasonable approach is to systematically examine polynomials of increasing order.

Simplicity in a linear model can be furthered by translating the given data values into 'deviation' or 'standard' values so that the intercept of the fitted line always lies at the origin. Then the equation only has to specify the direction of the line. If z_{1i} and z_{2i} are the standard values of subject i at times 1 and 2, then the regression equation for predicting z_{2i} from z_{1i} may be written

$\hat{z}_{2i} = r_{12} z_{1i}$ where r_{12} is the slope coefficient, $\hat{z}_{2i}$ is the predicted value and no intercept constant is required. The standard value z_{1i} is calculated from

$z_{1i} = (X_{1i} - \overline{X}_1)/\hat{\sigma}_1$ where $\hat{\sigma}_1$ is the maximum likelihood estimate of the population standard deviation. When there are two or more independent variables the standard value regression equation is extended thus

$$\hat{z}_{mi} = \beta_1 z_{1i} + \beta_2 z_{2i} + \beta_3 z_{3i} + \cdots\cdots\cdots + \beta_{m-1} z_{(m-1)i}$$

in the case of an m-dimensional space. The beta coefficients, also called beta weights, are not simple correlations of each independent variable with the dependent variable; they are also influenced by the intercorrelations between the independent variables. A comparison of the absolute values of the beta weights, for a given set of independent variables, indicates the relative contributions of the corresponding variables to the prediction of the dependent variable. A coefficient of multiple correlation R, which has the range $0 \leq R \leq 1$ can be calculated as described below. The coefficient R^2 is a measure of the over-all effectiveness of the multiple regression being an estimate of the proportion of the total variance in the dependent variable that can be predicted from the known variance in the independent variables.

Once the beta weights have been obtained they are used to calculate the coefficients, b, in the formula for the given data

$$\hat{X}_{mi} = b_1 X_{1i} + b_2 X_{2i} + b_3 X_{3i} + \cdots\cdots\cdots + b_{m-1} X_{(m-1)i} + C$$

where C is an intercept constant involving the means of the m standard values of subject i at times 1 and 2, then the regression equation for predicting z_{2i} from z_{1i} may be written

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where C is an intercept constant involving the means of the m variables as will be shown below. The b coefficients are derived from the corresponding beta weights by scaling each beta weight by the ratio of the standard deviation of the dependent variable to that of the indepent variable. Thus $b_j=(\hat{\sigma}_m/\hat{\sigma}_j)\beta_j$.

The multiple regression model is derived using differential calculus to obtain a solution for the weights in the linear function that minimizes the average squared error of prediction. Thus, if the difference between the actual and predicted value for the i^{th} variable is called the error e_i ($e_i = z_{mi} - \hat{z}_{mi}$), then the purpose of multiple regression is to minimize the function of e

$f(e)=\sum_i (z_{mi} - \hat{z}_{mi})^2/N$ where N is the number of independent variables. Substituting the earlier obtained expression for $\hat{z}_{mi}$ the function becomes

$$f(e)=(1/N)\sum(z_{mi} - (\beta_1 z_{1i} + \beta_2 z_{2i} + \cdots + \beta_{m-1} z_{(m-1)i}))^2.$$

When the partial derivative of f(e) with respect to each β_j is taken we obtain a group of m-1 normal equations in m-1 unknowns. These normal equations have the form

$$\begin{array}{l}
\beta_1 + r_{12}\beta_2 + r_{13}\beta_3 + \cdots\cdots + r_{1(m-1)}\beta_{m-1} = r_{1m} \\
r_{21}\beta_1 + \beta_2 + r_{23}\beta_3 + \cdots + r_{2(m-1)}\beta_{m-1} = r_{2m} \\
r_{31}\beta_1 + r_{32}\beta_2 + \beta_3 + \cdots + r_{3(m-1)}\beta_{m-1} = r_{3m} \\
\vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots \\
r_{(m-1)1}\beta_1 + r_{(m-1)2}\beta_2 + r_{(m-1)3}\beta_3 + \cdots\cdots + \beta_{m-1} = r_{(m-1)m}.
\end{array}$$

On the left of these equations, apart from the unknown beta weights, we have the intercorrelations between the m-1 independent variables whilst on the right is the correlation of each independent variable with the dependent variable. In order to solve this system of simultaneous equations the problem is first translated into matrix notation. An m-square symmetric matrix is then formed from the intercorrelations among the m variables and it is called $\underline{R}$. Matrix $\underline{R}$ is divided into four segments as follows

$$\underline{R} = \begin{bmatrix} r_{11} & r_{12} & r_{13} \cdots\cdots & r_{1(m-1)} & r_{1m} \\ r_{21} & r_{22} & r_{23} \cdots\cdots & r_{2(m-1)} & r_{2m} \\ r_{31} & r_{32} & r_{33} \cdots\cdots & r_{3(m-1)} & r_{3m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{(m-1)1} & r_{(m-1)2} & r_{(m-1)3} \cdots & r_{(m-1)(m-1)} & r_{(m-1)m} \\ \hline r_{m1} & r_{m2} & r_{m3} \cdots\cdots & r_{m(m-1)} & r_{mm} \end{bmatrix} = \begin{bmatrix} \underline{R}_{11} & \underline{R}_{12} \\ \underline{R}_{21} & \underline{R}_{22} \end{bmatrix}$$

$\underline{R}_{11}$ is the matrix of intercorrelations of the independent variables. $\underline{R}_{12}=\underline{R}'_{21}$ is the column vector of the correlations of the dependent variable with each of the independent variables and $\underline{R}_{22}$ is the scalar 1. The required vector of beta weights β is computed from the relationship

$\beta = \underline{R}_{21} \cdot \underline{R}_{11}^{-1}$ where $\underline{R}_{11}^{-1}$ is the inverse of the matrix $\underline{R}_{11}$ which is computed in the subroutine MINV. The coefficients b are obtained by computing

$\underline{b} = \underline{A} \cdot \beta$ where $\underline{A}$ is a diagonal matrix of order m-1. The standard deviation of the dependent variable is divided by that of the independent variable to form each element of the diagonal

e.g. $a_{11} = \sigma_m / \sigma_1$.

The intercept constant C is computed as

$C = M_m - (\underline{b} \cdot \underline{M})$ where $\underline{M}$ is the m-1 element vector of the independent vector means, and M_m is the mean of the dependent variable. The multiple correlation coefficient R is obtained from the relationship

$$R^2 = \beta \cdot \underline{R}_{12} = \sum_i \beta_i r_{mi}$$

The computer program consists of the main routine named MNTOIL, a special input subroutine named DATA, and four subroutines from the Scientific Subroutine Package: CORRE, ORDER, MINV and MULTR. The purpose of MNTOIL is fourfold

1. To read the problem parameter card for a multiple regression

2. To read subset selection cards used to specify a dependent variable and a set of independent variables

3. To call the subroutines to calculate means, standard deviations, simple and multiple correlation coefficients, T-values and analysis of variance for multiple regression

4. To print the results.

The purpose of CORRE is to compute means, standard deviations, sums of cross-products of deviations and correlation coefficients. It uses subroutine DATA to read an observation (M data values) from the input device (M is the number of variables in an observation). The purpose of ORDER is to segment the matrix **R** into four as described above. The purpose of MINV is to invert a matrix. Many of the results produced by the routines CORRE, ORDER and MINV are used as inputs to the last subroutine MULTR. The purpose of MULTR is to perform the multiple regression analysis for a dependent variable and a set of independent variables as described above. Listings of MULTR and MNTOIL appear in appendix II. The coefficient R^2 is calculated and used as a measure of the goodness of fit of the trial data, shown in table 4.3.1.1, to the dependent variable.

The first run of the program gives a goodness of fit, measured by R^2, of 0.75 and attempts were then made to improve on this in the following manner. The data pertaining to the first factor was moved one month in advance of or behind the price data. If the goodness of fit

YEAR	MONTH	MLR	FT index	OECD indust.[1] prodn. (1970=100)	Price index[1] indust. mat.[1] (1970=100)	£ (1970=100)	Price of gold £/oz.
1971	J	7.0	320.0	101.2	102.2	99	38
	F	7.0	314.0	100.2	103.3	98	39
	M	7.0	326.0	99.1	103.6	98	39
	A	6.0	364.0	100.6	105.1	97	40
	M	6.0	376.0	101.9	104.6	97	41
	J	6.0	398.0	100.3	105.0	96	41
	J	6.0	4[illegible]3.0	100.4	106.6	95	42
	A	6.0	433.0	101.0	105.4	95	44
	S	5.0	435.0	100.5	104.9	94	43
	O	5.0	427.0	100.6	104.5	93	43
	N	5.0	435.0	100.2	104.7	92	44
	D	5.0	450.0	100.3	105.1	91	44
1972	J	5.0	451.0	99.2	105.6	90	47
	F	5.0	471.0	93.1	105.4	89	48
	M	5.0	471.0	101.0	105.9	88	48
	A	5.0	489.0	101.7	106.1	87	50
	M	5.0	475.0	103.1	105.9	86	59
	J	6.0	453.0	103.5	106.2	86	65
	J	6.0	488.0	101.8	107.7	85	68
	A	6.0	490.0	101.4	109.6	84	67
	S	6.0	451.0	103.9	110.7	84	64
	O	7.25	453.0	105.1	112.9	83	64
	N	7.5	481.0	105.7	115.3	82	64
	D	8.0	475.0	106.1	118.7	81	65
1973	J	9.0	455.0	108.6	122.7	81	66
	F	8.75	442.0	110.7	126.0	80	85
	M	8.5	447.0	111.9	129.4	80	90
	A	8.25	453.4	110.0	130.5	80	91
	M	7.75	454.0	109.9	132.4	79	115
	J	7.5	450.0	111.1	137.3	79	123
	J	9.0	433.0	111.5	145.1	78	116
	A	11.5	422.0	111.0	152.4	77	104
	S	11.5	432.0	111.6	153.8	76	100
	O	11.5	434.7	112.7	161.7	76	98
	N	11.25	401.5	110.6	166.0	75	101
	D	13.0	329.9	106.3	175.1	75	112
1974	J	12.75	324.8	101.2	209.5	73	133
	F	12.5	316.5	103.3	213.1	72	163
	M	12.5	297.5	105.9	215.0	71	173
	A	12.25	290.0	107.3	215.4	69	169
	M	12.0	269.6	107.5	214.0	68	157
	J	11.75	267.5	108.6	211.7	67	144
	J	11.75	254.8	109.2	212.3	67	156
	A	11.75	222.9	108.9	213.7	67	156
	S	11.75	203.5	107.2	212.8	66	151
	O	11.5	199.4	105.7	220.1	65	167
	N	11.5	181.0	105.5	223.8	64	184
	D	11.5	160.1	103.0	222.5	63	187

contd.

YEAR	MONTH	MLR	FT INDEX	OECD indust. prodn (1970=100)[1]	Price index indust. mat. (1970=100)[1]	£ (1970=100)	Price of gold £/oz.
1975	J	11.25	183.7	105.5	222.1	61	176
	F	10.75	262.6	105.2	218.8	60	182
	M	10.25	292.6	103.6	221.9	59	177
	A	10.0	314.9	101.5	222.9	57	167
	M	10.0	339.0	99.4	226.2	55	167
	J	10.0	332.6	99.7	227.7	54	166
	J	10.0	304.4	100.6	233.2	53	167
	A	11.0	293.3	98.5	241.4	53	160
	S	11.0	328.9	100.3	243.2	52	141
	O	12.0	341.9	100.6	252.2	52	143
	N	11.75	367.9	100.8	256.7	51	138
	D	11.25	365.8	99.8	259.5	50	140
1976	J	10.0	397.0	101.4	261.5	50	128
	F	9.25	404.2	102.6	263.9	49	132
	M	9.0	404.7	102.1	274.2	49	130
	A	10.50	406.0	102.3	286.3	48	128
	M	11.50	406.6	104.4	292.0	47	126
	J	11.50	378.6	100.4	299.6	47	123
	J	11.50	383.8	101.3	302.0	47	113
	A	11.50	368.1	100.5	304.0	46	104
	S	13.0	344.0	102.1	314.4	46	116
	O	15.0	293.6	102.5	327.7	45	123
	N	14.75	301.0	103.4	331.8	44	130
	D	14.25	328.6	103.5	330.2	44	135
1977	J	12.25	374.7	103.7	337.8	42	132
	F	12.0	393.8	103.5	339.5	42	143
	M	10.25	418.2	103.6	347.2	42	149
	A	8.75	415.1	102.5	349.7	41	147
	M	8.0	456.7	103.7	348.3	40	143
	J	8.0	450.5	100.2	345.2	40	143
	J	8.0	443.1	102.8	344.5	40	144
	A	7.0	478.6	102.7	338.8	40	146
	S	6.0	522.8	102.7	338.1	39	154
	O	5.0	511.9	101.4	333.9	39	162
	N	7.0	480.5	105.4	358.0	40	160
	D	7.0	481.6	106.3	355.0	40	165
1978	J	6.5	482.3	106.8	351.3	40	176
	F	6.5	457.9	107.4	351.1	40	182
	M	6.5	454.9	107.1	358.0	39	182
	A	7.5	460.9	111.5	365.4	39	171
	M	9.0	476.6	110.2	370.8	39	184
	J	10.0	466.1	111.8	370.8	38	183
	J	10.0	472.2	111.3	369.0	38	200
	A	10.0	508.8	111.4	363.6	38	209
	S	10.0	516.0	110.4	367.2	38	217
	O	10.0	497.5	109.3	366.3	38	243
	N	12.5	476.9	109.7	370.8	38	193
	D	12.5	482.4	111.1	375.3	37	226

TABLE 4.3.1.1 DATA USED IN MULTIPLE REGRESSION ANALYSIS TRIALS

deteriorated then a movement was made in the other direction. If the goodness of fit improved, the program continued to move the data another month, then a third and so on each time running through the regression analysis to obtain the goodness of fit.

When the best fit, i.e. the maximum value of R^2, was obtained with the first factor it was fixed that number of months either in advance of or behind the dependent variable. The program then took the second factor and repeated the procedure until the best fit was obtained. The same process was repeated with the third and fourth factors. When all four factors have been examined once, the program returns to examine the first factor and the whole procedure is repeated because the alterations in the other three factors may have upset the optimum setting of the first. Any change made at the second iteration in any of the factors causes a third iteration of the whole procedure and so the program continues. After each iteration a check is made to see if any of the factors have been altered from the previous iteration. If no change has been made the results are printed otherwise another iteration commences. Since R^2 has both maximum and minimum values it is clear that a solution will always be obtained except in the case where an oscillation occurs. By this I mean that the solution may almost be reached when a change in one factor causes a change in a second. On the next iteration the first factor reverts to its former value and on the next so does the second. This would continue indefinately except that after one hundred iterations the program stops and allows a manual check to be performed.

When this program was running correctly a 'best' result was obtained with the data in the positions shown in table 4.3.1.2 giving an R^2 of 0.85. The terms 'in advance' and 'behind' are used to mean the following. Say the fourth variable is best arranged so that the July figure correlates with the September figure for price. It is then said to be two months 'in advance' and will appear in the resultant regression equation

$$Y(t) = \ldots\ldots\ldots + a_4X_4(t-2) + \ldots\ldots\ldots \quad .$$

FACTOR	SETTING
Index of Industrial Production	9 months in advance
Wholesale Prices	5 months in advance
Gold Price	4 months in advance
Value of £(1970=100)	3 months behind
FT Index	1 month behind
Minimum Lending Rate	8 months in advance

TABLE 4.3.1.2 BEST SETTINGS OF FACTORS IN REGRESSION ANALYSIS

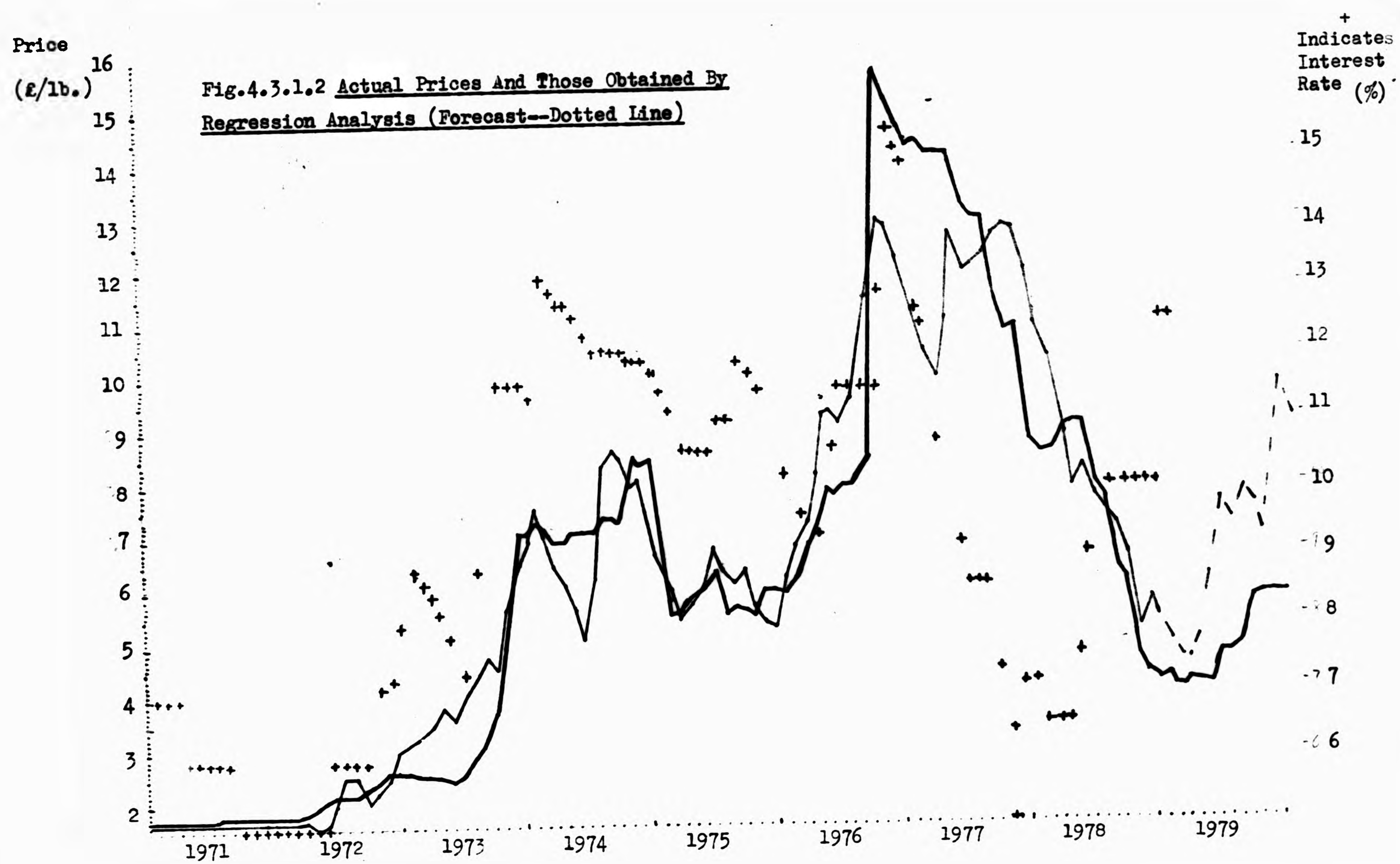
The equation obtained from the regression analysis is of the form

$$Y(t)=-8.6+0.5\ X_1(t-9)+0.03X_2(t-5)-0.12X_3(t-4)-0.33X_4(t+3)-0.02X_5(t+1)$$
$$+0.68X_6(t-8)$$

This equation gives good explanations of the movements in the dollar price inspite of the fact that the economic indicators being used are British. Correlating the same factors against the Sterling price gives a much lower value of R^2,0.72. The R^2 for the above equation is 0.85. The equation as it stands is unsuitable for forecasting because the fourth and fifth variables lag the dependent variable.

The variables X_4 and X_5 were then set to be 4 months in advance and the regression rerun. The R^2 fell to 0.79. It was then decided for the reasons which are fully discussed in section 7.2 to rerun the analysis with all the variables one year in advance. Fair fortune smiling the R^2 improved to 0.84 with a standard error of estimate 0.09. The equation now obtained gives the results shown in Table 4.3.1.3 and illustrated in Fig. 4.3.1.2. The two factors that appear to have the greatest weight

Fig.4.3.1.2 <u>Actual Prices And Those Obtained By Regression Analysis (Forecast--Dotted Line)</u>



in the equation are the value of the pound (a measure of inflation) and the MLR. Indeed discarding the other factors does not significantly alter the results obtained. The improved equation is of the form

$$Y(t) = 39.1 + 0.02X_1(t-12) - 0.08X_2(t-12) - 0.05X_3(t-12) - 0.49X_4(t-12) + 0.02X_5(t-12) + 1.87X_6(t-12).$$

As the value of the pound drops we would expect the price to rise hence the negative coefficient of X_4. As the minimum lending rate increases we would expect the price to rise hence the positive coefficient of X_6.

Although the prices given by the correlation are not always accurate they do have the merit of following the jump in price in Autumn 1973 and again in both Autumn 1974 and Spring 1976. The fall in December 1977 was only followed some four months after the event. On this basis it might be expected that the equation was going to give a fairly reliable indication of the direction of price movements in 1979. Forecasts were produced for the twelve months Jan.-Dec. 1979. These were then compared with the actual price of the oil. The trough in the price in the Spring was correct. The results are shown in

Price (£/lb.)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Actual	4.37	4.00	4.12	4.10	4.10	4.70	4.70	4.90	5.60	5.75	5.75	5.75
Forecast	5.29	4.87	4.81	5.83	6.91	8.00	7.76	8.22	7.98	7.18	10.23	9.64

TABLE 4.3.1.4 A COMPARISON OF ACTUAL WITH FORECAST PRICE THE LATTER COMPUTED 12 MONTHS BEFORE THE FORMER BECAME AVAILABLE

Table 4.3.1.4 above. A buyer using this equation in December 1978 would have obtained forecasts showing a £5.35 increase in place of the £1.46 increase that actually occured. This is a totally unacceptable error in terms of making a decision whether to buy or not. Anticipating the purchasing formula developed in 5.5.3 on page 166, we see that the buyer would receive a signal to purchase the maximum amount of oil possible. Had the actual price been known then only six month's supply of the oil would have been purchased. In the event a large purchase of stock at this time would not have been a very sensible action because during 1979 interest rates rose alarmingly to

Note

It might be thought that the dollar price of the peppermint oil under discussion would be influenced, in the main, by US economic factors. Life for the forecaster would be relatively simple if this were so. In the years 1971-1978 the quantities, shown in Table 4.3.1.5, of oil were produced in the states of Washington and Oregon i.e. Yakima/Willamette quality oil (see map pg. A14). The amount of that oil exported is also shown both in absolute terms and as a percentage of the oil produced.

	1971	1972	1973	1974	1975	1976	1977	1978
A Produced(1,000 lb.)	2832	2447	2592	2549	2937	2844	3599	4432
B Exported(1,000 lb.)	2266	2387	2590	1652	1806	2149	2127	2856
B as % of A	88	92	100	66	60	65	60	60

TABLE 4.3.1.5 Yakima/Willamette Production and Exports (1971-1978)

Unlike such commodities as cocoa, wheat and silver, peppermint oil is not marketed through any form of international exchange(Ch.3 and pg.220). The prices quoted in this work are usually those quoted by a New York essential oil dealer in $/lb. converted to £/lb. at the appropriate exchange rate. The United Kingdom and Japan together account for 40% of the oil exports from the US whilst France and West Germany together account for a further 20%. Must the forecaster then consider the relationships between the Yen, Franc, Marc, Pound and Dollar? No! If a representative of each of these five countries were to walk through Wentworth Street, El market at different times of day and each stop to buy a piece of cauliflower marked 35p the actual price that each pays may be very different as every street trader knows. The 35p is an asking price (and even that changes as the day grows old). Peppermint Oil is no different because all the sellers are competing with one another as are the buyers. The British buyer may or may not pay the asking price depending on his bargaining strength and his view of British economic factors.Like him, when a bargain is struck, the US seller is affected by his home conditions. According to one's viewpoint one can regress either set of economic variables against the dependent variable. The results obtained are satisfactory from the United Kingdom standpoint. Exchange Control and exchange rates are quite another matter and have been carefully excluded from this work except where unavoidable!

16% which would have considerably increased his carrying costs. The

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1971	1.74	1.74	1.74	1.74	1.74	1.74	1.80	1.78	1.79	1.79	1.79	1.84
Regression	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.66	1.63	1.63	1.63	1.59
1972	1.81	1.80	1.89	2.06	2.18	2.34	2.33	2.33	2.44	2.65	2.85	2.85
Regression	1.56	1.63	1.74	1.50	1.62	2.13	2.61	2.61	2.12	2.33	2.59	2.94
1973	2.82	2.69	2.70	2.69	2.61	2.79	2.97	3.21	3.73	4.90	7.03	7.09
Regression	3.04	3.22	3.49	3.82	3.63	4.01	4.55	4.81	4.56	5.63	6.50	6.98
1974	7.21	7.12	6.88	6.92	6.98	7.01	7.01	7.28	7.25	7.22	8.37	8.30
Regression	7.51	6.89	6.32	6.04	5.40	4.89	5.98	8.25	8.57	8.35	7.82	7.85
1975	8.38	5.56	5.63	5.74	5.84	6.19	5.35	5.45	5.39	5.29	5.69	5.69
Regression	6.33	5.49	5.34	5.67	5.84	6.54	6.23	5.91	6.25	5.48	5.17	5.06
1976	5.67	5.91	6.77	7.34	7.81	7.72	7.87	7.87	8.38	15.72	15.15	14.71
Regression	5.87	6.58	7.08	8.15	9.23	9.28	8.92	9.61	11.50	12.97	12.83	11.97
1977	14.39	14.47	14.39	14.39	14.39	13.23	13.07	13.07	11.43	10.87	10.99	8.72
Regression	11.15	10.59	9.84	11.29	12.49	11.78	11.87	12.06	12.52	12.81	12.73	11.87
1978	8.59	8.63	9.00	9.15	9.15	7.80	7.51	6.06	5.96	4.78	4.64	4.29
Regression	10.62	10.34	8.88	7.64	7.88	7.57	7.41	7.05	6.62	5.19	6.00	5.74
1979	4.37	4.00	4.12	4.10	4.10	4.70	4.70	4.90	5.65	5.75	5.75	5.75
Forecast	5.29	4.87	4.81	5.83	6.91	8.00	7.76	8.22	7.98	7.18	10.23	9.64

TABLE 4.3.1.3 PRICE OF PEPPERMINT OIL (£/lb) AND RESULTS OF REGRESSION (1971-1979)

buyer would then still have been faced with a decision whether to hold or sell based on his own view of the future.

This equation, on its own, would not be a trustworthy method of purchasing oil. It might however give some clue to the direction of future price changes. Against this advantage must be set the disadvantage of the confusion thst would arise over the timing of such changes. One result that the equation strongly indicates is the link between interest rates and the price of the commodity,(see note opposite about dependent variable).

4.3.2 The Exponential Smoothing Method

It is clear that in exceptional market situations methods which are intended to relate a variable to influences with which it is causally related are likely to be ineffective. Regression analysis itself, of course, does not depend on causality, but in order to avoid an essentially undirected quest for factors which might give a reliable indication of future prices it was decided to employ the exponential smoothing method suggested by Brown[3]. It is a simple method of forecasting future results, taking account of trends and seasonal patterns in the past results. It requires only a small amount of data and is well suited for use as a routine forecasting procedure on a computer.

Let the price of oil in the t^{th} month be x_t. In order to describe the method we assume the observations of x_t are random samples from some distribution and that the mean of that distribution does not change significantly with time. We envisage an underlying process ξ_t such that $\xi_t = a$ where 'a' is the 'true value'. The observations x_t include some random 'noise' so that $x_t = \xi_t + e_t$ where the noise samples, e_t, have an average value of zero. In the sequence of prices the value of the coefficient 'a' will change at different parts but in any local part a single value gives a reasonable approximation to the price.

The aim is to estimate the current value of 'a' by some kind of average. As the value changes with time the average should be arranged so as to give more weight to current observations than to those more distant. The moving average is commonly used for this purpose. In order to explain the actual averaging method used by Brown's model it is helpful first to describe the moving average.

Consider the five successive observations of price: $x_1=42$, $x_2=45$, $x_3=43$, $x_4=41$, $x_5=39$. The average of these prices is $M_5=42$. A reasonable estimate of the coefficient, written here as $\hat{a}$ because it is an estimate, is that average

$\hat{a}_5 = M_5 = 42$. The forecast for any future price is $\hat{x}_{5+r}=42$, since the errors have an average value of zero.

Suppose now that the sixth observation is $x_6=44$. Now the actual average is $M_6=42\frac{2}{5}$ if we continue to average only the most recent five observations. In general

$M_t = (x_t + x_{t-1} + \ldots\ldots\ldots + x_{t-N+1})/N$ is the actual average of the N latest observations at time t. Another way of calculating M_t is to use the previous average thus

$M_t = M_{t-1} + (x_t - x_{t-N})/N$. Thus if the next observation is $x_7=40$

$M_7 = 212/5 + (40 - 45)/5 = 207/5 = 41\frac{2}{5}$. The successive estimates of the coefficients would be

$a_5=42$, $a_6=42\frac{2}{5}$, $a_7=41\frac{2}{5}$. Using the moving average it is difficult to alter the rate of response in a system. This is because the rate of response is controlled by the choice of the number of observations, N, to be averaged. A large value of N is suitable in a series of prices that are not changing much. When there is change however it is better to use a small value of N to obtain a more rapid response.

Using the moving average can result in large amounts of data having to be stored especially when N is large and many series of data are held. It would be helpful to have some way of calculating the moving average without storing all the past data. One way gives a good approximation. Consider again the seven price observations above. Suppose that after calculating $M_7(=41\frac{2}{5})$ all the items of data were lost. A new observation $x_8=46$ is obtained. The revised average would then be given by

$M_8 = M_7 + (x_8 - x_3)/5$ but the value of x_3 has been lost. The nearest approximation is to give x_3 the average of all the data, $M_7=41\frac{2}{5}$. Now the new estimate of the average, M, is given by

$M_8 = M_7 + (x_8 - M_7)/5 = x_8/5 + (1 - \frac{1}{5})M_7$ which is an estimate of the actual moving average M_8. Brown uses the notation S (for smoothing) in place of the M (for moving average) to describe this process. If the process were used for every observation the smoothed function of the observations is

$S_t(x) = \alpha x_t + (1-\alpha)S_{t-1}(x)$ where the smoothing constant α is like but not equal to 1/N in a moving average. Its value will lie between 0 and 1. In our example

$S_8 = 46/5 + (4/5)207/5 = 1058/25 = 42\frac{8}{25}$. The new smoothed value is equal to the previous smoothed value plus a fraction α of the difference between the new observation and the previous smoothed value. Performing this operation on any sequence of observations is called exponential smoothing. It is possible to gradually eliminate the previous smoothed values so that $S_t(x)$ is a linear combination of all past observations as follows.

$$\begin{aligned}
S_t(x) &= \alpha x_t + (1-\alpha)S_{t-1}(x) \\
&= \alpha x_t + (1-\alpha)(\alpha x_{t-1} + (1-\alpha)S_{t-2}(x)) \\
&= \alpha x_t + \alpha(1-\alpha)x_{t-1} + (1-\alpha)^2(\alpha x_{t-2} + (1-\alpha)S_{t-3}(x)) \\
&= \alpha x_t + \alpha(1-\alpha)x_{t-1} + \alpha(1-\alpha)^2 x_{t-2} + \dots + \alpha(1-\alpha)^n x_{t-n} + \dots + (1-\alpha)^t x_0 \\
&= \alpha \sum_{k=0}^{t-1} (1-\alpha)^k x_{t-k} + (1-\alpha)^t x_0 \, .
\end{aligned}$$

With this method of averaging the weight given to previous observations decreases geometrically with age. For example if the smoothing constant is $\alpha = 0.2$, then the current observation has weight 0.2, the previous observations have weights 0.16, 0.128, 0.1024 and so on. When the smoothing constant is small, the function S(x) responds slowly like the average of a great deal of past data and therefore the variance of the estimate of the coefficient is small. Alternatively when α is large, S(x) will respond rapidly to changes in the data. It should be clear therefore that the selection of a value for α is of some importance. Generally α is set arbitrarily at some value in the range 0.1-0.3. Brown suggests that, should the smoothing constant appear to require a value higher than 0.3, a check should be made on the validity of using a constant model. However higher values of α than 0.3 can be appropriate. The ability of the model to smooth out random fluctuations in the price series will be reduced as α increases whilst at the same time the rate of response increases.

Now if the data exhibit no obvious trend and contain no seasonal pattern then $S_t(x)$ is the best estimate of the price at time t. However should a trend be present the underlying process $\xi_t = a$ has to be amended to $\xi_t = a + bt$ to accomodate the trend b. The true value of b, as in the case of a, is not known but must be estimated from the past data. It can be estimated by an expression similar to that for the smoothing function

$B_t = \gamma(S_t(x) - S_{t-1}(x)) + (1-\gamma)B_{t-1}$ where γ is another weighting coefficient again lying in the range 0 to 1. The presence of a trend causes the smoothing function $S_t(x)$ to lag behind the true values. This lag is corrected so that the estimate of the current average price, $\hat{p}_{t,0}$, is no longer $S_t(x)$ but $S_t(x) + B_t(1-\alpha)/\alpha$. The second term in this expression is known as the bias correction factor. To obtain a forecast of future prices then the estimate of this current price is made and then the estimated monthly trend is added to it as many times as there are months ahead to be forecast.

Should there be seasonal effects to take into account they can be estimated as follows. The estimate for one month in a particular year is given by the ratio of the actual month's result, x_t, to the estimated average price that month, $\hat{p}_{t,0}$. Again the exponential smoothing form of equation is used to give an estimate of the seasonal factor for that same month in any year a weighted average being taken of the

most recent estimate and the previous value of the factor. So if the estimate of the seasonal factor for the t^{th} month, and the same month in following years, made in the t^{th} month is C_t then

$C_t = \delta x_t/p_{t,0} + (1 - \delta)C_{t-12}$ where δ is another weighting coefficient lying in the range 0 to 1. The coefficients γ and δ are given values arbitrarily in the same way as a value is given to α .

When a seasonal effect is present it is necessary to alter the initial equation for the smoothing function. The actual price in the t^{th} month x_t is replaced by p_t, the deseasonalized price for the t^{th} month ($p_t = x_t/C_{t-12}$). The forecast of price T months ahead without seasonal allowances, $\hat{p}_{t,T}$, is calculated

$$\hat{p}_{t,T} = \hat{p}_{t,0} + T.B_t .$$

To complete the forecast when seasonal effects are included the estimated price for the $(t + T)^{th}$ month made in the t^{th} month, $\hat{x}_{t,T}$, is given by

$$\hat{x}_{t,T} = \hat{p}_{t,T}.C_{t-12+T} .$$

Exponential smoothing always requires a previous value of the smoothing function. There must be some value that can be used for S_{t-1} when the process is started. In the case where there is earlier data in the series at the time the exponential smoothing is started then the best initial value is the average of the most recent N observations. Thus $S_{t-1} = M_{t-1}$ initially.

More often than not the smoothing begins with the first item of data. In this case a prediction of the average price is made. In the case of the trend an initial value is needed for B. It is simplest to set $B_0 = 0$ if earlier data is available because a current estimate of the trend can be made. However if no past data is available an estimate has to be made as in the case of the price. In the case of the

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seasonal factor, for the first twelve months the price x_t is divided by C_{t-12}. To minimize any changes to the actual price in the first twelve months therefore it is probably safest to set $C_0, C_{-1}, C_{-2}, C_{-3}, \ldots\ldots, C_{-11} = 1$. There is however no hard and fast rule.

Apart from the hazards of setting the values of S_0, B_0 and C_0 this method is dependent on suitable values being given to the weighting values α, γ and δ. The values given to α, γ and δ effectively determine the magnitude of the forecast value. The operator is therefore in effect predicting the price changes when he decides which values of α, γ and δ give the model the best chance of success. The most skilled operators of the model are those endowed with the best forecasting abilities and, as it is argued later, it is the operator that is responsible for any successful forecasts made, not the method.

We have available the price of peppermint oil each month over the five years 1971-1975 which gives sixty data points. Brown recommends that where possible at least fifty and preferably more observations be used. As the research continued the prices in 1976, 1977 and 1978 became available to extend the data base and furnish checks on the forecasts. The three factors α, γ and δ described above were altered for a number of computer runs in an attempt to find the best combination of settings which would allow the predicted prices to closely approximate the actual prices. In one series of runs the following method was used. The predicted price of peppermint oil on the basis of data available in month n-1 is denoted by $\hat{P}_n$. We then find α, γ and δ so as to minimize

$\sum_n (P_n - \hat{P}_n)^2$ where P_n is the actual price in month n. In table 4.3.2.1 the above sum appears in the line labelled SUM1. The factors α and γ were varied from .1 to .99 holding δ constant at .81. The lowest values of SUM1 appeared at the top end of the range and δ was then varied until the minimum value 80.53 of SUM1 appeared at $\alpha_1 = \gamma_1 = .99$ and $\delta_1 = .19$. This result is the best setting for α, γ and δ when predicting prices one month ahead on the basis of the

α, γ	.01	.1	.4	.6	.7	.8	.9	.99	.99	.99	.99	.99	.99	.99	.99	.99
δ	.81	.81	.81	.81	.81	.81	.81	.81	.70	.6	.20	.19	.18	.17	.1	.01
SUM1	1536	198	167	126	120	117	115	114	104	96	80.55	80.53	80.54	80.57	82	86

TABLE 4.3.2.1 VALUES OF α, γ AND δ USED IN SEARCH FOR MINIMUM VALUE OF SUM1

data available up to the end of 1975.

A similar problem was then solved for the predicted price of oil on the basis of data available in month n-6 denoted by $\hat{P}_n^{(6)}$. Here we minimize

$\sum_n (P_n - \hat{P}_n^{(6)})^2$ and this sum is represented by SUM2 in table 4.3.2.2. The factors α and γ are again varied from .1 to .99 holding δ constant. The lowest value of SUM2 appeared at the bottom end of the range. Then δ was varied until the minimum value 1630.1 of SUM2 appeared at $\alpha_2 = \gamma_2 = .01$ and $\delta_2 = .26$.

α, γ	.80	.60	.40	.10	.01	.01	.01	.01	.01	.01	.01	.01	.01
δ	.81	.81	.81	.81	.81	.70	.40	.32	.28	.27	.26	.25	.20
SUM2	176000	130000	92000	14000	2014	1919	1680	1640	1631	1630.3	1630.1	1630.8	1647

TABLE 4.3.2.2 VALUES OF α, γ AND δ USED IN SEARCH FOR MINIMUM VALUE OF SUM2

These two extreme results are reproduced in full here to show the extent to which alterations in the values of α, γ and to a lesser extent δ affect the predicted values of prices.

By a process of trial and error it was found that neither of these extreme settings gave the best results. Nor indeed did any fixed setting of α, γ and δ give consistently reliable predictions. For example in September 1976 the price was £8.38 per lb. and in October it jumped to £15.72 per lb. staying at that level for the next six months. The best predictions of this series of prices was obtained by giving a high value to δ at .83 and setting $\alpha = \gamma = .87$. These values of α, γ and δ give the predictions shown in table 4.3.2.3. The prediction

1976-1977	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Predicted price	7.79	8.88	14.40	14.77	15.24	20.68	22.95
Actual price	7.87	15.72	15.15	14.71	14.39	14.47	14.39

TABLE 4.3.2.3 PREDICTED VERSUS ACTUAL PRICES WITH $\alpha = \gamma = .87$, $\delta = .83$

for October, the actual price for September being the last piece of data given to the computer, is far too low. However the importance attached to the seasonal factor δ gives great weight to the jumps in price between October and November in 1973,1974 and to 1975 when a downward trend was reversed.

With different values of α, γ and δ it is possible to obtain a much higher prediction in the first month and also different spreads between the first and six monthly values predicted. It is not difficult once the actual price is known to find the values of α, γ and δ that would have given a prediction close to that price. The difficulty is in selecting suitable values of α, γ and δ BEFORE the actual prices are known. The operator of this method in selecting his values for α, γ and δ has in effect to make an implicit prediction of the price. The argument has been advanced that with practice the operator of this method can obtain better results than the first time user. To my mind this is not an argument in favour of the method because it is simply saying the operator is better able to manipulate α, γ and δ. It is more accurate to say that the operator has become better at predicting whatever is to be predicted, in our case the price of peppermint oil.

4.3.3 The Box and Jenkins Forecasting Method.

A model that can be used to calculate the probability of a future value in a time series lying between two specified limits is called a stochastic model. Box and Jenkins[1] (1970) discuss a class of stochastic models. The type of time series represented by our peppermint oil price series has no natural mean level and thus is non-stationary. We have already seen an example in section 4.3.2 of a forecasting method that uses exponentially weighted moving averages which is appropriate for one type of non-stationary stochastic process. The class of non-stationary processes that contains the stochastic model for which the exponentially weighted moving average forecast is optimal are called autoregressive-integrated moving average processes or ARIMA processes for short. The Box and Jenkins approach to forecasting is first to derive an adequate stochastic model for the particular time series under study. Once a model is chosen they claim the optimal forecasting procedure follows immediately. The exponentially weighted moving average forecast, they point out, is a special case of such forecasting procedures.

Before following a short derivation of their model we note the use of a backward shift operator B which is defined by $Bz_t = z_{t-1}$; also its cousin a backward difference operator ∇ which is defined by $\nabla z_t = z_t - z_{t-1} = (1 - B)z_t$. One stochastic model useful in representing certain series is the autoregressive model. The current value of, say, price is expressed as a finite linear aggregate of past prices and a shock a_t. Let price at times t, t-1, ... be z_t, z_{t-1}, ... and let $\hat{z}_t$, $\hat{z}_{t-1}$, ... be deviations from μ, e.g. $\hat{z}_t = z_t - \mu$. Then

$$\hat{z}_t = \phi_1\hat{z}_{t-1} + \phi_2\hat{z}_{t-2} + \cdots\cdots + \phi_p\hat{z}_{t-p} + a_t \ldots \quad \ldots \qquad (4.3.3.1)$$

is called an autoregressive process of order p. The variable z is regressed on itself hence the name autoregressive. If we define an autoregressive operator of order p by

$\phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \cdots\cdots - \phi_p B^p$ then the autoregressive model can be written

$\phi(B)z_t = a_t$ in which the p+2 unknown parameters μ, ϕ_1, ϕ_2, ...ϕ_p, σ_a^2 have to be estimated from the data. The variance of the white noise process a_t is σ_a^2.

Another useful model is the moving average process already described in section 4.3.2. Here $\hat{z}_t$ is made linearly dependent on a finite number q of previous a's. Thus

$$\hat{z}_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \cdots\cdots - \theta_q a_{t-q} \ldots \quad \ldots \quad ..(4.3.3.2)$$

is called a moving average process of order q. If we define a moving average operator of order q by

$\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \cdots\cdots - \theta_q B_q$

then the model may be written

$\hat{z}_t = \theta(B)a_t$ in which the q+2 unknown parameters μ, θ_1, θ_2, ... θ_q, σ_a^2 have to be estimated from the data.

Box and Jenkins combine these two types of model (4.3.3.1 and 4.3.3.2) to form a mixed autoregressive-moving average model

$$\hat{z}_t = \phi_1\hat{z}_{t-1} + \cdots\cdots + \phi_p\hat{z}_{t-p} + a_t - \theta_1 a_{t-1} - \cdots\cdots - \theta_q a_{t-q}$$

or $\phi(B)\hat{z}_t = \theta(B)a_t$ in which the p+q+2 parameters detailed above have to be estimated from the data. In practice it turns out that p and q are rarely greater than, and often less than, two.

The price series which we are considering is a non-stationary model because it does not vary about a fixed mean. Box and Jenkins say that such series behave in a similar fashion even though the general level about which fluctuations are taking place may be different at different times. They represent this behaviour by a generalized autoregressive operator $\varphi(B)$ which is related to $\phi(B)$

$$\varphi(B) = \phi(B)(1 - B)^d \quad \text{where } \phi(B) \text{ is a stationary operator as above.}$$

From this they obtain the general model for non-stationary behaviour

$$\varphi(B)z_t = \phi(B)(1 - B)^d z_t = \theta(B)a_t.$$

In practice the degree of differencing d is 0, 1 or at most 2. It is this combination of the two types of model that gives the title which is represented by the acronym ARIMA and the process is of order (p,d,q). Thus, for the ARIMA (0,1,1) model, the forecast for all future time is an exponentially weighted moving average of current and past z's; this is exponential smoothing.

The selection of values for p,d and q determine the type of model to be used whilst the values assigned the parameters in the polynomials $\theta(B)$ and $\phi(B)$ completes the definition of the model. Should the model thus defined give an unsatisfactory account of the data then the above process is repeated.

Box and Jenkins describe a recursive method for calculating the parameters in $\theta(B)$ and $\phi(B)$ which depends on the operator making an initial estimate. The criterion for deciding when the parameters are correct is, as usual, the minimum sum of squares. Details of this can be found in chapter 7 of their book.

The Box and Jenkins contribution to the subject is therefore to combine two types of model, autoregressive and moving average, into one the mix being determined by the operator. There are no independent variables which has the merit of avoiding the problems faced by the method of section 4.3.1. However the criticisms levelled at the method of 4.3.2 are still active in this case. The values assigned by the operator to the various coefficients mentioned above will necessarily depend on his attitude to risk. The subjects of risk and uncertainty are discussed more fully in Chapter V (see section 5.3.5.1).

Most commentators on Box and Jenkins seem to face their generalized method with some trepidation. I have tried to reduce it to a fairly simple arrangement which might give some idea of the complexity of the original. As with other forecasting methods that rely on the operator to provide values for various coefficients the importance of the selection of these values is played down. This is a pity because a healthy discussion of what affects the operator's choice sheds considerable light on the shadier areas of the forecasting problem. Some discussion on this topic is presented in Chapter V.

Trials using the Box and Jenkins method were made using programs based on the algorithms in part five of their book and very kindly loaned by the London School of Business Studies. Two different models were found which satisfied all of the diagnostic tests yet clearly bore little relation to the actual series of data. Both models had the same serious failing of being unable to predict changes in the price that did not conform with past trends; that is both those points on Fig.1 in Appendix I where the direction of price changes alters and those points that appear as discontinuities. Many such discontinuities and directional changes appear in our data which makes the task of finding a suitable forecasting model not only formidable but also probably a waste of effort. A full description of the trials made appears in Appendix I.

4.4 The Price of Peppermint Oil (1971-1975)

The price of peppermint oil is not only affected by outside factors such as crop yields and industrial demand but also, and probably more strongly, by the dealings as the oil passes along the chain of intermediaries between grower and end user. During the years we are examining there was one period when the price of the oil more than doubled over four months. This was between August and November 1973 when the price moved from £3.21 to £7.03. The usual reason for a rapidly rising price is high demand generated by fear of future shortages. Is there any evidence to suggest there would be a shortage of oil in 1974? The accompanying table 4.4.1 shows the production figures for the state of Washington and the total US production. These figures do show a fall in production compared with the previous year 1972 but it is small when compared with the drop in production

	1970	1971	1972	1973	1974	1975
Washington Production ('000 lbs.)	1169	721	480	402	561	697
Yield per Acre (lbs.)	74	70	60	55	66	82
Total US Production ('000 lbs.)	5007	3746	3004	3173	3302	3759

TABLE 4.4.1 WASHINGTON PEPPERMINT OIL PRODUCTION AND YIELD PER ACRE TOGETHER WITH TOTAL US PRODUCTION 1970-1975

between 1971 and 1972. That drop resulted in a price change, between August and November 1972, from £2.33 to £2.85. It is hard to relate the relatively small drop in production in 1973 to the vast price increases that year. The total US production of peppermint oil rose in 1973 as did the amoumt imported by the UK.

The prices of peppermint oil shown in table 4.3.1.2 are not in fact indicative of the average amount paid by importers in the UK over the whole year. Figures provided by HM Customs and Excise (see table 4.4.2) show the total amount of oil imported from the US and the average price paid for the years 1971-1975. This price should be compared with the average prices quoted for those years by the New York broker. At this

	1971	1972	1973	1974	1975
Oil imported from US ('000 lbs)	521	505	561	389	248
Average price paid (£/lb)	1.84	2.11	2.64	5.30	4.80
Broker's average price (£/lb)	1.80	2.17	3.34	7.32	5.40

TABLE 4.4.2 UK IMPORTS OF PEPPERMINT OIL FROM US AND PRICES PAID 1971-1975

point it is helpful to indicate which of the many possible figures available for price is to be used. Is the price of oil the figure quoted by a broker or is it the figure actually paid on purchase ? Should one consider the average amount paid over the year by all importers as being the price for that year ? Clearly it does not help to say that the price of a good is that sum which a purchaser is prepared to pay for it, since the purchaser may be in receipt of a 'buyer's surplus'. The purchaser may pay, if he is fortunate, less than he was prepared to pay or indeed be obliged to pay more through lack of choice in a tight situation where he needs quick delivery for an important order. The dictionary defines price as 'money value paid or asked for goods' which is not very helpful in the case of peppermint oil. We can see from table 4.4.2 that the money value paid in 1971 was greater than that which was asked for by the broker whilst in the years 1972-1975 it was less. Throughout this work unless otherwise stated, the price of peppermint oil used is that asked for by the New York broker each month. This is because, if the company where I was studying this problem had needed to purchase oil that month, that is the price they would have had to pay. That the average price paid by UK companies was less than those quoted by this particular broker over the four years 1972-1975 is due partly to deals being made with other brokers at lower prices and partly to importers buying when prices were lower than average.

In trying to understand the fluctuations in the price during the five years under study it is necessary to know the prices at each stage in the chain from farmer to importer. The Washington farmer received, on average, the prices shown in table 4.4.3 for his oil

	1970	1971	1972	1973	1974
Price (£/lb)	1.54	1.57	2.06	4.13	5.40

TABLE 4.4.3 PRICE RECEIVED BY WASHINGTON FARMERS FOR PEPPERMINT OIL[7]

over the years 1970-1974.

The price received by the farmer one year is not really reflected in the New York broker's price until the following year owing to the harvest taking place in September. For comparison therefore I have put the 1970-1974 farmer's price received alongside the 1971-1975 (years 1-5 in table) broker's price asked to obtain the table 4.4.4. That the UK importers did, on average pay considerably less than the price asked for by the broker, especially in year 4 following the world fuel oil price rises, is partly due to the largest importers beginning to contract directly with the farmer and partly to buying at times during the year when the broker's price was lower than his average. One company who provided data for this study did not buy enough oil to make direct contacts with the farmer worthwhile. They bought, at most, two thousand pounds weight of oil in year one (1971) for an outlay of around £4,000. The great jump in price from year two to year three caused them to lose their major customer for peppermint flavouring using this grade of oil. The price since year five has continued to rise to new heights in excess of ten pounds sterling per pound weight and consequently no peppermint oil has been imported by this company since 1972 from the USA.

Some explanation is needed for the sudden drop in the price asked by

	1	2	3	4	5
Farmer's Price (£/lb)	1.54	1.57	2.06	4.13	5.40
Broker's Price (£/lb)	1.80	2.17	3.34	7.32	5.40
UK Price Paid (£/lb)	1.84	2.11	2.64	5.30	4.80
Broker's % mark-up	14	47	51	75	0.4

TABLE 4.4.4 A COMPARISON OF PRICES AT DIFFERENT STAGES IN THE JOURNEY OF OIL FROM FARMER TO USER

the broker from year four to year five. Until the end of the sixties brokers were content with selling oil 10-12½% above the price paid to the farmer. The costs of collecting, rectifying and blending the oil are estimated to take some 2-5% of the mark-up leaving a profit from the difference of 5-10½% over the farmer's received price. In year two, as can be seen in table 4.4.4, this mark-up rose dramatically from the year one figure of fourteen per cent to forty-seven per cent. This margin was repeated in year three but meant a greater return in cash because the farmer received nearly fifty per cent more than in year two. It was not long however before certain Oregon and Washington farmers realized the vast profits that the 'middlemen' were making. It was particularly hard on the farmer who agreed a fixed sum, say three pounds per pound, for the season following his year three crop. The price received by his fellows averaged nearly five pounds per pound. This difference in price has usually been accepted with equanimity by the farmer growing to a fixed contract because he knows that in some years he will be receiving an above average price and is prepared to lose from time to time for the sake of restful nights. However the price at which he saw his oil being resold was far in excess of his estimates in year three and the year four results must have been most frustrating to farmers on a fixed contract however equitable their natures.

Meetings were held amongst the farmers to try to organise some resistance against the monopoly buying power of the four large dealers and the largest industrial buyers in the US, manufacturers of toothpaste and chewing gum. These meetings resulted in united action by the farmers to hold out for better prices with the threat of instituting legal proceedings under the US anti-trust laws. As can be seen from table 4.4.4 their action resulted in good prices in year five, particularly good when compared with the prices being paid by UK importers.

The figures in years four and five can be a little misleading because they do not reveal, for it is the very heart of the broker's business, the carry over of oil from one year to the next. Although extensive enquiries were made it soon became apparent that particulars of this kind were closely guarded secrets by the companies concerned. In the case of our New York broker it would appear that quite a lot of oil was carried over from year four to year five because he cannot have sold a great amount at his asking price in year four. The asking price in year five should probably be compared against the farmer's price in year FOUR due to this carry over; in this case the broker is not making the loss that at first sight he seems to be doing. It is idle to dwell on this however without accurate figures showing the stocks available for the broker to call upon each year. Doubtless he is an investor, in the Samuelson sense, for years one through four and possibly a speculator in the last year.

4.5 Options Open To The Buyer.

The buyer in the UK wishing to purchase peppermint oil has at most two options open to him depending on the amount of his annual requirement. The first class of buyer, dealing in comparatively small shipments of say five to ten drums, each drum containing four hundred pounds of oil, has to date traditionally dealt through a broker. He pays for all his shipments at a price which usually covers all charges until the oil is on board the ship ready to sail to the UK. This means that all the stages, from the farmer's distillation plant to the ship, have been organised for him and included in his price. The second class of buyer has some scope for bargaining with the seller be it farmer or dealer. Until year four it was common practice for large quantities of oil to be bought through a dealer. When the farmers began to seek means to strengthen their position it quickly became apparent to some UK buyers that the potential existed for individual deals to be made direct with the farmer. Necessarily this type of transaction requires certain prerequisites.

The first consideration in purchasing oil is probably quality. The buyer knows what his manufacturing customers require in their flavourings. He knows that his blending colleagues have only a limited number of ways of meeting the requirements where price and quality limits are preset. The customer is said to be very sensitive to alterations in the taste that the flavouring imparts to his products. With peppermint oil it is technically difficult consistently to supply the same taste whilst saving on material costs. In practice this means that not only must mentha piperita be used for certain customers but also that it must come from a particular area in the United States or even from a particular farm. The chemical composition of the oil, of which details were given in table 3.3.2 in the last chapter, is important. The buyer needs a constant supply of a consistent quality of oil. It will be necessary therefore for him to contract with a farmer to guarantee his supply. It is in the contract that both farmer and buyer face their hardest decisions. They are both, in effect, acting as price speculators if they attempt to fix a price because the market may well contradict them at the year's end. Without fixing a price they are both putting themselves in a virtually impossible position. The buyer wishes his supply of oil at a given price in order that he can give adequate notice to his customers through his own blending concern's sales force. The farmer wishes to plan his five year growth cycle without living from hand to mouth at the mercy of the banks for his capital requirements.

The solution of fixing a price is usually the most satisfactory to both parties. There are those who claim that market forces will tend to encourage the breaking up of such arrangements. This need not be the case because the motives linking buyer and farmer together in their contract would outweigh considerations of short term gain. The farmer, when he finds his neighbour receiving a better price for his oil at the end of the season, will seek to drive a harder bargain in his next contract.The growth of these individual type of arrangements can only improve affairs for both the farmer and the UK importer. The farmer should, in general, receive a much better price than at present whilst the buyer will perhaps pay less than at present. The only sector of the market to be adversely affected by this type of arrangement are the present 'monopolistic' buyers who have had the market place effectively shut until very recently. To date only a few farmers have foreseen the benefits that these proposals open to them whilst the European buyer has still to take advantage of the changing relationship between dealer and farmer.

4.6 Discussion

One of the first studies of price fluctuations was made by Bachelier[8] in 1900. He postulates a mathematical model which assigns a probability to a market fluctuation of a given size and it is of interest that his discovery of Einstein's probabilistic model of diffusion antidates that of Einstein himself. He studies the static state of the market at a given instant to establish the law of price changes consistent with the market at that instant. In his preamble he makes the following interesting remarks concerning the Paris Bourse[9].

> 'The influences which determine fluctuations on the Exchange are innumerable; past, present and even discounted future events are reflected in market price, but often show no apparent relation to price changes.
> Besides the somewhat natural causes of price changes, artificial causes also intervene: the Exchange reacts on itself, and the current fluctuation is a function, not only of previous fluctuations, but also of the orientation of the current state.
> The determination of these fluctuations depends on an infinite number of factors; it is therefore impossible to aspire to mathematical prediction of it. Contradictory opinions concerning these changes diverge so much that at the same instant buyers believe in a price increase and sellers in a price decrease.'

It is not impossible to aspire to mathematical prediction but the success of such aspirations without additional help are in doubt. Most forecasters depend at least as much on a 'feel for the market' as on hard market information. Some of this 'feel' is, of course, due to the retained memory of past situations, of almost forgotten conversations about the state of the trade, of the consistency of the formal market 'picture' with information about other events not necessarily closely related and so on, but some of it is not.

In our analysis of economic decision making, we see the decision maker as being influenced by his system of beliefs about the nature of the world as well as by information flows. Each decision maker has an awareness that the market situation is constantly influenced by the expressed intentions and actions of every other market decision maker. These many influences, some of Bachelier's 'infinite number of factors', form a very wide network. It should be remembered further that each decision maker is acting on factors of a material sort which affect demand and supply in the market as well as on his 'feel' for the market. Thus we have a network of influences which is very closely woven so that the threads form, as it were, a 'whole cloth' which is not well represented by partial analysis. Under these circumstances not only is formal analysis difficult but unrelated events can affect each other so that the simultaneity of events may appear to supplant clearly causal trains.

The most hopeful course for the buyer therefore, wishing to guarantee his supply at a certain price, is to locate a farmer who can supply his grade of oil and to contract with him in the manner suggested. There is no easy solution to long term forecasting of price depending as it does on such a variety of factors many of them intangible. In the short term however, through contracting directly with the source of supply, the buyer is able to exercise some control over the price he will pay.

4.7 Summary

The chapter opens with further consideration of the position of the middlemen and of dealers in the chain of supply from grower to UK importer. Their position at the 'information crossroads' is considered to be of great importance in governing the prices paid to the growers and the prices paid by the importers. The dealer's exploitation of his position is said to establish a 'false equilibrium' in the market place and we are able to see an unpredictable hand at work in the forces that govern the price of peppermint oil.

Three prediction methods are tested for their ability to forecast the price of peppermint oil. Multiple regression analysis reveals but two factors, the value of the pound and the MLR, as having the most important influence on the price in the years 1971-1978. Closer examination shows the equation as a poor indicator of the magnitude of price changes but better at indicating their direction up to twelve months before they occur. The second method tested is one devised by Brown. The accuracy of the predictions produced by this method depend on the skill of the operator in setting factors to aid the fit of a stochastic model to the data available. This skill is directly related to his ability to predict price changes. The Box and Jenkins method revealed at least two models to explain the data, which showed the consistency of the market process studied even if they were unsatisfactory in producing useful forecasts. Of these three methods tested the most hopeful for future development is the first. The interested buyer might, over a period of seven or eight years, refine and improve the model to produce forecasts of a more realistic magnitude. It will at its best be no more than an aid to forecasting.

Even in times of relatively stable prices unforeseen shocks can disturb market equilibrium and involve the buyer in unexpected losses. After a close examination of the way in which prices change and of the difficulty in making an effective forecast, and bearing in mind the role of the middleman in a market situation which is by no means as uncomplicated as the text book case, it is suggested that a buyer wishing to avoid risks due to fluctuations in price should make direct contracts with a grower or growers if possible. It may be, however, that a buyer cannot do this, either because his requirements are too small or because he lacks the information or bargaining skill, as was mentioned earlier in the discussion of the middleman's function (see 4.2). It may also be the case that the buyer is not a risk-avoider, but may be willing to accept the uncertainty involved in order to have the chance of making a greater profit.

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CHAPTER V

THE WAY IN WHICH THE PRACTICAL TASK OF THE DECISION-MAKERS WITHIN THE FIRM RELATES TO THEORETICAL ANALYSIS.

5.1 Introduction

An important part of this study is the placing of normative models of the inventory decision and of related decision areas in a practical context. The present research, therefore, involved at an early stage a close observation of the way in which a firm handled these decisions. An extensive period was spent in a business which imported many different essential oils both for its manufacturing process and for further trading in untreated oils. This chapter, therefore, contains a description of the method of stock control used and of the way the stock control procedures were related to the people responsible for the underlying decisions.

It was due to the management's awareness that stock control procedures could be improved that the writer was permitted to make a study and to offer suggestions as to how they might best do this. It was clear that variations in the prices of the materials bought in affected the stocks held, but the way in which this effect operated was not immediately apparent and was difficult to quantify. The effects of interest rate were also difficult to estimate in a period in which the firm's turnover almost doubled. However, both prices and interest rates seemed to have an effect on the amount of stocks held, and if their changes could be foreseen, then the inventory decision could be modified.

The familiar economic order quantity formula, described in section 5.4.1, can be adjusted to take account of changing prices and interest rates and in this chapter a revised version is presented. The successful use of such a formula will depend to a large extent on the buyer's ability to forecast both future prices and future interest rates. The problems of providing a methodical way to forecast prices have been discussed in the previous chapter whilst the effect on stock-holdings of varying interest rates was discussed in Chapter II. That buyers do make decisions on the likely future prices is indisputable but only the passage of time can show how accurate their forecasts have been.

If these decisions could be embodied in an amended economic order quantity formula, a more efficient stock ordering system could be provided. Such formulas, based on normative models of the inventory decision which assume a fairly simple structure for the problem and for the environment in which the decision takes place, may not reflect complexities in the actual situation which are likely to seem very important to the decision maker himself. It may also be the case that the decision maker may have legitimate business objectives which are more complex than short-run cost-minimisation or profit-maximisation.

Much of the detail of the way in which buyers arrive at their decisions, therefore, is likely to be difficult to observe or to report. It concerns qualitative factors which are subtle and not susceptible to measurement. It is the presence of these factors, together with intangible qualities of the individual buyer's psyche that make attempts to formulate the forecasting process and its relationship with the inventory decision likely to be only partially successful.

The forecasts are, of course, crucial in decisions where stock is to be bought not for the manufacturing process but for further trading, that is to say the purchases are speculative. In this type of purchase the economic order quantity is not so central to the decision as when buying for the day-to-day manufacturing process. The buyer thinks the price will rise and therefore purchases; at the same time he is aware that there is a risk involved and so he will not become too heavily committed to one particular oil. He will spread his risk over the range of oils carried as a general rule.

There are times however when he is so certain that the price will rise that he does in fact sink substantial amounts of capital into one oil. The amount purchased in this case is limited, in theory, only by the capital and storage space available so long as the net percentage return anticipated is greater than the return which could be gained by an alternative risk-free investment. It follows that in practice the amount purchased will be limited by the buyer's sense of caution which is affected by his confidence in his price prediction. This sort of situation is difficult to quantify since it involves both the buyer's confidence in his prediction and his attitude to the risks involved. It is also clear from the above that a further element in the inventory decision is the appropriate definition and calculation of capital costs, which are involved in both speculative and non-speculative decisions.

5.2 Capital Costs and the Inventory Decision

In discussion a senior manager at the firm studied held that shortage of funds presented no difficulties for a good project. In the context of the discussion it was clear that this would be considered to apply to inventory investment which included a speculative element. Even so, there must be some awareness of the cost which is represented by the commitment of funds to an investment project. The consideration of the amount of capital 'tied up' in stock is, in fact, an important element in the firm's investment decision.

The problem of capital costs in the inventory decision falls into two parts: an accurate calculation of the money value of the capital sunk, or to be sunk, in inventories and an evaluation of the return sacrificed by the commitment of this capital to inventory investment. The second of these two elements may be based on either the cost of obtaining funds for inventory investment from banks or elsewhere or on the cost of diverting capital from other profitable uses, i.e. the opportunity cost. There is an extensive literature on the cost of capital and on whether a 'lending rate' or a 'borrowing rate' should be used in the evaluation of investment projects, see for example Hirschleiffer.[1] Occasionally, the mistake is made in business of thinking that cash tied up in inventories costs nothing, especially if the cash to finance inventory is generated internally through profits and depreciation. However this implies that the cash in inventories otherwise would sit idle. In fact, the cash could be invested in government securities, at least, if not in inventories. And if it were really idle, the cash very likely should be released to shareholders for profitable investment elsewhere.

A further difficulty in the case of inventory investment is that it is difficult to define in a precise way the rate of return to be attributed to holding stocks. So far as precautionary holdings are concerned the risks due to stock outs, and the loss of profits associated with them, are predominant in the decision. For speculative inventory investment, the period of holding is likely to be comparitively short and while the expected gains will be related to forecast price rises they are likely in the nature of the situation, to be too uncertain to warrant a sophisticated approach. In any case, it is likely, too, that the risk-taking manager who might be willing to engage in substantial speculative inventory would also be the managerial type least likely to find probabilistic methods credible. This problem is referred to later in the chapter.

For the practical decision maker, therefore, the rate of return on capital investment, in inventories or elsewhere, is seen as the ratio of the additional profit earned as a result of the investment to the additional out-of-pocket investment made. In inventory investment, however, the identification of this incremental profit is almost impossible to disclose in many cases.

The other element of the inventory-investment decision is the money value of capital tied up in stocks. Here again, there are many complicating factors. The true inventory investment is the out-of-pocket, or available cash cost of the goods in inventory and these costs must be distinguished from the 'book' or accounting value of inventory. Raw materials, for example, need only be purchased when required by the production schedule and if the purchase can be delayed then the money might be better used elsewhere. The timing of the production schedule does not influence inventories representing equipment and facilities already bought and paid for. Therefore while depreciation on these items represents a legitimate cost for accounting purposes it should not be counted as part of the inventory investment for planning purposes.

Sometimes raw materials have to be purchased at a certain time of year due to the seasonal nature of the crop. Such investment is unavoidable and is not included in the computation of inventory value for planning purposes. It does however still represent capital tied up but not in the investment sense defined above. These purchases must be distinguished from speculative purchases which do not fall into any of the above categories.

Returning to the question of the rate of imputed interest or of desired return on investment, the firm purchasing peppermint oil based their return on that which could be earned by an alternative use of internal funds. The rate of return charged may depend on the type of investment. For example, permanent investment (as in relatively permanent inventories) may be financed internally at a relatively high rate, while seasonal inventory stock may be financed by bank borrowings at a relatively low rate. Furthermore where the investment varies substantially from one time of the year to another, the capital cost of inventory investment may at times be based on the maximum amount of funds tied up. The latter basis may be appropriate where cash released during low-inventory periods cannot be profitably invested elsewhere.

It is generally accepted that average or expected earnings which merely equal capital costs are not enough in risk bearing circumstances; something additional is required to compensate for assuming the risk. Manufacturing and merchandising organisations are in business to bear the risks of these activities and to earn the resulting risk taker's profits. When the question of an appropriate rate of return to charge against investment is raised, the Bank of England minimum lending rate is sometimes suggested when this rate is in fact inconsistent with the company's financial policy. It is important that the inconsistency be noted since the use of minimum lending rate, when in fact the company is not inclined to use outside funds, typically results in a much lower rate of imputed interest and a much higher drain on capital than is consistent with true company policy.

When inventory investment is normally financed internally a rate of return of up to 25% is considered by many businessmen not to be unreasonable. In choosing a truly appropriate rate - a matter of financial policy - Magee[2] suggests that businessmen consider the following questions:

1. Where is the cash coming from - from inside earnings or outside financing?

2. What else could be done with the funds and what could they earn?

3. When can the investment be retrieved, if ever?

4. How much risk of sales disappointment and obsolescence is really connected with this inventory?

5. How much of a return is required, in view of what could be earned elsewhere, or in view of the cost of money and the risk the inventory investment entails?

The use of a capital cost based either in external or internal interest rates is not a cost readily calculated in accounting records; a fact which soon becomes apparent on scrutiny of company reports. It is, however, a very real cost which is implicit in many problems which arise in inventory control.

5.3 Stock Control System Used in the Factory

At the time of the study (1975-6) no computer facilities were available to the stock controller, although with the assistance of the writer, computer systems were subsequently installed.

The system in use during the period of observation was the conventional one of a set of stock record cards, one for each of the raw materials used. The form of the card, which had seven columns, is illustrated in table 5.3. The card is headed so as to show which material it relates to, the unit of measure used, the level at which a further order for the material should be placed and the amount to reorder. The amount to reorder had been established in the case of frequently used materials through experience. In some cases the instruction to consult the manager/buyer replaces the quantity as is explained later. No calculations had ever been made to see if the reorder quantity was in fact optimal taking into account reordering costs, storage costs and possible discounts on larger orders. Where the material was only used occasionally or was purchased for speculative as well as manufacturing reasons the stock controller consulted with the works manager before a decision on how much to reorder was made.

Material:PEPPERMINT OIL Unit:LBS Order Level:400 Quantity CONSULT						
Date	Amount Ordered	Order No.	In	Out	Bal. Available	Actual Bal.
12.8.71	1200	A 6032			280	320
20.8.71				40	280	280
16.9.71		C 291		70	210	280
22.9.71		A 6032	1200	70	1410	1410

TABLE 5.3 TYPICAL RAW MATERIAL STOCKCARD LAYOUT

The first column of the card carries the date to which the entry in that line refers. Any orders placed with the supplier for further stocks of the material are entered in the second column and the order number is noted in the third column to facilitate reference. In the third column also are noted the order numbers given to a customer's order that uses the material. The amount of the material that will be required for that order is then entered in the fifth column and deducted from the balance available for future orders in the sixth column although the actual balance of material in the store is not yet affected. This is because there was usually a delay between the time that the stock controller saw the order and the time when it was processed in the factory. When the material was actually removed from stock the stock controller was notified and the actual balance in column seven amended. A short description of the lines shown in table 5.3 now follows.

The first line records an order placed for a further 1200 lbs. of peppermint oil which is delivered five weeks later. The delivery is recorded in the fourth line of the card and the balances made up. In the first line the balance available is 280 lbs. against an actual balance of 320 lbs. This is because on the previous card an order has been marked off that will need 40 lbs. of oil although the order has not yet been processed in the factory. The purpose of the two balance columns is to give the stock controller earlier notice of the need to reorder materials than if he simply had the final column's balance to work with. It also allows the customer to be given earlier notice of any impending delays due to the non-availability of material for completing his order. The second line records the day on which the material for the order recorded on the previous card is actually removed from the physical stock. The actual balance is now amended to 280 lbs. Sometimes in the case of frequent orders for the same compound it is more economic to produce a larger batch of the compound than is actually ordered. In that case stocks of finished compounds or part-completed compounds are kept and recorded on different cards. The customer's orders are then first checked against these cards and only the balance of what is required to be manufactured is removed from the card in our example.

The third line records customer's order number C 291 which will require 70 lbs. of oil for completion and thus the balance available for further orders is reduced although the amount actually in stock remains the same. On the date, six days later, that further supplies of oil arrive the 70 lbs. of oil is drawn from the stock available and used. This is recorded in the fourth line and the actual balance comes back into line with the balance available.

The stock controller's task was to keep all the raw material stock cards, as well as the part-completed and completed compound stock cards, up-to-date. In order to verify the correctness of his records from time to time he made a physical check of the stock. This might be quarterly, half-yearly or yearly depending on the frequency of use of the particular material. Where the amount in stock falls short of the total recorded on the card every effort is made to discover the cause. A likely reason might be that when oil was drawn off for use in the factory the note recording the withdrawal might be forgotten or mislaid whilst travelling to the stock controller. In this case he can check the amounts removed against the amount needed for orders and soon see where a discrepancy has arisen. Where leakage or spillage has occured there will also be discrepancies. When the amount in stock is more than expected then only two likely causes can be investigated. The first is that a mistake has been made either in the records of the amounts drawn off or in the subtraction on the stock card. The second is that no record has been made of material returned to stock. This might happen where an order is cancelled just as it is about to be manufactured. Another reason might be the discovery that less needs to be manufactured than was originally allowed for. This could be when more of the finished compound is discovered in store than is recorded on the stock card. This sometimes occurs when a customer returns a consignment of goods for one reason or another and the return to stock is not notified to the stock controller.

In cases where the amount of material to be reordered was already established the stock controller sent through to the order clerk notification of the amount and type of material to be reordered when the stock dropped below the reorder point. In the case of peppermint oil most of the oil purchased from North America was used to satisfy one particular customer's needs over the year. This customer was very sensitive to changes in the price of the compound supplied to him. Consequently the peppermint oil was usually purchased at the most favourable price obtainable and sometimes in a batch large enough for a year's usage. This type of transaction was handled by the general manager who also handled the buying and selling of all stocks of material held for speculative reasons the stock controller being merely a recorder of the transactions in these instances. The general manager was directly responsible to the managing director and was in effect the financial controller also without holding the title. Purchases requiring a heavy investment of cash were however always a joint decision made by all the senior management. In cases where it looked to the manager that prices would fall he purchased as little as possible whilst fulfilling orders. Where it looked as if prices would rise then larger supplies were ordered consistent with the annual usage.

The method used by the manager in judging the amount to purchase was not much different whether or not the purchase was of a speculative nature. When purchasing material for the manufacturing process the manager knows how much is needed, based on forecasts of demand, and, having judged which way the price will move, he makes his decision on whether to purchase immediately or to defer some of the purchase to a later date. Similarly when purchasing for speculative reasons he has a fair idea of the demand he can expect and adjusts his purchase quantity accordingly. The most important factor in his decision in either case is his judgement of the way in which the price will move. In the case of peppermint oil this has been discussed in the previous chapter. Once the decision of WHEN to buy has been made the decision on HOW MUCH to buy follows. In the organization studied no formulas of any kind were used in this decision; the manager used his experience and feel for the market. In the next chapter the manager's assessments of the best amount to purchase at a given time are compared with the results we obtain using the amended economic order quantity formula presented later in this chapter.

The method of inventory control and its interaction with the discretionary decisions of senior management has been set out in some detail for five reasons. Firstly in order to stress the systematic but essentially unsophisticated way in which routine material ordering procedures were handled. Although scrutiny of available holdings was close, involving both careful record-keeping and checks of actual inventories, no attempt was made to apply cost-minimising principles to inventories. Secondly, although the management were aware of the costs associated with capital tied up in inventories, such considerations weighed less than the need to avoid 'stock-outs'. Thirdly, both senior managers and larger customers were sensitive to price fluctuations, the general manager intervening when anticipated price changes seemed to make it advisable. Fourthly, provision was made by the 'consult' instruction for managerial intervention in relatively high value-density commodities as a matter of policy. Whilst there was great care to investigate discrepancies and wastage, there was not a comparable scrupulousness in recording 'returns to stores'; there was thus a lack of symmetry in the attention paid to cost-saving and the conservation of a valuable commodity.

The stock control system used by this company could easily be transferred to a computer from the point of view of keeping the records and issuing warnings when stocks are low. In the cases where the card is marked 'consult', however, it is hard to see how the manager's function could be automated for the computer. Using a computer for the stock control would not be justified unless the computer system was already in use elsewhere in the company, for example in the accounts department. However, once in use for stock control much of the clerical drudgery in the stock controller's task would be eliminated and more time could be given to stock checks and purchasing.

5.4 Economic Decisions Made Under Uncertainty

Economic decisions, including managerial decisions, depend for their effectiveness on adequate information flows. These flows may be of many kinds and might concern market information, including price movements to be expected, information about technical processes, information about crops or about industrial relations amongst other things. From the points which emerged from the theory of the decision, as well as from observation of the practical decision-making in the company concerned, it was clear that this was very much the case with the inventory decision. The flows of information available to the decision-makers included current and past prices of the commodities stocked, current and past rates of usage, current and past inventory levels, the history of lead times between order and delivery, market conditions for the essential oils held, conditions of weather and cultivation, a history of past relationships with dealers and importers, information about prices and volumes traded in related markets and about financial conditions. With all this information, the inventory decisions still retained elements of uncertainty to the extent that they concerned future situations about which information could not be available.

It is conventional, in the analysis of decisions made under conditions of other than complete certainty, to distinguish between decision-making under 'risk' and decision-making under 'uncertainty'. In some aspects of the inventory decision, such as the estimation of lead times between order and delivery, it might have been possible for the decision-makers to have calculated the probability that particular outcomes would occur. However no evidence was found of decisions based on such calculations being taken even in the areas mentioned. In other situations it would have been possible to have approached the estimation of probabilities intuitively and to have used procedures appropriate to situations of 'subjective risk'. Again, there was no evidence of such approaches being used and it is this writer's opinion that the managers encountered during the study would have found such an approach to be at variance with their genuine intuitive feel for the total situation. For those aspects of the decision in which a speculative element was present, that is when buying in anticipation of a substantial price rise, the situation was more clearly one of true uncertainty. In the absence of firm information and with the links with past observations difficult to discover, it is not surprising that attitudes towards decision making and to the risks involved should tend to become intuitive rather than coldly rational. As will be seen in the next chapter, the buyer responsible for the peppermint oil inventory decision, having operated a rule-of-thumb policy quite lacking in the application of sophisticated techniques, responded with considerable flair to barely discernible indications of future price increases.

Possibly the more natural approach for many decision-makers is not unlike that postulated by Shackle[3], in which 'potential surprise' and 'stimulus' focus attention on situations which are likely to be most worth consideration. However decision-makers may find it more in keeping with the entrepreneurial aspects of their role to 'gamble' that one of the several possible, alternative, future states of the world will be the one in which their decisions will bear fruit than to deal probabilistically with several such states.

Finally whatever outcomes are envisaged must be related to decision-makers' preferences and to their attitudes to risk. Ideas of decision-makers' utility functions are notoriously difficult to make use of although assumptions may be made about them. In many aspects of the inventory decision, risk-aversion seems to be the rule, with the danger of stock-outs an important consideration, but under conditions calling for a speculative response this may change. In view of the remoteness of probabilistic approaches from the behaviour observed we shall not pursue this discussion further here.

5.4.1 A Simple Version of the Peppermint Oil Situation

The market situation previously discussed is complex and here we shall examine only one aspect. The importer of peppermint oil is dealing in a product of moderately high value-density. Since the basic product depends on an agricultural crop prices tend to fluctuate, although these prices are influenced and perhaps even to some extent controlled, by the dealers. However peppermint oil can be stored, albeit for a limited time, perhaps a year, and so both speculation, in a risk-taking sense, and prudent stocking, to avoid higher future prices, can

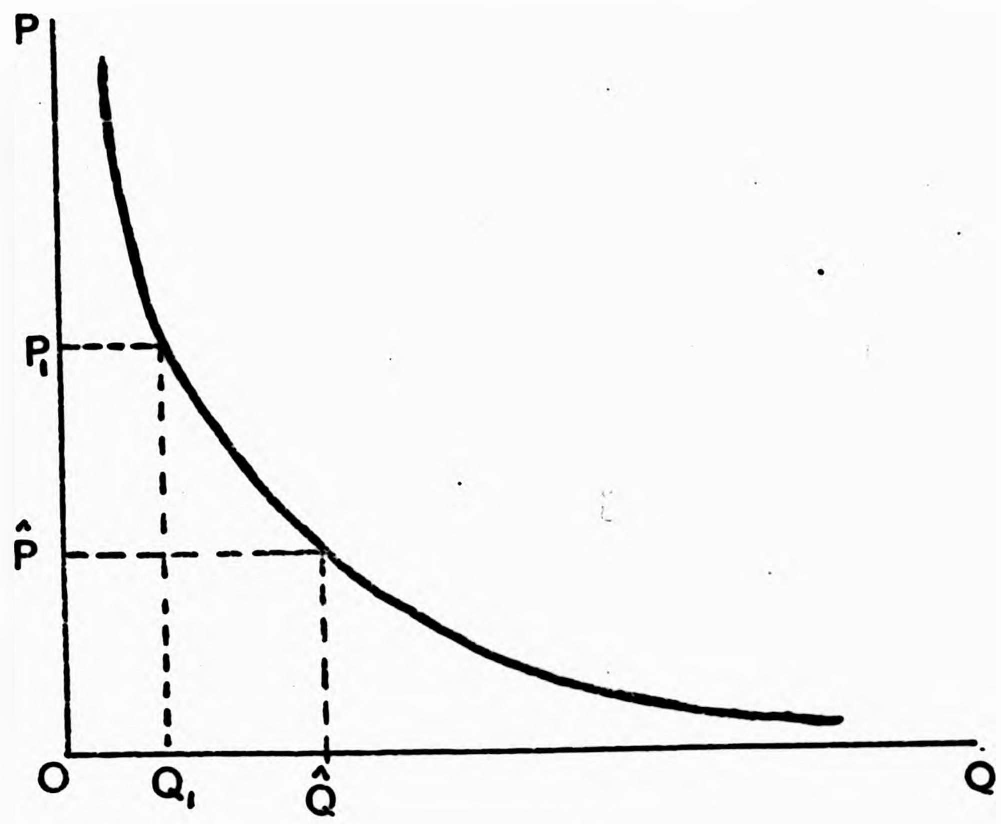

Figure 5.4.1

Importers' Demand: Quantity demanded varying with price

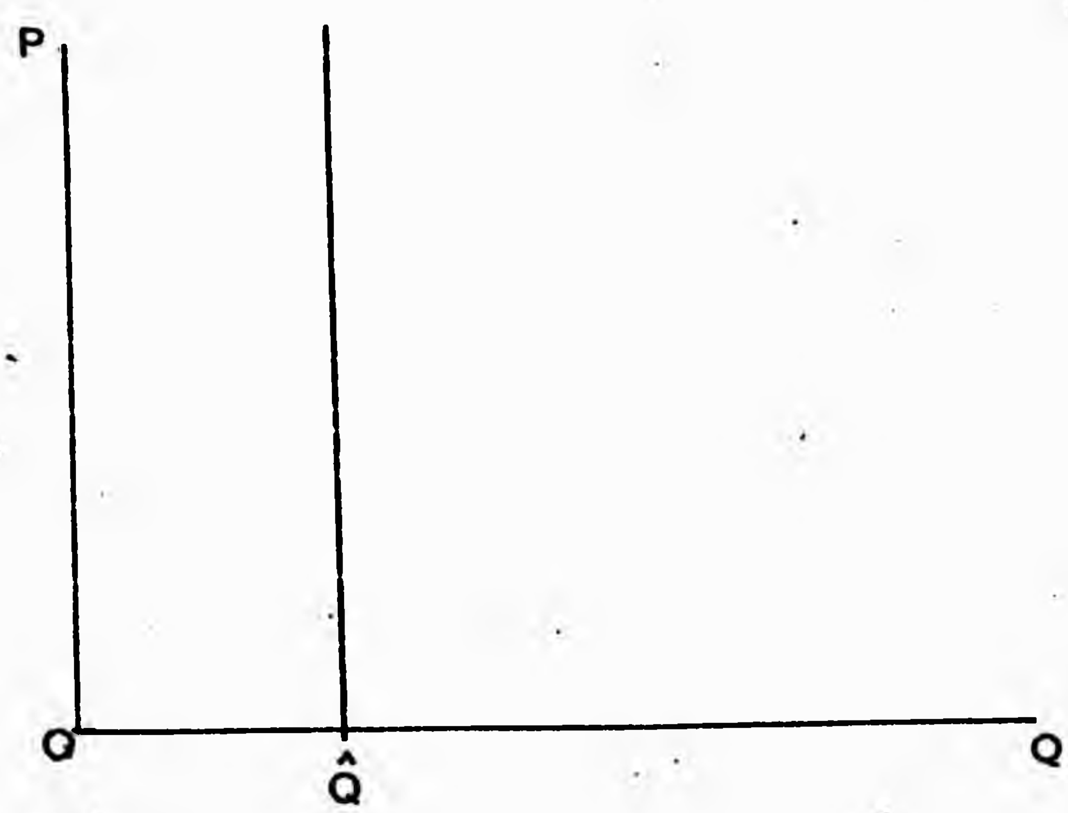

Figure 5.4.2

Consumers' Demand

take place.

Patty's empirical research, which was cited earlier, indicates that the importer's demand is of unit elasticity with respect to price. However, consumer's demand is relatively <u>inelastic</u> with respect to price. It seems that importers tend to stock up when prices are low (i.e. lower than the expected price which might perhaps be taken as the equilibrium) and to run down stocks, and to reduce purchases, when prices are higher. This would account for the discrepancies between the two elasticities. Importers' outlays would be fairly constant, this being a characteristic of demand with unit elasticity with respect to price. It could be said that the importer, typically - but not, of course, invariably - must have been applying some sort of 'rule of thumb', i.e. buy more when prices are lower than expected, less when prices are higher than expected, keeping total outlay roughly constant (assuming no significant change in <u>general</u> price level). This would mean that stocks were run up when prices were low and down when prices were high. The importer's decision, it appears, is not dominated by economic order quantity and risk of stockout considerations entirely, although the central level of stocks, around which the amounts of stock fluctuated might be. The conventional decision making rule (for cost minimization) would apply only when the price of oil is that which pertains to the average monthly demand (see fig. 5.4.1).

The question arises of whether the manufacturer might also follow such a rule of thumb or some more complex process is at work. Several levels of decision might well be involved:-

1. The ordinary decision based on the economic order quantity (EOQ) plus allowances for risk of stock-out.

2. Variations of (1) to allow for unexpectedly low (or high) price levels provided that the trend of prices can be established.

3. Purely speculative inventory decisions beyond (2) allowing for extraordinary (above P.Q) outlays and intended to yield speculative profits (and involving speculative risks).

Both (2) and (3) involve some degree of speculative risk, in fact. Even a very conservative manufacturer, governed only by the considerations of (1) and regarding price fluctuations as extraneous to his inventory decision would be involved in risk due to rising price. (The risks involved in inventory situations due to rising prices and the attendant paper profits arising from inventory valuations have been extensively discussed).[10]

In the particular situation studied our manager plays both the role of manufacturer and of importer. When buying materials for the manufacturing process he would usually be governed by considerations of (1) above although with certain materials (2) might be followed. Otherwise when buying for speculative reasons (3) would be followed.

5.4.2 The Manufacturer's Avoidance of Risk

The normative theory of economic decisions taken under risk must take account of the decision-maker's attitude towards risk. Often he is taken to be risk-neutral or to be a risk avoider. These two possibilities do not cover the case of the speculator, or of the manufacturer who is willing to seize a speculative opportunity for profit. Such a person would be a risk-lover who would gain some part of his satisfaction (or utility) from the risk involved in the situation.

If a manufacturer were indeed risk-averse he would try to avoid all risk due to unexpected price fluctuations. He would attempt this by hedging. This, in the typical textbook example, involves covering an actual purchase (or sale) for trading or manufacturing purposes by a speculative sale (or purchase). In the covering transaction, which is undertaken in the appropriate 'futures' market, any loss made on the actual physical trade is exactly counterbalanced by the speculative profit. It is also the case that any actual profit made will be counterbalanced by a speculative loss. All risk due to price fluctuation can therefore be avoided if there are opportunities for an appropriate and effective hedge - the prime requirement being the existence of an active futures market that mirrors the movements of the physical market.

The situation is less clear when there is no futures market for the commodity concerned as is the case for peppermint oil. Hedging can take place by covering a physical deal in a commodity with a speculative sale or purchase in a market for another commodity (or for securities even) that experiences price movements of the same kind - i.e. of a similar magnitude and direction. If the price movements in the alternative market are roughly predictable and are known to go in the opposite direction to that in the primary market, it will also be possible to cover the transaction. Without deliberately matching one commodity with another this is in effect what the manager in our study does when buying for speculative reasons. He spreads his risk over a range of materials. This approach is however of little help when prices are fluctuating wildly at different times such as in late 1973. Fortunately these times are only of intermittent occurrence.

5.4.3 An Approach to the Formulation of Decision Making

In extending from the firm's actual decision, made on the basis of imperfect information and strongly influenced by the decision maker's feel for the market situation, to more normative models, it may be well to set out the formal structure of economic decisions. In doing so however it is worth noting that decisions made in the day to day running of a business are of necessity based on imperfect information and they are bound to be influenced by the decision maker's feel for the market. It could be said then that such an extension is a step away from reality and consequently of limited assistance in considering actual market situations.

The ideal conceptual model of economic decisions made under uncertainty would no doubt be similar to the 'General Decision Model' discussed by Menges[5] in which all the possible courses of action and foreseeable states of the world are related to a matrix of outcomes which in turn are related to some decision criterion, perhaps derived from the decision maker's utility function. The operational use of such a model is small: a complete scan of courses of action and states of the world is not possible and the probability distribution over future states of the world is unknown and, perhaps, unknowable. These points and the problems of establishing a preference ordering are confirmed by Menges and less ambitious procedures must be sought. Even these present many problems when applied in practical circumstances.

For example we might consider a game theory approach (see von Neumann and Morgenstern[6]), or we might consider the use of probabilities and decision trees. A serious objection arises, however, to face the unwary pursuer of such methods.

Consider the position faced daily by the prospective purchaser of peppermint oil. He bases his decision on whether or not to purchase more than his immediate requirements on two criteria. The first is his view of the price of the oil over a period extending from one to perhaps twenty four months ahead. The second is his view of the cost of the capital with which he would make his purchase. The cost of capital was discussed in section 5.2. Now the action taken by the purchasers of peppermint that the writer has met has been influenced largely by the first view and to a lesser extent by the second. Their view in either case is compounded under very many different influences many of which are qualitative and not quantitative. Indeed it is necessary to go further and assert that there exist influences neither qualitative nor quantitative yet still possessing a power over the decision maker. A trivial example of such influences would be the psychological state of the purchaser. The same man might purchase one day what he has declined the previous day and may even regret the purchase on the following day; the price each day being the same and without any noticeable change taking place meantime in the outside world. The difference between this sort of influence and a qualitative influence is sometimes hard to discern. The aroma from a particular sample of oil is a qualitative influence that would affect the buyer's decision to purchase. The percentage of menthofuran in the oil is a quantifiable influence. Now the aroma may be pleasing to the buyer one day and not on another. Why? It just happens that way, but the factor influencing the decision maker's assessment of that aroma is something else. It is a subtle influence the nature of which was hinted at in Chapter One. A picture was described in which three figures were portrayed in the midst of a grey background. The subtle influences alluded to here might be said to inhabit that background.

So far, the discussion has been concerned with the purchaser influenced, one way or another, and his personal view of the future. In common with other decision makers in industry and commerce, such a person may look to professional advisers to ease the burden of decision. The appropriate advise for a purchaser of a high value-density commodity at a time of price uncertainty might include statistical forecasts. The report presented by the forecaster is likely to be impressive; after some twenty or so pages of analysis the conclusion might be

> 'In conclusion it is the estimate of this forecaster that the price of oil next June will be £5 per lb. The confidence interval of this estimate is £3.50 - £6.50 at the 1% significance level and £4 - £6 at the 5% significance level.'

What should the decision maker do on the basis of such a report? It depends not only on his attitude to risk or on his posture in the face of uncertainty but also on his faith in the forecaster. He has not gained any more definite information than before he asked for the report. He knew the price of oil would lie around £5 but the real question was not 'what are the chances of the price being £5 but 'what will the price be'? Nobody can answer the real question unless they can 'see' the future. It should be pointed out that in such a situation the buyer might purchase at £4.75 but not at £5.25 hence his need for accurate foreknowledge.

The forecaster could make his report in a different form. He might list the probabilities of the price being above $10+\epsilon$ or below $10-\eta$ for various $\epsilon, \eta > 0$ but here again the best course of action will not be immediately obvious to the buyer as is discussed in the next section 5.4.4.

The buyer can look to the technicians for clarification of much of the data on which he will base his decision but the technicians or 'experts' cannot tell the buyer if his decision is the right one. The ultimate decision as to what risks should be taken rests solely on the buyer himself. It is perhaps an awareness of this responsibility that causes some buyers to seek to spread the burden of responsibility onto technical advisers.

5.4.4 Risk and Uncertainty

Some further explanation of the above sweeping dismissal of probability theory is necessary. In classical economic theory it is basic to assume that the businessman wants to maximise his profits. When faced with the choice between two courses of action A and B the first of which results in a gain of £50 and the second in a gain of £75 then it is assumed that B will be chosen. This assumption is not always correct because the typical businessman is only interested in profits so long as they are consistent with the continuance of his business. The continuance of the business is of first importance because without it there is no vehicle for profit making. Profitability should not always be taken as the most accurate guide to that continuance.

The situation is not so clear when action A gives £50 with certainty and B gives £75 or £25 depending on whether a coin lands 'heads' or 'tails'. Consider the case where the choice lies between the actions A_0, A_1, ..., A_n, ... If he decides on A_n he will get either $\$S_n$ with probability P_n or nothing with probability $1-P_n$. The classical rule is to maximize the expected gain E_n which is achieved by picking the action A_n for which the product P_nS_n takes the greatest value. If formulas are available for P_n and S_n and E_n is taken as a continuous function of n then the maximum value of E_n is found by the differential calculus. However, if the probabilities P_r are based on observation over a long period the decision is valid only in the 'long term' sense.

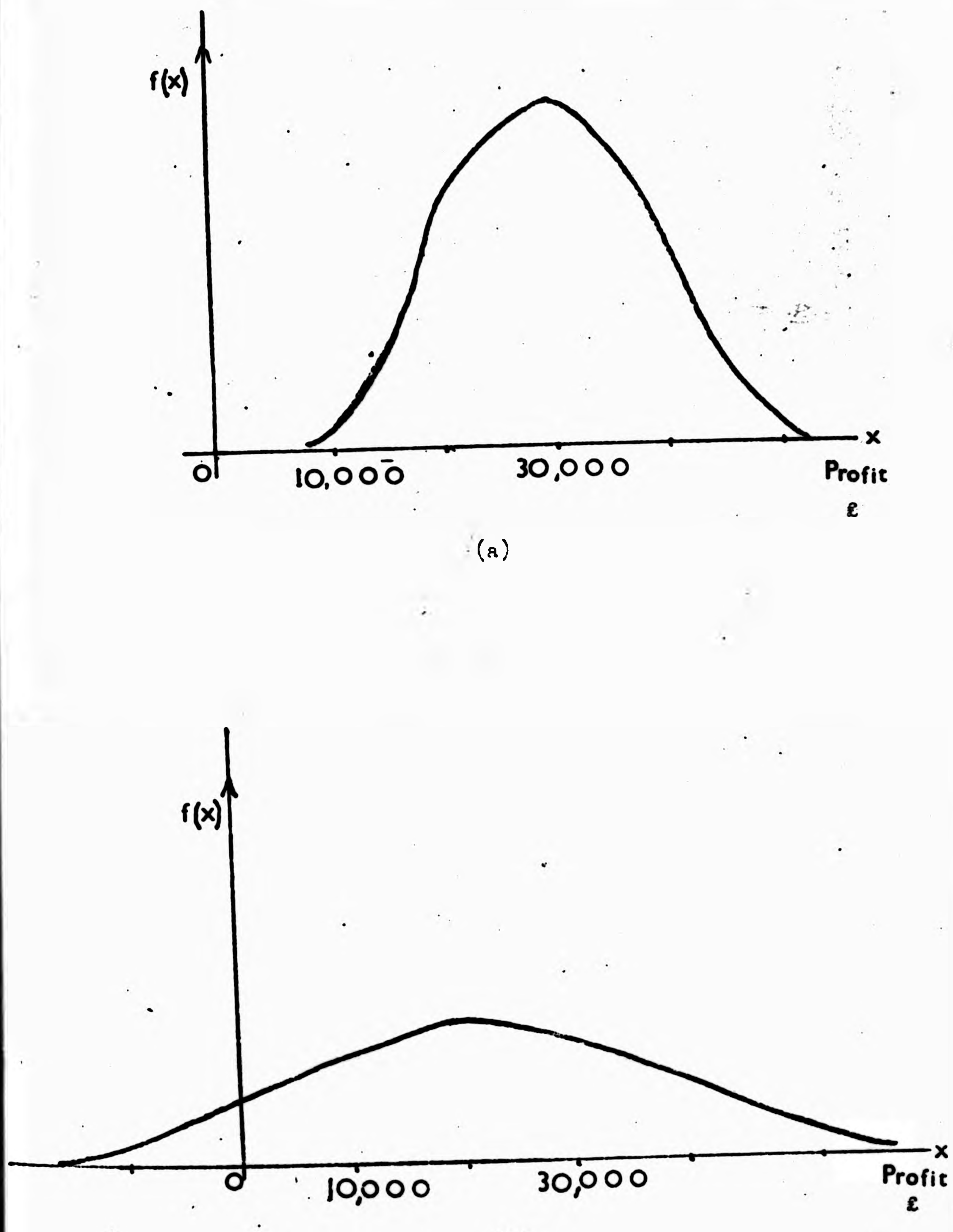

Figure 5.4.3

Probability Distributions of Likely Outcomes of Two Courses of Action

Our buyer is not interested in the 'long run'. He wants to know what to do in a one off situation.

Even where a businessman is presented with a solution, to the choice between two courses of action A and B, in the form shown in figures 5.4.3 (a) and (b) where A leads to the profit distribution in (a) and B to that in (b), the best action is not obvious. What is 'best' here depends on the businessman's attitude to risk, his confidence in the accuracy of the distribution illustrated or on some other general principle. That is to say that what set out to be a normative solution is reduced to a subjective choice.

Even when no uncertainty exists in a decision problem the choice can be difficult. For example when offered two bags containing one orange and one apple in the first and two of each fruit in the second it is usually assumed the second would be chosen. This means that 'more' of anything is better; there is an assumption of non-satiety. It is clear that subjective elements are involved and, moreover, decision-makers may not always make choices which are rational in the economist's simple sense: less fruit may be chosen in order to avoid waste or in order to avoid the guilt feelings that accompany greed. In order to provide a simple framework for discussion, economists postulate that a person confronted with many bags of fruit can arrange them in order of preference. Also it is required that if A is preferred to B and B is preferred to C then A is preferred to C. In economic theory this preferrence ordering is often illustrated by <u>an indifference map</u> which is intuitively and mathematically extended to cover more than the two dimensions discussed here i.e. pineapples and other fruits might be added.

Let x_n represent the number of apples and y_n the number of oranges in the n^{th} bag. Then the preference ordering can be represented by a utility function u(x,y) such that

$u(x_1,y_1) > u(x_2,y_2)$ if and only if bag $\{x_{1a},y_{1o}\}$ is preferred to bag $\{x_{2a},y_{2o}\}$, where a represents apples and o oranges, provided x and y are finite numbers. The representation of a preference ordering by a utility function was discussed by Wold[7] and the relation between the two concepts has been extensively researched by Samuelson and others. To continue this line of discussion one has to assume what is not always true namely that 'everything has its price'. That is if (x_1,y_1) is preferred to (x_2,y_2) there exists

$y > y_2$ such that (x_2,y) is preferred to (x_1,y).

It is not the intention to pursue this discussion here because we have already passed too many assumptions which are open to dispute. The problems of applying utility theory to practical decision-making are compounded when the decision concerns <u>expected</u> utility and the principles to be followed, and the conditions to be met if they are to be valid, are referred to by Borch[8] (1968). These problems are compounded if the decision-maker is not risk-neutral. For the risk-loving manager seeking a one-off solution to his forecasting problem there is no comfort in these ideas which are made unreliable by the number of assumptions on which they are based.

5.5 Formal Approaches and the Practical Decision

It is clear that although the methods employed in the firm under analysis seem uncomplicated, and even primitive, all of the elements of the decision problem are present. The firm would not have been slow to adopt more sophisticated methods IF such methods existed. The fact that they have not tends to highlight the absence of credible and better practical methods than those employed. The essential method is one in which decision is by 'rule of thumb', or standard operating procedure, to use a more impressive term, subject to intervention by a senior decision maker when, as in the case of the commodity in question, circumstances so warrant. Thus the reorder quantity in the case of peppermint oil is subject to the instruction 'CONSULT'. The use of a sophisticated re-order rule, or EOQ rule, is negated in the one case by fluctuating market conditions and in the other by the stability of the quantity demanded per period; this is very much in line with the position indicated by the earlier considerations of possible demand conditions.

In order to apply an EOQ model it would be necessary to incorporate some concept of the cost of capital, the compexities of which have been discussed in 5.2, and the variations in the price. It is in forecasting price changes that the decision maker's attitude to risk will become apparent as the quantities he orders very much depend on his forecasts. In the next section an attempt is made to develop the standard EOQ model to incorporate some of these ideas.

5.5.1 The Standard Replenishment Procedure

An early reference to the most elementary policy for economic order quantity is found in Mellen[9] (1925). A typical model might be as follows

1. Demand. Let the demand be constant at $\underline{a}$ units per time unit. Hence the number of units drawn from stock up to time t after the given origin is at.

2. Price. Let the price be £c/unit. We assume that for any order of whatever size there is a fixed set up charge of £K.

3. Storage or 'rental' charge. For each unit in store there is an associated cost of £r per time unit. Let us suppose that an initial quantity Q is ordered. This will be exhausted after time $T = Q/a$. It is required to choose Q (and hence T) in such a way as to minimize the average cost per unit of time. The overall cost is taken to be composed as follows:

a. Ordering. The ordering cost is the sum of the set up charge and the cost of the material purchased, $K + cQ$.

b. Storage. After time t the stock level is $Q - at$ units and the rental charge on them between t and $t + \delta t$ is $£(Q - at)r\delta t$. Over the period $T = Q/a$ this amounts to

$$r\int_0^{Q/a}(Q - at)dt = \tfrac{1}{2}rQ^2/a.$$

Hence total cost is

$$K + cQ + \tfrac{1}{2}rQ^2/a$$

and the cost per unit time is A, say, where

$$A = (K + cQ + \tfrac{1}{2}rQ^2/a)/Q/a = aK/Q + ac + \tfrac{1}{2}rQ$$

$\frac{dA}{dQ} = -aK/Q^2 + \frac{1}{2}r$ and A is concave upwards. A then has a turning value for $Q = Q^*$ given by

$$Q^* = (2aK/r)^{\frac{1}{2}}$$, which clearly minimizes A.

5.5.2 Modification By Virtue of Appreciation in Value of Stock

Let the predicted increase in value of one unit of stock per time unit be a fraction b of its initial price c. Integrated over the whole time period this reduces costs by an amount

$$bc\int_0^{Q/a}(Q - at)dt = \tfrac{1}{2}bcQ^2/a.$$

Thus the cost per unit time is reduced by $\frac{1}{2}bcQ$ so

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and the cost per unit time is A, say, where

$$A = (K + cQ + \tfrac{1}{2}rQ^2/a)/Q/a = aK/Q + ac + \tfrac{1}{2}rQ$$

$\frac{dA}{dQ} = -aK/Q^2 + \frac{1}{2}r$ and A is concave upwards. A then has a turning value for $Q = Q^*$ given by

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$$bc\int_0^{Q/a}(Q - at)dt = \tfrac{1}{2}bcQ^2/a.$$

Thus the cost per unit time is reduced by $\frac{1}{2}bcQ$ so

$$A = aK/Q + ac + \tfrac{1}{2}(r - bc)Q \quad \text{and}$$

$$\frac{dA}{dQ} = -aK/Q^2 + \tfrac{1}{2}(r - bc).$$

The optimal value Q^* is now given by

$Q^* = (2aK/(r - bc))^{\frac{1}{2}}$ for $bc < r$. If $bc = r$ then the policy should be to order as much as possible consistent with the confidence placed in the prediction. Should there be a predicted decrease in price then b becomes negative and Q^* decreases as it should.

5.5.3 Inclusion of Option to Invest

Suppose that the merchant has an initial amount of capital B which is partly used for the peppermint operation and the rest is invested elsewhere at a rate of d per £ per time unit. Then if a quantity Q of oil is purchased at a cost of £Qc this leaves $B - Qc$ for investment and the interest on this reduces the operating cost overall. This interest amounts to $(B - Qc)Qd/a$ for the whole period $T(=Q/a)$ and the cost A per unit time is therefore given by

$$A = aK/Q + ac + \tfrac{1}{2}(r - bc)Q - (B - Qc)d$$
$$= aK/Q + (ac - Bd) + Q(\tfrac{1}{2}r - \tfrac{1}{2}bc + cd)$$

whence

$Q^* = (2aK/(r - bc + 2cd))^{\frac{1}{2}}$ $\quad r > (bc - 2cd)$. If the denominator is negative or zero then Q^* should be as large as possible but the more attractive the interest rate, i.e. as d increases, then the smaller becomes Q^*. This accords with common sense.

In the next chapter we use these simple models as a yardstick for comparison with the performance of a particular dealer in peppermint oil during the period under study.

5.6 Summary

The chapter opens with a discussion of capital costs. The cost of capital is the cost of obtaining capital for use in financing operations. This cost may be based either on the cost of borrowings from the bank or on the cost of diverting capital from other possible uses or on some combination of the two. For capital invested in inventory the average time that goods remain in inventory before they are sold is a factor determining the cost.

The chapter continues with a description of the stock control system practised by the company with whose help this study was made. The way in which materials are divided into those purchased for manufacturing and those purchased for future resale is described. Different methods of purchase are used in each case. A discussion then follows in general terms of economic decisions made under uncertainty. Reference is made to the peppermint oil situation and both the importer's and manufacturer's decision problems are discussed. The topic of decision making using probabilities and expected values is discussed briefly. The lack of a futures market in peppermint oil is also noted in the discussion on hedging.

The chapter concludes with a restatement of the standard elementary replenishment procedure described in most textbooks. An extension is made to this procedure that takes into account price fluctuations and alternative investment strategies.

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CHAPTER VI

PURCHASING PEPPERMINT OIL FOR INVENTORY: OBSERVATION AND ANALYSIS OF DECISIONS.

6.1 Introduction

The main current of ideas concerning the influence of changes in the levels of prices and interest rates was reviewed in Chapter II and the practical inventory decision was considered within a context of theoretical analysis in Chapter V. In this chapter I shall examine how much oil an individual buyer actually purchased during the eight years under consideration and when he purchased it. In this way the total expenditure on the oil over the eight years can be built up. In calculating the cost allowance is made for stock appreciation and the variation in a fixed capital sum available for investment elsewhere at varying interest rates. Next the standard economic order quantity formula is used over the same period without any regard to fluctuations in price or interest rate to purchase oil at regular intervals. A total expenditure for the eight years is again obtained. Purchases are made at different times over the eight years.* This is used to illustrate the effectiveness of the amended economic order quantity formula introduced in the last chapter. The amended formula is used to determine the amount to purchase with the assumption that price changes can be foreseen accurately twelve months in advance. A constant demand is assumed throughout the period and for further simplification the storage and set-up charges are assumed to remain constant over the eight years. These assumptions have little effect on the results as any changes not only affect each strategy in the same way but are in any case dwarfed by the size of the changes in the prices.

*The amounts spent in each case are not directly comparable owing to the changing value of money (i.e. inflation).

The importance of fairly accurate forecasting is discussed in view of the results obtained. The methods of forecasting used by other researchers in the field of commodity price forecasting are then considered to see if any better results have been obtained elsewhere.

6.2 The Buyer's Purchases

For ease of reference, the prices of peppermint oil and the minimum lending rate (MLR) during the eight years (1971-1978) are reproduced here in table 6 .2.1 The annual demand for the products using

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1971 £/lb	1.74	1.74	1.74	1.74	1.74	1.74	1.80	1.78	1.79	1.79	1.79	1.84
%	7	7	7	6	6	6	6	6	5	5	5	5
1972 £/lb	1.81	1.80	1.89	2.06	2.18	2.34	2.33	2.33	2.44	2.65	2.85	2.85
%	5	5	5	5	5	6	6	6	6	7.25	7.50	8
1973 £/lb	2.82	2.69	2.70	2.69	2.61	2.79	2.97	3.21	3.73	4.90	7.03	7.09
%	9	8.75	8.50	8.25	7.75	7.50	9	11.50	11.50	11.50	11.25	13
1974 £/lb	7.21	7.12	6.88	6.92	6.98	7.01	7.01	7.28	7.25	7.22	8.37	8.30
%	12.75	12.50	12.50	12.25	12	11.75	11.75	11.75	11.75	11.50	11.50	11.50
1975 £/lb	8.38	5.56	5.63	5.74	5.84	6.19	5.35	5.45	5.39	5.29	5.69	5.69
%	11.25	10.75	10.25	10	10	10	10	11	11	12	11.75	11.50
1976 £/lb	5.67	5.91	6.77	7.34	7.81	7.72	7.87	7.87	8.38	15.72	15.15	14.71
%	10	9.25	9	10.50	11.50	11.50	11.50	11.50	13	15	14.75	14.25
1977 £/lb	14.39	14.47	14.39	14.39	14.39	13.23	13.07	13.07	11.43	10.87	10.99	8.72
%	12.25	12	10.25	8.75	8	8	8	7	6	5	7	7
1978 £/lb	8.59	8.63	9.00	9.15	9.15	7.80	7.51	6.06	5.96	4.78	4.64	4.29
%	6.50	6.50	6.50	7.50	9	10	10	10	10	10	12.50	12.50

TABLE 6.2.1 PRICE OF PEPPERMINT OIL AND MINIMUM LENDING RATE 1971-1978

peppermint oil, in the company under consideration, causes the oil to be drawn from stock at the rate of four hundred pounds each month. The annual demand for the oil is therefore 4,800 lbs. So long as the price is not fluctuating it is the buyer's practice to purchase lots quarterly. However during the eight years in question it appears from the quantities that he purchased that in 1973 he foresaw a sizeable price increase in 1974 and in 1976 he foresaw the leap in price at the end of the year that continued into 1977. At one point he considered it worth holding nearly two years supply of oil (see table 6.2.2). The cost to the company of these purchases is detailed in

Weight Purchased (lbs)								
	1971	1972	1973	1974	1975	1976	1977	1978
JAN	1200	2400	1200	-	-	4400	-	1200
APR	1200	-	6000	-	1200	1200	-	1200
JUL	1200	2400	3600	-	1200	1200	JUN 1600	1200
OCT	1200	-	-	-	1200	-	1200	1200

TABLE 6.2.2 WEIGHT OF PEPPERMINT OIL PURCHASED BY A BUYER 1971-1978

table 6.2.3. When calculating the cost of a particular investment strategy we shall take into account the reduction or increase in costs due to an appreciation or a depreciation in the value of stock held, described in 5.5.2, and also include the investment option described in 5.5.3. This means that the total cost C over a period T is given by the formula

$$C = K + Q^{*}c + \tfrac{1}{2}Q^{*}T(r-bc) - (B-Q^{*}c)dT$$

as described in 5.5.3. The values for K, the set-up charge, and the holding cost, r, were estimated by the buyer to be £12 and £0.12 per lb. per year on average over the period. Doubling or halving r and K does not make much difference to the end result in view of the magnitude of the price changes. The initial amount of capital available for investment, B, is taken to be equal to £25,000 since the maximum amount of cash that the buyer had tied up in stock never exceeded this amount.

In January 1971 when the buyer purchases 1,200 lbs. the cost is calculated thus

$$C = 12 + 1200*1.74 + \frac{1}{2}*1200*\frac{1}{4}(0.12-0) - (25000 - (1200*1.74))*\frac{1}{4}*0.07$$

$$= 12 + 2088 + 18 - 401$$

$$= 1717$$

The remaining purchases are costed in a similar fachion to give the results shown in table 6.2.3. The total expenditure over the eight

COSTS £								
	1971	1972	1973	1974	1975	1976	1977	1978
JAN	1717	3600	2961	-	-	6959	- -	10015
APR	1765	-	1149	-	6524	8815	-	10941
JUL	1849	4727	5324	-	5964	8377	JUN 21758	9052
OCT	1829	-	-	-	5776	-	13227	5278

TABLE 6.2.3. <u>COST OF PEPPERMINT OIL PURCHASED BY A BUYER 1971-1978</u>

year period by this company on peppermint oil was £135,309. When asked how it was in April 1973 that he purchased five quarterly supplies at one time the buyer could give no reason except that he felt prices were going to rise considerably more than usual over the next year and that he felt it prudent to lay in a good stock. In July he reinforced this view by buying further stocks. The buyer was not concerned about holding too much oil because he was confident the price would stay firm once it had risen. At the beginning of July 1973 there were twenty-one months supply in stock (or on order) an extraordinarily high amount. He argued further that even if the price began to fall again he could still sell his surplus at a profit. From this it seems that he expected a considerable price increase measured in dollars rather than cents. The effect of doubling both the set-up charge and the rental charge caused an increase in the total cost of £1120 or only 0.8%.

6.3 Purchasing With An Economic Order Quantity Formula

6.31 Without Foreknowledge of Price Changes

The standard economic order quantity formula allows Q^*, the economic quantity to be purchased, to be calculated from

$Q^* = (2aK/r)^{\frac{1}{2}}$ where the demand is a units per time unit, there is a fixed set-up charge of £K and storage charge of £r per time unit. In the case of peppermint oil we have for the particular company under consideration:

a = 4800 lbs. per year

K = £20

r = £0.20 per lb. per year

which gives $Q^* = 100\,(96)^{\frac{1}{2}} \simeq 980$.

If K is underestimated by 10%, $Q^* \simeq 1025$

.... overestimated ...., $Q^* \simeq 930$

.. r .. underestimated ...., $Q^* \simeq 930$

.... overestimated........., $Q^* \simeq 1030$

If both K were underestimated by 10% and r overestimated by 10%, Q^* would still only be about 1080 which would not affect the ordering strategy.

Now as the oil is shipped in drums of 400 lbs. or 200 lbs. this would mean purchasing 1000 lbs. for each order with one of 800 lbs. in January say. The other orders would then be placed in March, May, August and October that is about every ten or eleven weeks. The cost of purchasing with this strategy is calculated in the same way as in

6.2 to give the results shown in table 6.3.1.1 which totals £226,986.

COSTS £								
	1971	1972	1973	1974	1975	1976	1977	1978
JAN	1137	1266	1952	5406	6580	4159	11279	6668
MAR	1425	1644	2440	6432	5225	6287	14216	8759
MAY	1470	1904	2152	6530	5506	7416	14375	9166
AUG	1562	1993	2536	6879	5043	6613	12716	5823
OCT	1571	2294	4181	6698	4803	15603	10926	4351

TABLE 6.3.1.1 COST OF PURCHASES USING EOQ FORMULA WITHOUT FOREKNOWLEDGE

6.3.2 With Foreknowledge of Price Changes

It is now assumed that by some means the user of this formula is able to forecast accurately changes in the price up to twelve months in advance of their happening. This assumption, unrealistic though it may be, is made in order to gauge the improvement in purchasing strategy that can be made using the new formula. We have from the previous chapter

$Q^* = (2aK/(r-bc+2cd))^{\frac{1}{2}}$ where a, K and r are as in 6.3.1 and the predicted increase in value of one unit of stock per time unit is a fraction b of its initial price c, with an interest rate of d per £ per time unit. It is decided to review the stock position every three months unless the stock in hand demands more frequent replenishment. There is a minimum order quantity of 400 lbs.

In January 1971

$Q^* = (2*4800*20/(0.20-0.50+2*4.20*0.07))^{\frac{1}{2}}$

$= (4800*40/(0.288)^{\frac{1}{2}} \simeq 815$ therefore purchase 800 lbs.

In March 1971

$Q^* = (4800*40/(0.20-0.75+0.588))^{\frac{1}{2}}$

$= (4800*40/0.038)^{\frac{1}{2}} \simeq 2225$ therefore purchase 2200 lbs.

In June 1971, 1000 lbs. are still in stock but $r + 2cd \leqslant bc$

therefore the best strategy is to buy as much as possible. A limit of one year's supply is imposed on the amount of stock that can be held at one time as one year is the extent to which our foreknowledge of price changes reaches (this restriction is lifted later). Thus in June 1971 3800 lbs. is purchased. In September 1971 $r + 2cd \leqslant bc$ thus the amount in hand is brought up to its limit by purchasing 1200 lbs. This situation is repeated every three months until March 1974. In that month the drop in price in February 1975 is foreseen and only a further two month's supply purchased. From June 1974 until February 1975 (2cd-bc) is always positive because bc is negative. This means that the amount to purchase will always be less than three month's supply and never more than one month's supply. Meantime the amount in stock is always at least two month's supply until February 1975;

WEIGHT (LBS.)								
	1971	1972	1973	1974	1975	1976	1977	1978
JAN	800	-	-	-	Feb to Aug 400 mnthly	-	-	Jan to Dec 400 per mnth
MAR	2200	1200	1200	800		1200	Jun to Dec 400 mntly	
JUN	3800	1200	1200	-		1200		
SEP	1200	1200	1200	-	4400	400		
DEC	1200	1200	1200	-	1200	-		

TABLE 6.3.2.1 AMOUNTS PURCHASED USING EOQ WITH FOREKNOWLEDGE OF PRICE CHANGES.

therefore no further purchases are made until this date.

From February - August 1975 the minimum order quantity is purchased each month. In September the price rises in 1976 are foreseen and the maximum purchased. This amounts to 4400 lbs. due to the restriction on capital expenditure. It should be noted that if the huge jump in price in October 1976 had been foreseen at this stage the purchase would have been delayed a couple of months hence effecting a considerable saving in cost. The maximum stock is kept until September 1976 and then run down until exhausted in June the following year. With falling prices the minimum quantity is then purchased until the end of 1978. The amounts purchased are shown in table 6.3.2.1. The cost of the purchases made using this strategy are shown in table 6.3.2.2.

	COST £							
	1971	1972	1973	1974	1975	1976	1977	1978
JAN	1137	-	-	-	-	-	-	3333
FEB		-	-	-	2070	-	-	3343
MAR	3298	2025	2937	5209	2114	8021	-	3496
APR	-	-	-	-	2119	-	-	3541
MAY	-	-	-	-	2155	-	-	3537
JUN	5686	2587	2891	-	2316	9238	5177	2957
JUL	-	-	-	-	1962	-	5110	2859
AUG	-	-	-	-	1984	-	5154	2252
SEP	1963	2620	3592	-	23236	3238	4493	2229
OCT	--	-	-	-	-	-	4274	1736
NOV	-	-	-	-	-	-	4328	1635
DEC	2024	3147	8243	-	6673	-	3379	1488

TABLE 6.3.2.2 COST OF PURCHASES USING EOQ FORMULA WITH FOREKNOWLEDGE

The total cost in this case is £176,800.

6.4 The Ideal Strategy

Let us now introduce a speculative element to our purchasing policy by removing the restriction on the amount that can be purchased and held in stock. We now say that the maximum that can be invested in stock is the maximum fixed earlier namely £25,000. In June 1971 £1,740 worth of stock (1,000 lbs.) remains in hand therefore £23,260 is available for further purchases at £1.74 per lb. The amount purchased is 10,800 lbs., enough for a little over two years normal usage, costing £18,792. The total stock held now cost £20,532. By

September £2,088 worth of stock has been used and the price one year ahead is still sufficiently high to warrant topping up the stock at £1.79 per lb. A further 1200 lbs. can be purchased bringing the total stock to £20,592. In December the stock remaining £18,504 is topped up with a purchase of 1000 lbs. at £1.84 per lb. In the same way purchases of 1000, 800, 1000 and 600 lbs. are made in March, June, September and December 1972 respectively. In 1973 and 1974 the amounts shown in table 6.4.1 are purchased. At the end of December 1974 the

	WEIGHT (LBS.)							
	1971	1972	1973	1974	1975	1976	1977	1978
JAN	800	-	-	-	(2000)	-	2000	-
FEB	-	-	-	-	400	1000	-	-
MAR	2200	1000	800	-	400	1000	-	-
APR	-	-	-	-	400	-	-	-
MAY	-	-	-	-	400	-	-	-
JUN	10800	800	800	-	400	1000	1200	800
JUL	-	-	-	-	6400	-	-	-
AUG	-	-	-	-	-	-	-	800
SEP	1200	1000	600	-	1200	1000	1200	-
OCT	-	-	-	-	-	-	-	400
NOV	-	-	-	-	-	-	-	400
DEC	1000	600	-	-	1400	(6400)	2400	400

TABLE 6.4.1 <u>AMOUNTS PURCHASED AND SOLD USING IDEAL STRATEGY</u>

quantity in stock is 2,400 lbs. of which 400 lbs. is needed to last till February. The remaining 2,000 lbs. is resold in January at £8.38 per lb. realizing £16,760. The amounts sold are shown in the table by brackets. This oil was purchased in June, September and part of March 1973 at a cost of £5724 . The sale therefore produces a profit of £11,036 which is added to the capital available for investment making a total of £36,036. From February until June 1975 the price is falling. Thus only the minimum required is purchased. In July the maximum amount is invested in oil and thus £34,240 is spent on 6,400 lbs. The stock is kept topped up until December 1976 when the excess, 4800 lbs., is sold realizing £70,608 . These 4,800 lbs. cost £25,680 so the profit is £44,928 which makes the total available for investment £80,964 . For the remaining two years the price gradually falls and purchases of the minimum amounts consistent with requirements are made at suitable intervals.

The cost of these purchases is calculated in the same way as before.

COST £								
	1971	1972	1973	1974	1975	1976	1977	1978
JAN	1137	-	-	-	-16760	-	26483	-
FEB	-	-	-	-	1883		-	-
MAR	3298	1815	2072	-	1927	6800	-	-
APR	-	-	-	-	1980	-	-	-
MAY	-	-	-	-	2016	-	-	-
JUN	-44573	1832	2081	-	2177	7841	15957	6063
JUL	--	-	-	-	-10573	-	-	-
AUG	--	-	-	-	-	-	-	4618
SEP	2115	2341	2089	-	6297	8000	13983	-
OCT	-	-	-	-	-	-	-	1736
NOV	-	-	-	-	-	-	-	1635
DEC	1810	1662	-	-	7670	-94144	21421	1488

TABLE 6.4.2 COST OF PURCHASES USING IDEAL STRATEGY

For example June 1971 yields a curious result owing to the large amount purchased and the large increase in price anticipated over the 27 months.

$$\textbf{Cost} = 12+10{,}800*1.74+\tfrac{1}{2}*10{,}800*(0.12-(3.73-1.74))*27/12-(25000-(10800*1.74))*27/12$$

$$= -44573$$

The costs are shown in table 6.4.2 and total £5,061 allowing for the negative quantities. This does not take into account the fact that the capital available for investment has been increased by £55,964. The true cost is therefore not a cost but a net profit of £50,903. For ease of comparison the three different purchasing strategies are compared together with the ideal strategy in table 6.4.3. From this it is seen that the company buyer performs best but is still

STRATEGY	TOTAL COST OF PURCHASES £
EOQ formula without foreknowledge	226,986
EOQ formula with foreknowledge	176,800
Company buyer	135,309
Ideal	- 50,903

TABLE 6.4.3. A COMPARISON OF THE COST OF PURCHASES USING DIFFERENT STRATEGIES

left with room for possible gains if he speculates (which he did not do).

6.5 The Significance of Accuracy in Forecasting

The effectiveness of the method outlined in section 6.3.2 depends on foreknowledge of the direction and magnitude of any future price changes if any. Let us consider again the eight years 1971-1978 with a view to seeing how accurate the operator of this method need be with the magnitude of his forecast price changes. Let us consider two cases in both of which the direction of the price change is foreseen correctly. In the first the forecaster always underestimates by 50% the magnitude of the price change; in the second the forecaster always overestimates the price changes by 50%.

6.5.1 Underestimating Magnitude of Price Changes

Let the wrongly estimated increase in value of one unit of stock per time unit be a fraction b' of initial price c and the consequent economic order quantity be Q'^*. Consider first the case where the forecaster underestimates the price changes by 50%. In January 1971 instead of bc = 0.07 we have b'c = 0.04 from which we calculate

$Q'^* = 595$, therefore purchases 600 lbs. In February a similar amount is purchased. In April instead of bc = 0.32 we have b'c = 0.16 which gives

$Q'^* = 1385$, therefore purchases 1400 lbs. In July,

$Q'^* = 1958$, therefore purchases 2000 lbs. In October

$r + 2cd \leqslant b'c$ thus the stock is brought up to its maximum level by

	COST £							
	1971	1972	1973	1974	1975	1976	1977	1978
JAN	892	1960	3102	8416				
FEB	894	-	-	8282				
APR	2065	2260	2919	-	AS IN TABLE 6.3.2.2			
JUL	3207	2542	2911	-				
OCT	5533	2911	5183	-				

TABLE 6.5.1 COST OF PURCHASES WITH UNDERESTIMATES OF PRICE CHANGES

purchasing 3,800 lbs. The eight years continue as in 6.3.2 except for 1974 resulting in the costs shown in table 6.5.1. The total cost of the purchases is £182,524 an increase of £5,700 over the case where the price changes are forecast exactly. It must be remembered that the price changes in the period under consideration are large and halving them has little effect on the purchasing strategy.

6.5.2 Overestimating Price Changes

Now consider the case where the forecaster overestimates the price changes by 50%. Let b' be as in the previous case. In January 1971 with b'c = 0.14, $r + 2cd \leqslant b'c$ hence the maximum amount is purchased. Every three months the stock would be topped up thereafter as in the first case resulting in the costs shown in table 6.5.2. Thus the overestimate of price increases causes the stock to be built up earlier than before when the price is lower. The total cost of the purchases that results is £183,230. This is £6400less than the total obtained using the EOQ formula with foreknowledge of price changes.

COST £		
	1971	1972-1978
JAN	7485	As in table 6.5.1
APR	1859	
JUL	1984	
OCT	1959	

TABLE 6.5.2 COST OF PURCHASES WITH OVERESTIMATES OF PRICE CHANGES

In these eight years therefore an error of 50% in forecasting the magnitude of price changes results in, at most, a change in the cost of purchases of less than 4%. Forecasting the magnitude of price changes accurately is therefore not so important as forecasting correctly the direction which the price change will take.

The forecasting equation obtained by multiple regression analysis produced results that gave 12 months warning of changes in the direction of price movements. The year ahead model was chosen therefore when comparing the buyer's purchasing strategy with the other strategies developed. This was of course an arbitrary choice and the one year's purchasing restriction was lifted in formulating the ideal strategy. It should be noted that at one stage the buyer held nearly two year's stock which indicates the sort of time span that he must have had in mind.

The best forecasting equation obtained using a Box and Jenkins type model was unable to predict the downturn in prices in 1975 nor the upturn at the end of 1975 nor the downturn at the beginning of 1977. The method was not practical for forecasting prices over the period as a whole.

6.6 Discussion

In order to improve on the results obtained using the simple economic order quantity formula in times of price instability it is therefore necessary in the case of peppermint oil to have an accurate forecast of the direction in which price will move, and a fairly good idea of the magnitude of the change, up to twelve months in advance. The various methods of forecasting price examined in earlier chapters have not produced results which one could hope to use successfully in the order quantity formula. Is there something peculiar about peppermint oil that makes its price difficult to predict? Perhaps the method chosen to forecast the price could be improved upon. Research has been made into forecasting the price of other commodities using different methods by others which it is helpful to examine to see if they encountered similar problems. In particular let us examine a study, made by Labys and Granger in 1970[1], of different forecasting methods applied to six commodities.

Their analysis included the following forecasting techniques: (1) single econometric equation (2) simultaneous econometric equations (3) adaptive or exponential smoothing (4) naive or mechanical (5) Box and Jenkins models (6) balance sheet (7) charting and (8) gaming. They eventually used 1, 3, 4 and 5 and an averaged random walk method. To give a background to the work of Labys and Granger, the eight techniques used are briefly reviewed.

6.6.1 The Various Forecasting Techniques

6.6.1.1 Single Econometric Equation

The single econometric equation is the first method used in Chapter IV. The first stage is to discover, according to the principles of economic theory, a set of influences which display a definite relationship to the commodity price series. Once these influences are identified in the form of appropriate variables, they can be arranged into a multiple linear regression. At this stage the explanatory variables must not only be reasonably correlated with prices; they must also be relatively independent of one another (although the degree of independence can, in fact, be relatively low when the equation is purely of a forecasting nature). The only remaining requirement is that the explanatory variables be lagged one or more periods behind the price series. The coefficients necessary for prediction are estimated according to the method of least squares, and greater independence among the explanatory variables ensures that the estimates will be unbiased.

6.6.1.2 Simultaneous Econometric Equations

The simultaneous equation approach has proven to be more useful for predicting annual and quarterly prices. It represents the only method which attempts to include all of the relevant variables in the market and in the economy. When the various market factors are highly multi-collinear as, for example, in production and inventory models, the method becomes less suitable for forecasting. In addition, the expense of constructing a multi-equation system is such that, to be justified, the method must produce forecasts consistently superior to the single equation approach.

6.6.1.3 Exponential Smoothing

The exponential smoothing approach can also be considered a single equation method, but emphasis is shifted from economic influences to a purely statistical analysis of past price behaviour. The method can be applied to annual, quarterly or monthly prices; but it is more effective in the shorter run, where prices may contain seasonal components. Its principal advantage is that under the appropriate circumstances, it can inexpensively supply a large number of routine forecasts. This is the second method used in Chapter IV where a full description appears (see 4.3.2).

6.6.1.4 Naive Methods

The naive methods are extremely simple and normally involve nothing more than a forecast based on a simple or weighted average of the most recent observations. In some instances, the magnitude of previous forecast errors is also taken into account. The principal advantage of this method is that forecasts are practically cost free.

The more simple forms of naive models can be classified as 'no change' and 'same change'. The no-change model is particularly useful for price forecast comparisons since its prediction of no change in prices is that of the random walk hypothesis,

$\hat{P}_{t+1} = P_t$ where $\hat{P}_{t+1}$ is the predicted price at time t+1 and P_t is the current price at time t.

The same change model is slightly different and implies that a particular price will continue to change in the same direction and by the same magnitude as the previous change. Thus the best predictor of next period's price change is the current price change,

$\Delta\hat{P}_{t+1} = P_t - P_{t-1}$. Expressed in terms of price levels it becomes a weighted sum $\hat{P}_{t+1} = 2P_t - P_{t-1}$.

6.6.1.5 Box and Jenkins

The naive forecasts are based on very simple models independent of the actual data. One would usually expect to produce better forecasts by considering a wider class of models and then finding the particular model of this class which apparently best fits the past data. An interesting class of models is that suggested by Box and Jenkins and described in Chapter IV.

6.6.1.6 Balance Sheet Approach

The balance sheet approach is used where commodities are traded on the world market. In particular, the supply and demand for a commodity must be spread over a sufficient number of countries such that the world totals are the most important influence in price determination. Under these circumstances, only annual prices are likely to be of interest. The principal advantage of the method is that it provides a means of prediction in a situation where the lack of extensive data prevents econometric or statistical analysis. Its principal drawbacks, however, are not only its high cost in terms of data collection and maintenance but its subjectivity. The method consists essentially of building up a picture of world demand and supply and of determining their relative effect on price. The writer feels this is simply an elaborate way of describing the price forecaster's gathering of experience.

6.6.1.7 Charting

The price following method of the chartist differs considerably from the above methods of the economist and the statistician. Their only resemblance is that charting also relies on the past history of prices. Charting is more popularly known in stock market applications where it is referred to as 'technical analysis'. The chartist follows the attitude that any attempt to follow supply, demand or new information leads to substantial forecast error. Market action is the best guide to forecasting prices; accordingly, the patterns which develop in price formation provide the best indication of whether prices are going to rise or fall. Furthermore, it is only these patterns which furnish a reasonable estimate of the relative strength of demand and supply. While such an approach may be irrelevant for quarterly or annual price movements, some speculators believe that it is useful for predicting shorter run price movements.

To forecast price changes by the charting method, which to many smacks of necromancy, one must be attentive to the actual geometric patterns which prices form. These may take the form of triangles, head and shoulders, or tops and bottoms. The basic philosophy of charting is that patterns will repeat themselves. The chartists claim that by identifying a particular pattern or trend developement, one can subsequently predict the extent of price movement as well as the timing of turning points. It must be pointed out though that any configuration of prices can give rise to different interpretations by different people. The method has the merit therefore of allowing a an individual's intuition to play a part in the forecast. However it should be emphasised that the individual produces the forecasts and the method is really incidental.

6.6.1.8 Gaming

Gaming has been suggested as a possible method for predicting commodity price fluctuations. That simulation, principally in the form of a business game, can be applied to the problem of commodity price fluctuations can be understood from some of its characteristics. Games can describe a competitive situation; include a large number of players or traders; lead to a minimax or determinate solution; and, lastly, can be constructed to provide a scenario of almost any market. Their principal advantage is that the results of each period of play are fed back into the decision process for the following period. This provides a degree of realism for commodity markets since traders are constantly evaluating opinions of others as to what the price should be. At the same time, the approximation of reality is a drawback for gaming. One must be able to abstract from the real market of commodity price fluctuations to obtain a workable set of economic relationships. If this set becomes too large, then the simulation process becomes too costly to produce efficient results. Since many random elements such as new information influence commodity markets, it is doubtful that this method could ever produce any meaningful forecasts.

6.6.2 The Application of the Forecasting Models

For their study Labys and Granger chose six commodities. These were soybean oil, cottonseed oil, soybean meal, soybeans, rye and wheat. To each commodity they applied the four forecasting techniques; single econometric equation (6.6.1.1), exponential smoothing (6.6.1.3), simple random walk (6.6.1.4), and Box and Jenkins (6.6.1.5). They also used the random walk hypothesis in conjunction with average monthly data to produce an averaged random walk model which was also applied to the six commodities. In each case they found that either the averaged random walk or simple random walk model best described the runs of data applied, of five models tried. They summarise their results as folloes:

> 'Using only twelve pieces of data it is obviously difficult to differentiate between two very similar models. The models we have called the simple and averaged random walks do, in fact, differ only slightly when producing forecasts. For all of the six commodities considered one or the other of these random walk models seems to provide the best forecast. The weight of evidence suggests that the averaged random walk, when using averaged monthly data, provides almost the best available forecast for five of our six commodities. This suggests that the simple random walk will

> prove to be, at worst, an excellent approximation to the truth when using end-of-month closing prices. The only commodity which seemed to be clearly different from the others was rye, for which the simple random walk model proved to be the best.
> The fact that we have not been able to find a consistently better forecasting model than random walk is surprising. It is true that in other speculative markets, particularly the stock market, the random walk model has not been improved upon when using monthly data. However, commodity markets are less active than a stock market, involve fewer participants, in some cases have prices exhibiting seasonal components, and they can feature real supply and demand pressures. All of these factors suggest that one could predict price changes. The results do not confirm that belief. It seems that information on supply and demand pressures, for instance, is largely in the public domain and so is already reflected in the price. Any new, unexpected piece of information then causes an unpredictable change in price. If this is true then it seems that the efforts made by some companies to determine the current supply or crop situation before it is generally known may be worthwhile if it can be shown that the market reacts strongly to news about supply. However it is quite possible that price changes due to speculative activity swamp those due to demand and supply information '.[2]

The best results obtained by Labys and Granger as measured by the proportion of variance of price change explained by the model was 33% which illustrates well the extreme difficulty in finding a model to predict commodity price changes.

6.6.3 Random Walk

In their conclusion, Labys and Granger state that they have been unable to find a consistently better forecasting model than random walk. Their conclusion was anticipated by Kendall[3] in 1953 who made an analysis of twenty-two price-series ranging from Chicago spot prices of wheat to iron and steel. He began by constructing models to fit the data only to find that the pattern of events in the price series was much less systematic than was generally believed. His results were broadly speaking as follows

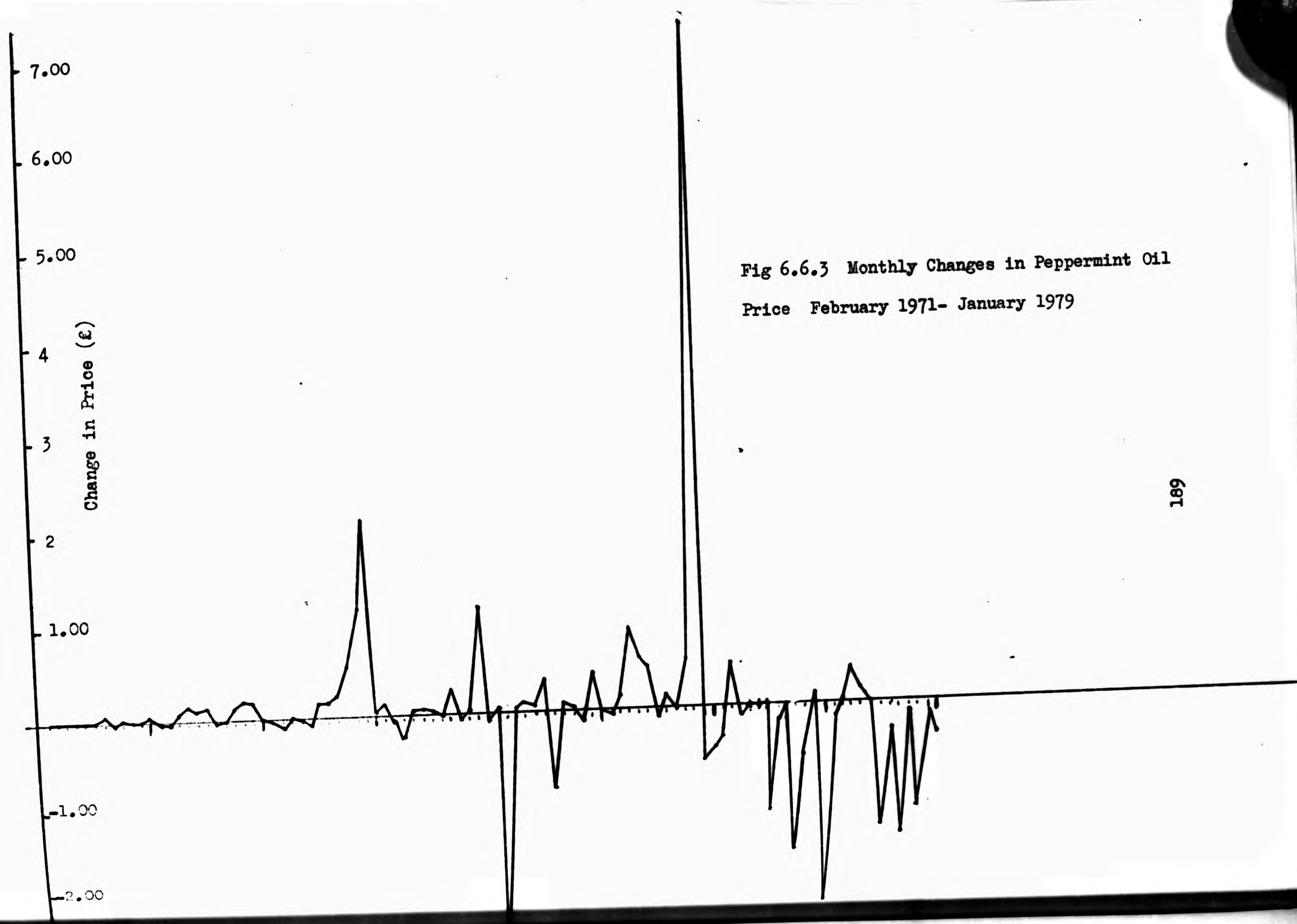

Fig 6.6.3 Monthly Changes in Peppermint Oil Price February 1971- January 1979

' (a) In series of prices which are observed at fairly close intervals the random changes from one term to the next are so large as to swamp any systematic effect which may be present. The data behave almost like wandering series.'

This conclusion is supported by looking at the changes in our price series for peppermint oil which are shown in table 6.6.3 and illustrated in fig. 6.6.3.

CHANGE IN PRICE								
	1971	1972	1973	1974	1975	1976	1977	1978
JAN	0(1979)	-0.03	-0.03	0.12	0.08	-0.02	-0.32	-0.13
FEB	0	-0.01	-0.13	-0.09	-2.82	0.24	0.48	0.04
MAR	0	0.09	0.01	-0.24	0.07	0.86	-0.08	0.37
APR	0	0.17	-0.01	0.04	0.11	0.57	0	0.15
MAY	0	0.12	-0.08	0.06	0.10	0.47	0	0
JUN	0	0.16	0.18	0.03	0.35	-0.09	-1.16	-1.35
JUL	0.06	-0.01	0.18	0	-0.84	0.15	-0.16	-0.29
AUG	-0.02	0	0.24	0.27	0.10	0	0	-1.45
SEP	0.01	0.11	0.52	-0.03	-0.06	0.51	-1.63	-0.10
OCT	0	0.21	1.17	0.03	-0.10	7.34	-0.56	-1.18
NOV	0	0.20	2.13	1.15	0.40	-0.57	0.12	-0.14
DEC	0.05	0	0.06	-0.07	0	-0.44	-2.27	-0.35

TABLE 6.6.3 MONTHLY CHANGES IN PEPPERMINT OIL PRICE FEB.1971-JAN.1979

' (b) It is therefore difficult to distinguish by statistical methods between a genuine wandering series and one wherein the systematic element is weak.

(c) Until some way has been found of circumnavigating this difficulty, trend fitting, and perhaps the fitting of any model, is a highly hazerdous undertaking.....'

In short the future path of the price level of a security (or commodity) is no more predictable than the path of a series of cumulated random numbers.

The first premise of the random walk is that the market is efficient that is to say a market where numbers of rational profit maximising buyers and sellers are competing, with roughly equal access to information, in trying to predict the future course of prices. The second premise is that stocks do have an equilibrium price and that at any point in time the price of a stock will be a good estimate of its equilibrium, the equilibrium price depending on the earning power of the stock. The actions of the many competing participants should cause the actual price of a security or commodity to wander randomly about its equilibrium price,

The beliefs of the followers of charting, described briefly above (see 6.4.1.7), are diametrically opposed to those of the random walk theorists. In support of the critics of random walk one can question the first premise that the market is efficient, that it is a market where numbers of rational, profit-maximizing investors are competing. Human beings, even professional commodity buyers, are certainly not 100% rational and could not be human if they were, but more like a machine. The statement 'there is nothing so disasterous as a rational investment policy in an irrational world' has been attributed to Keynes. No one has yet learned how to put emotions into serial correlation coefficients and analyses of runs. It is true that statistically the price of a commodity has no relation tomorrow to what it was yesterday. But people do have a memory that extends from day to day and is bound to affect their judgement.

Meantime there are not known to be many rich Chartists and Random Walkers. Successful investors, on the other hand, employing no identifiable system,are known to exist (e.g. players in the stock exchanges and football pools). Perhaps they are the lucky holders of serial runs: perhaps they are more rational, or have better access to information or, more simply, they are perhaps better students of psychology. One quality that they will all possess is intuition.

Intuition is an immediate apprehension by the mind apparently without reasoning. The dictionary defines it as immediate apprehension by sense. It is likely to be this quality of intuition that the successful price forecaster possesses, and is the key to his success. At the same time intuition is as yet incapable of physical modelling and therefore cannot be 'fed into' a potential forecasting method. Perhaps this is another reason for the lack of successful methods.

6.7 Summary

The first part of the chapter is taken up with examining the amounts of peppermint oil actually purchased over the eight year period by a buyer. The costs of his purchases are calculated. The standard economic order quantity formula is then applied over the same period without any regard to fluctuations in price. The purchases of oil made at regular intervals in amounts determined by the formula are then totalled to give a sum nearly 70% higher than that actually spent by the buyer. The economic order quantity formula that takes account of fluctuating prices and interest rate is then applied with the assumption that prices have been accurately forecast for up to twelve months in the future. The purchases of oil made in amounts determined by this formula are totalled to show a considerable improvement on the standard formula. The sum is still some 25% higher than that actually spent by the buyer.

In a search for better forecasting methods work by other researchers in this field is examined, which considers six forecasting methods, three of which we have already used, applied to various commodity prices. Their conclusion was that only a random walk could suitably describe the price series. A brief discussion of random walk concludes the chapter, showing that our peppermint oil series can be classified in this type.

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CHAPTER VII

PRICE INSTABILITY AND THE INVENTORY DECISIONS OF THE FIRM

7.1 Introduction

In this chapter, the various influences on the inventory decision are summarised and the way in which they contribute to the decision are considered in principle. In doing this, the extent to which the problems encountered are fundemental, rather than merely specific to the firm and the commodity studied, should emerge.

The previous chapters have been concerned with various aspects of the market conditions relating to a commodity, peppermint oil, which embodies in its high value, susceptibility to speculation and rapid price change some of the characteristics of commodities which are likely to cause problems for purchasing officers and their superiors in manufacturing firms. The study has also considered the actual course of price fluctuations of this commodity and the problems of attempting to predict future prices since these matters have a fairly clear connection with the level of inventories to be held. Naturally some revision of the standard inventory models has been necessary in order to accomodate price predictions. In combining price forecasts and inventory models, however, it became clear, at least in the case studied, that the practical decision maker, attuned to changing market conditions, was able to out-perform the more mechanistic approaches to inventory decision making.

In this chapter, the elements of the situation are reconsidered in order to assess the extent to which attempts to apply price forecasts, produced by some routine method, to inventory decisions must necessarily produce questionable results. Further, we examine the extent to which the relatively poor performance of the methods suggested is due to (1) inadequacies in the particular forecasting methods,

(2) peculiarities in the market conditions for peppermint oil and

(3) the large price rises in 1973-1974 and 1976.

Finally, the question is considered whether the favourable performance of the decision-maker in the firm, when compared with that produced by the other methods tried, is due to some unusual prescience of the particular buyer or is to be expected.

7.2 The Economic Structure of the Market

The market for peppermint oil, as for many other commodities, is by no means a simple one in which the major influences can be isolated and expressed in the form of two structural equations and an equilibrium condition. To some extent, the variables on the supply side have tended to become less important as technology, for instance in respect of irrigation and pest control, has superseded purely natural factors. Yet the overshadowing variable is the acreage under cultivation which depends largely on the farmers' expectations of the price that he will receive. His decision as to whether he should increase or decrease his acreage will depend upon how that expected price compares with his price expectations for alternative crops.

This sort of situation is one which might give rise to the oscillations in price described by the 'cobweb theorem' in economics. The figures that we have for the price received by the farmer do not lend themselves to this idea. It is true that in 1973 and 1974 a sort of 'expanding cobweb' situation existed but this was due to the farmer catching up on the difference between the prices he was receiving from the dealers and those pertaining on the open market (see section 4.4).

After those years the price received by the farmer has been a steady proportion of the market price used in this study. The market price has tended to oscillate in an unpredictable manner and there is not enough evidence to show whether this is a perpetual oscillation or a damped oscillation that will settle to an equilibrium price. This writer suspects that it is a mixture of the two with periods of erratic behaviour being followed by periods of stability and so on.

On the demand side, the picture is complicated by the monopsonistic power of a small number of dealers, although this, itself, has provoked countervailing moves among growers in the area studied. Between the importer/manufacturer whose inventory decisions have been studied and the dealers buying the peppermint oil from the farmers, however, lies another level of trading; that between dealers and brokers. This level is complicated by the fact that some dealers are active on both sides of the market having a broking side to their businesses.

It is at this stage of trading between the dealer/brokers and the importer/manufacturers that the price oscillations discussed above tend to be generated. Both sides hold stocks of peppermint oil and it depends on the size of their stockholdings as to which side has the advantage. If the broker holds high stocks he will be anxious to lower them when he believes prices have peaked hence will be susceptable to lower prices. When the importer has high stocks he can resist high prices better than when he has a need for stocks. Our study has thrown up a good example of this in the firm studied (see Chapter VI). The scope for price fluctuations is greater at this level of trading than at the level between farmer and dealer.

It may help to consider the block diagram fig.7.2 at this point. Here

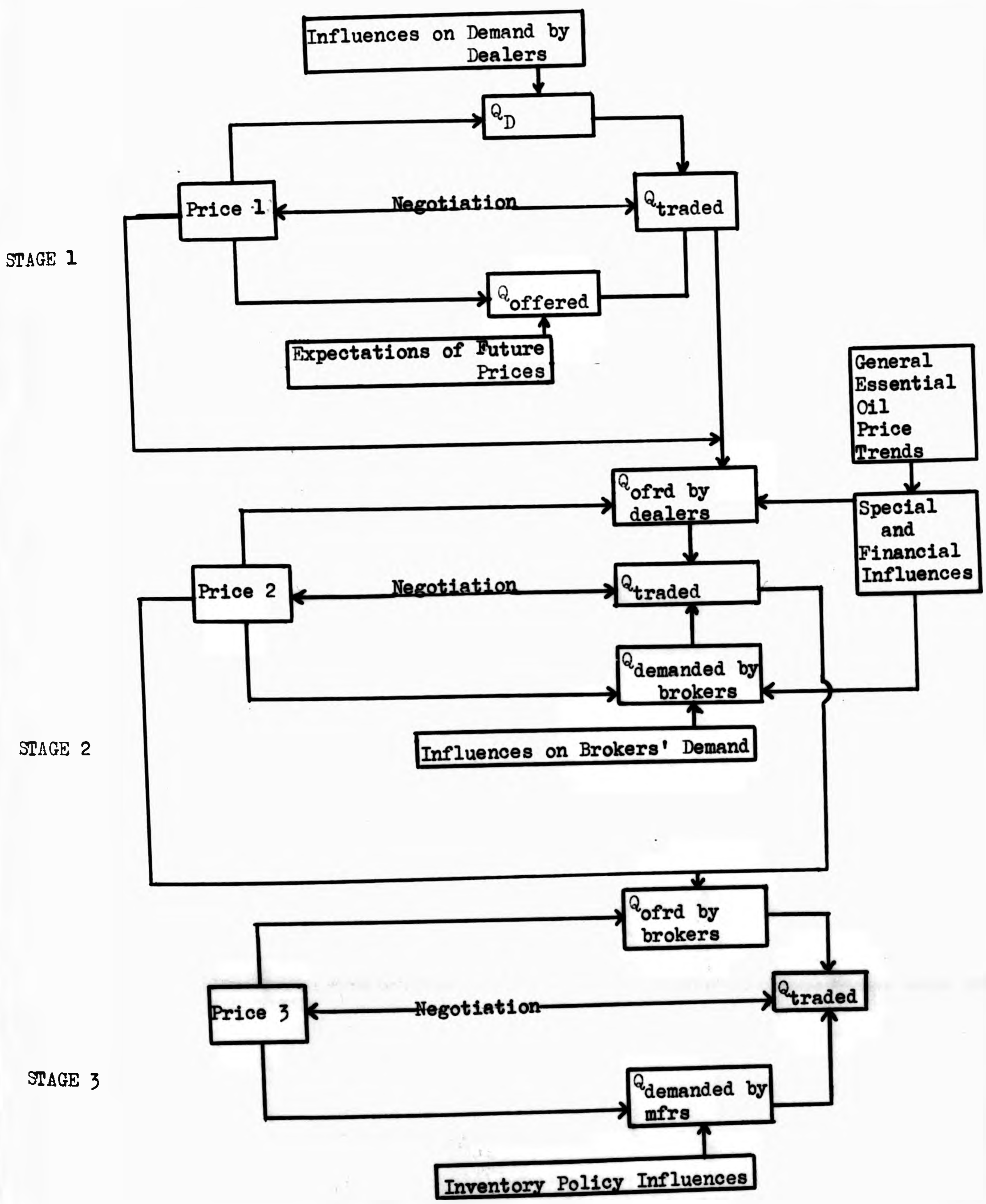


Fig. 7.2 **The Three Stages of Price-Formation**

we see the three stages over which the price is gradually formed. At the first stage the quantity demanded by the dealers, Q_D, together with the quantity offered by the growers, Q_{OFF}, give rise through negotiations to a price. The influences on Q_D are the price the dealer expects to ask from the broker, his physical and financial capacity to store oil and his concern with keeping his sources of supply solvent enough to continue growing not to mention his longer term view of future prices. The quantity traded together with the price paid by the dealers influences the quantity offered by the dealers in the second stage. Also influencing them here again will be financial considerations such as the capital available for holding stock, the cost of that capital and possible alternative uses for that capital. Here the attraction of other essential oils may play a part and hence the appearance of the General Essential Oil Trends block in the figure.

In the second stage the processes of the first stage are repeated. The demand made by the brokers will be influenced by their expectations of how much they will be able to resell. These expectations will depend on the price at which they can offer the oil for sale in stage three. Other influences will be the prices of other oils and again the financial conditions pertaining at the time of negotiations. Once trading has taken place the price at which the trade was made and the quantity traded initially determine the amount offered by the brokers and the price they demand.

The third stage is then entered where the manufacturer's demand is set against the broker's supply. Influencing the manufacturer's demand is his inventory policy, and vice versa, which will include financial considerations and his knowledge of the prices that his end users will tolerate. So here again the price that he is asked to pay plays an important role in determining the quantity he can purchase.

At every stage then we can see that both sides in each negotiation are influenced by factors some of which are easily recognisable and quantifiable and others of which are both indeterminate and nebulous. These are the 'expectation' factors such as, for example, when the dealer in stage one is influenced by expectations of the price he MIGHT receive in stage two. These expectations are themselves influenced by his perceived state of the world and other more intangible factors such as those discussed in section 7.6.2. The price-formation process was compared in an earlier chapter with the formation of a raindrop because of the nebulous nature of these expectations.

A rigid categorisation into three levels of trading is, it will be appreciated, a considerable simplification. The dealer who acts also as a broker has already been mentioned whilst the writer knows at least one case where the importer/manufacturer trades directly with the dealer and has even resold oil back to the dealer. However, it is at the final level, the price to the manufacturer, that this study is concerned. A successful trader at the manufacturing level would have to be aware, one might imagine, of all these influences, have some idea of their relative importance and the timing of their interactions in order to evolve his optimal purchasing strategy.

However at the time when a manufacturer is making his speculative purchases he is forecasting prices which have yet to have begun to be formed and thus even stage one has not been reached. The daunting fact then becomes apparent to the analyst that knowledge of the economic structure of the market is not necessary to the price forecaster.

7.3 Essential Oil Price Speculation and Arbitrage

In conversations and correspondence with dealers and manufacturers in the peppermint oil business one common quality clearly emerged. They were neither risk-neutral nor risk-avoiders but rather risk-preferers who were deeply engaged in speculative activities. It was clear that much of their 'utility' was derived from the risk and financial danger inherent in their activities.

Arbitrage is defined as 'traffic in bills of exchange drawn on various places or stocks to take advantage of the difference in prices and rates in the various markets'. The idea of arbitrage dealings can be extended to other market situations. The speculative activities mentioned above were likely to include arbitrage between peppermint oil and other essential oils and also between the oils, including that studied, and stocks and shares. This means that the amount of money which buyers wish to invest in peppermint oil will depend to some extent on the course of other essential oil prices, since peppermint oil is likely to be just one of several oils in their 'portfolios', and on financial conditions such as the cost of capital. Arbitrage differs from pure price speculation in that it involves profit from imperfections between the different sectors of a market. Speculation on the other hand involves making profits from the uncertainties concerning price that exist from one period to another.

In the case of the manufacturer peppermint oil is just one of hundreds of essential oils that he purchases. So far as investment in other commodities unrelated to their manufacturing requirements is concerned no evidence has been uncovered that the manufacturer places cash uninvested in essential oils in any market otherthan the financial one. So far as the firm studied was concerned surplus cash awaiting a suitably priced oil was not placed in stocks and shares but rather on short-term deposit. The interest rates that such cash could earn, even when at the high level of 15% in October 1976, were never enough to provide a serious attraction for funds. The capital gains to be made in the speculative side of the business were much higher, sometimes 300-400%, than the additions to capital from interest. Even the manufacturing side of the business expected to make a return on capital at least twice as high as the best interest rate.

The impact of interest rates on the buyer's expectations of future prices is another matter however but would vary from buyer to buyer and in any case be difficult to quantify.

Theoretically then if peppermint oil is priced high as compared with the generality of related oils then it is advantageous to sell. The effect, theoretically, is to keep the prices of related commodities 'in line' with each other. The reality of the market in essential oils is of course not so tidy. Coming from all over the world as they do, political factors and weather alone can play havoc with an individual oil's price so that it bears no relation to the 'average' price levels and their movements. To rely on any such theory of arbitrage would be an extremely hazardous undertaking for the potential speculator.

What is important in this discussion are the expectations, held by the buyer, of future price movements. In mathematical models the usual way of including price-expectations is to look into the past. The expected price is taken as the weighted average of all past prices with the weights geometrically declining and summing to unity. Thus the expected price P'_{t+1} in the next period is given by

$$P'_{t+1} = (1 - \lambda) \sum_{k=0}^{\infty} \lambda^k P_{t-k}$$

which, on suitable manipulation gives the well known smoothing model

$$P'_{t+1} = P_t + \lambda(P'_t - P_t).$$

This model has already been examined closely in chapter IV and found, at least for the peppermint oil price series, to give poor forecasts of future prices. It has been pointed out that the problem with this and related models is their basic assumption that past prices give rise to current and future prices. With the benefit of hindsight this may appear to be so but one can never be sure when a turning point in a price series has been reached. This means that at each period there is doubt about whether the trend will persist or be reversed. The determination of turning points is the stumbling block of all such price forecasting models.

7.4 The Inventory Decision and the Manufacturing Firm

7.4.1 Influences on the Firm

The commercial and financial influences common to most UK firms during the period studied have been discussed earlier but two factors deserve a final mention. The first is that firms using a high value input are under especial pressure to follow an alert purchasing policy in times of rapidly changing prices and to ensure that the capital tied up in stocks is working for the firm as hard as possible. At times the stresses induced have been greater due to the emergence of paper profits caused by stock appreciation, which for a time were liable to UK tax in spite of the fact that they did not confer the usual benefits of increased profitability. The second aspect is more specific to the company studied and that is the existence of one large price-sensitive customer for a peppermint flavoured concentrate. While demand for the concentrate does not appear to have fluctuated greatly, failure to

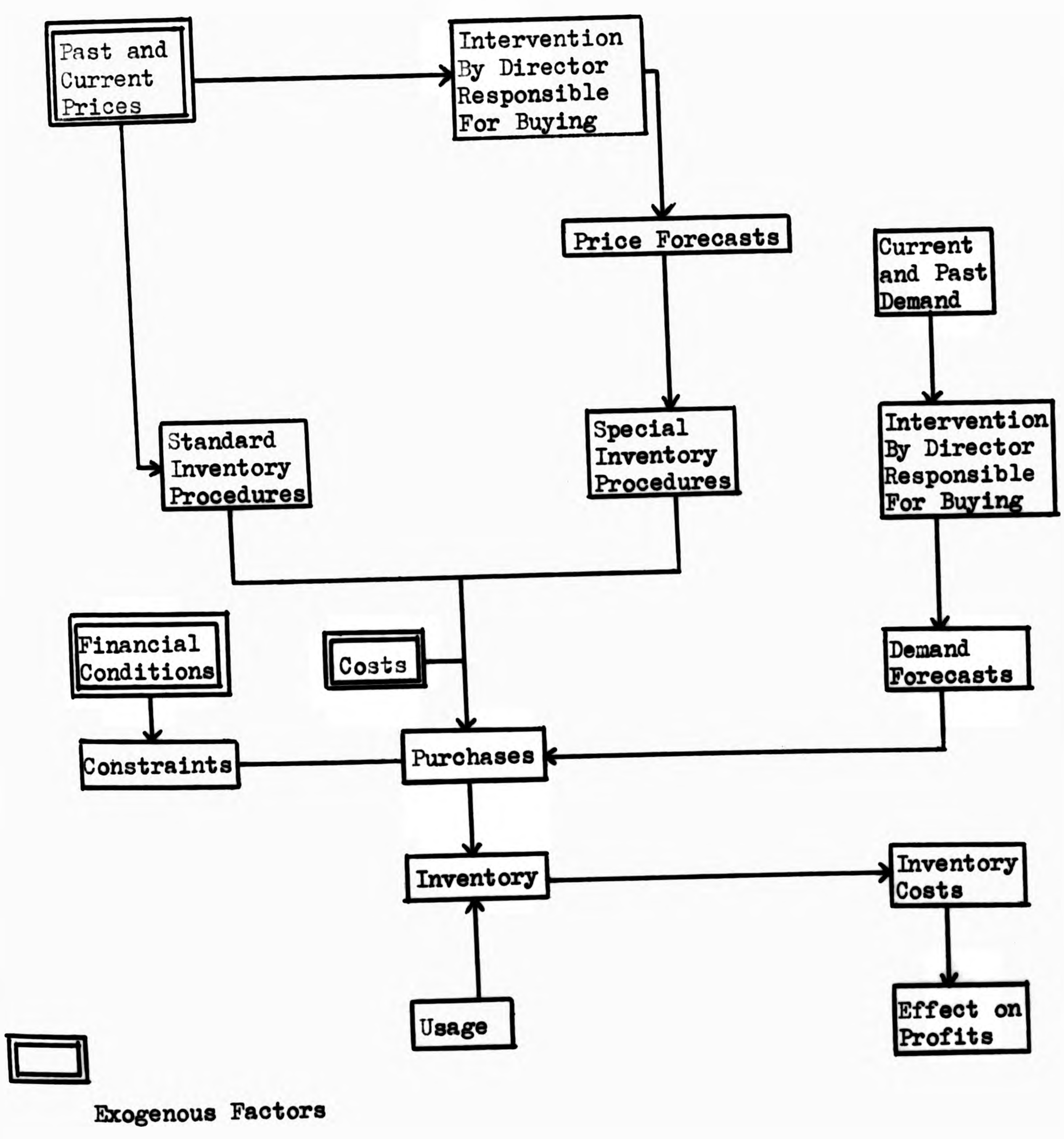


Fig 7.4 The Inventory Decision of the Firm

trade at competitive prices would have led no doubt to falling sales of the products. In both cases, input prices were clearly a matter of concern.

7.4.2 The Inventory Decision

It may be helpful here again to illustrate the various influences on the inventory decision of the firm with the aid of a block diagram (see fig. 7.4). At first glance we can see that the director responsible for buying is an important influence. He is subject to his 'system of beliefs' about the state of the world and to his perception of past and current events. He produces the price forecasts for those oils which are prone to fluctuations in price. These forecasts are utilised in the special inventory procedures where allowance can be made for speculative purchases. Those oils whose prices are relatively stable are dealt with under the standard inventory procedure. The director responsible for buying again appears in the forecasting of demand. The costs associated with purchasing and holding stock together with the financial conditions prevalent such as the cost of capital are the other inputs to the 'purchases' block. The amounts purchased are the positive input to the inventory whilst the 'usage' block represents the negative side.

Now if the director responsible for purchasing is removed from the decision making process the block diagram would remain very similar to figure 7.4 with only a few alterations. The major change would be the use of a model to make the price forecasts. The demand forecasts would also be modelled but would lack some of the information previously supplied by the director such as the price at which customers might no longer be attracted by the end product. The least price that can be asked is dependent on the price paid for the oil in the first place.

The inventory procedures would be replaced by purchasing models such as the EOQ models discussed in Chapter V.

It is clear that a great deal of richness of influences is lost in the removal of the director responsible for purchases. The many influences on the 'buyer', including his perceptions of market conditions are lost as is his 'system of beliefs' about the state of the world. But it is the intuitive flair that the successful forecaster possesses that is most hard to replace. The models that can be substituted for his function can not even begin to approach these sort of highly individual factors.

The inventory decision is seen then to be dependent on a network of information strands, few of which are likely to have been susceptible to analysis in a formal sense at the level of the single firm. In attempting a formalisation, two components can be modelled: the price forecast and the decision itself. It is not necessarily a drawback that many aspects of reality are omitted from a formal model; models are by their nature simplifications and abstractions. In the case considered, however, one component, the forecast, was shown to be inaccurate even with the best methods available. The other component, the inventory decision model, although improved to show the effects of predicted price changes and alternative investment opportunities, even with the artificial assumption of perfect price anticipation performed less well than the buyer in the firm.

It appears then that the senior manager's attitude to risk, intervening to buy at just the right time, and his'feel' for the market are of central importance in the inventory decision. It is hard to see how a machine based system could begin to embody attributes of this kind.

7.5 Forecasting Methods and the Inventory Decision

It has been seen that forecasting price changes is necessary for around half of the items carried in stock by the manufacturer studied. Forecasts are necessary both for oils being purchased for the company's own use and for oils being purchased on a speculative basis possibly for later resale. The two cases intermingle and are not separable because often stock purchased for future resale is used to replenish the stock required for manufacturing. In attempting to formulate the inventory decision then it has become clear that an accurate price forecasting method is vital.

7.5.1 Further Comments on Box and Jenkins Method

Tests have been made of various forecasting methods in earlier chapters. It is generally acknowledged in the literature that of the methods developed to date that most likely to succeed is due to Box and Jenkins. The Box and Jenkins method was applied to the peppermint oil data with a singular lack of success. This is not an isolated occurrence. Chatfield and Prothero (1973)[1] applied a Box-Jenkins analysis to some sales figures. In their case four models fitted the data with about the same accuracy but gave quite different point forecasts. They ended up selecting the model which appeared to give the most reasonable forecasts when examined visually and question whether 'Bold Freehand Extrapolation' might not have been better used in the first place. Box and Jenkins made the curious and rather weak reply[2] that 'alternative and traditional common-sense forecasting methods - - - - are for the most part special cases of the ARIMA models'. The ARIMA class of models is described in Chapter IV. Chatfield and Prothero's response[3] to this was that although it may be true it doesn't follow that the Box-Jenkins forecasts will be better than or even as good as other forecasts. They instance regression models where it is easily shown that the Box-Jenkins procedure is less efficient. Their remarks about distinguishing between models was borne out in the case of peppermint oil (see Chapter IV appendix).

7.5.2 General Remarks on Forecasting

Is there perhaps something faulty in our approach to the forecasting problem? Chatfield and Prothero concluded their above mentioned application of the Box-Jenkins analysis with some more general remarks on forecasting. They point out that the first consideration in selecting a forecasting procedure is how the forecast is to be used. They list three main ways in which forecasts are useful. Firstly as a 'standard' with which the actual performance may be compared. Secondly in stock control, production control and other planning applications. Thirdly in decision making, although this last is already inherent in the first two. They remind us that most statistical forecasting procedures are univariate being based solely on past values of the variable to be forecast. For planning decisions they recommend multivariate models, to which the writer would add that only multivariate models based on reliable leading indicators are of any practical value (see Chapter IV). They then make the revealing remark that even where a multivariate model is available one is still extrapolating from the past into the future, '- - - with all the inherent dangers. If the structure changes, then the forecasts may be incorrect, so clearly one should always be prepared to modify forecasts in the light of other information'. This is indeed close to the root of the forecasting problem for the structure is always changing when dealing with such variables as those provided by commodity price series.

Other research also calls into question the usefulness of attempting to produce forecasting methods. The observations of I.C.I. (1964)[4], for example, concerning salesmen and forecasts of sales figures might equally well be made on buyers and prices of commodities. I.C.I. suggest that if a company manufacture only a few items then the salesmen concerned can probably produce the best forecasts by subjective methods; it is assumed that by subjective methods they mean largely intuition. This is generally frowned upon in academic circles, say Chatfield and Prothero, but the evidence available seems to agree that subjective methods may often be superior. Gearing (1971)[5] gets better results with a rule-of-thumb technique than with an adaptive smoothing method whilst Myers (1971)[6] says forecasting should never be entirely objective and recommends extrapolating by eye then estimating the effects of external factors on a subjective basis. Chatfield and Prothero call for a method of making a fair comparison between subjective and statistical methods which is to this writer a call in vain. So called 'subjective methods' are largely intuitive guesses about the future based on the individuals past experience and his psychological make-up as has been discussed already. Comparing forecasts made in this way with extrapolations, however disguised, produced statistically is not comparing like with like. It is about as useful as trying to compare the flavour of an apple with that of an orange.

In principle then it is questionable whether we should be trying to produce forecasts objectively and a clear examination of the qualities employed by the forecaster is clearly desirable. The forecaster's past experience and psychological make-up give rise to certain expectations of the pattern of future events. This is discussed further in the following section where some of the more intangible factors mentioned earlier are also outlined.

7.6 The Price Forecaster

7.6.1 Intuition in the Forecaster

When considering the likely course of future events the individual is in the process of coming to a decision on what action to take in the light of his expectations. If the view is taken that all future events and their outcomes are predetermined then it would not matter what the individual might do and the believer of such a state of affairs will have no interest in this discussion. Such a view is related to the idea that an individual's decision is merely a response to prevailing circumstances and past events. This writer holds the contrary view that decision, by which an individual discovers and selects one from the many possible acts which may lead to the outcome desired, is not simply a response to circumstances but contains some other element. The idea that decision is merely response is distasteful to most human beings as it reduces them to the level of machines. There must then be in decision something that goes beyond the level of rational coping with a problem. The mathematician would probably call this something a random element and this writer also likes Shackle's[7] use of the term inspiration to cover this element in decision. It is the element of inspiration that Shackle claims introduces the 'essential novelty into the historical sequence of states of affairs'.

Whether it is called a random element or inspiration does not much matter but in any event this is the major stumbling block to the production of objective forecasts. It is this writer's contention that intuition is the faculty through which the random element or inspiration plays its part in the decision making process but this still avoids giving an understanding of the quality of inspiration. However it is possible to go no further because inspiration is usually associated with divine or supernatural agencies; for example that which is thought to visit poets or under which books of Scripture are written. To go further would necessitate propounding a system of beliefs. This is where the director responsible for buying scores over any price forecasting routines because he holds a system of beliefs that give body to his forecasts. However it is not usually thought necessary to explain the meaning of the random element introduced in a mathematical equation although a little consideration shows that the same problem would be faced if an explanation were attempted.

7.6.2 Intangible Influences on the Forecaster

One approach to an explanation of the meaning of 'intangible influences' might be by way of a simile. For example consider a sailing boat as it travels along a lake surrounded by hills. Normally the helmsman can see the wind ruffling the water surface before it reaches his craft's sails. With experience of the locality too he might have some advance warning of sudden gusts or squalls due to the configuration of the surrounding hills. Yet when visibility is poor due to rain or approaching nightfall none of these indicators is available and the first thing he knows about the wind direction is when it reaches his craft. Our forecaster might be compared to the helmsman. The movement of prices is indicated in some measure to him by his perception of current events linked with his past experience akin to the surface of the lake rippled by the wind. With experience the forecaster develops a 'feel' for the sudden changes in price as the experienced helmsman acquires a 'feel' for the locality in which he sails and the sudden changes of wind caused by the surrounds. Yet with no amount of experience can that helmsman obtain warning of the wind when the light alters and fades. The strength of the light is the controlling factor in the case of the helmsman. That which affects the forecaster's perception and 'feel' is the corresponding influence. It is an 'intangible' factor. By definition something that is intangible neither can be touched by the finger nor grasped by the mind. All similes are going to be inadeq-uate as a result even though they are the only means of exposition available.

Nor are these intangible factors solely something outside the fore-caster for they are both within and without. Within the individual reside the memories that make up experience which will to some extent affect his future expectations. Again these memories, even though identical to those shared by another individual, will be filtered through the one's psychological make-up, together with the inspiration that reaches him via his intuition, to produce a different set of expectations than another's. The shades of light and dark are 'within' in the psychological make-up and 'without' amidst the inspiration.

The experienced forecaster is only representable by some mechanistic forecasting process when the forecast to be made is not open to the influences of either inspiration or such intangible factors. An example of the type of process that lends itself to this type of fore-casting would be the application of heat at a known rate to a known volume of water. The temperatures at various times can be accurately forecast.

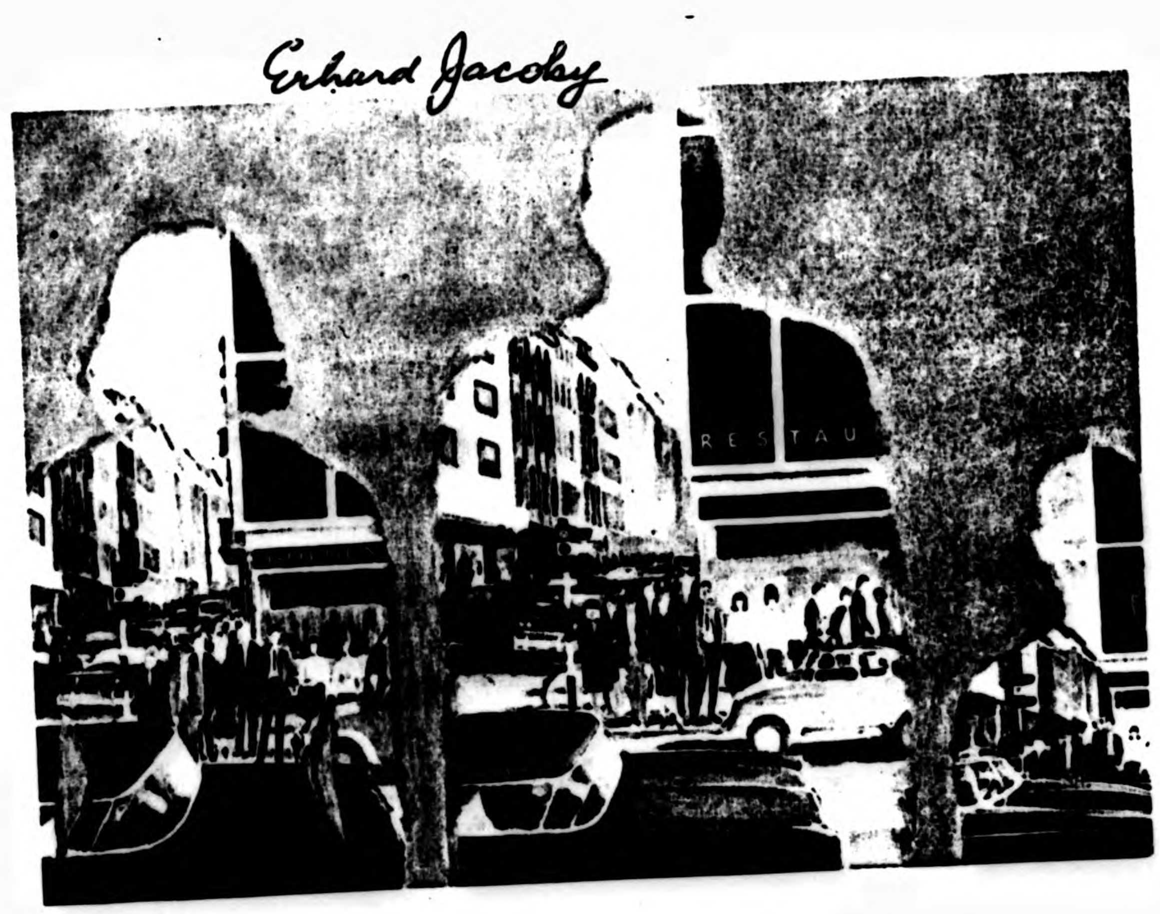
7.6.3 Gaining Future Knowledge

The writer is not alone in condemning attempts to make forecasts of the type described i.e. mechanistic forecasts. Lachmann[8] goes further in saying that prediction in economics is impossible.

> 'We are able to imagine a world in which tastes do not change but unable to imagine one in which knowledge does not spread from some minds to others. Even continuity of ends does not entail an invariant means-ends pattern; men would still be eager to make better use of the means at their disposal. Time and Knowledge belong together. The creative acts of the mind need not be reflected in changing preferences, but they cannot but be reflected in acts grasping experience and constituting objects of knowledge and plans of action. All such acts bear the stamp of the individuality of the actor.
>
> The impossibility of prediction in economics follows from the facts that economic change is linked to change in knowledge, and future knowledge cannot be gained before its time.
>
> As soon as we permit time to elapse we must permit knowledge to change, and knowledge cannot be regarded as a function of anything else. It is not the subjective nature of expectations, any more than that of individual preferences, which makes them such unsuitable elements of dynamic theories, it is the fact that time cannot pass without modifying knowledge which appears to destroy the possibility of treating expectations as data of a dynamic equilibrium system'.

The key phrases 'future knowledge cannot be gained before its time' and 'knowledge cannot be regarded as a function of anything else' (other than time) are sound reasons for the impossibility of economic forecasting if one accepts them. There is however still the possibility that future knowledge is created by the inspired action of the decision maker. In this way he makes his forecast come true. Yet another possibility is that inspiration transcends time and hence breaks the time/knowledge bound mentioned above.

Whatever the explanation some people give the appearance of gaining



This painting (by Erhard Jacoby) illustrates the fact that each of us, perceiving the world through an individual psyche, perceives it in a slightly different way from others. The man, woman, and child are looking at the same scene ; but, for each, different details become clear or obscured. Only by means of our conscious perception does the world exist "outside" : We are surrounded by something completely unknown and unknowable (here represented by the painting's grey background).

future knowledge before its time; these are the successful speculators (investors) in the various exchanges. Perhaps Lachmann is perfectly right and those giving the appearance of holding future knowledge in fact do not and are merely lucky. We are back again, full circle, to the painting by Erhard Jacoby described in Chapter One. Even though we look at the same phemomenon we all see it differently and we are surrounded by something completely unknown and unknowable.

7.7 Summary

This chapter is concerned with the inadequacies that have shown up in the tests of forecasting models. The economic structure of the market is reexamined in order to view the price formation process as systematically as possible. The market is simplified into three stages but after careful consideration it is shown that the successful price forecaster has no need of such a detailed knowledge of the market. Next we consider the possibility of using the prices of other essential oils as a guide to the price of peppermint oil. Even if all the prices were to move together this has the obvious drawback that one would still have to forecast the direction in which the generality of prices were about to move. As it is any theory of arbitrage applied to essential oils should be treated with extreme caution.

The various components that make up the inventory decision are again examined this time with the aid of a block diagram to draw them all together. The importance of the director responsible for buying is emphasised since his removal makes many of the vital qualities for successful forecasting inaccessible.

Some further comments are made on the Box-Jenkins method which has been shown to be of little help in the forecasting of peppermint oil prices. These comments are extended to a more general discussion on the validity of attempting to produce forecasts by data based methods. This discussion shows that the failure of such data based methods is not due to the more obvious factors such as the large price fluctuations in 1973/74 and 1976. Rather it is due to their inability to cater for the subtler influences that can act on the price forecaster. This leads to a final discussion about the price forecaster and those subtle influences. Intuition is seen to be a vital quality but not sufficient on its own for the successful forecasts produced by people with an indefinable 'feel' for their market.

Successful forecasters are merely lucky if those writers, who hold that accurate and effective forecasts are impossible, are correct. There are many points of view and, as the painting by Jacoby so cleverly illustrates, each of us is a prisoner of our individuality and experience; each person necessarily attaches different significance to what is seen.

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CHAPTER VIII

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

8.1 Introduction

The purpose of this study has been to investigate the problems of inventory control in a medium sized firm at a time of fluctuating prices and interest rates. It soon became apparent that improvements in the stock control, whether to take advantage of opportunities for speculative gains or simply to minimise the effects of changes in material costs, would depend on improvements in price forecasting. Initially methods of forecasting price were examined that operated independently of the firm's buyer. Later it was decided that no method could match the present intuitively produced forecasts of the buyer. It is clear, in the writer's view, that the difficulties experienced in devising effective price forecasting methods lie at the heart of the problem being researched. In this chapter the research findings are summarised. There then follows a discussion on them and related matters which leads finally to suggestions for further research.

8.2 The Research Findings

1. It has been possible to devise a relatively simple but effective model which takes account of changing prices and interest rates. The model is described in section 5.5 and is an extension of the basic economic order quantity model. The production of such a model, however, is not the main problem.

2. At the level of the firm investigated very simple rule-of-thumb stock control methods existed which, together with intervention by the buyer for price forecasts, worked with a minimum of cost and formality in both stable and price-fluctuating situations.

3. The model developed was not as effective as the method of controlled intervention by the buyer over the period examined (see Chapter VI), even when 'perfect' price forecasting was embodied in the calculations.

4. It has not proved possible to develop an adequate method of forecasting price. This finding is discussed further in the following section.

5. At all levels of the peppermint oil trade those involved have been found to display a preference for taking risks whenever alternatives existed. There does seem to be an increasing preference for taking risks the further the trader is from the farmer but this finding only can be stated with surety in the cases met by the writer.

8.3 Discussion

The failure to devise an adequate system of price forecasting is not, as might at first be expected, due to fundamental features of the market process for peppermint oil. It is true that there is a complexity and lack of stability in the process of price formation caused by various factors which include

1) variations in supply in response to earlier price fluctuations and
2) speculation at all levels of the trade (which is itself an indication of various expectations of future prices).

Nor is it due to the breaking of the clear supply-demand relationship which makes econometric modelling ineffective. To admit that the failure was due to such features would be to imply that if the theoretical analysis were improved a successful price forecasting model might possibly be devised. In attempts to produce purchasing formulas that approach the buyer's performance it has become clear that accurate forecasts of changes in the direction of price movements and fairly accurate forecasts of the magnitude of the movements are necessary.

Various price forecasting methods have been tried with little success. The conclusion has somewhat reluctantly been drawn that the many qualitative factors considered by the forecaster together with his faculty of intuition make vain the search for a peppermint oil price forecasting formula.

It has been tentatively suggested too that the contradiction between Lachmann's view that economic forecasting is impossible and the activities of successful investors is due to that faculty of intuition transcending time in some way to break the logical barrier of Lachmann's dictum.

The aim of the risk-averse buyer should be to cut out the middleman and make a direct approach to the farmer. Although many farmers are risk-lovers and prefer to sell their oil at the best price prevailing at the end of the season not all are so. There are those who contract with the middlemen, before the season starts, to sell their oil at a fixed price. These are the farmers who should be located and approached for there can be bargains struck satisfactory to both parties which will avoid the uncertainties involved in the present methods. There is no reason why even the smallest user should not do this though he will have to weigh his costs carefully against the possible advantages. Part of the user's costs in such a search are usually included in the price of the oil from the dealer one of whose functions is to save this search. The contracts would be made on a year-to-year basis and should not affect the farmer's relations with his other customers.

Finally a comment should be made on a recent paper presented at the Royal Statistical Society. It was an empirical study on accuracy of forecasting by Makridakis and Hibbon[1] (1979) and stimulated a lively discussion about the various forecasting methods. The fact that forecasting procedures work best on repetitive data[2] when they can often better human performance again emerges. The authors feel that ARMA models are best suited to engineering applications and exponential smoothing methods to business and economic data. The discussion following the paper demonstrated a lively difference in views on the merits of the various methods. It is apt to close this discussion with the comment by Hogarth.

> ''Finally, an issue that needs to be faced squarely is whether forecasting based on mechanistic methods is possible beyond short time horizons. As stated above, relative inertia of phenomena across time permits short-term forecasting. However, where are the limits? Interest in forecasting methodology attests to the fact that we need to believe we can make model-based forecasts. However, can we learn to live with the fact that often we cannot? The future is not necessarily 'ours to see'.''[3]

8.4 Developments and Suggestions for Further Research

It is logical in consequence of the foregoing that more should be done to understand the process of intuitive forecasting. It is not suggested that intuition should be examined with a view to attempting to turn it in some way into a quantifiable factor. Rather with the aim of understanding the circumstances under which the quality flowers and hence perhaps to develop methods of training potential price forecasters.

It is not only the peppermint oil market that displays the characteristics described here. Risk-preference and speculation are frequently found among commodity dealers and on the stock and share exchanges. Perhaps dealings in the less well known commodities such as peppermint oil should be more organised to eliminate some of the unfair practices that exist today. The activities of the peppermint oil middlemen are a case in point and their operations could well bear further investigation in the public interest. The development of an orderly futures market would enable buyers in the UK to separate their commercial risk from their speculative risk.

****

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APPENDIX I

Trials with Box and Jenkins' Method

1. The Data

In addition to the five years of price data tabulated in Chapter IV a further three years of data were available for this application making, with the extra month, 97 observations in total. Box and Jenkins (1970, p.18) recommend that, at least 50 and preferably 100 observations or more should be used. The additional data is shown together with the original data in Table 1 and plotted in Fig. 1. There is no obvious

	1971	1972	1973	1974	1975	1976	1977	1978	1979
Jan	1.74	1.81	2.82	7.21	8.38	5.67	14.39	8.59	4.29
Feb	1.74	1.80	2.69	7.12	5.56	5.91	14.47	8.63	-
Mar	1.74	1.89	2.70	6.88	5.63	6.77	14.39	9.00	-
Apr	1.74	2.06	2.69	6.92	5.74	7.34	14.39	9.15	-
May	1.74	2.18	2.61	6.98	5.84	7.81	14.39	9.15	-
Jun	1.74	2.34	2.79	7.01	6.19	7.72	13.23	7.80	-
Jul	1.80	2.33	2.97	7.01	5.35	7.87	13.07	7.51	-
Aug	1.78	2.33	3.21	7.28	5.45	7.87	13.07	6.06	-
Sep	1.79	2.44	3.73	7.25	5.39	8.38	11.43	5.96	-
Oct	1.79	2.65	4.90	7.22	5.29	15.72	10.87	4.78	-
Nov	1.79	2.85	7.03	8.37	5.69	15.15	10.99	4.64	-
Dec	1.84	2.85	7.09	8.30	5.69	14.71	8.72	4.29	-

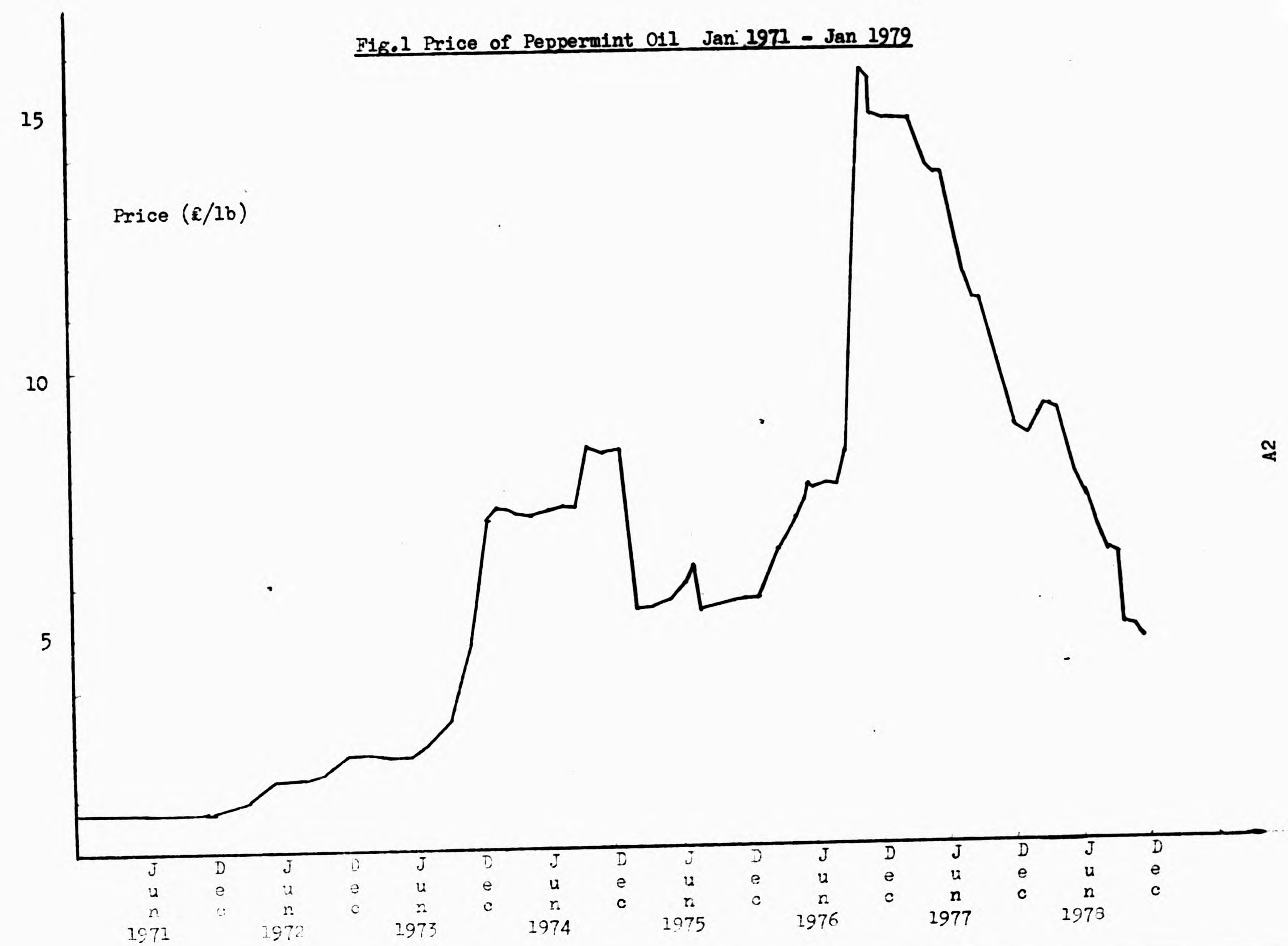
TABLE 1. Price of peppermint oil Jan. 1971 - Jan.1979

trend in the series nor is there any seasonal pattern.

2. Differencing and Identification

The first stage in the Box-Jenkins procedure is to difference the series $\{z_t\}$ until a stationary series $\{w_t\}$ is obtained. The sample autocorrelation functions for the series $\{z_t\}$, $\{\nabla z_t\}$ and $\{\nabla\nabla z_t\}$ are given in Table 2. The autocorrelation function for z_t decays in an

Fig.1 Price of Peppermint Oil Jan 1971 - Jan 1979



Autocorrelations						
		1	2	3	4	5
z_t Lags	1-5	.960	.917	.870	.823	.777
	6-10	.726	.672	.613	.558	.504
	11-15	.445	.390	.333	.276	.232
	16-20	.200	.167	.135	.101	.069
∇z_t Lags	1-5	-.001	-.028	-.043	-.054	-.157
	6-10	.272	.112	.031	-.034	-.040
	11-15	-.018	-.054	-.006	.109	.055
	16-20	-.078	-.036	.008	-.081	-.123
$\nabla\nabla z_t$ Lags	1-5	.248	.014	.001	-.041	-.032
	6-10	-.027	-.028	.005	.012	-.128
	11-15	.001	.080	-.144	.066	.028
	16-20	-.021	-.013	-.024	-.027	.072

Table 2. Sample autocorrelation function of $\nabla^d z_t$ for d=0,1,2

approximation to an exponential fashion approaching zero after the 19th value. Examination of the partial autocorrelations shown in Table 3 reveals that for the series $\{z_t\}$ only the first lag is non-zero to any significant extent. In order to preliminarily identify the model reference was made to Box and Jenkins (1970, p.176) where a process of

Partial Autocorrelations						
		1	2	3	4	5
z_t Lags	1-5	.960	-.070	-.055	-.034	-.011
	6-10	-.087	-.058	-.105	.032	-.034
	11-15	-.088	.001	-.045	-.061	.145
	16-20	.099	-.057	-.016	-.063	-.026
∇z_t Lags	1-5	-.001	-.028	-.043	-.055	-.161
	6-10	.272	.103	.030	-.029	-.034
	11-15	.088	-.106	-.066	.080	.061
	16-20	-.058	-.082	.055	-.017	-.187
$\nabla\nabla z_t$ Lags	1-5	.248	-.051	.010	-.046	-.011
	6-10	-.019	-.018	.016	.005	-.143
	11-15	.074	.061	-.196	.168	-.047
	16-20	-.022	-.009	-.015	-.013	.067

Table 3. Sample partial autocorrelation function of $\nabla^d z_t$ for d=0,1,2

order (1,d,0) exhibits the characteristics shown by our series for the d^{th} difference. Namely the autocorrelations decay exponentially and only the first partial autocorrelation is non-zero. The series would appear to be best described by a model of order (1,0,0). It is suggested that a good preliminary estimate for the autoregressive parameter is the value of the first autocorrelation. Thus a possible model is

$$(1 - 0.960B)z_t = a_t \quad \text{- - - - - - - - - - - - - -(1).}$$

The program used to estimate the model parameters is based on Box and Jenkins (1970, pp.231-242) which uses a non-linear estimation procedure similar to hill-climbing which finds the least squares estimates by numerical iteration. This program made no improvement on the initial value of $\phi_1 = 0.960$ offered.

3. <u>Diagnostic Check of Model</u>

The overall adequacy of the model is tested by the method described in Box and Jenkins (1970, section 8.2.2). If the fitted model is appropriate

$Q = n\sum_{k=1}^{k} r_k^2(\hat{a})$ is approximately distributed as $\chi^2(k - p - q)$,

where $n = N - d$ is the number of w's used to fit the model, k is the number of autocorrelations $r_k(\hat{a})$ of the residuals and N is the number of observations. In our case N = 97, p = 1, q = 0 and for k = 20

$$Q = 97 \times \left\{(-.014)^2 + (.008)^2 + (-.008)^2 + \; - - - - - + (-.363)^2\right\}$$

$$\approx 97 \times 0.262$$

$$= 25.4$$

Now with 19 degrees of freedom the 5% and 2.5% points χ^2 are 30.1 and 32.9. The value of Q is within the range which suggests the adequacy of the model. The autocorrelations of the residuals are shown in Table 4 below. Most of the coefficients are fairly small but the coefficients

Autocorrelations						
		1	2	3	4	5
Lags	1-5	-.014	.008	-.008	-.002	.082
	6-10	.049	.070	-.118	-.020	-.018
	11-15	-.125	-.010	-.060	-.203	-.123
	16-20	.008	-.013	-.005	-.013	-.363

Table 4. Sample autocorrelations $r_k(\hat{a})$ of the residuals ; order (1,0,0)

at lags 14 and 20 are greater than twice their standard error ($\simeq 1/(97)^{\frac{1}{2}} \simeq .1$). Overall it is not unacceptable to find 2 'significant' values in 20 coefficients. The checks suggest that the (1,0,0) model appears to give a reasonable fit to the data.

Our series also displays some of the characteristics of a process of order (1,d,1) for the second difference. With suitable starting values for ϕ_1 and ρ_1 the model obtained is

$$z_t = -.01 + 2.08z_{(t-1)} + 1.00a_{(t-1)}$$

The same diagnostic checking procedure is used as before except the values of the coefficients are different (see Table 5) and N = 97, p = 1, q = 1. Thus for k = 24

$$Q = 95 \times \left\{(-.033)^2 + (.063)^2 + \text{ - - - - - - - - } + (-.073)^2\right\}$$

$$\simeq 95 \times .305$$

$$= 28.98$$

Autocorrelations							
		1	2	3	4	5	6
Lags	1-6	-.033	.063	-.006	.005	.071	.052
	7-12	.047	-.076	.004	.003	-.070	.066
	13-18	.002	-.102	-.205	-.040	-.019	-.007
	19-24	.029	-.453	.035	-.166	.153	-.073

Table 5. Sample autocorrelations $r_k(\hat{a})$ of the residuals; order (1,2,1)

Now with 22 degrees of freedom the 5% and 2.5% points for χ^2 are 33.9

and 36.8. The value of Q is within the range which again suggests the adequacy of the model. The only coefficients greater than twice their standard error are at lags 15 and 20 which is acceptable over 24 coefficients. The checks suggest therefore that the (1,2,1) model also appears to give a reasonable fit to the data.

4. The Forecasts and Discussion

The (1,0,0) model is simple to make forecasts with since the forecast value one month ahead is the current value multiplied by 0.960. The model is equivalent to the series being represented by a straight line sloping gradually down to the right (i.e. with gradient = 0.960). A glance at Fig. 1 shows that forecasts made with such a model will be largely meaningless and could in no circumstances foresee anything other than a gradual decrease in the price of oil.

The (1,2,1) model can also be used fairly easily. The a's are the one-step ahead forecast errors already computed, that is, $a_{t-1} = z_{t-1} - \hat{z}_{t-2}(1)$. The forecasting equation can be written

$$z_t = -.01 + 2.08z_{(t-1)} + 1.00a_{(t-1)}$$
$$= -.01 + 3.08z_{(t-1)} - \hat{z}_{(t-2)}(1).$$

To start the process the unknown a is taken to be zero. The forecast value is then roughly double the previous value. Again referring to figure 1 it is only in September 1976 that such a forecast would have been anywhere near correct.

It is curious that both models should have satisfied Box and Jenkins' diagnostic tests yet so clearly provide totally unsatisfactory forecasts.

APPENDIX II

1. Listing of subroutine MULTR

```
      SUBROUTINE MULTR
C     DESCRIPTION OF PARAMETERS
C        N     -NUMBER OF OBSERVATIONS.
C        K     -NUMBER OF INDEPENDENT VARIABLES IN THIS REGRESSION.
C        XBAR  -INPUT VECTOR OF LENGTH M CONTAINING MEANS OF ALL
C               VARIABLES. M IS NUMBER OF VARIABLES IN OBSERVATIONS.
C        STD   -INPUT VECTOR OF LENGTH M CONTAINING STANDARD DEVI-
C               ATIONS OF ALL VARIABLES.
C        D     -INPUT VECTOR OF LENGTH M CONTAINING THE DIAGONAL OF
C               THE MATRIX OF SUMS OF CROSS-PRODUCTS OF DEVIATIONS
C               FROM MEANS FOR ALL VARIABLES.
C        RX    -INPUT MATRIX (K x K) CONTAINING THE INVERSE OF
C               INTERCORRELATIONS AMONG INDEPENDENT VARIABLES.
C        RY    -INPUT VECTOR OF LENGTH K CONTAINING INTERCORRELA-
C               TIONS OF INDEPENDENT VARIABLES WITH DEPENDENT
C               VARIABLE.
C        ISAVE -INPUT VECTOR OF LENGTH K+1 CONTAINING SUBSCRIPTS OF
C               INDEPENDENT VARIABLES IN ASCENDING ORDER. THE
C               SUBSCRIPT OF THE DEPENDENT VARIABLE IS STORED IN
C               THE LAST, K+1, POSITION.
C        B     -OUTPUT VECTOR OF LENGTH K CONTAINING REGRESSION
C               COEFFICIENTS.
C        SB    -OUTPUT VECTOR OF LENGTH K CONTAINING STANDARD
C               DEVIATIONS OF REGRESSION COEFFICIENTS.
C        T     -OUTPUT VECTOR OF LENGTH K CONTAINING T-VALUES.
C        ANS   -OUTPUT VECTOR OF LENGTH 16 CONTAINING THE FOLLOWING
C               INFORMATION. . .
C               ANS(1)  INTERCEPT
C               ANS(2)  MULTIPLE CORRELATION COEFFICIENT
C               ANS(3)  STANDARD ERROR OF ESTIMATE
C               ANS(4)  SUM OF SQUARES ATTRIBUTABLE TO REGRESSION
C                       (SSAR)
C               ANS(5)  DEGREES OF FREEDOM ASSOCIATED WITH SSAR
C               ANS(6)  MEAN SQUARE OF SSAR
```

```
C                    ANS(7)  SUM OF SQUARES OF DEVIATIONS FROM REGRES-
C                            SION (SSDR)
C                    ANS(8)  DEGREES OF FREEDOM ASSOCIATED WITH SSDR
C                    ANS(9)  MEAN SQUARE OF SSDR
C                    ANS(10) F-VALUE
C                    ANS(11)-ANS(16)  FIRST SIX REGRESSION COEFFICIENTS
C                REMARKS
C                    N MUST BE GREATER THAN K+1.
      SUBROUTINE MULTR(N,K,XBAR,STD,D,RX,RY,ISAVE,B,SB,T,ANS)
      DIMENSION XBAR(10),STD(10),D(10),RX(100),RY(10),ISAVE(10),B(10),SB(10),
     1          T(10),ANS(20)
      MM=K+1
C
C                BETA WEIGHTS
C
      DO 100 J=1,K
  100 B(J)=0.0
      DO 110 J=1,K
      L1=K*(J-1)
      DO 110 I=1,K
      L=L1+I
  110 B(J)=B(J)+RY(I)*RX(L)
      RM=0.0
      L1=ISAVE(MM)
C
C                COEFFICIENT OF DETERMINATION
C
      DO 120 I=1,K
      RM=RM+B(I)*RY(I)
C
C                REGRESSION COEFFICIENTS
C
      L=ISAVE(I)
      B(I)=B(I)*(STD(L1)/STD(L))
C
C                INTERCEPT
C
  120 BO=BO+B(I)*XBAR(L)
```

```
      BO=XBAR(L1)-BO
C
C              SUM OF SQUARES ATTRIBUTABLE TO REGRESSION
C
      SSAR=RM*D(L1)
C
C              MULTIPLE CORRELATION COEFFICIENT
C
      RM=SQRT(ABS(RM))
C
C              SUM OF SQUARES OF DEVIATIONS FROM REGRESSION
C
      SSDR=D(L1)-SSAR
C
C              VARIANCE OF ESTIMATE
C
      FN=N-K-1
      SY=SSDR/FN
C
C              STANDARD DEVIATIONS OF REGRESSION COEFFICIENTS
C
      DO 130 J=1,K
      L1=K*(J-1)+J
      L=ISAVE(J)
      SB(J)=SQRT(ABS((RX(L1)/D(L))*SY))
C
C              STANDARD ERROR OF ESTIMATE
C
      SY=SQRT(ABS(SY))
C
C              F-VALUE
C
      FK=K
      SSARM=SSAR/FK
      SSDRM=SSDR/FN
      F=SSARM/SSDRM
C
```

```
ANS(1)=BO
ANS(2)=RM
ANS(3)=SY
ANS(4)=SSAR
ANS(5)=FK
ANS(6)=SSARM
ANS(7)=SSDR
ANS(8)=FN
ANS(9)=SSDRM
ANS(10)=F
ANS(11)=B(1)
ANS(12)=B(2)
ANS(13)=B(3)
ANS(14)=B(4)
ANS(15)=B(5)
ANS(16)=B(6)
RETURN
END
```

2. <u>Listing of main routine MNTOIL</u>

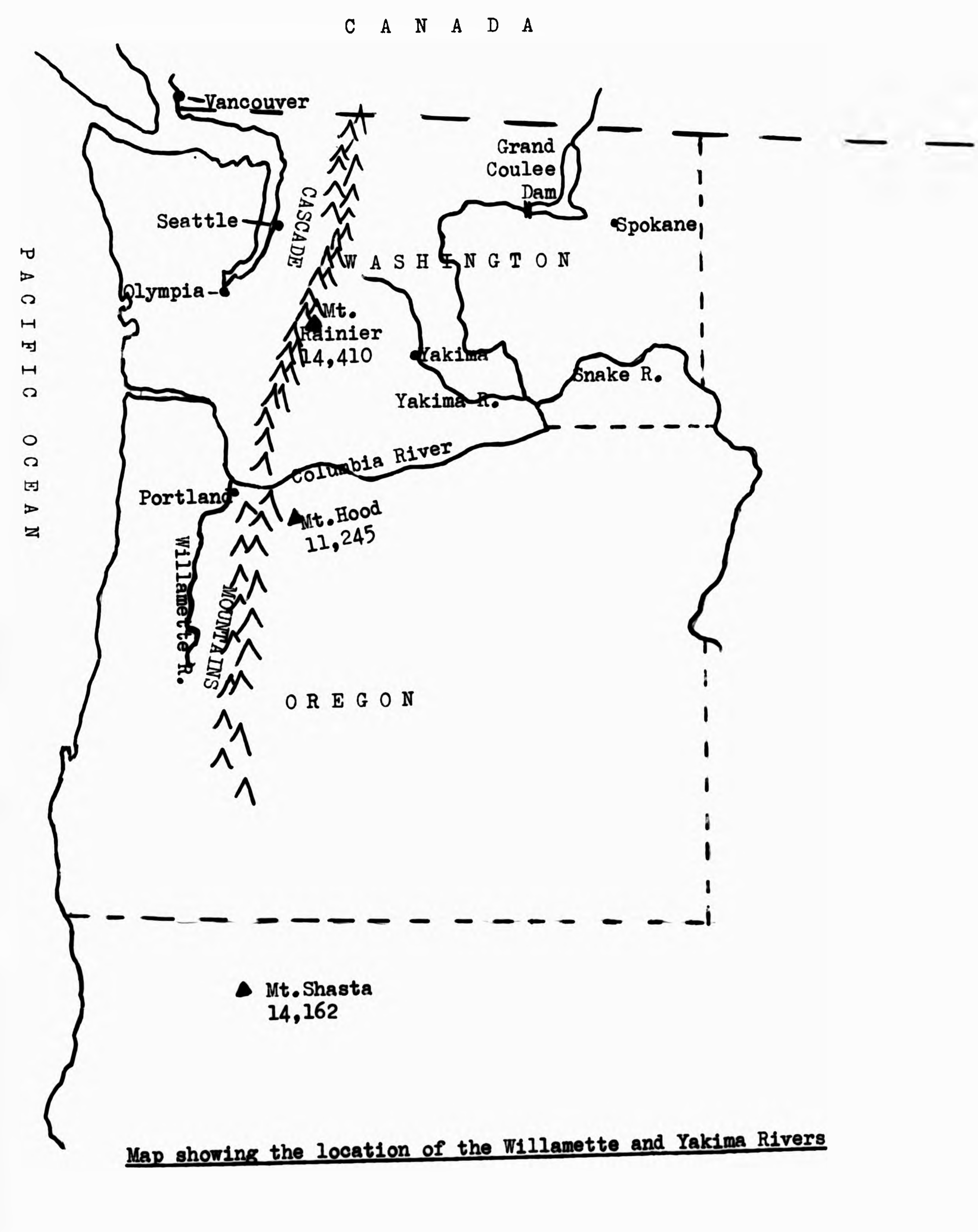
```
C        PROGRAM   MNTOIL
C        ______________
C
C
 1 FORMAT(A4,A2,I3,2I2)
 2 FORMAT(5F6.0,F12.0,F24.0,F6.0)
 3 FORMAT(52H1NUMBER OF SELECTIONS NOT SPECIFIED. JOB TERMINATED.)
 4 FORMAT(25H1MULTIPLE REGRESSION-----A4,A2//6X,14H SELECTION----
  1,I3//)
 5 FORMAT( 10I4)
 6 FORMAT(52H0THE MATRIX IS SINGULAR.  THIS SELECTION IS SKIPPED.)
 7 FORMAT(25H1PROGRAM STILL LOOPING C=,F4.0/38H THE SIX (OR M) VALU
  1ES OF J FOLLOW----,10I4)
 8 FORMAT(39H1REGRESSION CORRELATION COEFFICIENT R2=,F13.5//13H INT
  1ERCEPT A=,F10.5/29 H REGRESSION COEFFICIENTS B1-B,I1,4H ARE//9F8.5)
   DIMENSION X(60,10),Y(180,10),XBAR(10),STD(10),RX(100),R(55),G(10
  1),D(10),T(10),ISAVE(10),RY(10),SB(10),ANS(20),J(10),F(10)
 9 FORMAT(36I2)
10 FORMAT(17H0THE VALUE OF C =,F4.0,2X,13H THAT OF R2 =,F9.5)
```

```
 60 READ (5,1)PR,PR1,N,M,NS
C       PR---------PROBLEM NUMBER (MAY BE ALPHAMERIC)
C       PR1--------PROBLEM NUMBER (CONTINUED)
C       N----------NUMBER OF OBSERVATIONS
C       M----------NUMBER OF VARIABLES
C       NS---------NUMBER OF SELECTIONS
      DO 90 I=1,N
      KA=I+60
      READ(8,2)(Y(KA,JA),JA=1,M)
      DO 80 JA=1,M
      IF(I.NE.1)GOTO 60
      DO 50 KB=1,60
   50 Y(KB,JA)=Y(KA,JA)
   60 IF(I.NE.N)GOTO 80
      DO 70 KC=1,60
      KD=KC+156
   70 Y(KD,JA)=Y(KA,JA)
   80 X(I,JA)=Y(KA,JA)
   90 CONTINUE
C       TEST NUMBER OF SELECTIONS
C
      IF(NS)95,95,98
   95 TYPE 3
      GO TO 280
C
   98 DO 270 IB=1,NS
      TYPE 4,PR,PR1,IB
C
C       READ SUBSET SELECTION CARD
C
      READ (5,5)NRES1,NDEP,K,(ISAVE(JJJ),JJJ=1,K)
C       NRES1----OPTION CODE FOR TABLE OF RESIDUALS
C                  0 IF IT IS NOT DESIRED
C                  1 IF IT IS DESIRED
C       NDEP-----NUMBER OF THE DEPENDENT VARIABLE
C       K--------NUMBER OF INDEPENDENT VARIABLES INCLUDED
C       ISAVE----A VECTOR CONTAINING THE INDEPENDENT VARIABLES INCLUDED
C
      R1=0.0
      B=0.0
```

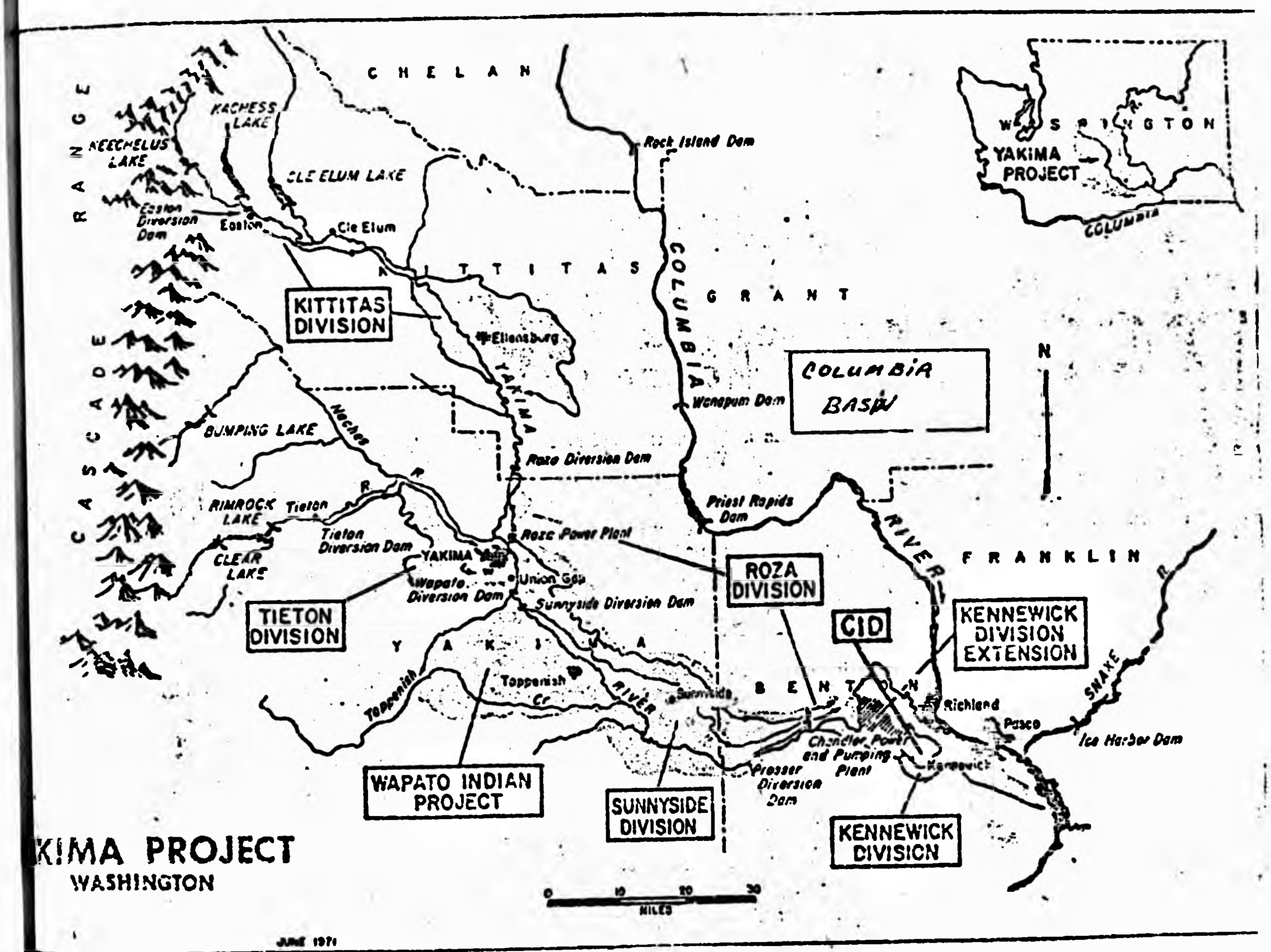
```
      C=0.0
      D1=0.0
   99 DO 100 JJ=1,10
      F(JJ)=0
  100 J(JJ)=-1
      M1=M-1
      N1=N+1
  105 DO 210 I=1,M1
      DO 200 L=1,N1
      IF(B.EQ.1.0)GO TO 110
      J(I)=J(I)+1
C
C      THIS LEADS THE DEPENDENT VARIABLE
C
      GO TO 120
  110 J(I)=J(I)-1
C
C      THIS LAGS THE DEPENDENT VARIABLE
C
      IF(IABS(J(I)).GT.N)GO TO 205
  120 IF(J(I).EQ.0)GO TO 140
      DO 130 IA=1,N
      KA=IA+60-J(I)
  130 X(IA,I)=Y(KA,I)
  140 CALL CORRE(N,M,1,X,XBAR,STD,RX,R,G,D,T)
C
      CALL ORDER(M,R,NDEP,K,ISAVE,RX,RY)
C
      CALL MINV(RX,K,DET,G,T)
C
C      TEST SINGULARITY OF THE MATRIX INVERTED
C
      IF(DET)152,150,152
  150 TYPE 6
      GO TO 60
C
  152 CALL MULTR(N,K,XBAR,STD,D,RX,RY,ISAVE,G,SB,T,ANS)
      R2=(ANS(2))**2
```

```
      IF(L.EQ.1)GO TO 160
      GO TO 170
  160 R1=R2
      GO TO 200
C       TESTING TO SEE IF R2 IS GETTING BIGGER
C
  170 IF(R2.GE.R1)go to 190
C
C       R2 IS FALLING SO WE TEST TO SEE IF BOTH TIME DIRECTIONS HAVE
C       BEEN TRIED
C
      IF(B.EQ.1.0)GO TO 180
      J(I)=J(I)-1
      IF(L.EQ.2)GO TO 195
      GO TO 181
C
C       RETURN MATRIX CONTAINING DATA TO LAST POSITION WHERE R2 WAS BIGGER
C
  180 J(I)=J(I)+1
  181 DO 185 IB=1,N
      KB=IB+60-J(I)
  185 X(IB,I)=Y(KB,I)
      GO TO 205
  190 R1=R2
      GO TO 200
  195 IF(L.EQ.2)B=1.0
  200 CONTINUE
  205 B=0.0
  210 CONTINUE
      DO 220 KI=1,M1
      IF(IFIX(F(KI)).EQ.J(KI))GO TO 220
C
C       TESTING TO SEE IF THERE HAS BEEN ANY CHANGE IN THE LAGS OR LEADS
C       FROM LAST COMPLETE CYCLE
C
      D1=1.0
      F(KI)=J(KI)
  220 CONTINUE
      IF(D1.EQ.1.0)GO TO 230
      GO TO 250
  230 D1=0.0
      TYPE 10,C,R2
      TYPE 11,(D(KI),KI=1,M1)
   11 FORMAT(18HOMATRIX D CONTAINS,8F12.5)
      C=C+1
      IF(C.EQ.100)GO TO 240
      GO TO 105
  240 TYPE 7,C,(J(KI),KI=1,M1)
      GO TO 260
  250 TYPE 5,(J(KI),KI=1,M1)
  260 TYPE 8,R2,ANS(1),(ANS(I),I=11,16)
  270 CONTINUE
      GO TO 60
  280 CONTINUE
      END
```

APPENDIX III



Map showing the location of the Willamette and Yakima Rivers



This map shows the Yakima River basin and the irrigation districts

DISTRIBUTION OF 1976 MINT ACREAGE AMONG EASTERN WASHINGTON IRRIGATION DISTRICTS

rrigation District	Spearmint Scotch		Spearmint Native		Peppermint	
	Acres	%	Acres	%	Acres	%
Vapato	40	1	5,150	70	4,914	59
unnyside	866	16	318	.4	103	1
oza	4,142	80	708	10	1,533	18
Columbia Basin	150	3	1,201	16	1,833	22
otal	5,198	100	7,377	100	8,383	100

D39193'82

END