FLEXIBILITY IN A COMPUTABLE BEHAVIOURAL MODEL OF THE FIRM

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DECLARATION

I declare that this thesis has been composed entirely by myself and that all the work incorporated in it is my own.

R.A.Lee 13th September 1992

ABSTRACT

This thesis takes the micro-economic notion of flexibility in the firm, and seeks to describe formally its significant features. It develops a theoretical approach to flexibility in a behavioural model of the firm, following the principles set down by Herbert Simon in his work on complex systems. This approach is then applied to the small entrepreneurial firm, (S.E.F.), taking fish processing as an example. The computer implementation used models the S.E.F. as a set of linked spreadsheets.

Building upon a theoretical base provided by George Stigler (1939), Herbert Simon (1962), and Richard Cyert (1963), it aims to extend our knowledge of how firms respond to sudden external change. George Stigler's short-run static analysis of flexibility in terms of the convexity of the unit cost curve is extended to take account of dynamic, behavioural and stochastic aspects. The theoretical extensions include a separation of flexibility into two elements: choice flexibility and response flexibility. Using a behavioural analysis of actual decisions taken, a model is developed in which various aspects of flexibility can be studied. Consideration is given to recent work in the flexibility field, such as Marvin Mandelbaum and John Buzacott (1990), Burton Klein (1984) and Bo Carlsson (1989), and to the impact on flexibility issues of authors such as Harold Demsetz (1988), Armen Alchian (1972) and Oliver Williamson (1986). Emphasis is placed throughout the work on the grounding of the theory in its empirical context, using behavioural data gained from fieldwork in the fish processing industry in Scotland.

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Contents

PART I

BACKGROUND

Chapter 1 Introduction and Summary of Thesis.

Summary

1.1 This analysis takes the notion of flexibility in an industrial organisation context and seeks to formally describe its significant features. It is a theoretical approach to flexibility in a behavioural firm model, and follows some of the principles set down by Herbert Simon in his work on complex systems. The thesis describes research into flexibility in the small entrepreneurial firm (S.E.F.). Building upon a theoretical base provided by George Stigler (1939), Herbert Simon (1962), and Richard Cyert (1963) it aims to extend our knowledge of how firms respond to sudden external change. George Stigler's short-run static analysis of flexibility in terms of the convexity of the unit cost curve is extended to take account of dynamic, behavioural, and stochastic aspects. The theoretical extensions include a separation of flexibility into two elements: choice flexibility and response flexibility. Using a behavioural analysis of actual decisions taken, a model is developed in which various aspects of flexibility can be studied. Consideration is given to recent work in the flexibility field, such as Marvin Mandelbaum and John Buzacott (1990), Burton Klein (1984) and Bo Carlsson (1989), and to the impact on flexibility issues of authors such as Harold Demsetz (1988), Armen Alchian (1972) and Oliver

Williamson (1986). Emphasis is placed throughout the work on the grounding of the theory in its empirical context, using behavioural data gained from fieldwork.

1.2 The project has a contribution to make in its methodological approach, both with its original set of computer routines, and also its interdisciplinary scope, blending the extensive industrial experience of the researcher, the sociological analyses of management science, and the formal modelling of the microeconomist. The industrial experience preceding, and contributing to, the research, consists of a twenty year career analysing business procedures and implementing computer-based decision and information systems. A pragmatic operational approach is followed, typified by authors such as Michael Porter (1980) in industrial economics, and by Thomas Peters & Robert Waterman (1982) in management science.

1.3 Empirical investigations into the behavioural mechanisms deployed by a set of firms are used as the basis for a set of computer routines which display how the theory of flexibility can be operationalised. Firstly extensive formal investigations into the behaviour of firms in general was undertaken. This was initially done with the objective of improving their internal information processes, rather than for research purposes. Secondly, to gain specific knowledge a questionnaire was devised. In order to have specific data sources to highlight the flexibility issues, it was necessary to sample behavioural material from an industry exhibiting frequent change. The respondents used were decision makers controlling the operation of fish processing firms. Through the questionnaire schedule they contributed information on how they responded to external changes.

1.4 Drawing firstly upon the early computer implementation of the behavioural model produced by Cyert & March (1963), and secondly upon the models used by the firms themselves, a technique has been developed for representing the behaviour of the firm. Formally, it displays this behaviour by a set of linked spreadsheets. The software approach uses techniques developed from the work on complex systems of Herbert Simon (1982) and applied to software systems by P Courtois (1985). Parameters for the model of the firm are extracted from the survey results. The subsystems in the model are grouped according to the main organisational divisions described by Michael Porter (1980).

1.5 The benefits to be gained by adopting this modelling technique, as distinct from one which is more neo-classically influenced, are fourfold.

Firstly, dynamic and non-equilibrium modelling can be incorporated easily;
secondly, the greater complexity required to represent the behavioural processes can be accommodated within a computerised model;
thirdly, the individual organisational elements of a firm's activities (e.g. sales strategy), may be easily incorporated as self-contained sections of a hierarchical model as suggested by Herbert Simon (1961);
fourthly the specific form of the functions used and the parameters assigned enables one to display the results explicitly and therefore give greater insights into the processes involved.

1.6 The model is used to investigate aspects of the flexibility of the firm's performance. Behavioural factors are identified which, in a static model, affect the upward concavity of the unit cost curve. The analysis first considers intrinsic flexibility elements within a particular plant or firm structure (e.g. scale of production considerations, or plant capable of producing two products), and then proceeds to a consideration of flexibility elements in factor market operations (e.g. labour contracts). Following the static analysis, the model is used to investigate dynamic performance, and to introduce a set of flexibility variables related to speed of response. Exogenous shocks are applied to the model and the performance of flexibility parameters is analysed with respect both to speed of adjustment, and to response to repeated variation.

1.7 Principal conclusions are drawn as to how flexible responses may be classified and in what circumstances they are important, both as parameters in the modelling of firms behaviour, and in the substantive activities of the firms. Some useful methodological insights are drawn both from the empirical side of the study and from the utilisation of the computer for empirically based modelling.

The content, scope and structure of the research.

1.8 The motivation for the research arose from observations made by the author concerning differences in the structure and operations of firms with which he became involved. Initially the observations were made over a ten year period pursuing a systems development and data processing management career in large corporations. Subsequently the author founded his own company advising on and implementing new information systems in a range of firms, principally in the north of Scotland. This company has continued successfully for a further eleven years. It has provided first hand experience of the entrepreneurial role and the behavioural decision making processes involved. Its customers have provided an extensive informal empirical base from which to draw evidence. It is worth noting that advice and implementation of information systems is a process which depends heavily for its success upon acquiring accurate structured formal knowledge of the behavioural patterns established by the target organisations. The information processing procedures of the firms are investigated and formally documented, using a number of standardised techniques most of which have parallels in the data acquisition techniques adopted in academic research. In common with the latter, extended experience of fieldwork also produces an expert knowledge base which is not necessarily consciously structured, but which provides examples, precedents and decision rules about the information processing and decision making behaviour of the firms studied. Thus the basis for setting down a formal model representing information flows and behavioural decision processes was already present prior to commencement of the project. However, the variables relating to flexibility do not initially appear suitable for symbolic modelling. Alertness, speed of response to change, and disposition to change appeared to be significant factors in the growth and survival of firms.

The questions as to whether economic and social theory identifies these elements, and whether policy takes account of them prompted the decision to structure the investigation as a formal research project. It is apparent from discussion and appraisal of the literature, that there is both a need for empirical work to support progress in industrial economic theory, and that the behavioural elements observed by the author can make a contribution to the study of flexibility in the context of this theory.

1.9 Thus establishing the broad research area, it is necessary to give consideration to the specific form the research takes. Firstly, the empirical knowledge of the author provides a major contribution, and secondly, the methodological content draws extensively upon the applied computer skills used by the author in his industrial work. A formal empirical study specifically related to the model has been undertaken to complement the informal evidence. The research is thus further defined as an empirically based project studying behavioural aspects of flexibility in firms. It uses computer techniques to enhance the handling of complexity and detail in the behavioural firm model. The content of the research topic having thus been mapped out, two further definitional tasks remain: to place the project in its context and to describe the formal structure of the research report.

1.10 The research might be placed in three separate contexts. Firstly there is the applied industrial context. It might be that a contribution to knowledge will be made by the consideration of specific events and organisational structures occurring in the fish processing industry. This however is not the principal context of the project. Secondly, it might be that a methodological contribution is being made through the presentation of an example of how particular computer techniques may be applied in microeconomic modelling. Neither is this the *principal* purpose of the project, though it is hoped that the techniques developed will prove useful in further research in industrial economics. Thirdly, extending the formal analysis of flexibility in the firm within the context of industrial economics could describe the context of the project. This is put forward as the principal context for the research within which its contribution to theory and the empirical base is made. It should be noted in passing that whilst each of these three elements formed a significant aspect of the research, at the outset it was not clear which should be pre-eminent. All three were and are considered worthy targets and whilst it became clear during the research that formal flexibility modelling would be the key element, it also became clear that separation or exclusion of the other elements would detract from the value of the work.

1.11 The nature of the thesis is that it is a single argument which progresses from assumptions to conclusion, rather than a broad view of three aspects of the subject area. The decision was therefore taken that the key element emphasised in the thesis should be the flexibility issues. The empirical data should be used as a source for exemplifying, confirming, and perhaps questioning the theoretical work on flexibility presented by the literature, and extended by this research. The computer model should be used to illustrate and analyse the issues presented by the flexibility theory and examples. The content, scope, and structure of the research project thus being determined, the topic was given the title *"Flexibility in a computable behavioural model of the firm"*.

The background.

1.12 Flexibility is a key issue in industrial organisation, and in the wider disciplines of management and economics. Its importance is increasing relative to other factors determining industrial organisation such as economies of scale and long run equilibrium. It is growing in its importance to current management practice.

Its significance extends beyond flexible production machinery and techniques into the structure and function of the enterprise.

1.13 Economic theorists such as Richard Cyert (1963) have put forward alternative models for behaviour within the firm, and have taken early steps towards illustrating the principles with computer software. This study follows the behavioural approach in identifying the functions requiring to be incorporated within the computer model. As a start point for exploring the methodology, Cyert & March's software, fully documented in chapter 5 pp 150 - 160 of *A Behavioural Theory of the Firm* (1963) was converted to the current usage formulated for the study.

1.14 Cyert and March are concerned with linking the theory to the practice. Their firm is a self conscious entity, not simply a collection of abstract processes, and so they look at how individuals within firms operationalise their profit maximising or other aims. They examine the internal operation of the firm, and build their model from observations of the conscious activities of organisation members. They find that the firm as a whole has multiple aims, and pursues iterative searches to reach these aims. They are able to construct models which incorporate management utility functions. Whilst they see the firm as a coalition of individuals with differing aims, their emphasis is upon the relationships between those individuals and measurable entities such as sales and stock levels. As well as being capable of computer representation, these relationships are readily observable in terms of how they respond to change. Flexibility as it relates to these behavioural functions form the main content of the empirical survey and the model itself.

1.15 It is worth-while seeking further relationships and mechanisms operating within and upon the firm to supplement those illustrated by Cyert (1963). Several authors have examined the firm in its economic setting from distinct, but related, perspectives. Following Coase's (1937) work models have been proposed for explaining which activities are internal and which governed by external market processes. Harold Demsetz (1988) provides a useful framework for formalising the definition of the firm and some of the functions operating within it. O.E. Williamson (1979) approaches the topic from a transaction cost standpoint. On another level, the firm has been examined from the management strategist's and sociologist's perspective, and as a result much light has been recently thrown upon the behaviour of individuals within organisations. The observations on flexibility put forward here draw together within a behavioural computer model these different perspectives.

Flexibility

1.16 For present purposes flexibility is defined as the ability of an organisation to modify itself in response to external change. In particular the research project is interested in sudden external shocks and the effect they have on firms. This thesis proposes one way of investigating flexibility in response to external shocks. It aims to describe formally the firm as a set of behavioural relationships which can be dynamically modelled on a computer. This set of behavioural relationships has its empirical justification in primary source data. Chapter 2 covers the literature from which the theory has been drawn in constructing the model, chapters 3 and 4 the methodology used obtaining the new empirical data upon which the model is grounded, and chapters 5, 6 and 7 the theoretical elements of the model.

1.17 Flexibility has been given consideration by many theorists, though seldom as a principal issue. The literature which touches upon flexibility, particularly in the field of industrial economics, includes the work of Harold Demsetz (1988), Oliver Williamson (1985), Richard Cyert (1963, 1987), and Michael Porter (1980, 1985). Extensive background material has been provided by the work of Gavin Reid (1987,1988,1989). More specific consideration has been given to flexibility itself by Stigler (1939), Marvin Mandelbaum and John Buzacott (1990), Burton Klein (1984), Bo Carlsson (1989), and by other authors (eg Mills 1984,1985; Gustavsson 1984; Taymaz 1991) whose works are directly relevant to the topic. It is from these works that this study draws its theoretical elements. They are used as start points from which to proceed further to empirical implementation. It is of importance, in view of the behavioural nature of the model, to maintain close links with the management and business strategy literature. The empirical base upon which the present research is grounded comprises firms in an industrial sector where small and medium size enterprises are common. The literature viewing small firms from a sociological standpoint (e.g Binks and Coyne 1983; Levicki 1984) has useful insights to offer. The UK literature over the last two decades following upon the publication of the Bolton Report (HMSO Cmnd 4811 1971), as represented by Scott, Gibb et al (1986), Curran Stanworth and Watkins (1986), and Storey (1983) contributes to the general background as well as providing some specific guidance on empirical issues.

Levels of abstraction in the model.

1.18 Let us assume that the set of functions governing the behaviour of an individual firm is not simply a set of continuous functions, but a set which also may include step functions, and discontinuities. Shocks in external variables controlling the operation of the firm may strike the firm at either of two close but different points on a particular objective function within the firm. The size of the original shock may well be amplified in the response by the discontinuities within the objective function. Within real individual firms, sudden large changes do take place. This may not be predicted by a model incorporating generally continuous functions aggregating the behaviour of firms in the industry as a whole to a "typical" firm. The degree of abstraction in such models acts like a filter smoothing out individual shocks. However, the behavioural responses taken from a primary data source will have no such filtering, and the methodology needs to take account of this.

1.19 Thus, in order to reflect the behavioural richness of the primary data source, the model put forward here requires the incorporation of step functions reflecting available empirical evidence. Further, the model requires to be specifically structured to study the effects of external shocks and show how flexible firms aim to produce a damped response to such shocks. It is useful to consider which computer techniques may be utilised to meet these requirements, and whether current software developments used by the firms themselves may be applied with benefit to these modelling tasks.

1.20 There are three distinct levels of abstraction which may be present in a model of the firm. The highest level of abstraction models those essential characteristics of the firm which are sufficient to generate general predictions about the actions of firms as a whole within the general economic domain. The mathematical representation of the firm is as a set of determinate equations, whose characteristics can be readily analysed with a formal calculus. In turn, this may be transferred directly to a computer model. The benefit given to the economic analysis by such a transfer lies in the ability to handle increased complexity and larger numbers of equations and variables, rather than any new qualitative perspective. Such representations are included in the thesis as an illustration of the methodology, though not in advocacy of it.

1.21 A second, lower level of abstraction may also be identified, one which is of more importance in relation to the present work. At this level, the firm is not represented as a black box, whose output responses to given input stimuli are the principal, if not only, consideration. This second level retains an interest in the output responses to input stimuli, but it is equally interested in representing the actual mechanisms within the firm which produce the responses. As a result, it is not sufficient that the model meets the logical internal consistency criterion applied, for example, by Paul A. Samuelson in *Foundations of Economic Analysis* 2nd edition (1983). It is also necessary that the model meets the empirical realism found in the expositions presented by Cyert and March in *A Behavioural Theory of the Firm* (1963), or Michael Porter in *Competitive Strategy* (1980).

1.22 At a third level of abstraction, much closer to the operations of the firm itself, simulation exercises can also be conducted using a computer model, which are essentially concerned with mimicking the internal mechanisms present within the operations of an individual firm. Here the emphasis is upon the representation, and the ability of the software to emulate the behavioural processes involved in order to pass on information about these processes themselves. This is of greater concern than the ultimate position of the model after a series of events. Such a level of abstraction is of use to the firm itself. The special circumstances pertaining to that particular firm may be incorporated into the model.

General predictions about the industry or the nature of firms are a side issue. Specific predictions about the responses of individual firms to specific external data are the objective. The aim of the computer model in this research is to combine the two competing intellectual strands of abstract formal modelling of the firm and behavioural veracity, in a model which conforms substantially to the second category of abstraction described above. Examples are given, however, of the methodology applied to the other two categories.

Computer software approach.

1.23 The use of a spreadsheet format to represent the firms has several attractions in meeting this aim, although as described in Chapter 8, several alternative computing techniques were also evaluated. The first of these advantages is the extensive use of such software by the firms themselves. The research examines the behavioural rules followed by firms, and if they use spreadsheets to predict their own actions, this lends support to spreadsheet use in formal modelling. The second modelling advantage of the spreadsheet is the ease with which non-linear relationships can be set up. The cell structure used in the model development process, provides a more natural means of incorporating set to set operations (for example mapping continuous values onto a limited set of discrete values), inequalities, and logical operations, without excluding continuous functions, to represent the links between cells. The third advantage of the spreadsheet approach in comparison with alternative computer techniques, is that the presentation of the model, both structurally and graphically, is not highly abstracted away from the firm itself. That is to say, the output of the model is similar to sets of figures used in practice to document the performance of firms, so it is easy to relate to familiar business concepts. There is consequently less likelihood that pure modelling considerations, detached from the study of the firm itself, will form a major part of the research task.

1.24 In several respects the exposition of the computer model follows by a more modern route the course first taken by the Austrian writers on economic matters. Like the tabular presentations of Carl Menger in his *Grundsätze der Volkswirthschaftslehre* (1871), the computer model contains many step functions and break points. As with the frequent allusions to specific practical decisions presented by Menger, this attribute of the computer model is considered important for realism. Equally importantly, step functions and non-continuous variables are there because the essence of the topic is how particular economic agents react to sudden, generally unexpected change. The work on marginal utility led by Carl Menger, relied heavily on the discrete choices faced by individual economic agents. The methodology allows for the extensive use of step functions to link the various factors within the firm. This also applies to the dynamic content of the model. Functional relationships may be linked to specific time periods within the model in a non-continuous fashion. This is not to counter Alfred Marshall's dictum *natura non facit saltum*, as aggregation may still smooth the overall effects. Rather, it is to allow the modelling of jerky responses to external shocks, as they are experienced by individual firms. This aspect of flexibility, the predisposition to cope with sudden unexpected change, has been distinguished both by Bo Carlsson (1989) and Burton Klein (1984), and is to be distinguished from programmed flexibility to cope with known variations in, for instance, demand.

Behavioural approach

1.25 Following Cyert, we are interested in what agents within the firm *consciously* do in acting out their economic role. The model thus contains internal decision structures which mirror the structure of the real firm. Cyert's formal computer model, documented in Chapter 5 of *A Behavioural Theory of the Firm*, is similarly structured. Our interest is not in the internal workings of the firm per se. Whilst they are a proper object of study, of interest in themselves, our interest arises because of the accuracy it may bring to predictions concerning the behaviour of the firm as a whole. Analysis of aggregate behaviour is equally valid, but part of the purpose of this research project is to provide links between the aggregate behaviour of an industry on the one hand, and the conscious actions of its constituent agents on the other.

Dynamic and uncertainty factors.

1.26 The research addresses the *dynamic* elements of the firm structure at the individual firm level. This is also a key element of Burton Klein's (1984) approach, which he then uses to study the aggregate effect in any particular industry. Klein relates risk-taking at the micro level to the behaviour of the industry at the macro level. In the same way, the present study looks at flexibility at the micro level in order to provide a basis for predicting effects at the industry level. This contrasts with for example the flexibility analysis of D.E Mills (1984) which contrasts aggregate industry solutions for different situations in which flexibility is, or is not, present. The mechanisms for moving to a particular solution are not given specific consideration.

1.27 If, after a system receives an exogenous shock, there is an inevitable movement towards a new equilibrium position, and if that new equilibrium position is reached before any further unpredictable exogenous change occurs then there is no necessity for a dynamic model. As Paul A. Samuelson (1983, page 331), puts it " If one can be sure that the system is stable and strongly damped, there is no great harm in neglecting to analyze the exact path from one equilibrium to another". This research addresses the possibility that discontinuities and response thresholds challenge the inevitability of the direct movement to equilibrium. Comparison between two equilibrium solutions is interesting, but it may also be important to understand the route taken towards a new equilibrium. The research also addresses, as does Klein's analysis, the difference between on the one hand, an entrepreneur selecting from a set of production functions a flexibility solution which meets a known variability in exogenous factors, and on the other the positioning of the firm to cope with unknown variability. The last consideration in this context is that of the rate of response to the change in external factors. There is a need to address the situation where change is always present, and firms and industries do not *eventually* reach a new equilibrium position. Rapid adjustment to fluctuations may be more important than the eventual never-to-be-reached equilibrium.

Empirical considerations

1.28 Borrowing a technique from personnel management (Ingleton 1988), the empirical questions used in the survey concentrate on the agents' own evaluation of significant external changes and key decisions. The emphasis is upon what actually occurred in critical situations. The aim is to get the respondents themselves to chart significant flexibility elements in their decision processes, but to temper this with checks to real decisions. This is achieved by relating their answers to actual events which have occurred, rather than putative decisions in hypothetical scenarios. A further strand running throughout the survey is its emphasis on the dynamic elements of the economic agents' decision making. "When" and "For how long" are the questions most asked throughout the empirical study. It may be that the key element in a firm's survival in response to external shock is not the response itself, but the speed with which the external shock is recognised, the speed with which the response is formulated, and the speed with which the action is implemented.

1.29 New empirical evidence is fundamental to the development of the model and the research into flexibility. Of interest in respect of the data collection are the experiences of the Department of

Economics at Edinburgh where preceding studies in the same general research field have been considered[1]. Equally important, and preceding the formal structured questionnaire, are the direct personal experiences observing, comparing, and contrasting the behaviour of numerous businesses both large and small, over the last two decades. Sociological researchers such as Gibb and Scott (1986) have advocated working closely with firms in order to fully understand the behavioural mechanisms driving them. They term such active participation *action research*. The background of the author extends such an approach to data gathering. Sometimes from a detached, disinterested viewpoint, sometimes from a position more committed than any action researcher[2] these experiences have proved a major supplement to the literature in providing the a priori sources of the hypotheses. They have also provided a broad empirical landscape within which to place the formal, controlled data collection of the research. Finally, the experiences have enabled valuable methodological cross-fertilisation to take place, between the procedures appropriate to academic investigation of economic behaviour, on the one hand, and the procedures which the decision makers use to investigate and monitor their own behaviour, on the other. This participant observation by the author over an extended period forms a major part of the primary data source material upon which the thesis is grounded.

Analytical considerations.

1.30 At the same time as the theory of the firm has developed and expanded over the last two centuries, the nature of the firm itself has been changing, perhaps even more rapidly. There have been major qualitative changes in the socio-economic environment within which firms operate. Shorter product life cycles, more rapid technological developments, shorter supply lead times, fast local and global transport are all changes in the same direction. They characterise the differences between today's business and its predecessors. Of particular interest are the changes which have occurred in information processes. Both the scope and the transfer rate of information have assumed a role in the firm's own operational perceptions which was absent when traditional models of the firm were first proposed. Consequent upon this development is the increased complexity of many of the rules governing the firm's behaviour. Regulatory bodies, customers, suppliers, employees and owners all create the need for the firm to establish more complex functions to be effective, and this is only possible with the use of new developments in information handling and processing. Partly, this may result in purely quantitative changes, and although the resulting firm is much more complex, its behaviour can still be approximated by simple traditional models. If this is the case, and if the value of economic models lies only in their ability to generalise and to predict average behaviour, then theory may be unaffected by increased complexity in the firm being modelled. In other respects, however, major qualitative changes have resulted from information related developments.

1.31 Today's firm, operating in its complex information environment, has changed substantially from the firm which earlier models aimed to describe. It is necessary that new work to develop models of the firm takes place not simply because the old ones are inaccurate or incomplete, but because the firms themselves are changing. Furthermore, different approaches to models emphasize different aspects of the firm. These may be more or less appropriate to transient characteristics arising as a result of new information or other changes in the environment of the firm. The behavioural model with its dual emphasis both on the firm as a process, and the mechanisms within the firm as processes, is highly appropriate to the analysis of the more complex information processing entities which typify today's firm. It is not sufficient for a full economic description of the firm to have formal descriptions of the relationships between inputs and outputs. It is also necessary to describe the internal processes which bring these about. Such processes have been and are being addressed by research. The key new behavioural issue which is addressed in this study is flexibility, the ability of the firm to modify itself in response to external change.

1.32 On the methodological side, it is possible that the changes in the information environment may also benefit the development of economic models. The amount of data potentially available for analysis, and the sophistication of the analytical tools available enable a complex modern model to be developed. The complexity of the processes operating within small companies, and the multiplicity of external factors acting upon them, may be matched by powerful computer modelling software able to mirror much more closely the structure and relationships operating within the firm. There is no fundamental change in the objective compared to formal mathematical analysis but the logistical task of handling large numbers of variables and relations is much enhanced by computer use.

1.33 The remainder of the thesis is structured as follows. Part 2 considers basic principles of flexibility in economic behaviour. In two chapters it reviews the literature relevant to the modelling of flexibility and then goes on to propose possible extensions to the theory. Part 3 addresses the empirics of the research. Chapters 5 and 6 describe the methodology used to provide the grounding of the research. Chapter 7 details the development path of the computer model and compares it with alternative methodological strategies which might have been adopted. Chapter 8 describes the model of the small fish processing firm, and Chapter 9 evaluates the model. The fourth and final part of the thesis reviews the work, summarises the principal conclusions, and considers their implications both for flexibility modelling and for strategies firms themselves might adopt.

Notes to Chapter 1.

1. The Small Entrepreneurial Firm, 1988 by G.C.Reid and L.R.Jacobsen documents in detail one of these projects, which cover small young companies operating in a variety of industries. A second, addressing the operation of franchises, can be found in the thesis submitted in 1988 by A.Dnes.

2. In particular, successfully evaluating and contributing to the performance of other businesses has been a key feature of the business owned and managed by the researcher since 1981. A broad spectrum, in organisation size, structure, and industrial variety, has been observed, whose only common feature has been a link with the economy of northern Scotland.

PART II
PRINCIPLES OF FLEXIBILITY

Chapter 2 Literature Review.

Introduction

2.1. The literature provides the foundation for the theoretical approach. This identifies the firm as the unit of analysis, and uses a behavioural approach to analysing the firm's internal structure and dynamic characteristics. The modelling approach also follows a path, established in the literature, of formal representation of the economic entities as computer source code. Additionally published works underpin the analysis of flexibility in the derived firm model. This analysis considers the definition of flexibility in an economic context, the classification of flexibility attributes, the exogenous conditions determining flexibility, and the effects which flexibility itself in turn produces. It is appropriate to demonstrate the relevance of preceding authors to the present work, and to show how the literature provides specific support for the present work.

Sources

2.2. A review of the literature which has relevance to the behavioural modelling of flexibility in the firm reveals a wide variety of potential source material. Before assessing in detail the content of these works, it is useful to classify the principal relevant subject areas. This broad classification will then be used to provide the structure for the detailed consideration of the literature which supports the thesis. *Firstly*, there is the broad formal microeconomic theory used by economists to describe the firm, including Paul Samuelson's (1983) *Foundations of Economic Analysis*, and Carl Menger's (1871) *Grundsätze der Volkswirthschaftslehre*, translated (1981) by J. Dingwall and B. Hoselitz. *Secondly*, there is the behavioural modelling work addressing the mechanisms operating within the firm. Herbert Simon (1955,1957,1959) provided a base upon which Richard Cyert and James March (1963) established a comprehensive behavioural model of the firm, further developed by Richard Cyert and Morris DeGroot (1987). Herbert Simon's work on complex systems also provides the base for subsequent developments in software representation used in the present modelling process. Courtois (1985), following Simon (1982) addresses complexity in software systems. *Thirdly,* there is a body of literature in industrial economics which has considerable relevance to the issues considered in the present research. This third subject area extends further from the applied economics domain (Michael Porter 1980), into the more sociologically based topic of management studies (Thomas Peters and Robert Waterman 1982), and on into the more practical and technical topic of production engineering in specific industries (eg Pall Jensson 1988 *Daily Production Planning in fish processing firms*). A *fourth* set exists, of small firm organisation studies which have been largely conducted within the last two decades. These studies address the specific behaviour of small firms, and have considerable relevance to behaviourally based economic research such as the present thesis. Authors include Gavin Reid (1988, 1990, 1992), and contributors to several collections of papers such as Michael Scott, Gibb, et al (1986), Curran, Stanworth and Watkins (1986), and Burns and Dewhurst (1986) *Fifthly*, and finally there have been a series of studies undertaken which specifically address the topic of flexibility in an economic context. Starting with George Stigler in 1939, the works specifically addressing flexibility include Marvin Mandelbaum and John Buzacott (1990), Bo Carlsson (1989) and Burton Klein (1984). The present work is intended to add a further member to this series. *Lastly*, there is a body of methodological literature relating to development of the computer model and documentation of firms information systems. This includes authors such as Courtois (1985), and Zave (1984) on the object oriented systems approach, and Yourdon (1979,1989) and Wirth, (1974) on structured systems. Additionally there exist various standards for information systems analysis and documentation both from public bodies such as the British Standards Institute, and the National Computing Centre, and internally within corporations such as IBM. The foregoing six areas thus comprise the literature relevant to the research. The following paragraphs analyse them in more detail.

Economics literature describing the firm.

The economic domain - firms, markets, contracts

2.3. Firstly, consideration is given to the broad formal microeconomic theory used by economists to describe the firm. The formal approach to defining the economic domain, upon which this work draws, has its origins in the authors who have established and developed microeconomic theory from the base provided in eighteenth century Scotland by Adam Smith. Adam Smith's findings relating to economic specialisation, and his innovative analysis of the functions of the market, provided a theoretical base for subsequent economists to develop, amongst other economic topics, the beginnings of the theory of the firm (Reid 1989). Building upon this base Carl Menger in Vienna, and Stanley Jevons in Manchester derived concepts of marginal utility which laid the basis for a more general marginalist approach. This was further developed by Alfred Marshall in Cambridge into the modern theory of price and output determination.

2.4. Because the analysis presented in this thesis makes considerable use of functions which are not highly abstracted away from the behavioural processes involved, it is appropriate to examine the sources of microeconomic analysis and evaluate their use of, for example continuous and non-continuous functions, cardinal and ordinal preference functions. Expositions by Carl Menger, Alfred Marshall, and Paul Samuelson typify three basic and different approaches. Discontinuous functions are used by Carl Menger (1871) in his *Grundsätze der Volkswirthschaftslehre* to determine optimum price and quantity equilibrium points. In contrast to this, in his Principles of Economics (1890), Alfred Marshall analyses equilibrium points via the mechanisms of the formal calculus of continuous functions. In his title page, Marshall wrote "natura non facit saltum", emphasising the importance of continuous functions in the real world. Paul Samuelson, in his *Foundations of Economic Analysis* (1983), traces the theoretical analysis of the firm back to Cournot, and makes many relevant arguments in favour of greater abstraction of analysis, suggesting that continuity of functions is not *necessary* for equilibrium analysis and formal characterisation of equilibrium positions by inequalities. It is important at this stage to distinguish a second, behaviourally related, usage of the step function form of analysis used by Carl Menger. In the formal analysis of Alfred Marshall (1890), continuous functions are employed as an indirect representational device to enable deductions about the behaviour of firms to be made through use of the mathematics of continuous functions. Marshall does not suggest that within the operations of the firm, conscious decisions are made using such a technique, but rather that it is a suitable modelling or formal representation of the general behaviour of firms. In this he follows a parallel position to that taken by Adam Smith when describing the "invisible hand" of market forces. With Alfred Marshall's analysis it is the representative firm which models the industry, and it is the model of the representative firm which responds not with steps but continuously. Individual firms may behave according to discontinuous functions, (e.g. because of discontinuities in production). What matters is that their overall responses can be *represented* in toto by continuous functions. This degree of abstraction from the actual process is made greater in the interests of a clearer, more concise and more determinable set of outcomes.

2.5. Carl Menger on the other hand, employs analytical methods that may be interpreted as directly translated from conscious decisions by the agents concerned. The degree of abstraction from the empirical events is less, though the approach remains theoretical. The examples used in his exposition do not so much extrapolate from real conscious decisions to a generalised formal model (as in, for example Cournot), but instead retain contact with behavioural variations in processes at the individual level. Thus, they are groupings of instances of conscious decisions into formal categories which are then used to describe, or model, the individuals behaviour. The analysis described, (for instance in the Grundsätze on pp 203-207), is a description of the modal or typical, rather than the mean or average, sequence of events. It concerns the determination of price in a monopoly situation. Here Menger chooses specific amounts from a particular situation to expound the principles involved. His method is to describe the sequence of events in a typical case and as a result he reaches his conclusions without losing any behavioural detail or realism in the exposition. His example is of a monopoly supplier of horses conducting an exchange with several competing suppliers of grain. Rather than describing the relationship in terms of, say, generalised, continuous, differentiable indifference functions, (as in Edgeworth's analysis of contracts), he picks out and tabulates (Grundsätze p.204) particular datum points at which equal values are assigned to a quantity of grain and a number of horses. Thus he retains important aspects of the problem such as the large size of the units of one side of the transaction relative to the units of the other good, which in turn limits the precision with which the solution to the exchange relationship may be expressed. Thus, within a range, a pricing outcome is determinable, though not strictly determinate. This wish to retain behavioural detail within the exposition is a key element in the design of the model presented here, and in the methodological approach which has been adopted.

2.6. Paul Samuelson's (1983) view is that the reasons for the lack of continuous, differentiable functions in the analyses of earlier theorists lie, in some measure, in the limitations of the mathematical techniques available to them. As he puts it his *Foundations of Economic Analysis* (p.35) - "The classical economists, lacking the precise notion of an infinitesimal, were forced to employ the concept of a broad extensive margin". He is clearly correct. What the advances in mathematical technique allowed was a greater degree of abstraction, and the ability to build a more compact, but still logically consistent set of equations to represent the firm. That does not of itself imply a greater degree of behavioural accuracy, nor even the reverse. However, it is possible to apply Samuelson's principles more specifically, and to examine some limitations to behavioural accuracy imposed by a concise symbolic representation, which includes only determinable continuous functions. For example, suppose that the classical economists' concept of a broad extensive margin were in fact to be the case in a particular instance. That is to say: suppose that a much looser functional relationship existed which was not strictly determinable, but which followed certain rules which could be described behaviourally by reference to empirical examples. Menger for instance, has an example in his theory of price which postulates such a broad margin, determinable only through the inclusion of stochastic behavioural variables[1]. He also points out elsewhere that the satisfaction or utility function is a subjective one, and one that is frequently subject to error[2]. Determinate predictive models cannot be built because of the lack of a completely defined variable set. It is the case that multiple sets of functions and parameters may be derived which fit particular sets of observations. Nevertheless, because observations are not necessarily consistent, because of the broad extensive margin a single, logically consistent and determinable symbolic model appears to be methodologically unachievable. One route which takes account of such indeterminate relationships in a precise way is Bayesian analysis, where the looseness of the relationships may be represented by the probability sets perceived by the agents within the firm. A second route is to use a set of software rules to represent the observed behavioural rules which restrict the functional relationships employed. This is entirely consistent with Samuelson's analytic method, though it effectively substitutes behavioural accuracy and complexity for symbolic elegance and conciseness. However, the use of a computer model to handle the complexity means that it is possible both to have the usefulness contributed by behavioural accuracy *and* the ability to manipulate the consequentially less concise set of equations. A key point also follows on from Samuelson's observation on methodological limitations to theory development. Computer software technique, as well as mathematical technique is a developing subject. A case can now be put that the object oriented techniques available for handling complexity and behavioural accuracy which are offered by current computing facilities, can be combined with formal structural definitions in a way which was impossible when Cyert and March wrote their pioneering work. The synthesis of procedure and structure, which is made possible through object oriented computing techniques, adds behavioural realism to the model, but is still able to retain the functional conciseness of a formal model.

Paul Samuelson (1983) defines comparative dynamics, and suggests an approach for investigating the properties of a dynamic model. Samuelson first analyses static systems, and expounds the method of comparative statics. Following Professor Ragnar Frisch (1935), Samuelson defines a dynamic system as one whose behaviour over time is determined by functional equations in which variables at different points of time are involved in an essential way. Then, comparative dynamics is defined as a study in which one of a broad class of changes is made to a dynamic system, and this change is then followed by examination of the subsequent behaviour of the system. Firstly, changes may be made to the initial conditions present in the model. Samuelson then defines a stable system as one where, given a sufficiently long period, there will no final alteration in the behaviour of the system. Conversely, an unstable system is one whose behaviour will continue to alter over an infinite period. Secondly, changes may be made to exogenous variables. Samuelson identifies three cases: the change may be permanent; it may be intermittent; it may be transient or instantaneous. Thirdly, Samuelson suggests another type of change. This is a change to the internal parameters of the system. The three methods suggested by Paul Samuelson determine the agenda for the analysis of the model described in Chapter 9.

Herbert Simon and the representation of complexity - the behavioural model literature, and industrial organisation.

2.7. There is a set of more recent writers who are relevant to the matter in hand as they consider the internal mechanisms of the firm, and it is worthwhile considering what they find, and whether their findings can be applied to flexibility issues. They comprise the authors of the behavioural theory of the firm, and their theoretical sources, and the industrial organisation theorists. Several fundamental assumptions used in the analysis of this thesis are based upon the ideas developed by Herbert Simon, for example in his (1962) consideration of complex systems. These ideas and their relationship to the behavioural theorists, and the software development theorists are discussed below.

2.8. Firstly, the software approach to the model is derived from Simon, and subsequent work on complex software systems. Simon (1982) describes the nature of nearly decomposable subsystems. Intracomponent linkages are generally stronger than intercomponent linkages. This has the effect of separating the high-frequency dynamics within components from the low frequency dynamics between components. Courtois, (1985) applies the work of Simon and Ando (1961) to software systems, and suggests that complexity takes the form of a hierarchy. A complex software system is composed of interrelated subsystems that have in turn their own subsystems, and so on, until some lowest form of elementary component is reached. Flood and Carson (1988) give a formal description in systems science terms.

2.9. Secondly, in the economic analysis presented here the firm is treated as a hierarchy which displays the attributes of a nearly decomposable system. Simon (1982 p. 221) observes that hierarchic systems are usually composed of only a few different kinds of subsystem in various combinations and arrangements. The empirically based model, described in section 3 of the present work, treats the firm as a complex information processing system. It is divided into subsystems along similar lines to the functional subdivisions of Michael Porter (1980). This is not the same hierarchical analysis applied by Oliver Williamson (1975) which also relies upon Simon's work on complex systems. Williamson (1975) and Williamson and Ouchi (1983) discuss an administrative hierarchy structure of human participants in an organisation. The organisational and motivational structures are the basis of Williamson's hierarchy. It is a hierarchy of superiors and subordinates linked by formal and informal contracts. In contrast, the hierarchy being considered here is applied to classes of information processing structures. That is to say that the firm, considered as an information processing system, can be split up into a lower level of component parts each of which forms a separate subsystem. Within these functional subsystems, for example purchasing, production, control, etcetera, interactions are stronger than they are between the subsystems. It is also possible to distinguish a further, lower, level of subsystem within these functional subsystems. This further subdivision consists of the individual decisions taken within each of the functional subsystems. These decisions constitute the lowest level of analysis considered here, and each decision is a subsystem composed of the information inputs to the decision, the action outputs, the functional subsystem to which the decision belongs, and the time attributes of occurrence, and response. Herbert Simon (1957) himself identified the decision premise as a possible lowest level datum for economic analysis.

2.10. Simon's approach to state descriptions and process descriptions is also relied upon in the model presented here, where the computer software is the process description pertaining to the firm, but may also contain the data describing the state of the firm at a particular instant. Simon's model of human problem solving behaviour also forms the basis for the approach to the substantive behaviour being modelled. As Simon (1962 p. 479) puts it: "The distinction between the world as sensed and the world as acted upon defines the basic condition for the survival of adaptive organisms. The organism must develop correlations between goals in the sensed world and actions in the world of process". Simon and Newell (1962) take a similar approach to computer modelling of decisions.

2.11. Richard Cyert and James March (1963) address the same problem, i.e. not one related to defining the interfaces between firms, but more specifically related to the processes operating within a given set of boundaries which define the firm. They place the conscious behaviour of the participants at the forefront of the analysis and in doing so provide a theoretical justification for the empirical survey undertaken as part of this work, a survey which specifically addresses how individual decisions are consciously taken in a specific industrial context. Grounding the model upon empirical data is considered vital to the study, and other later authors have emphasised the need for empirical studies. For example Gavin Reid (1987a), in the field of small entrepreneurial firms, stresses the importance of quantitative empirical grounding for economic theory. Bo Carlsson (1989), addressing flexibility in industrial organisation, has called for more empirical flexibility studies. The contribution to this project of Cyert and March's theoretical insight is the accent upon conscious decision making processes as a key determinant of flexibility. It is argued elsewhere within the present thesis that the degree of abstraction in the model is important. This is the principal feature that separates, on the one hand, models using simple summary functions to predict input/output relationships, from, on the other hand, models which emphasise the internal, and often less easily determinable, mechanisms within the firm. Richard Cyert looks at the micro-forces which operate in the firm and makes the point that not only should the internal mechanisms be modelled, but that understanding the conscious motivations of the participants is necessary to in order to understand the operation of the firm at any degree of abstraction. It is worth examining this particular view further.

2.12. Milton Friedman (1953) emphasises that detailed empirical assumptions are not necessary for a valid theory, provided that the general predictive ability of the theory is acceptable. This view contrasts with the behaviouralist view that if a basic assumption of a theory, say profit maximisation, is not observed empirically, then the theory requires amendment. Both views have their merits. On the one hand, if by removing behavioural complications, a theory can provide a clarity of view and simplicity of construction which is otherwise unobtainable, then it is a more useful theory, on these counts, than one burdened with unnecessary behavioural complexity. On the other hand, if the theory is then put to a *use* which is closely concerned with the theoretical simplification, then the *validity* of the theory has to be questioned. It is valid to ignore friction, when developing a simple formal description of the movement of a pendulum. It is less valid to ignore it when designing a pendulum clock. It is quite invalid to ignore friction when oiling a pendulum clock. The validity of the behavioural theory lies in its application. For example, when applied to the prediction of macroeconomic variables such as the general levels of prices and output, a concise profit maximisation assumption which ignores behavioural complications is a vital simplifying assumption. It is valid when formally describing, for example, the macroeconomic effects of general interest rate changes. It is less valid to ignore the behavioural complexities when applying the same basic theory to the design of an industry regulatory regime. It is quite invalid to ignore the behavioural complexities when analysing adjustments in the behaviour of individual firms, or small groups of firms. The difference lies not in the theory being applied, but in the field of application. As Cyert and March (1963 p15) put it:

> "*The theory of the firm, which is primarily a theory of markets, purports to explain at a general level the way resources are allocated by a price system. To the extent to which the model does this successfully, its gross assumptions will be justified. However, there are a number of important and interesting questions relating specifically to firm behaviour that the theory cannot answer and was never developed to answer, especially with regard to the internal allocation of resources and the process of setting prices and outputs*".

2.13. Turning to the present research topic, the choice of economic theory should be determined by the field of application. The economic theory to be used here is applied to the field of *individual* firm performance. General conclusions about the cumulative influence of S.E.F.s' is not the objective of the present research. The present research aims to draw conclusions about how individual firms react to external shocks. It is concerned with S.E.F.s as a group, but it is as much concerned with the differences encountered between individual firms as it is with the effects of their cumulative behaviour. If the identification of these differences provides insights into the cumulative behaviour of the industry or of S.E.F.s in general, then so much the better. Nevertheless, the fundamental application is to the individual firm. The behavioural model is therefore the appropriate approach, and the modelling of empirically determined decision processes is the primary theoretical device. Assumptions such as profit maximising are still incorporated in the model, but not to the exclusion of the more complex behaviour observable in the field.

2.14. J. R. Commons (1934) suggests that the transaction, a lower level than the firm, should be the basic unit of analysis. R H Coase (1937) considered the reasons for handling transactions within the firm or through a market and Oliver Williamson (1979) built upon this a theory of transactions which operates at a lower analytical level than the firm. The unit of analysis in the present project is not simply the firm, but for some purposes the firm and for other purposes individual decision. This follows both Herbert Simon's (1957) and Oliver Williamson's (1979) suggestions and enables the study to comment upon important phenomena observed within the firm. Following a behavioural approach firstly enables this greater analytical detail. Secondly it narrows the empirical gap between the raw data obtainable from the field, and the manipulable theoretical model. Thirdly, it allows closer linkage of the theory to other disciplines where the sociological and psychological factors are given greater emphasis.

2.15. Richard Cyert's view (Cyert and March 1963, Cyert and Degroot 1987), sees the firm as composed of pragmatic decision takers whose incomplete observations and knowledge lead to satisficing behaviour rather than the optimisation of a single function. This is echoed in the model used here which follows such procedures iteratively. Each iteration sets control variables within the bounds of which optimisation takes place for that period.

2.16. Cyert and March also make an important methodological step in the use of computer modelling techniques to illustrate and investigate their behavioural propositions. In chapter 5 of *A Behavioural Theory of the Firm*, a detailed computer model is set out using the software techniques available at the time. This is used to illustrate the theoretical principles. It shows how other, more complex processes than simple profit maximisation may be modelled, with limits on internal variables and lags in response, which are tightly linked to conscious decision rules. As described in section 3, the translation of this model into current software provided a proving exercise to check the suitability of the particular software techniques used. Richard Cyert (1988) notes that the advantage of computer simulation over mathematical modelling is that more complex relations can be developed in the simulation. He does also sound a note of caution, however, regarding the power of the computer to make a complex simulation nearly as complex, and as difficult to analyse as the real world.

2.17. Having established the appropriateness of a behavioural approach which looks at the processes operating within the firm, the literature review now turns to those authors who have made contributions to microanalytic intra-firm theory. Harold Demsetz (1988) and Armen Alchian (1972), together with Oliver Williamson (1985), are the principal authors concerned. Following R.M. Coase (1937) their analysis is directed towards defining the firm. The analytical framework developed by these authors to examine the firm components is of direct use to the present investigation. In their 1972 study, Armen Alchian and Harold Demsetz introduce the team concept as an explicit way of distinguishing which activities will be internal to a firm, and which take place using transactions external to the firm.

2.18. Demsetz and Alchian base their models upon one internal relationship, a behavioural function describing a set of procedural rules, rather than an algebraic relationship between variables. They develop this supervision/slacking function, and produce a set of preconditions for defining the firm. These preconditions relate to team formation and are used to define the structure of the firm as a team with an entrepreneur performing a monitoring function over the other team members and claiming the residual profit.

> They define the ownership of the firm as the following set of rights accruing to the owner:
>
> (1) the right to be a residual claimant
>
> (2) the right to observe input behaviour

(3) the right to be the central party common to all contracts with inputs

(4) the right to alter the membership of the team

(5) the right to sell these rights (H Demsetz 1988, *Ownership, Control and the Firm* p. 121).

These preconditions relate largely to the entrepreneur's power to build, monitor and provide capital for the team, in exchange for profits. The authors also correctly observe that metering of productivity of team members is an important firm function in its own right. As they put it: "If the economic organisation meters poorly, with rewards and productivity only loosely connected, then productivity will be smaller, but is the economic organisation meters well, productivity will be greater." (H Demsetz 1988, *Ownership, Control and the Firm* p. 121). This principal is well understood both by practising managers and in management and sociological disciplines. Thus the relevance of Demsetz and Alchian's work for the present research lies in their explicit description of the firm as control mechanism, with input data, performance data, and a monitoring process. This is the structure followed in the model described in chapters 7 - 9 below.

2.19. Oliver Williamson (1981) has pointed out that scale factors may be significant in team production, and that consequently the team approach has limited applicability. The point is made that teamwork is only found in particular small scale operations and cannot therefore be applied to large corporations. The use of the team control model for describing the group of *small* firms which are the object of the present research is thus still valid. However, the scope of flexibility issues discussed in the present thesis is not restricted to small firms only, and it is worth studying Williamson's point further. His comments upon Demsetz and Alchian's approach relates to a technical definition of teamwork. That is the definition that teams form *if and only if* it is not possible to observe the individual team members productivity. Members of the executive **teams** which do run large corporations would not recognise such a strict definition. It is worthwhile considering the effect on the criticism if the definition is relaxed to state that teams are defined also when simple *improvement* can take place in the ability to observe productivity. Taking this less restrictive definition as an axiom no major change to subsequent reasoning is necessary. With this modification the criticism of lack of wide application fails and the teamwork model may be applied to the full spectrum of organisations. This is important for the present work. The flexibility issues studied in the present work are grounded on an empirical base of small firms. However, writers in the management field (Thomas Peters and Robert Waterman 1982) view small teams in large organisations with favour. They see them as a mechanism for combatting the disadvantages which result from organisational complexity in large corporations. Their view is that use of the self monitoring team structure within the organisation is a behavioural attribute of successful corporations. The same may be said of flexibility. If flexibility attributes can be identified which contribute to the success of S.E.F.s then perhaps they may also be applied to corporations. If problems of organisational complexity are improved by teamwork structures found in small firms, then similarly problems of organisational change may also be improved by flexibility attributes found in small firms.

2.20. In the management literature, the use of self monitoring team structures is recommended as a means for achieving flexibility and innovation in large organisations. Thomas Peters and Robert Waterman (*1982 In Search of Excellence page 131*) describe the behavioural processes for selecting and designing the 360 product line at IBM, which subsequently determined IBM's overall production strategy for the following two decades. They emphasise the self monitoring team operating within the corporation. Several of Demsetz's firm definition conditions are consonant with this example. Further issues relating to teams in large corporations are discussed in Thomas Peters and Nancy Austin (*1985 pp. 213-251*). Although the translation from a single theoretical team led by a hypothetical individual entrepreneur to a concrete example of documented teamwork within a large firm is a substantial step, the message concerning the behavioural concept in general is that teams are perceived within the firms themselves as important factors for organisational success.

2.21. The self monitoring team model is important for two reasons, as a guide to empirical sources, and as a pattern for the structure of the computer model. Firstly, the empirical task, both of the formal project data collection exercise, and of the pre-project work in the field, requires access to the data concerning the firm's conscious responses to external change. Demsetz and Alchian's analysis supports the approach taken here, that the observers of the teams' productivity, ie the entrepreneurs, are the best source for the empirical study, and that interactions within the team are an appropriate object of study. Secondly, the emphasis by Demsetz and Alchian upon monitoring of internal performance, provides support for the use within the computer model of specific internal monitoring functions in determining decisions, rather than directly linking responses to the external stimuli. This complements the approach of Cyert, so that the model has a control mechanism mode of operation where an observable variable is monitored, and improving actions are taken in consequence.

2.22. The supervision/slacking function described by Demsetz and Alchian is greatly simplified for the purposes of setting up their model, and translating it into real situations may perhaps reduce its validity. At one end of the process there is the profit of the firm, and at the other end there is the large collection of day to day price setting and output setting actions. In between is the mechanism for relating the one to the other. This mechanism is the team. There may be several threads to the control mechanism operating in the team. These might concern such diverse aspects as maintaining the firm's reputation for product quality, controlling high risk activity, and evaluating new markets. The supervision/ slacking monitoring behaviour is thus only one of a number of similar monitoring interactions which operate internally within the firm. It concerns one aspect of monitoring which relates specifically to the inability to directly observe individual productivity and thus have it priced through the market. That is to say it relates to the pricing of one factor, labour, which is accordingly internalised within the firm. Observation and mensuration problems occur with other factor inputs, with product outputs and with forecast costs and returns. The control mechanisms described by Demsetz and Alchian provide the pattern for the present control model, but to incorporate these other aspects of monitoring and observation it is useful to turn to the work of Oliver Williamson.

2.23. Oliver Williamson (1989) adopts a contractual approach to the study of economic organisations. Following Commons (1934) and Coase (1937) he emphasises the relations between organisations. These take the form of transactions. The transactions have a cost which rational individuals will economize. They may be conducted according to the rules of a market, or they may be conducted according to different rules established within an organisation such as a firm. The relative costs of transacting in the market or transacting in the firm determine which mode is used for particular types of transaction. Thus a firm will form where the costs of transacting, for example, for labour supply, are lower within a firm than in the market. Production is not the key element governing firm formation. Contractual relationships are. Transaction cost issues raised by O.E Williamson (1985) on vertical integration and asset specificity do imply that a firm may be defined in terms of its contracts related to a particular set of productive assets. However the behavioural issues relating to the contracts are the primary determinants of the organisation form, rather than the physical characteristics of the plant. These are important matters affecting the analysis of flexibility because conducting transactions in a particular way may enable the firm to respond more quickly to external change. Incorporating these issues into the present model requires a mechanism for comparing the results of two different types of transacting. The model therefore has to be able to compare, for example, a fixed price factor input, with a market derived factor input, or an internally predetermined output quantity, with a market driven one.

Applied economics and management literature.

2.24. There is a body of literature in industrial economics which has considerable relevance to the issues considered in the present research. This applied economics and management literature has aims which differ from the present research. Rather than simply endeavouring to describe and explain the firms actions, as is the aim of this thesis, the key expositions of authors such as Michael Porter, Thomas Peters and Robert

Waterman are additionally prescriptive studies aimed at the agents involved with the firms. Notwithstanding this prescriptive format, however, they provide a suitable pattern for a model building process. The analytical techniques and the internal structural schema used by Porter in *Competitive Strategy* (1980) are used directly in the software structure, determining the component parts of the model. Porter (1980 p xvii) following Andrews (1971), and Christensen, Andrews, and Bower, (1973), gives the following behavioural components of a firm:

Marketing
Sales
Distribution
Manufacturing
Labour
Purchasing
Research and Development
Finance and Control
Product Line
Target Markets

This list provides the pattern for the nearly decomposable decision sub-systems, used in the model described in chapters 7 - 9 below.

2.25. Porter (1980) categorizes industries using concentration, maturity, and exposure to international competition as the key dimensions. In this analysis he provides an interesting and relevant empirical example, from the fish processing industry. (Porter 1980, p. 211) Prelude Corporation, analysed in by the Harvard Business School, had the stated goal of being the "General Motors of the lobster industry". Prelude Corporation followed a strategy of vertical integration from fishing fleet to restaurant, combined with obtaining a large market share. The company ceased operations because of its failure to recognise the causes of fragmentation in the industry. Porter offers two reasons for its downfall, both of which have relevance for the present study. Firstly "the high overhead structure and heavy fixed costs maximised the company's vulnerability to the inherent fluctuations of the catch in the industry". What Porter is saying here is that, flexibility,(ie the ability to respond to exogenous fluctuations) should be the key strategy, rather than economies of scale, in this particular case. Secondly, Porter says "The high fixed costs also led to undercutting on price by small fishermen who did not measure their businesses against corporate return on investment targets but seemed satisfied with a much lower return". Porter is saying that, in this particular industry, profit maximising behaviour does not obtain. The survivors in this particular case were the non-maximisers who followed a more flexible strategy. Porter (1980) thus provides support firstly for the significance of flexible structure as an alterative to cost minimising structure, and secondly, for the usefulness of the behavioural approach for directly predicting economic consequences.

2.26. Peters and Waterman (1982), like Michael Porter, write at a much more pragmatic level. They use a practical, empirically based methodology, based upon a wide range of client corporations with whom they have worked. Their empirical data was collected principally for other purposes directed towards the firms themselves. This empirical methodology, conducted in a formal manner, but not for the immediate purposes of research provides the paradigm for part of the present study, detailed in chapter 3. Their work is to a certain degree parallel to that of Oliver Williamson at the theoretical level. They emphasise management style, communications, and interpersonal relationships. They seek to demonstrate the importance of behavioural factors over technological factors in determining firm characteristics. Adding to the theoretical behavioural sources such as Herbert Simon, Richard Cyert, and W. Baumol, their analysis of the distinguishing traits of successful corporations provides further justification for a major emphasis upon behavioural data in the modelling of flexibility. The present work does not address corporations, but the issues raised by Peters and Waterman are equally applicable to smaller business organisations.

2.27. The applied economics literature written by Gavin Reid provides sources for several themes which run through the present thesis. The first of these themes is the willingness to approach complex behavioural issues in a formal quantitative manner, in addition to the more tractable literary exposition. As Reid (1987 p 96) says in discussing the Austrian School: "there seems no intrinsic reason why any literary statement of a theory should not be expressible in mathematical terms." and "it seems likely that certain aspects of Austrianism are particularly amenable to mathematical analysis and provide rich material for deeper theoretical investigation." This is the source of the present aim to construct a formal computer model of processes previously described in literary terms only.

2.28. The second theme derived from Gavin Reid's work is the close methodological linkage between theoretical constructs and direct contact with firms themselves. Gavin Reid (1986) advocates the use of field research methods for the study of business enterprises. Fieldwork techniques, more widely used in other disciplines, should be applied to industrial economics. He illustrates the proposal with a description of an implementation of the technique. Reid (1987a) develops the idea further and establishes a methodology for conducting research into small entrepreneurial firms (S.E.F.s). The method includes participant observation followed up by collection of both quantitative and qualitative data by administered questionnaire and semi-structured interview. The same approach of using fieldwork techniques from other disciplines, and including participant observation in the empirical scheme has been used in the present field work described in section 3 below, although the resulting instruments differed considerably because of the topic and the greater possibilities for participant observation.

2.29. Face to face contact with the individuals who are implementing the flexibility propensities described in the model, in order to ensure close representation, follows on from the approach of Reid. Emphasis is throughout placed on grounding the economic theory in secure empirical experience. The work undertaken by Reid places particular stress upon returning to the close contact between the economist and the business enterprise which obtained with the great classical economists Adam Smith and Alfred Marshall. The link between merchant and academic was of fundamental importance to Adam Smith's work. The reality of business activity was also the direct concern of Alfred Marshall. Closing the gap between economics and business is a central aim of this research. The accent placed on grounded theory in Gavin Reid's work provides a key precedent for this aim.

2.30. One of the contributions made by George Stigler's 1939 paper is to isolate flexibility as an attribute of the factors which provide the inputs to the production function, and as an attribute which has a cost. T. Peters and N. Austin(Ch. 14 pp 213-251) provide extensive illustrations of this principle as seen from the participants point of view. The profit maximising aim is still present in the model, but it is one of a set of aims all of which have to co-exist for survival of the firm. In this sense, it is a type of constrained profit maximisation.

2.31. That flexibility is a key current issue is also well illustrated through reference to the industrial literature directed at the firms themselves. For example, the Professor of Industrial Production and Factory Management, H.J.Warnecke (1982), of the University of Stuttgart, writing with G.Vettin, Head of Manufacturing Systems at the Frauenhofer Institute of Production and Automation, has this to say: "Many production enterprises are currently being affected by structural changes which are caused by factors both internal and external to the company. The market demands an increasing variety of products and of product variants. For the manufacturer, the life of many products has a tendency to decrease. A steady rise in the cost of personnel, material and plants can be seen, as well as the declining cost of electronic controls" They go on to discuss practical problems associated with the need to deal specifically with flexibility in budgetary control of plant.

Small firm sociological studies.

2.32. The behavioural aspects of this treatise also prompt consideration of the many sociological studies conducted into the activities of small entrepreneurial firms. Following the Bolton Report (1971) in the UK, and greater political attention to small business in the late seventies and eighties, a considerable literature has developed investigating S.E.F. development patterns.

2.33. There is some difficulty in directly relating these sources to the current research task, and it may be thought that the sociological emphasis excludes them from contributing in a significant way to the present work. Many of the treatments tend to be of a broadly social nature, without the analytical precision to be found, for example, in Michael Porter's analyses of the large corporation. Much of the work has been undertaken from a normative standpoint, with the aim of providing a basis for the design of policy instruments, and it considers broader issues than are relevant to this thesis. For example James Curran, John Stanworth, and David Watkins (1986), in their two collections of papers entitled *The Survival of the Small Firm* address issues such as survival, entrepreneurship, employment, growth, new technology, and politics. These issues may not directly impinge upon the formal economic modelling of flexibility, but they do provide useful insights into the behavioural processes. Authors such as David Storey (1981,1987), and Michael Scott (1986) and others working in the field of small firm behaviour address some dynamic issues relating to small firms, and provide further behavioural background.

2.34. Balanced against this lack of formal analytical rigour, however, is the clear evidence, present throughout the greater part of this literature, that the writers have established a direct dialogue with real firms. This empirical closeness to the object of study, with its reliance on first hand evidence, provides further insights which are useful in understanding the key flexibility decisions taken by entrepreneurs. In a similar fashion to the firm interviews, and the industrial experience, these sociological studies have contributed to the very necessary behavioural colour in the present thesis.

Specific flexibility studies.

2.35. George Stigler in 1939 established a milestone for the analysis of flexibility in the firm. His 1939 article in the Journal of Political Economy provides a formal model of flexibility in the short run production function. He is the first to address flexibility as an attribute which may be modelled directly. He analyses flexibility as it relates to variation in demand and plant output levels. His formal analysis considers how much flexibility is built into the production function. For example, either by increasing the divisibility of fixed plant, or by reducing it relative to variable services, it is possible to produce a less steeply inclined marginal cost curve. For a given level of output, however, this will have a higher cost than a less flexible plant, and Stigler finds that flexibility will be added until its "accumulated" marginal cost equals the discounted marginal returns from savings due to that flexibility.

2.36. Flexibility itself forms the principal subject of a number of theoretical and empirical studies. Starting from the base provided by George Stigler (1939), Bo Carlsson (1989) has mapped out an agenda for further work. Burton Klein (1984), in his analysis of the dynamics of competitive operation gives flexibility issues a major rôle in determining the relative performances of firms, industries, and indeed whole economies. More specific, empirically based, studies are described by Mills (1984), and Mills and Schumann (1985). Sheshinski and Dreze (1976) have also contributed to the body of knowledge in the area of response to exogenous fluctuations. The present research work is an extension of this empirical work on flexibility. A conference addressing flexible manufacturing systems took place at Anne Arbor, Michigan in 1986. This produced several useful insights, in particular, an important contribution from Mandelbaum and Buzacott (1986), who produce a two stage dynamic model using a game theoretic approach, documented in Mandelbaum and Buzacott (1990).

2.37. Stigler's analysis follows Marshall's definition of the short run as the period within which there are fixed costs. With Marshall, Stigler observes that there are an infinity of "short runs", each applicable to different sets of fixed costs. He analyses flexibility through comparison of short run average cost curves, as shown in figure 2.1.

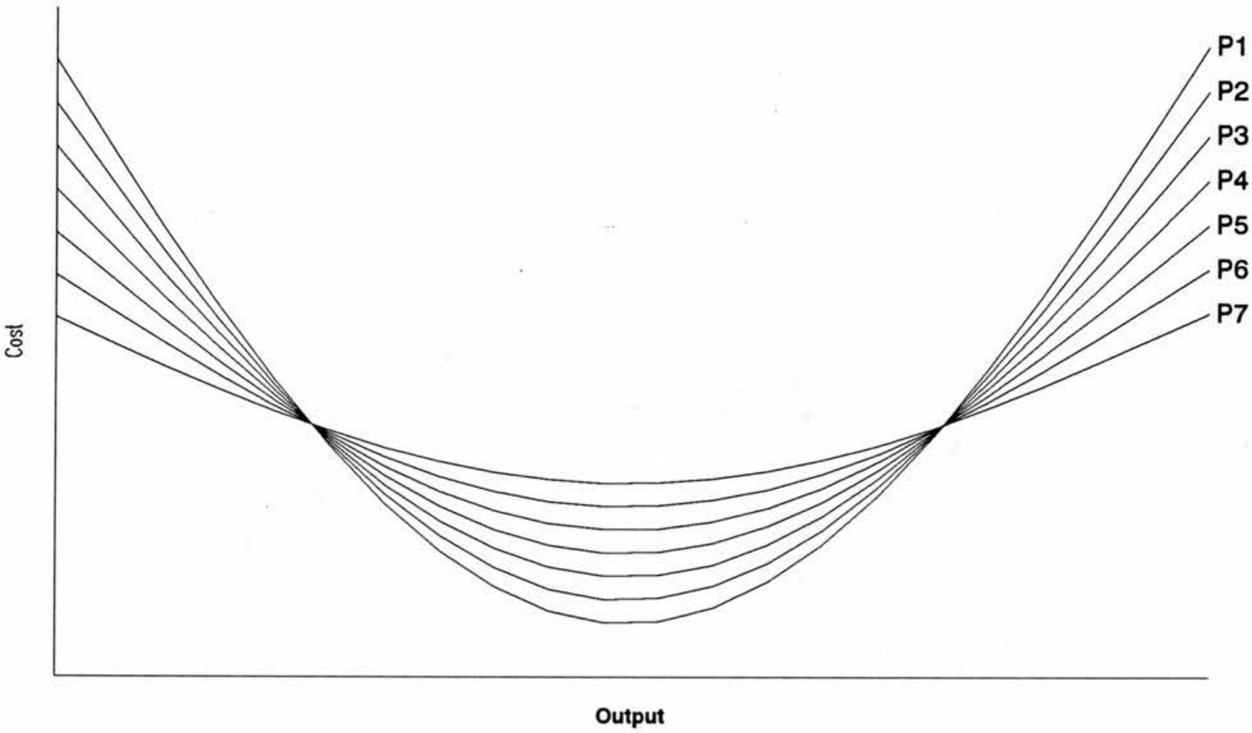


Figure 2.1

Average cost is measured on the vertical axis and output on the horizontal axis. Each of the curves p1,p2,...p7 represent the cost per unit of output which arises at different levels of output throughout the production range. Contrast is made between on the one hand, the inflexible plant represented by p1 in the diagram, with costs rising steeply at production levels above or below the optimum, and on the other hand, the flexible plant, represented by p7 on the diagram, where the average cost function is flatter in form around its minimum. Stigler observes that the minimum for the flexible plant situation will occur at a higher cost level than the minimum for a less flexible plant designed to operate at a specific output.

2.38. To simplify his analysis, Stigler uses the example of a fixed plant throughout as the element producing the fixed cost which defines the short run, although he does acknowledge the possibility of fixed salaries or other factors being fixed by contract or custom. However, his analysis can also be usefully applied where the fixed factor is not a set of tangible assets, but the set of entrepreneurial or organisational skills available within the firm. In this context, a flexible firm would be one in which such entrepreneurial skills were able to cope with a wide range of outputs, and an inflexible firm would be one in which these skills were themselves sharply optimised around one particular output level.

2.39. Stigler uses other simplifying assumptions in his consideration of flexibility. His analysis throughout is concerned with the output level of a single product from a single plant with no technological change. He puts forward a formal solution showing how the flexibility level will be determined. "Flexibility will be added until its accumulated marginal cost equals the discounted marginal returns from savings due to that additional flexibility." Implicit in this formal solution are the assumptions of complete rationality and perfect information. Nevertheless, the formalisation is a very useful reference point, and provides a reminder that flexibility, in a sense, can be bought. Part 3 considers the effects of removing some assumptions contained in Stigler's model, in particular the single product assumption, the static technology assumption, and the unbounded rationality assumption.

2.40. Although it is essentially a static analysis, Stigler (1939) introduces several useful ideas and observations which contribute to the dynamic aspects of the problem, . Discussing the short term alterability of plant (1939 p. 321) Stigler says

"If output is expanding, it is very likely that the plant will be expanded to handle rates of production in excess of the contemporary level... A crucial factor is the frequency with which anticipations are revised."

In this footnote to his short term cost curve discussion, Stigler identifies the frequency of forecast revisions as a flexibility issue. This issue, although raised only as an aside in Stigler's static analysis, is a key contribution to the dynamic analysis of flexibility. Stigler also raises as an issue the continuity or otherwise of movements from one cost curve to another. Building upon the analysis of Frank Knight (1921), Jacob Viner (1932), and Alfred Marshall (1890) Stigler puts forward a continuous cost surface based upon a series of cost curves varying continuously through time. He questions the previously received doctrine that the long-run cost curve is simply the envelope of the family of short run curves, sensibly observing that the plant existing at any time is in part determined by the previous plant.

2.41. It may be argued that in first defining the short run as the period within which plant costs are fixed, and then considering the consequences of some short-run variability in plant costs, Stigler has simply restated Marshall's marginal cost analysis in a more complicated fashion. However, this would be to ignore the two principal contributions of the Stigler paper. The first of these is that there is a continuum between fixed and variable costs, and the positioning of production factors such as plant cost upon that continuum is related to exogenous fluctuations in required output. The second contribution the paper makes is to isolate flexibility as an attribute of the factors which provide the inputs to the production function, and as an attribute which has a cost. George Stigler's 1939 contribution, is cited in much recent work on flexibility, and it is to this more recent, more specific, and more empirically based, work that the study now turns.

2.42. The formal analysis of flexibility as it relates to demand fluctuation has been taken further. Sheshinski and Dreze in 1976 studied its long run effects on industry equilibrium. Their findings, that greater demand fluctuations lead to more firms with smaller capacity and higher resource utilisation, are countered to an extent by Mills (1984), and Mills & Schumann (1985). They add two useful new aspects. Firstly technological and organisational variation are important. Secondly, within an industry there is diversity in the way demand fluctuations impinge upon individual firms, and diversity in their response. A more recent empirical study in this same area (Das 1990), found that market share was negatively related to sales variability, supporting the view that smaller firms are more flexible. Mandelbaum and Buzacott (1990) model flexibility in a two period decision model. In it, period one decisions lead to a set of period two opportunities. Flexibility is then defined as a measure of the size of the opportunity set presented by a course of action. I.e. a flexible course of action is one which enables more choice at a later stage. This defines one of the two important characteristics of flexibility as discussed in chapter 3 below.

2.43. Burton Klein (1984) makes an important distinction between two distinct types of flexibility present in the firm. He distinguishes between Type I and Type II flexibility, the former being concerned with coping with known variations and risks, and the latter addressing newly disclosed opportunities and uninsurable Knightian risks. Expected changes in short term demand are met by the firm which has Type I flexibility built into its operations. It may have plant which can be switched between two different products, or it may be able to vary its production levels without marginal cost changes. On the other hand, the circumstances requiring Type II flexibility are typified by an unexpected supply change or competitive technological development which undermines the basis upon which the firm has been operating. Klein's model of dynamic competition states that external shocks requiring Type II flexibility are continually occurring. He extends this from the individual firm level to predict the macro effects seen between the US economy and the Japanese and European economies. Overlapping functions, frequent and informal communication, and loosely defined structures are all identified as significant contributors to Type II flexibility. (Burton Klein 1984 pp. 51-67). In his findings, Klein concurs with the management literature, for example Peters and Waterman (1982), and Peters and

Austin (1985), who report discovering such attributes in the more successful US corporations.

2.44. Klein's (1984) model relates to the present research work in two ways. Firstly, it links the elemental study of individual firm production relationships with the macro effects upon industry as a whole. The study of the individual firm is not undertaken with a view to advising an individual firm what steps are required to become flexible. It is undertaken in order to predict the effect at the macro level of features found at the micro level, and thus provide a better knowledge base for macroeconomic decisions.

2.45. The second important theoretical element drawn from Klein is the importance of unpredictable dynamic shocks in determining long term performance. Stochastic functions are a key feature incorporated within the model presented here. Klein bases a large section of his competitive model upon differential propensities to engage in risk taking. The present computer model does not go as far as Klein in isolating this as a quasi-variable, and using it within functions. This is not to gainsay its validity. Rather, it is a reflection of the difficulty of allowing for speculative plant changes, for example, within the computer model.

2.46. Bo Carlsson has recently set out a broad description of flexibility and the theory of the firm, extending from the initial capacity utilization aspects analysed by Stigler, through to the organisational and technological issues raised by Mills and Schumann, and on into strategic questions relating to the direction of the firm. He also shifts the perspective to an operational view, and examines the specific attributes and approaches which constitute flexibility in the operational sense. This study aims to expand further the empirical base, to extend the behavioural analysis implicit in Carlsson's paper, and to formalise the results in a computer model.

2.47. Bo Carlsson (1989), following Sten-Olof Gustavsson (1984) has three clearly defined classes of flexibility. These three classes relate essentially to time scale. The classes are operational flexibility, tactical flexibility and strategic flexibility. The classes are defined as follows. Strategic flexibility encompasses the firm's choice of plant location and plant purpose. The firm's ability to replace plant is used to define tactical flexibility, i.e. the firm, at a location already determine strategically, and for a purpose also already determined, may make tactical changes to plant to provide flexibility. Lastly, operational flexibility does not concern plant, product, or location changes at all, but rather the day to day application of the variable factors in the use of the fixed plant.

2.48. By way of criticism, it may be said that the analytical approach, segmenting flexibility into categories for the purpose of identifying its essential characteristics, will only highlight the most obvious technologically based aspects of flexibility, such as are discussed by Gustavsson. Are there attitudinal aspects of a flexible approach to sudden external change present throughout the firm? Management writers such as Peters, and economists such as Klein, and Carlsson himself, indicate that there are. Whilst analysing the physical processes may be important, of equal importance is the identification of key differences between organisational attitudes as a whole. The approach taken in this project is not to prejudge the issue by structuring the questionnaire along Klein and Carlsson's analytical lines. Instead the empirical study follows the functional structure of the firm itself, loosely categorising market oriented and production oriented decisions, and only generally indicating where short term or long term considerations were involved. Eliciting the flexibility information proceeds by examining and comparing key decisions taken under conditions of external change.

Information systems methodology

2.49. The literature sources which contribute to the research from an information systems standpoint are generally proactive statements about information processing. They are meant not only to describe and analyse information processing systems. They are meant, in addition, to provide guidelines for the setting up of new information processing systems. The literature is therefore doubly relevant to the present research topic. This is, firstly, because the firms which are the object of study are themselves information processing entities, and secondly because the economic model of flexibility proposed here is itself an information processing structure. Yourdon and Constantine (1979) address the design of information processing systems using a structured analysis approach. From a software representation viewpoint, Wirth (1974,1986) also presents a structured approach. These authors break down information systems into a hierarchy of data and procedure subsystems, which themselves may be broken down further into subsystems until an elemental level is reached. This elemental level represents a single data item in the data hierarchy and a single procedural statement in the procedure hierarchy. The sequential algorithmic paradigm used in the structured approach has encountered problems when dealing with complexity and concurrent processes (Brooch 1991). The object-oriented approach has recently been developed to deal with these problems (Stroustrup 1982,1986,1988, Brooch 1991). The technique is appropriate to the technical investigation and modelling of complex behavioural processes. The structure they propose is still a hierarchical one. The difference lies both in the order of analysis, and in the procedures followed to develop the software representation. The approach does not attempt the cumbersome method of trying to define the entire system in procedural and data terms first, subsequently breaking these up into successively smaller subsystems, until a point is reached where a computer implementation can be defined for all elements. Instead, the emphasis is placed upon selecting small, implementable sub-systems, defined as objects with both data and procedural aspects. The whole system is not necessarily defined at the outset, but evolves as the model is implemented. The "objects" which form the building blocks relate directly to the real world concepts being represented. For example, in the present research context, "a forecast of demand", or "a sales department", constitute "objects". For those familiar with the context of the user interfaces used in computer systems, objects may be defined such as a desktop, a window, or a document.

2.50. A contribution to the empirical processes described in part 3 has been made by the establishing of several standards for both information analysis and documentation. These exist in proprietary form and published form. The present author's own set of standards for information systems analysis are derived from the proprietary standards used by IBM in the 1970s, the National Computing Centre documentation standards of the same period, and British Standard BS 5515.

Literature review - summary

2.51. This chapter has sought support for the thesis through consideration of existing works. The support provided may be divided into four categories. The purposes of these categories are: *firstly* to provide the foundation for the theoretical approach to the description of the firm given in the thesis; *secondly*, to provide the foundation for the behavioural approach to analysing the firm's dynamic characteristics as used in this investigation; *thirdly*, to provide the source of the modelling approach used to represent the activity of the firm in its economic environment; and *fourthly* to underpin the analysis of flexibility in the model of the firm which is derived. The categories are summarised below.

Firm functional description sources.

2.52. The principal foundations for the theoretical approach to the description of the firm given here are found in the works of Carl Menger (1871), Alfred Marshall (1890), Richard Cyert (1963), Paul Samuelson (1983), and Reid (1987b). They have provided a set of economic tools with which to build the model of the firm, and guidance as to which of the functional relationships are likely to be of the greatest significance for flexibility.

Behavioural Sources.

2.53. For the behavioural strategy which underpins the whole approach to the design of the present model, the work of Richard Cyert (1963,1987,1988) is the initial source. Having accepted Cyert's strategy of examining the conscious motivations of the agents, it follows that the literature written by others outwith the mainstream of economics has great relevance. In this respect, reference has been made firstly to the management strategy writers such as Michael Porter (1980,1985), Igor Ansoff (1965), and Peters and Waterman (1982), who describe at length the conscious decision making of corporations in the United States. Also relevant for a behavioural approach is the work of authors such as

David Storey (1981,1987), and Michael Scott (1986) and many others working in the field of small firm behaviour.

Modelling Sources.

2.54. The modelling approach has its roots in the tabular expositions of the Austrian economist Carl Menger (1871). The structure of the model is based upon that described by Christensen, Andrews and Bower at the Harvard Business School (1973), and further documented by Michael Porter (1980). The appraisal of the model draws upon the methodology put forward by Paul Samuelson (1983) for the study of comparative dynamics. The satisficing software model described by Cyert and March (1963 ch. 5) gave a useful example to which current software technique could be applied. Reid (1986) provides the justification for using a formal model to represent behavioural issues. The computer representation has derives from the structured techniques of Yourdon (1979) and Wirth (1986), with substantial modifications fro behavioural complexity derived from Booch (1991).

Flexibility Sources.

2.55. The principal specific writers on flexibility whose works have provided the literature sources for the present study comprise George Stigler, with his 1939 formal static analysis of flexibility; Burton Klein (1983,1984), with his industrial strategy approach; and Bo Carlsson (1989), who has identified a research agenda and made initial observations on the topic. Oliver Williamson, in his studies of aspects of firms transacting behaviour (1985,1989), provides a number of useful insights which are essentially concerned with flexibility, though not explicitly so. More recent researchers such as Sheshinski and Dreze (1976), and Mills & Schumann (1985), who have undertaken empirical studies, have also proved to be useful sources regarding specific flexibility issues.

Notes to chapter 2.

1. "Human caprice has some degree of influence on the results" Carl Menger (1871) Grundsätze p.196

2. ".. stupid men may, as a result of their defective knowledge, sometimes estimate the importance of various satisfactions in a manner contrary to their real importance" Carl Menger (1871) Grundsätze p 148

Chapter 3 Extensions of Flexibility Analysis.

Introduction

3.1 The present chapter puts forward extensions to the flexibility definitions of Stigler, (1939), Carlsson (1989), and Mandelbaum and Buzacott(1990). It extends the flexibility definition beyond the simple breadth of choice flexibility documented by Stigler (1939), and Mandelbaum and Buzacott (1990). This is achieved by introducing the rate of response as a significant element. It has goes beyond Carlsson's (1989) short- medium- and long-term classification of flexibility towards a more qualitative classification incorporating a distinction between physical and organisational flexibility attributes. Finally it has identified the three key behavioural parameters of flexibility in the firm, drawn from the behavioural principles of Herbert Simon and Richard Cyert. These three key parameters are (1) the speed of observation and response; (2) the accuracy of observations and forecasts; and (3) the accuracy of the response selection algorithm. These key behavioural elements distinguish the flexible firm from the inflexible firm. They are implemented as parameters of the present computable behavioural model of the firm.

3.2 The chapter is organised in the following way. Firstly the distinction between the two categories of flexible strategy is developed. Secondly the behavioural features which distinguish small entrepreneurial firms from corporations are detailed. This is done so that features specific to small entrepreneurial firms which contribute to flexibility can be considered. Detailed consideration is then given to flexibility issues which relate to the organisation structure, initially in general terms, and then in terms which relate to the S.E.F.s which form the subject of the research. Following the consideration of flexibility in organisation structure, the analysis examines some examples of flexibility which relate simply to choice of plant or product.

Two categories of flexible strategies.

3.3 Theoretical examination of the various aspects of flexibility is made easier if flexible strategies are first grouped into two exclusive categories. These two categories are *choice flexible strategies*, which are distinguished from *response flexible strategies*. The first of these terms, choice flexible, relates to the breadth of options, or choices, open to the firm prior to deciding on a particular course of action. The second term, response flexible, measures the rapidity with which the firm is able to track changes in the exogenous constraints acting upon it.

Choice flexible strategies and response flexible strategies.

3.4 Flexible means adaptable, versatile, able to bend without breaking[1]. Flexibility is characterised by a ready ability to adapt to new, different, or changing requirements[2]. In relation to an economic model, flexibility means the ability of a system to quickly adapt to permanent or temporary changes in exogenous variables. In order to have flexibility, a system must be able to take on different conformations, each of which is appropriate to a particular set of exogenous variable values. Thus George Stigler (1939) analyses flexibility as the range of output levels for which a firm can be tolerably efficient. He asserts that a firm which has a wider range of output levels, at which it is tolerably efficient, is more flexible than a firm with a narrower range of output levels. However in a dynamic context, this ability to take on different conformations is a necessary, but not sufficient requirement for flexibility. In order to have flexibility a system must also be able to move from one conformation to another rapidly. This is the second necessary condition for flexibility. These two necessary components of flexibility give rise to the two categories of flexible strategies which the firm can adopt. Strategies which act to extend the range of different conformations are *choice flexible* strategies. Strategies which reduce the time to move to a new conformation are *response flexible* strategies.

3.5 Examples of flexible strategies which fall into the two categories are listed in Figure 3.1. These are strategies which might be employed by the firm faced with fluctuations in exogenous variables such as demand, supply, or technology.

Flexibility class	**Example strategy**
Choice flexibility	more smaller machines vs fewer larger machines
	variable output processes
	multiproduct plant
	multiproduct materials
	multiple source markets
	wider skill range
	multiple locations
	range of different markets vs single market
	range of different products vs single product
Response flexibility	frequent observation of environment
	good internal communications
	short term contracts or ability to vary key elements
	short production runs
	rapid deliveries vs bulk contracts
	variable hours
	output related pay
	small group structure

Figure 3.1

3.6 Stigler (1939) provides the example of a firm adopting different types of plant which are tolerably efficient over varying ranges of output. The plant which can operate over a wider range of output levels has an unit cost curve which is less upwardly concave. The term flexible is applied to the plant having the greater output range and shallower, less upwardly concave, unit cost curve. More recent approaches to the same basic issue have been made using decision theory. Mandelbaum and Buzacott (1990), following Gupta (1968) and Rosenhead (1972), use a two period decision model and an expected loss function to describe the actions of a firm faced with different numbers of alternatives. Both of these theoretical analyses concern choice flexibility. The distinction between choice flexible strategies and response flexible strategies is similar to that between the function values and phase in a sine wave, i.e. the first expression relates to different values on the y axis at a given x value, and the second relates to a shift along a line parallel to the x-axis at a given y value.The differing effects of choice flexible strategies and response flexible strategies may be described in graphical terms, as shown in Figure 3.2. The example used assumes that the firm's level of output is one of the control system's target variables. Time is shown on the horizontal axis and output on the vertical axis.

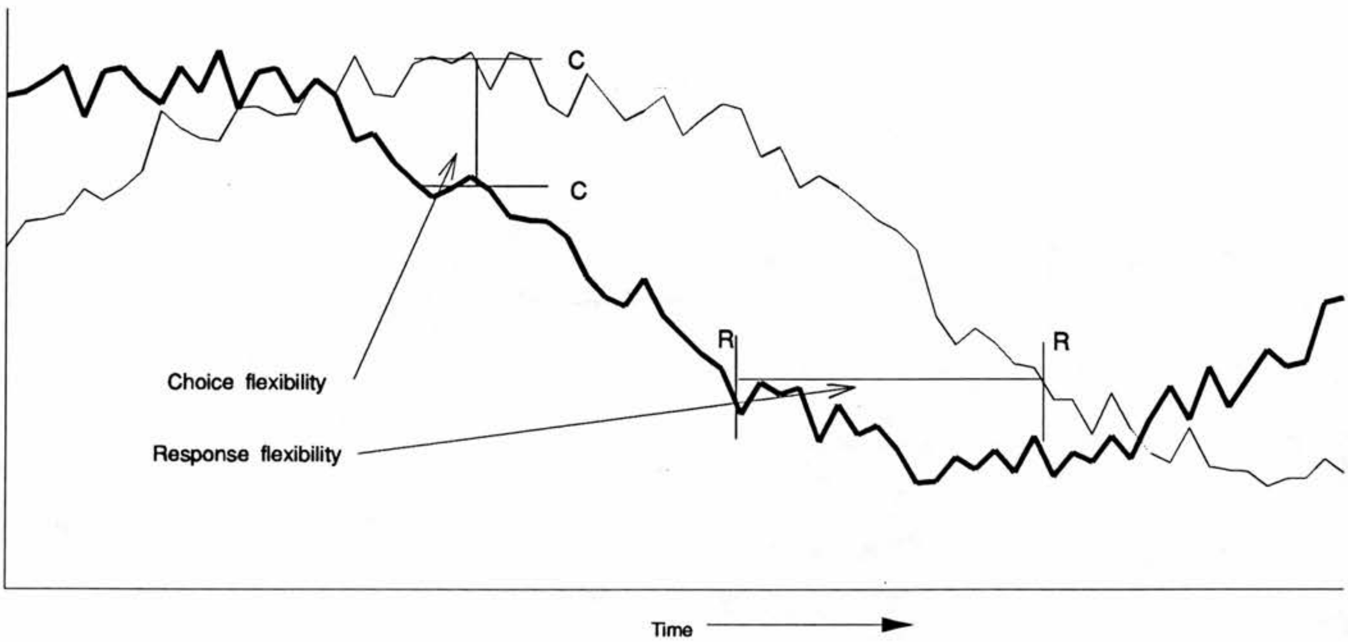


Figure 3.2

The value of the target variable, depicted by the heavy black line, varies as a result of fluctuations in exogenous variables. The firm achieves a series of actual output levels, which it compares with the target value. These result values are depicted by the fine line. The possession of flexibility attributes enables the firm to minimise the gap between the lines, and more closely match its performance to the fluctuating targets. Two non-exclusive general methods can be used. They are represented by the two gaps shown in the figure at CC and RR. The first type of flexible strategies enables the firm to have at its disposal more options which can be applied at any given time, spread over the range of output requirements likely to be met. This enables the firm to select an output level more closely matching the target level. Because this type of flexible strategies concerns a wider choice of options which can be exercised at a single time it is referred to as choice flexible strategies. Line CC shows the gap which choice flexible strategies aim to minimise. This is the type of flexibility referred to by Stigler (1939), and by the operational research writers such as Mandelbaum and Buzacott (1990). The analysis of Mandelbaum and Buzacott consider a two period decision model and describe a flexible outcome as one which provides a greater range of subsequent actions. Figure 3.3 illustrates this. The figure shows an enlarged portion of Figure 3.2 around the gap CC. The target output is again represented by a heavy line. The actual output to the left of t_0 is represented by a light line. Between t_0 and t_1 the firm has a choice of alternative output levels, shown by light lines in the figure. The vertical distance between the end points of these lines represents Stigler's (1939) flexibility, i.e. the output range over which the firm can operate with tolerable efficiency. Mandelbaum and Buzacott's flexibility is represented by the number of these lines, i.e. the opportunity set open to the decision maker at the start of period t_1, or the number of different levels the plant can operate at.

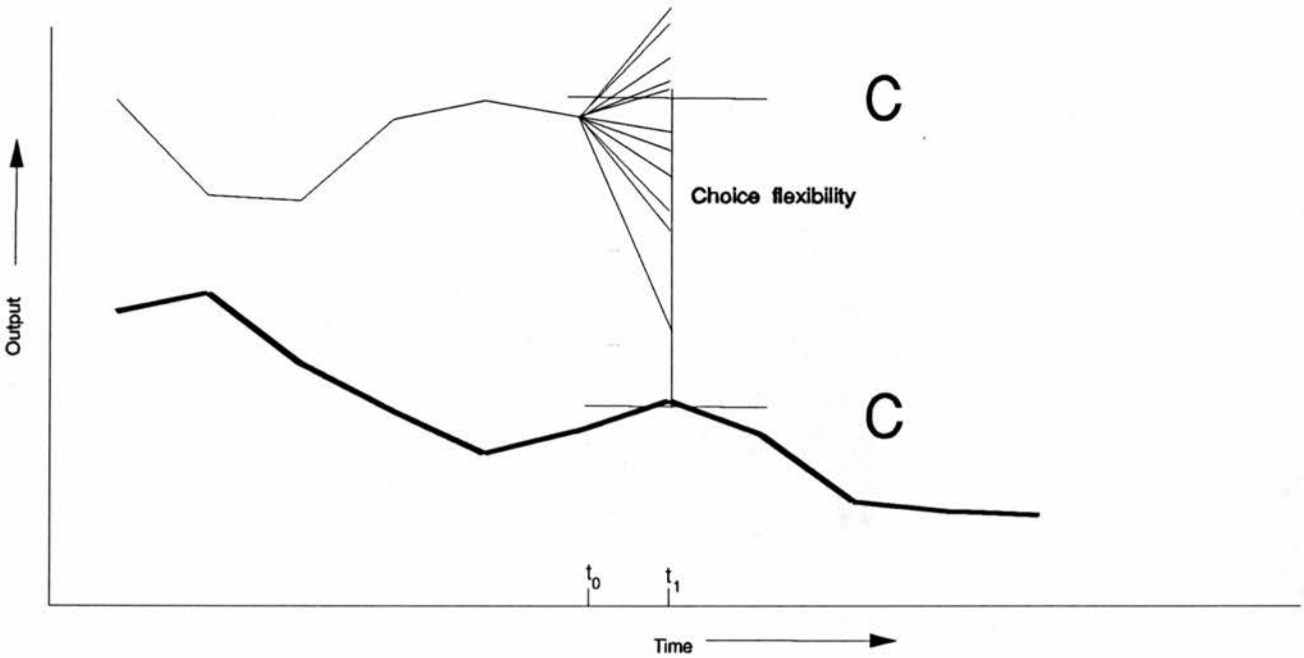


Figure 3.3

With reference to the above diagram Stigler's conclusion is as follows: The firm will economise on the cost of adding additional flexibility, i.e. of widening the range available at t_1. Mandelbaum and Buzacott's conclusion is that the firm will optimise using a flexibility criterion which reflects the number of alternative output levels. As the intervals between discrete levels of output tend to zero, i.e. as the set of output levels becomes a continuous function, the two conclusions become the same. That is to say the interval becomes less important and the range more important. However, the limits of the range are dependent upon the length of the time period. A sufficiently long period enables fixed plant to be duplicated or reduced, extending the upper and lower limits. This raises an issue of the relation, which flexibility has, to fixed and variable costs, and to different time bases. This issue is discussed in detail in paragraphs 3.18 - 3.23 below.

Choice flexible strategies.

3.7 The particular type of flexible strategies described by Stigler, and Mandelbaum and Buzacott, is readily translated into physical plant and factor input terms. As an example, let us take a fish grading process which has two alternative methods. A continuous process machine which grades fish by size and uses one operator, might grade fish at a rate of 50 Kg per hour. Interest charges and depreciation on the machine might amount to £200 per eight hour day, the operator costs £4 per hour, and all other costs are ignored. An alternative process exists which uses only operators, who can grade at 5 Kg per hour and cost £4 per hour. It is assumed that the operators are transferred to other tasks, or not paid, when not working on this process, but that the machine cannot be used for any other purpose. Fish must be processed within eight hours, and there are no limits on the number of machines or operators.

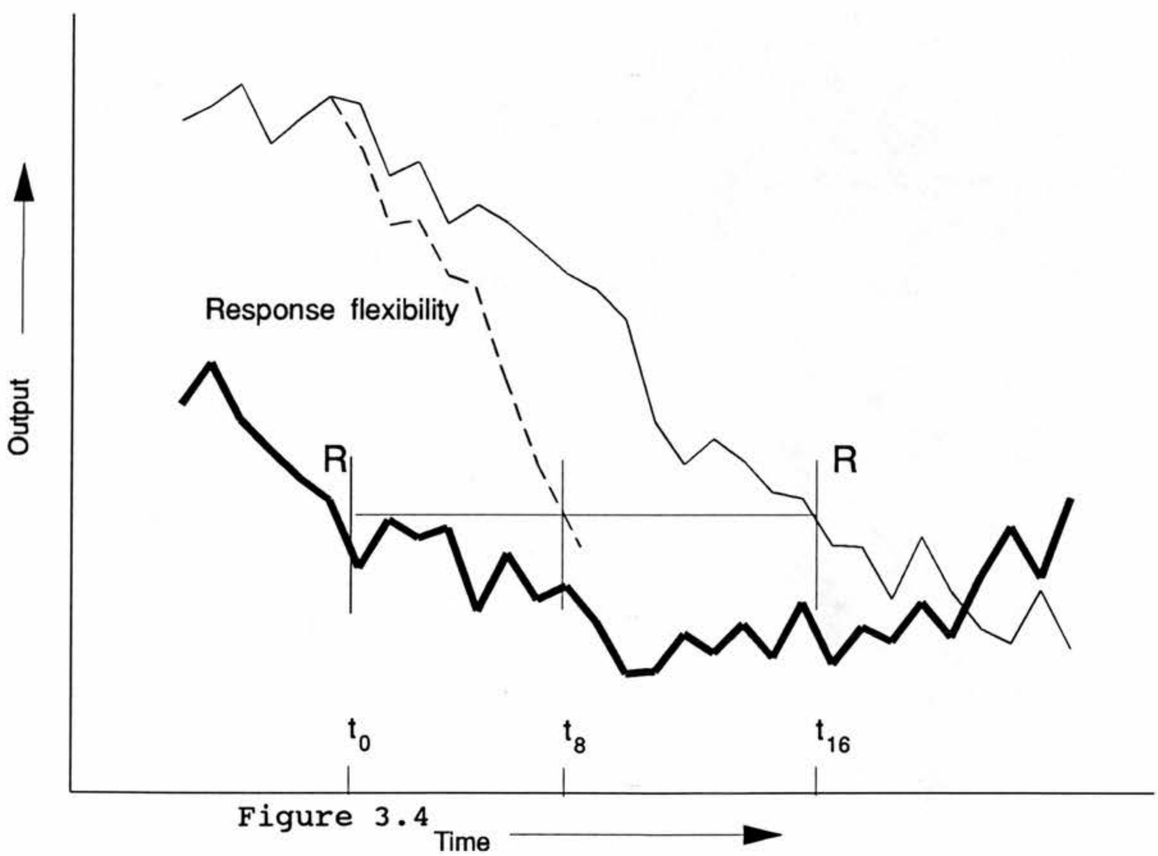


Figure 3.4

Suppose that the average output required is 300 Kg per day. The alternatives facing the firm are shown in Figure 3.4. The costs at the average output level of the first process are £224 per day, and the costs of the second process £240. Provided that output remains in the range which can be handled by one machine, then process 1 will be the preferred choice. However process 1 is less flexible because of the discontinuity at an output level of 400 Kg. If, as a result of daily variation in fish landings, the output required sometimes rises above 400 Kg then 2 machines will be required. This will make the process 1 more expensive over the 0-500 Kg range, not because of the *average* output required, but because of the *range* of alternative outputs required. This arises because of physical constraints in the plant used in process 1, which provides less choice to the firm. A firm using process 2 exclusively has a wider range of options available to it than a firm using process 1.

Response flexibility.

3.8 The second type of flexibility, which relates to the speed with which the firm is able to respond to an exogenous shock, is illustrated in figure 3.5. The figure shows an enlarged portion of Figure 3.2 around the gap RR. The target output is again represented by a heavy line. The actual output of the firm is represented by a light line. Commencing at time period t_0 a dashed line is shown. This represents the actual output if the firm is able to respond over a shorter time period. Instead of requiring 16 time periods to reach the target output set at period t_0, the greater flexibility results in the t_0 target being reached after 8 time periods.

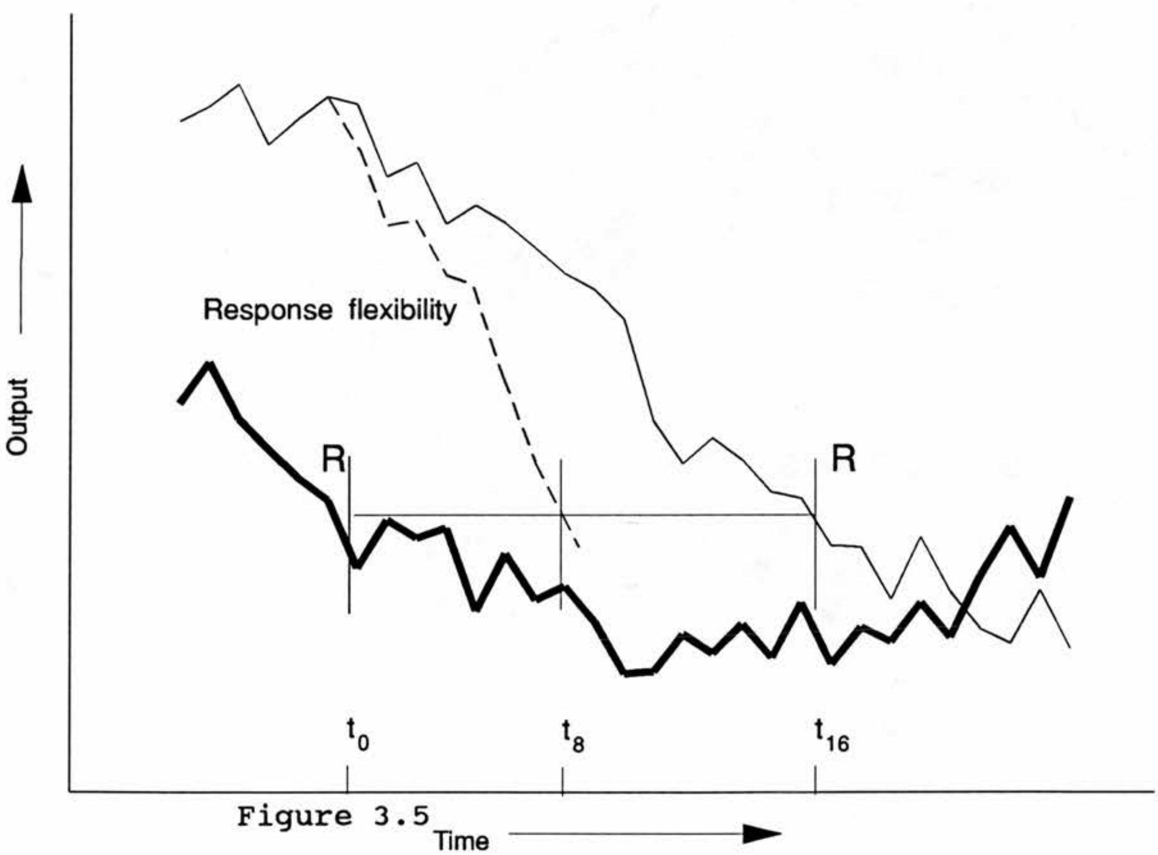


Figure 3.5

In the above diagram, response flexibility is illustrated by the dashed line, between periods t_0 and t_8, in comparison with the light line between periods t_0 and t_{16}. The firm which uses response flexibility, i.e. the firm which is able to react quickly, adjusts to the new target level in the shorter period.

Response flexible strategies.

3.9 To use a common metaphor, choice flexible strategies, so to speak, rely upon having a large number of shots in the locker. Response flexible strategies, on the other hand, require the firm to be "quick on its feet". For an example of response flexibility, suppose that production can be effected with either of two processes. Staff can be transferred from other work on a daily basis, but a machine takes six weeks to install or de-install. The optimal output required in each period regularly fluctuates back and forth over a four or five week cycle, observed weekly. The firm which uses the staff intensive process will be the more flexible, simply because it can respond within the requisite time. For the firm adopting the plant intensive option, inflexibility will be present, because of the plant changes which would be required to maintain the optimal output. This delay in achieving the optimal process 1 plant means that it again lacks physical flexibility, not because of the output level, or because of the range of alternative outputs required, but rather because of the *response time* which is required to react to the change.

The Small Entrepreneurial Firm (S.E.F.)

3.10 Because the research takes ideas developed for firms in general, and applies them to small, entrepreneurial firms, it is appropriate to consider the distinguishing features of the small, entrepreneurial firm. The Small Entrepreneurial Firm, or S.E.F., is used to describe the principal objects of study and follows the usage in Gavin Reid and Lowell Jacobsen's (1988) eponymous study. They present a theory of the firm grounded upon a wide empirical sample of small firms. Their S.E.F. sample is characterised by directly measurable attributes such as labour force, asset value, turnover, and age (1988, page 5). Their theoretical analysis views the small entrepreneurial firm not simply as a production function, but rather as a production function motivated by entrepreneurial endeavour and controlled by contractual relations (1988, pp 13-29). It is this analysis which is used to qualify the Cyert model. It provides the economic theory of the S.E.F. used in the information processing model developed below. Viewed as a class of information processing objects, the S.E.F. has a production function consisting of potential sets of inputs and outputs. The inputs are the exogenous variables describing demand, supply, and technology, and the outputs are factor prices and quantities, product prices and quantities, and plant type and capacity. The endogenous dynamic influences in the model are provided by the entrepreneurial function. This selects production function options, monitors production function outputs in comparison with entrepreneurial goals, and adjusts future options accordingly. This dynamic process takes place within limits formed by the set of contracts governing the S.E.F., and the transaction costs ensuing from these contracts. Thus the S.E.F. theory detailed by Reid & Jacobsen (1988) contributes the small firm characteristics to the model: a production function driven by entrepreneurial motivation, and constrained by contractual rules.

3.11 In defining the S.E.F., it is useful to consider the distinguishing features, in addition to size, which set the S.E.F. apart from larger firms. Reid and Jacobsen (1988 pp 20,24), following Oliver Williamson (1985) use the device of comparing the performance of two firms linked by the market with the same firms vertically integrated. they identify a number of advantages which the separate organisational form confers. These advantages counteract the apparent cost-saving benefits of a vertically integrated firm. These possible S.E.F.

advantages may be summarised under the headings communication and motivation. It is useful to view the firm as an information processing structure. From this viewpoint, these two generic S.E.F. advantages could be restated as more accurate internal data transfer, and a more closely coupled link between decision results and entrepreneurial returns. The view of the firm as an information processing structure, is used to develop the behavioural computer model in part 3 of the thesis. Before this, the S.E.F. characteristics are considered from a bvehavioural standpoint.

Behavioural features distinguishing the S.E.F.

3.12 The S.E.F. has been characterised above, as having two features which could potentially distinguish it from its corporate competitors. Described in information processing terms, these are: (1) less noisy Internal data transfer, and (2) more closely coupled motivating links between firm profits and firm decisions. To these two features, it is intended to add a third: flexibility. As with the theoretical assumptions above, it is not argued that small size and entrepreneurial organisation *necessarily* confers greater flexibility, only that such a *potential* exists in the S.E.F. It is appropriate at this stage to consider in more detail the distinguishing behavioural characteristics of the S.E.F. in the following paragraphs.

3.13 We shall take first take the communications/internal data transfer characteristic of the S.E.F. versus the larger, vertically integrated firm. In the larger firm, market signals are replaced by internal accounting. This internal accounting may include artificial transfer pricing, and it may include artificial allocations of cost and revenue. These artificial values may distort the inputs to the firm's decision process. In addition to the potential for artificial information, there is also the possibility of noise arising in the information because of the number of transformations it may undergo in the large corporation between source and decision taker. The foregoing remarks are not asserting that communication in the large firm is necessarily worse, only that such a potential exists. That this potential exists in the corporation is widely reported in the management literature which addresses internal firm communications as a topic in its own right. (Peters and Waterman 1982, Peters and Austin 1985) The effect may be that innovation is incorrectly attributed, reducing the incentive to innovate. It may be that potentially profitable lines are ignored through incorrect internal pricing. The S.E.F., on the other hand, receives direct unequivocal market signals on input and output prices, and consequently has less noise to remove from the data in order to make a production decision.

3.14 It is also worth noting here another aspect of the differing information flows existing in S.E.F.s and corporations. Although communications bandwidth is not an issue dealt with in either the economics texts or the management literature, it is relevant to the issue. The bandwidth of the communications within the firms is the volume of internal information being presented at any given time to the decision making process. This may be greater within the large corporation because of scale economies in, for example, the sales, accounts or purchasing departments. The S.E.F. may, on the other hand, have much higher information search costs and consequently produce a narrower bandwidth in its channel of information to the decision maker. For example, in fish processing, information presented on a particular day on product prices may be drawn from a much smaller sample of sales quotations in the case of the S.E.F. The apparently advantageous position of the larger firm in having a greater number of sales quotations, and hence a larger sample from which to deduce demand, will be much reduced, however, if the longer internal communications channel results in the information reaching the decision taker 24 hours later. Similar effects may be observed within the purchasing departments sampling factor prices, and in the accounts department measuring costs and profits. Thus a picture might be drawn of the integrated firm having much more information presented, but with more noise present, because of lags or errors in the communication channel. In contrast, the S.E.F. has a much smaller, but more accurate data set presented to the decision process. This difference in information transfer has considerable significance for S.E.F. flexibility in response to change.

3.15 In the larger firm bureaucratic incentives replace entrepreneurial incentives. Essentially, this means that the strong link between profitable decisions and entrepreneurial reward is weakened. This may take the form of dissipation of the benefits of innovation through appropriation by other parts of the organisation. It may take the form of a lack of concern to protect asset values on the part of the departmental manager who replaces the entrepreneur. The form which this potentially sub-optimal decision system takes will depend upon the particular set of contracts which replace the market driven entrepreneurial relationship. Again, this is not to say that the large firm *necessarily* has weaker or less effective incentives, only that greater potential for this state of affairs exists. Thus the small entrepreneurial firm is distinguished not simply by its size, and by its entrepreneurial form. It also has distinctive information flow characteristics.

Flexibility - some theoretical aspects

3.16 The following theoretical analysis of flexibility starts from the account of short run flexibility given by George Stigler in 1939. It extends Stigler's definition to include a much more widely based flexibility. This wider definition takes into account behavioural and dynamic issues and the resulting implications for model complexity. Several elements of the firm model are examined for flexibility features. These are firstly the division between the short and long runs. The infinity of short runs defined by Marshall are ordered according to the variability of their factor costs with respect to product quantity. The marginal and unit cost curves are examined in the light of this factor/ product quantity variability ranking. Flexibility in a marginalist context is re-interpreted as a result of this examination as the ratio of variable to fixed costs. The flexibility issues relating to a two product process and its average cost surface are investigated. The flexibility definition is extended from the static Marshallian analysis of Stigler to include behavioural and dynamic elements. The transaction cost model of Williamson (1975) is examined for its ability to describe flexibility issues. Finally, the flexibility definition is interpreted as the parameters of a grounded behavioural model.

Marginal analysis of flexibility - The short run.

3.17 George Stigler (1939) analysed flexibility as it relates to variation in demand and plant output levels. His formal analysis considers how much flexibility is built into the production function. For example, either by increasing the divisibility of fixed plant, or by reducing it relative to variable services, it is possible to produce a less steeply inclined marginal cost curve. For a given level of output, however, this will have a higher cost, and Stigler finds that *"Flexibility will be added until it's "accumulated" marginal cost equals the discounted marginal returns from savings due to that flexibility"* He follows Marshall's (1890) definition of the short run as the period within which there are fixed costs, and his observation that there are an infinity of "short runs", each applicable to different sets of fixed costs.

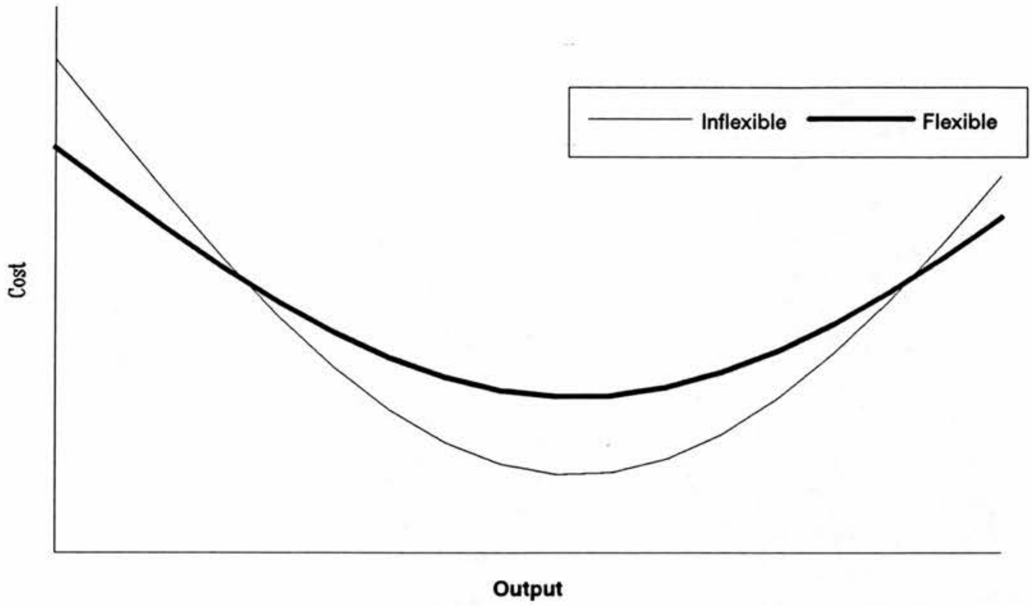


Figure 3.6

Following Stigler, flatness may be defined as the flatness, or relative upwards concavity of the short run cost curve. This is illustrated in Figure 3.6, which shows the unit cost curves of two processes. The flexible process has a less upwardly concave unit cost curve, shown by the heavy line. The inflexible process has a unit cost curve with more convexity, but a lower minimum.

3.18 The analysis above is a short run analysis. In the long term, the firm is able to progress from one set of plant and its associated cost curves to another, and so on through a series of cost functions. These may be represented by the usual set of short run unit cost curves to which an envelope curve representing the long run cost function is added. The familiar example of economies and diseconomies of scale is shown in Figure 3.7.

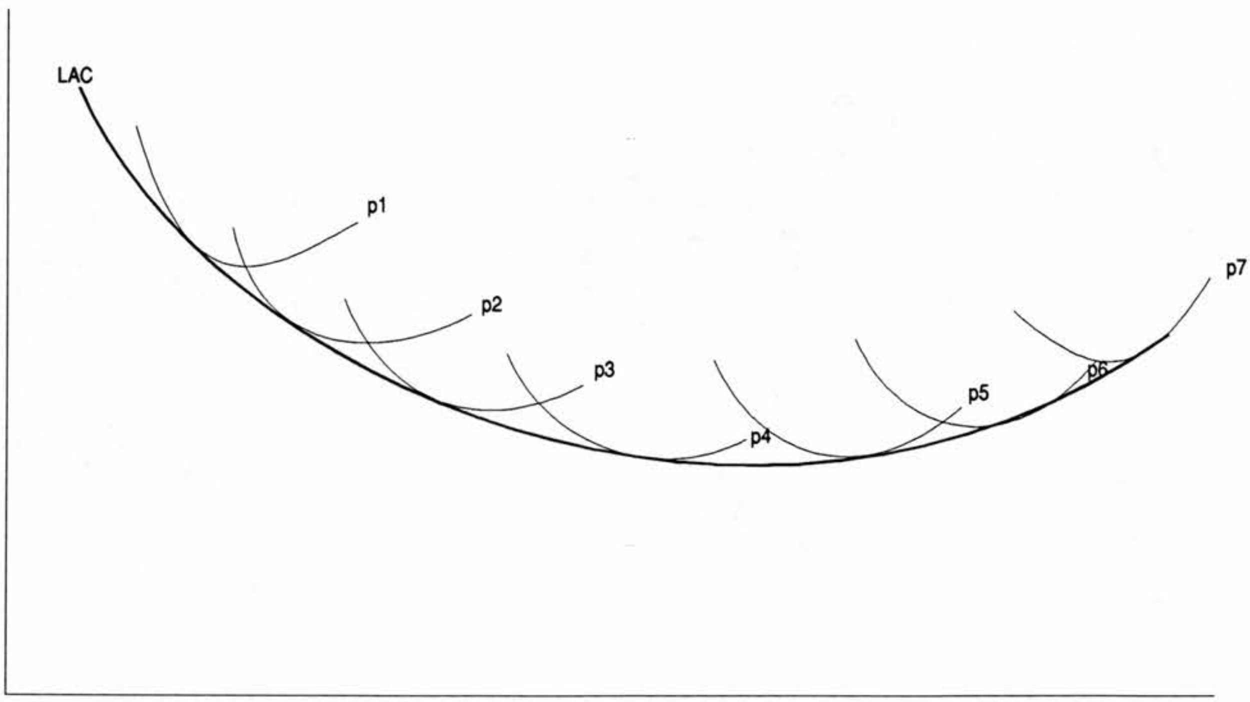
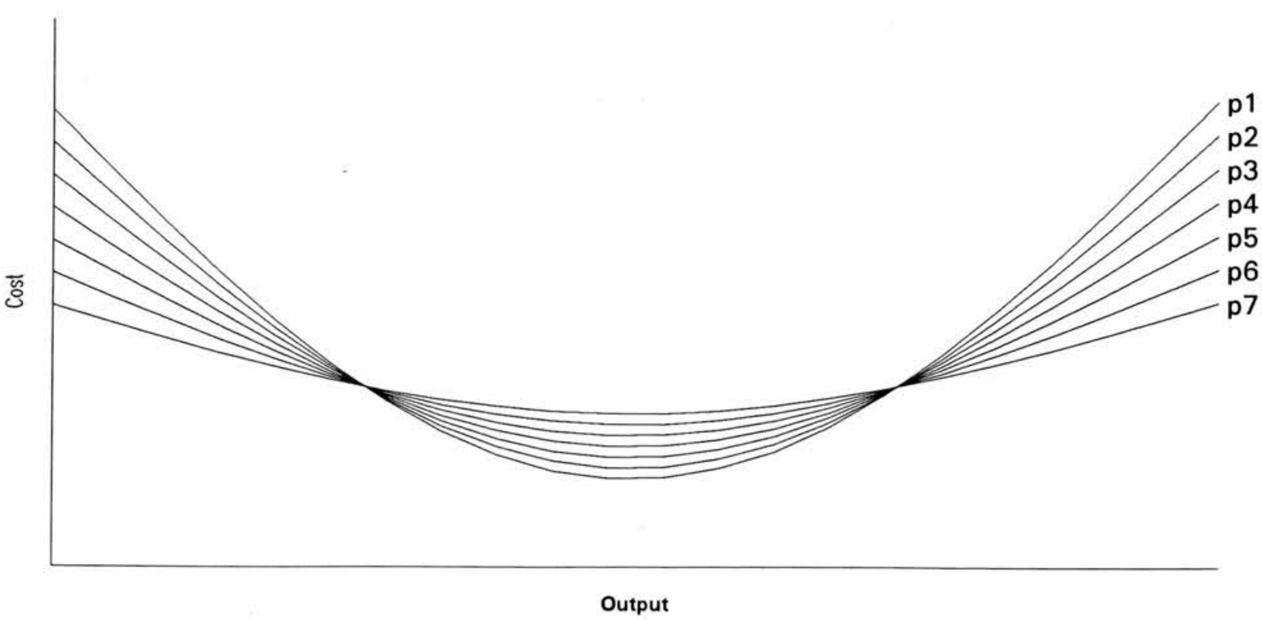


Figure 3.7

The short run unit cost curve for each type of plant is shown by the light lines labelled *p1, p2,....* The heavy line represents long run average cost. The figure assumes that each new plant to which the firm proceeds will have a greater or lesser output range, and thus will appear to the right or the left on the output axis. Economies of scale are represented by downward shifts on the cost axis. A key feature of this long run unit cost curve is that its convexity is always less than the short run cost curves which it envelopes. That is to say, following Stigler's (1939) paper, the long run production function is inherently more flexible (in terms of choice flexibility) than the short run. This is an important starting point for the flexibility analysis of paragraph 3.22 onwards. Firstly, however, the same long run analysis is applied to flexibility rather than economies of scale. This is illustrated in Fig 3.8.

Figure 3.8



3.19 Here the different plant types do not have unit cost curves displaced to the right or left on the output axis, as was the case where scale of output is being considered. The assumption of *ceteris paribus* is applied to scale economies between plant types, which are therefore shown as being positioned at the same output level. The long run flexibility position of the firm is therefore represented by the curves labelled *p1,p2,...* in Figure 3.8. Rather than a long run envelope, as in Figure 3.7, the long run unit cost curve depicting flexibility is represented by a surface with output variability measured on the third axis.

The short run as a continuum.

3.20 The concept of the short run has been adopted by economists since Alfred Marshall (1890), as an analytical tool to enable them to hold particular variables constant whilst deriving static equilibrium conditions for the remaining constituents of the production function. The use of the short run analytical technique implies that production costs can be broken down into elemental factors, some of which are then considered to have different dynamic variability than others. For a given short run there are then fixed costs, which remain constant during the short run period, and variable costs, which are allowed to vary during the particular short run under consideration. To give an example, a firm may install and pay for items of plant which it expects will have a life of five years. This physical installation, and the indivisible nature of the capital committed to it, produce the concept of a fixed cost. During the life of the plant, material may be applied to it to produce an end product. Three things can then be defined: the short term, which is the period of time during which plant is constant; fixed costs, i.e the cost of the plant, fixed over the short term; and variable costs, the cost of material, variable over the short term. These three definitions are interdependent: all must be defined before any one is defined.

3.21 It is clear that the short run is an analytical device rather than an observable entity. Plant purchased and installed one day may be replaced the next, provided that the change cost is justified. Commitment to a material supply contract may mean that the firm is saddled with relatively unchangeable material costs over a longer period than would otherwise be expected. The introduction of labour costs produces further complexity in the categorisation of costs into fixed and variable. The labour required to operate the plant may itself be differentiated into, on the one hand, staff with high recruitment cost, long term contracts; and on the other hand, staff easily recruited and trained and paid by the hour within wide ranges. Sometimes labour costs are similar to plant costs, an investment spread over an extended period not expected to cover its cost in the short term. Sometimes labour costs are similar to material costs, incurred only when the immediate circumstances warrant, and linked closely to the exigencies of the present. The conclusion to be drawn from the foregoing is that for a particular production function, the constituent costs may be placed upon a continuum of variability with respect to production quantity. The short run is then defined as a particular point upon that continuum at which all costs to the left are considered fixed costs, and all costs to the right considered variable costs.

Fixed costs vs variable costs implications.

3.22 Following the above analysis, specific short runs related to cost types may be selected and studied. For instance, by allowing no change in the principal tangible assets in a manufacturing company, the plant short run is defined. Keeping the assets and labour costs constant and allowing only material costs to vary gives the labour short run *(The foregoing assumes that, for the production function in question, plant costs are less alterable than labour costs, which are less alterable than material* *costs.)* In analysing flexibility it important to be specific about which particular short run is under consideration. That is to say, it is important to know what particular time frame is under consideration, which costs are to be considered fixed during that time frame and which costs are to be considered variable. Once the particular short run has been selected, with its associated set of fixed and variable costs, it is possible to analyse further the nature of flexibility, or the concavity of the unit cost curve.

Factors contributing to relative convexity.

3.23 From the foregoing an analytical division of the input factors to the production function into short run fixed and short run variable cost components. A particular short run, determined either by reference to a time period, or a set of fixed factors and variable factors. If the short run is determined as a particular time period, then a flexible production function will have a greater proportion of variable factors in its inputs, and an inflexible production function will have an lesser proportion of variable factors in its inputs.

3.24 Alternatively, the short run may be determined by reference to a set of factor inputs. *(for example plant may be fixed)*. The flexible production function then has a longer short run time period than the inflexible production function. This may be put another way. The longer the time period under consideration the more flexible the production function produced by a given set of factors will be *(i.e in the longer term all factors can be adjusted to reflect production variation)*. As noted in paragraph 3.16 the long run unit cost curve, which forms an envelope of short run curves is always less upwardly concave than the short run curves and thus more flexible. This result is produced because a static analysis has been employed. As described elsewhere in this chapter, flexibility may also be reflected by the speed of response of the production function to changes in product quantity. A short run static analysis cannot show this.

3.25 The foregoing analysis may summarised thus. A flexible production function is one which has a higher ratio of variable to fixed factor inputs relative to output level. The ratios of variable to fixed costs for a given short run time period could thus constitute an index of flexibility when a static analysis is used. This is an improvement upon the use of the convexity of the short run cost curve as the defining element. It is an improvement upon the descriptive definition because it relates that definition back to the contributing factors of production. Some dynamic elements have been referred to already. These are firstly the description of response flexibility given in paragraph 3.5 above; secondly the description of choice flexibility following upon Mandelbaum and Buzacott's (1990) two period decision model; and thirdly the consideration of expectations in the long run plant choice decision. More specific consideration of flexibility in a dynamic context is discussed below from paragraph 3.35 onwards. Firstly, however more detailed consideration is given to specific aspects of static flexibility.

A further analysis of fixed costs and their effect on flexibility.

3.26 Fixed costs may be said to be costs which do not change with production quantity during the period in question. Or, given the smooth transition described in paragraph 3.22 above, they are costs which are more weakly correlated to production costs than are variable costs. It is possible to analyse this independence further, into the **minimum cost effect** of fixed costs, and the **maximum capacity effect** of fixed costs.

3.27 As one moves away from the cost axis, ie as production quantity increases from zero, marginal cost initially falls. One way of viewing this is as follows: For any production to take place at all , an indivisible single cost is incurred *(for example plant purchase and installation)*. At small production quantities, fixed transaction costs, *(for example raw material search, or purchase order costs)* are incurred which will not rise with quantity. The effect of these costs being incurred at the minimum of a particular quantity range and are constant throughout that quantity range means that the marginal cost falls. This drop in marginal cost continues whilst these constituent fixed costs form a significant element of the whole. Average cost will reach a minimum when the effects of these constituent fixed costs has disappeared, or when these effects are counteracted by capacity related costs *(see below)*

3.28 The effect of incurring single costs at a particular minimum quantity thus produces the downward slope of the unit cost curve from the minimum cost. It may be described as the minimum cost effect upon the production function of fixed costs during the short run period. If there were only this effect, and the variable costs were simply proportionate to production quantity, then the average value would continue to fall to an asymptotic level equal to the variable cost per production unit.

3.29 There is a second mechanism through which fixed factors in the production function produce the convexity in the unit cost curve. This is similar to, or perhaps a particular case of, the effect of diminishing returns to one factor quantity in the presence of increased quantities of other factors. In choosing a particular short run, a subset of factor inputs become fixed, and the remainder vary with product quantity. The fixed factors, in addition to having indivisible cost characteristics as detailed above, may have a capacity limit with respect to product quantity. When that capacity limit is reached, the cost components of the production function change, with an increase in the marginal cost occurring. As an example, the personnel short run is the short run where the labour numbers and the working week are fixed. At production levels above that necessary to fully occupy the workforce increases in marginal costs occur such as overtime rates, productivity bonuses etc. This effects an increase in the marginal cost curve which in turn implies a rise in the unit cost curve. The rise occurs at levels above the normal, or optimum working level for the particular factor concerns, and the combination of capacity limits for fixed factors produces the right hand upward slope of the unit cost curve.

Economies of scale and economies of scope:

3.30 A static flexibility analysis is given in paragraphs 3.14 to 3.27 above. It considers the production function for the single product case where the choice open to the firm is between different technologies which give different degrees of convexity to the unit cost curve. The short run unit cost curves corresponding to a set of technologies which vary in flexibility are shown in Figure 3.8 above. As the flexibility of the plant increases, the concavity of the unit cost curve decreases and the value of is minimum increases. Figure 3.7 illustrates the choice facing the firm when selecting the size of its plant. A set of technologies is available to the firm each appropriate to a particular scale of operation. The unit cost curves pertaining to the different sizes or types of plant are shown in fig 3.7. These are the familiar family of short run cost curves forming an envelope approximating to the long run cost curve. Provided that conditions are stable and flexibility is not an issue, the firm adopting a technology represented by the minima of this long term cost curve will be the dominant form in the industry. Where both flexibility and economies of scale are optimised there will be a long run average cost surface tangential both to the series of short run unit cost curves and to the series of long run flexibility surfaces defined in section 3.17. In addition to being combined with economies of scale, flexibility optimisation may also be combined with economies of scope. The following analysis considers the two product case.

Flexibility analysed for the multiple product production function.

3.31 The analysis considers flexibility for one of the two products, and flexibility for them both. The average cost surface is defined as in Figure 3.9 below. The figure represents average cost for two products. The two horizontal axes represent the output level for each of the two products produced by the firm. Average cost is measured on the vertical axisand expressed as a function of two outputs represented by a surface in figure 3.9. The flexibility attribute for product one consists of the convexity of the series of sections through the surface. Consider the sections parallel to the product one quantity axis, shown in Figure 3.10. Each of these represents a particular fixed level of product two production. Figure 3.11 shows the same detail with respect to the average cost of product two at given product 1 output levels.

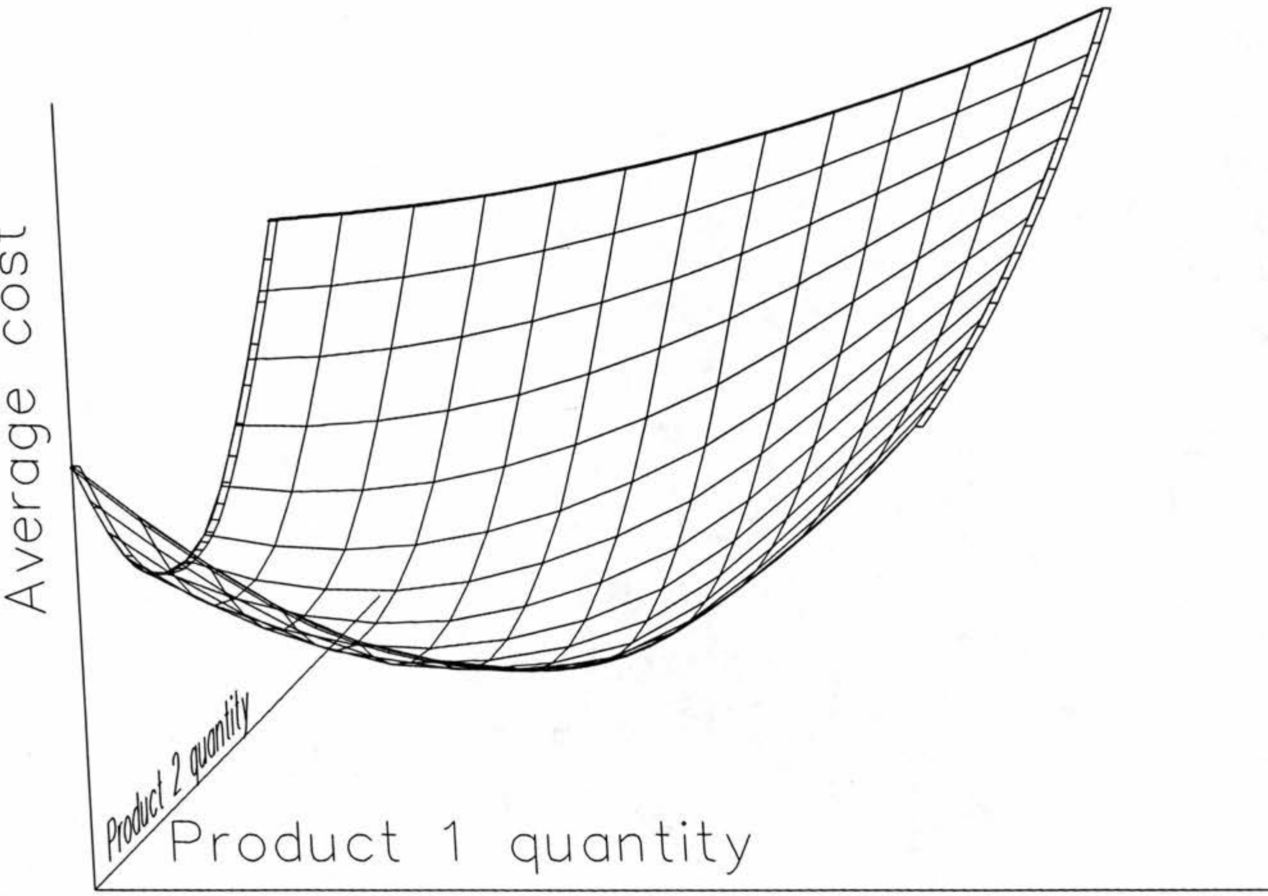


Figure 3.9

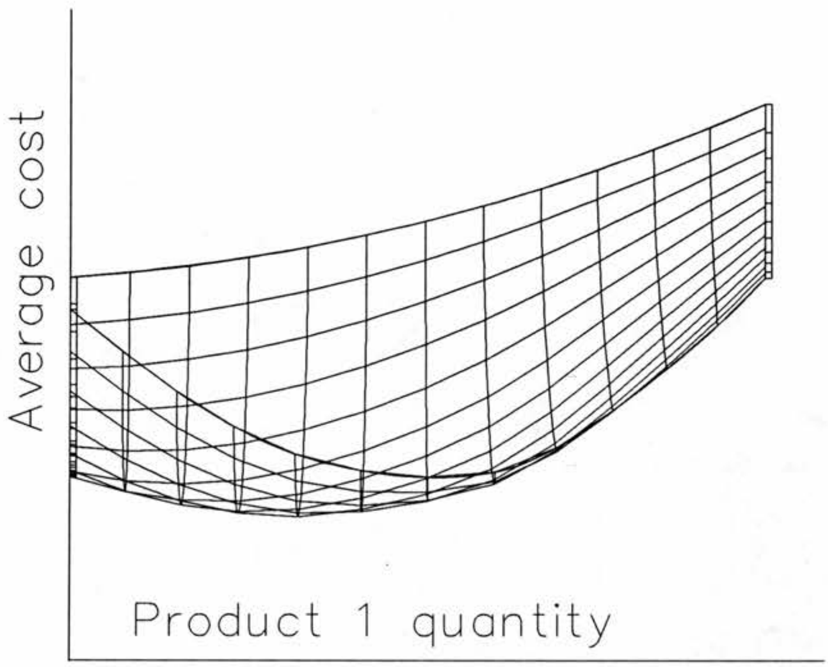


Figure 3.10

If moving from a low product one to a higher product one quantity implies a reciprocal change in product two quantity, then the unit cost curve is represented by a section not parallel to the product one quantity axis, but across it, in the direction of the valley formed in the average cost surface. The more the reciprocity the closer the average cost section comes to the valley centre line. This section is flatter than the simple product one cost curve, implying greater flexibility. Additional to the reciprocal production situation, the model can illustrate a flexibility measure for both products simultaneously.

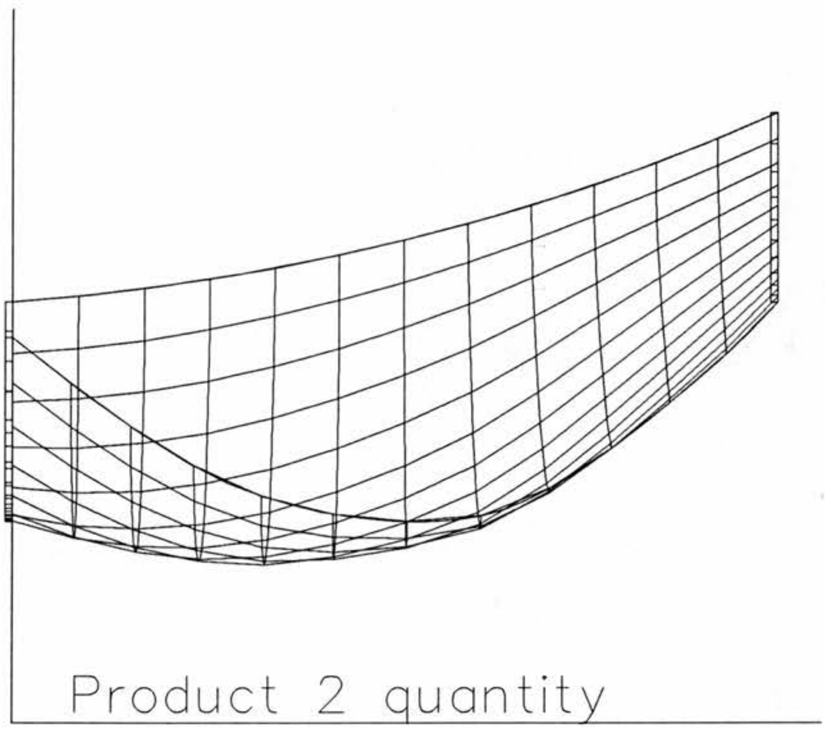


Figure 3.11

This may be described as the selection of a joint production function such that the average cost surface is more planar, the more flexible the production. Thus for any given product quantity combination, variation will lead to less change in the average cost than would be the case with a less flexible, less planar production function

Expectations in the long run plant decision

3.32 One dynamic modification to the static marginal analysis illustrated by Figure 3.9 might be made as follows. It is included to illustrate the way expectations will actually influence the entrepreneurs decision. The entrepreneur does not simply choose from the set of plant types available at a particular time. He also chooses the time. Therefore the choice facing him is one between a larger set of plant types which includes his expectations of what will be available in the future. A reasonable assumption might be that the entrepreneur will expect technology to improve as time goes on. The improvement may be in the costs or efficiency of the plant. However, the expected improvement may also be in the range of outputs which can be efficiently produced by the plant. This is not strictly within the terms of marginal analysis, which is a static analysis. The regular launches of new fish processing machinery indicates that a major factor in the long run plant decision in this industry at least, and probably others, is the technological developments likely to occur during the physical life of the plant. Plant is not generally replaced because of its age. Changes in the output requirements of the firm brought about by exogenous market changes are the principal cause of plant change. However the expectations of the firm play an important rôle in these plant change decisions, and in particular the expectations of technological change. Therefore it is perhaps more useful to incorporate these expectations in the long run flexibility analysis.

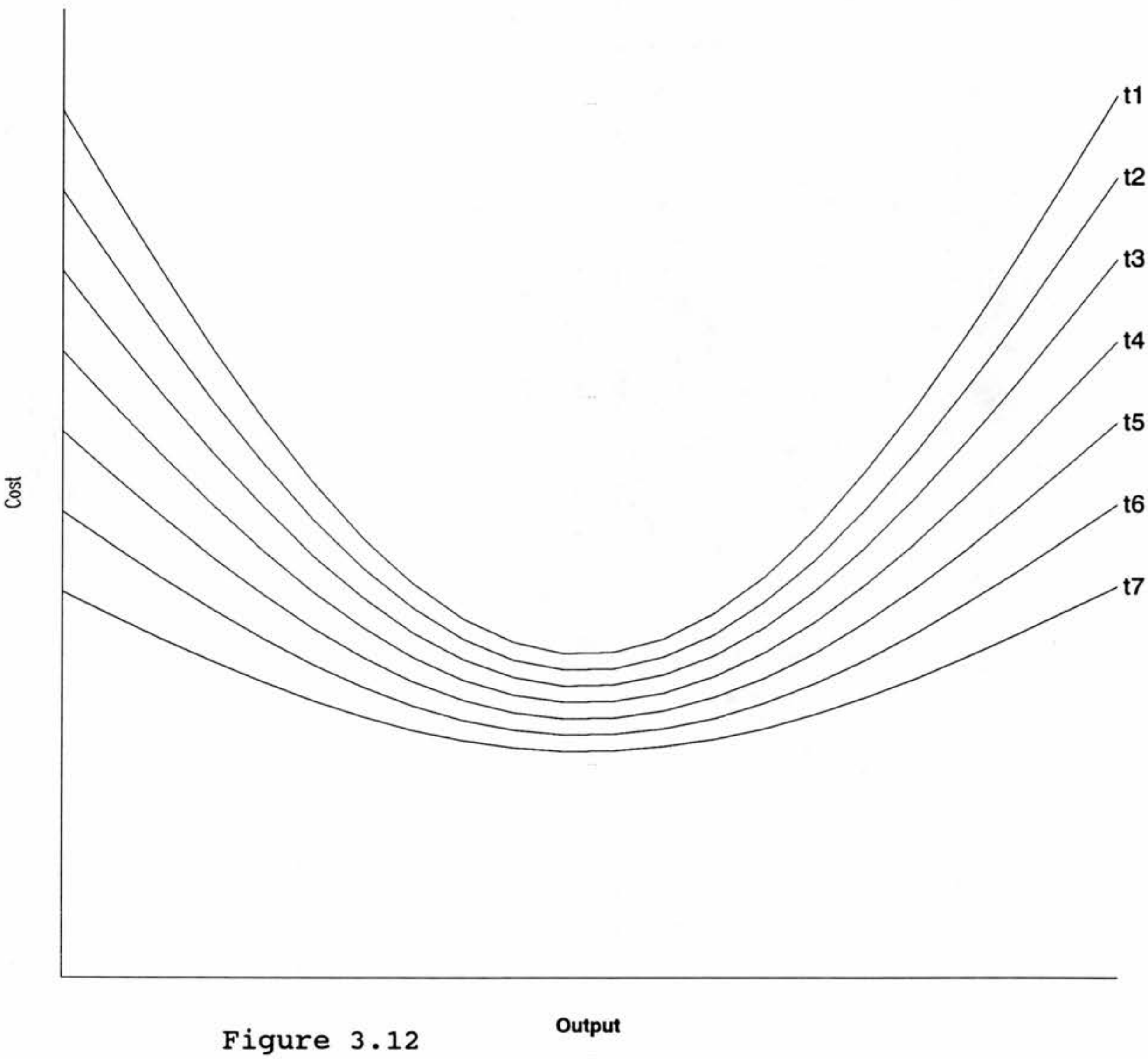


Figure 3.12

3.33 The situation facing the firm with regard to flexibility and cost, but ignoring scale economies, is depicted in Figure 3.12. The curves *t1,t2,...* represent the unit cost curves expected by the firm at successive future time periods. The firm expects that technological change will bring about improvements in flexibility and its average cost. That is to say, that if expectations are taken into account, and if technology is not fixed during the time period of the long run, then the minimum point of the less flexible plant is not *necessarily* lower than the minimum point of the flexible solution. Two important results follow from this: firstly, the timing of the plant change becomes a principal element of the decision, and secondly the firm's ability to predict the future becomes an important element of the decision.

3.34 As regards the timing of the plant change, a further important empirical element is the unidirectional nature of technological change expectations. Whereas exogenous demand and material or labour supply might be expected to change upwards or downwards, a firm's expectations of technological change are likely to be positive in the sense of reducing cost or increasing output range. This has the effect of reducing the incentive to change plant at any given time. The firm can now also consider benefits to be made by deferring the change and thus gaining a technological advantage in cost or physical flexibility. The firm will clearly economise on this aspect of the decision. Expectations of variation in product demand or factor supply may be handled by a Bayesian or other rational decision algorithm for dealing with uncertainty. In the same way, the expectations of technology change can be handled. The subjective probability distribution describing expected demand might include falls as well as rises in future demand, compared with current period demand. The subjective probability distribution describing expected required output range might similarly indicate less or more stability in required output. It is rather less likely, however, that the expectations of technological change will be that unit costs will rise or physical output flexibility will fall. Another way of putting this is that the subjective probability distribution describing the firm's expectations of technological change at any given future point is empirically likely to have a positive mean, where the technological change concerns unit costs or physical flexibility.

Organisational flexibility and the transaction cost model

3.35 Organisational flexibility attributes relate to those characteristics of motivation, observation, organisational structure, and control mechanisms, which between them enable the firm to adapt and meet changes in the external constraints limiting its behaviour. The types of entrepreneurial and management strategy which exhibit these attributes of organisational flexibility have been documented by management strategy writes such as Peter Drucker (1970), Thomas Peters and Robert Waterman (1982), and H Igor Ansoff(). Oliver Williamson's analysis (1975), used an alternative method for viewing the firm. The transaction cost model may also be usefully applied to the flexibility strategies which can be adopted by the firm. The choice between using the market or internalising a process is often a choice between short term transactional considerations and long term structural considerations. Williamson's analysis is directed to describing how transaction costs are economised. The same approach may be applied to describe how flexibility may be acquired. Renting an item of plant on a short term contract, or sub-contracting peak processing loads are both organisational options which add to the flexibility of the firm by adding to the range of output levels at which it can operate. These actions increase the choice flexibility of the firm by giving it more output options. Thus in the example given in paragraph 3.7 above, the fish processing firm could adopt two other strategies which would enable it to cope with fluctuations in output required. The firm could decide to rent an additional machine during period of peak demand, thus benefitting from the lower cost of machine grading without incurring a large step cost from buying an additional machine. The firm acquires flexibility by externalising the problem of transferring the machine to other tasks at periods of low firm output requirements. Similarly the firm may choose to sub-contract the peak processing load. This produces a similar effect of gaining optimum costs at each level of output by externalising some of the fixed costs. These examples of organisational flexibility have dynamic implications as well as choice implications. If it is possible to acquire and install a rented machine faster than a purchased one, and if terminating a rental is faster than reselling a purchased machine, then there is response flexibility. The firm could more quickly move to the optimum output level using the rental option. A similar dynamic effect may occur with sub-contracting production. Organisational flexibility strategies are limited by the law of contract, and entrepreneurial ingenuity, rather than technological constraints. The class of organisational flexibility thus extends the definition of flexibility to include the behavioural system characteristics described by H.Simon, R Cyert, J March, and the management writers.

3.36 An example of organisational flexibility encountered in fish processing is the payment of grading and processing operatives by the weight of product processed, rather than fixed weekly rates. For a given stable output level the two different methods may result in the same labour costs. The comparison between the two payment methods changes when frequent fluctuations in output are required. What the use of piece rates does from the firm's point of view is to transfer the variation in expected profits, and also the uncertainty, associated with the variation in demand or raw material supply, away from the firm itself to the factor suppliers, the workforce. The significance of this, for the analysis of flexibility, is that under conditions of variability in demand, and under conditions of uncertainty in demand, flexibility may be represented as an organisational ability to externalise the effects of the variability or uncertainty.

Dynamic flexibility categories: Bo Carlsson.

3.37 Bo Carlsson (1989), following Sten-Olof Gustavsson (1984) makes use of time scale and asset replacement periods in the consideration of flexibility, and a possible classification of different flexibility strategies. Gustavsson's analysis is very much concerned with the physical plant flexibility attributes. In particular he considers the physical flexibility found in flexible manufacturing systems, and his viewpoint that of the production engineer rather than the entrepreneur. This approach also is also followed by Carlsson (1989) whose empirical base lies in metal working manufacturing industries where flexible manufacturing refers specifically to production techniques such as the use of automation and robots, short product runs, and "just in time" material deliveries. Carlsson uses the time periods taken to change plant or processes as the basis for a classification of flexibility. The present model represents Carlsson's operational, tactical and strategic classes of flexibility as essentially three intervals upon a continuum. The classes are defined using fixed asset replacement periods to distinguish between operational and tactical flexibility, and factory location and product type to distinguish between tactical and strategic flexibility. Carlsson's physical production perspective could be broadened, and the categorisation, instead of being one of short, medium, and long terms, could be replaced by a division into physical flexibility, conferred by the actual plant, and organisational flexibility, relating more to the administrative and non-production oriented aspects of flexibility. The term *physical flexibility* could then be used for the certain physical attributes of the technology adopted by the firm, and the term *organisational flexibility* for the attributes of the organisational structure which confer flexibility.

Physical flexibility attributes relate to those characteristics of plant technology and factor inputs which give the firm a wider range of physical output possibilities when faced with variation in its environment. Organisational flexibility attributes relate to those characteristics of motivation, observation, organisational structure, and control mechanisms, which between them enable the firm to adapt and meet changes in the external constraints limiting its behaviour. Both these classes of flexibility can be related to the firms encountered in the empirical work, and to characteristics exhibited by the computer implementation of the model.

Behavioural lags

3.38 The report now considers the theoretical basis for three parameters of flexibility used in the dynamic behavioural model presented in section 3. These are firstly, lags and response times; secondly, information gathering and expectations; and thirdly, selection of appropriate responses. The first of these topics, lags and response times is of its nature dynamic. Because the model is multi-period with lags set as parameters in the spreadsheets it is able to model response flexibility. The modelling of response flexibility, defined in paragraph 3.4 above, requires to emphasise the differential between, on the one hand, the rate of change in the firm's environment, and, on the other hand, the rate at which the firm is able to change its performance in response. This is accomplished in the present model by the use of multiple periods. This means that, for example the firm's observations on factor prices may be lagged one, two or any number of periods, and the changes in, for example production level, may similarly be lagged any number of periods. By adjusting the settings of these lags in the model it is possible to produce a variety of results. A convergent result, where the firm rapidly and appropriately responds, can be achieved by appropriate parameter settings. The flexible firm responds sooner than the inflexible firm. It is thus modelled with behavioural lags less than the frequency of change in the exogenous variables. This will produce a convergent damping of the external changes, provided that the observations of the exogenous change are accurate, and the magnitude of the response is appropriate. *Inertia*, where the firm may see the change in its environment, but be unable to respond with sufficient speed, can also be modelled by appropriate setting of the lags in observation and response. Thus the first important dynamic characteristic of the model is the ability to set parameters for behavioural lags in observation and response.

Information gathering and expectations - accuracy of information flows and forecasting.

3.39 Burton Klein (1984) distinguishes Type I and Type II flexibility, the former being concerned with known variations and risks, and the latter addressing newly disclosed opportunities and uninsurable risks. He also introduces the issue of predisposition to adjust to change as being a flexibility issue. Adopting strategies designed to deal with external change requires the firm first to observe its environment accurately, and second to project its observations into the future. In order to model Klein's Type 1 flexibility, i.e. responses to predictable variations the model has parameters which represent the accuracy of the firm's observations. A random term is added to each observation variable. The parameter is used as a coefficient of the random term thus controlling the accuracy of the observation. A second parameter acts as a threshold value on the key variables which the firm uses to prompt action. The control model documented by Cyert and De Groot(1987) says that the firm observes its external environment, makes a plan, and then observes the difference between plan and actual. Their model says simply that if the variation is considered significant, action is taken. The present implementation of the behavioural model allows the accuracy of the observation, and the significance of the target variations to be parameterised. Klein's type II flexibility, i.e. the response the firm has to make to unpredictable change, is equally dependent on the firm's ability to observe the exogenous changes rapidly.

Selection of appropriate responses.

3.40 The third and last parameter of flexibility in the behavioural model concerns the selection of an appropriate response. Cyert and DeGroot (1984) propose an algorithm based upon subjective probabilities which the firm follows in order to select a particular response. The firm develops a knowledge base which it then uses to estimate the likely effects of each action on the target variables. When applied practically to the present model the algorithm has two dimensions to it. Firstly there is the question of how the firm establishes the range of possible actions from which it will select the optimal action. Secondly, having established a finite set of options, there is the use of the Bayesian approach for actually choosing the optimal action. Following Cyert and DeGroot, the present model addresses the latter aspect only. The knowledge base of the firm is represented in the present model by the actuals sheet. The number of prior periods which the firm uses in making predictions about the effects of current action is controlled by a parameter, which thus represents the firms experience. Cyert and March (1963 p 100) adopted a similar approach using weighted averages of past performance.

Conclusions

3.41 The present chapter has approached the topic of flexibility in the small entrepreneurial firm. There is a considerable breadth of industrial economics theory concerning the firm, in which flexibility may play a part. The chapter has therefore had to address several different aspects of this economic theory of the firm. Extensions to the flexibility definitions of Stigler, (1939), Carlsson (1989), and Mandelbaum and Buzacott(1990), have been proposed. The flexibility definition has been extended beyond the simple breadth of choice flexibility documented by Stigler (1939), and Mandelbaum and Buzacott (1990). The rate of response has been identified as a significant component of flexibility. The chapter has gone beyond Carlsson's (1989) short- medium- and long-term classification of flexibility based upon production engineering, to a more qualitative classification distinguishing physical flexibility attributes from organisational flexibility attributes. Finally the three key behavioural parameters of flexibility in the firm have been derived from the behavioural principles of Herbert Simon and Richard

Cyert. They are (1) the speed of observation and response; (2) the accuracy of observations and forecasts; and (3) the accuracy of the response selection algorithm. In the behavioural model, these three behavioural elements distinguish the flexible firm from the inflexible firm.

Notes:

1. *Concise Oxford Dictionary of Current English* 1982 Oxford University Press

2. *Webster's ninth new collegiate dictionary* 1983 Merriam Webster Inc.

PART III
EMPIRICS

Chapter 4 Industrial Experience.

Introduction.

4.1. This, the first of six chapters covering the empirics of the research, explains and evaluates the methodological aspects of a substantial body of experience gained whilst working in the industrial field with many diverse companies over an extended period. The behavioural patterns adopted by these companies were observed both formally and informally, and have provided much of the basis for the present behavioural model and the analysis of flexibility. A further empirical survey of fifty firms was conducted in order to parameterise the model, and this is dealt with in Chapter 5. Bo Carlsson (1989) has argued that more empirical studies need to be done. Furthermore, one of the principal motives for the research was a perceived need to provide a more solidly based link to the actual companies, using real events rather than putative scenarios, from which to draw conclusions. The value of theory thus grounded in empirical experience has been noted by Reid (1987a) and others as noted in chapter 2.

4.2. The motivation for the research arose from observations made by the author concerning differences in the structure and operations of firms with which he became involved. This experience also had a major influence upon the methodology. The skills acquired might prove useful both to the empirical work, and to the model development process. The objective of the present work is to study aspects of flexibility in the operations of small firms, and in particular to study flexibility from a behavioural point of view. The methodology chosen reflects this objective. There are three separate aspects to the behavioural approach taken in this thesis. Firstly, following authors such as Herbert Simon (1959,1961, 1979, 1982), Richard Cyert (1963. 1987. 1988) and Oliver Williamson (1963, 1988, 1989), it enables the unit of analysis to move from being only the firm, to being either the firm or the individual decision. Consequently, the study is able to comment upon important phenomena observed within the firm, in contrast to treating the firm as a simple set of inputs and outputs without significant internal mechanisms. Secondly it narrows the empirical gap between the raw data and the computer model of the firm. Thirdly, it allows closer linkage of the economic theory of the firm to other disciplines where the sociological and psychological factors are given greater emphasis. These issues are important determinants of the methodology adopted and the form of the empirical exercise.

4.3. The methodological process followed by the project comprised three distinct tasks, which were undertaken after establishing the definition of the project objectives and conducting a review of the supporting literature. The first of these tasks was an evaluation of the empirical evidence provided by the industrial experience of the author over an extended period. The second task was the design and implementation of a formal survey to provide parameters for the model. The third task was the design and implementation of the software entailed in the model, and the evaluation of the results generated by the model. A considerable degree of simultaneity existed between these tasks throughout the project. Thus, feedback from each section modified and extended the interpretation and development of the others. Typically, however, the process went from a general view, based upon an evaluation of the industrial experience, to a specific formulation of both the model and the survey, followed by the evaluation and refinement of the model. The format of the following empirical account takes the two data gathering aspects first, in the present chapter and in chapter 5, which covers survey design issues. This is followed by the discussion of the development and form of the model in chapters 6, 7 and 8. Chapter 9 discusses the comparitive dynamics of the model. Results are analysed for choice flexibility and response flexibility.

4.4. Considerable knowledge was gained, through personal experience, of the behavioural factors governing the operations of firms, and in particular their responses to sudden change. Because of the direct use of this knowledge in the conduct of the research project it is essential to explain in detail the nature of the tasks undertaken, and the observations made, during this industrial experience. The remainder of this chapter is organised as follows. Firstly, a description is given of the formal methods employed whilst investigating the behaviour of the firms. Secondly, consideration is given to the firms constituting the sample set, with a general categorisation of the events leading to their being studied. Thirdly, flexibility issues identified during the period are discussed. Finally, an evaluation is made of the resulting empirical knowledge and its contribution to the model.

Formal Systems Analysis

4.5. The industrial experience of the author commenced with a ten year period pursuing a systems development and data processing management career in large corporations, following a post-graduate course in information systems analysis and design. The task of systems analysis and design is widely found within industry. It is usually undertaken within an administrative structure which includes operational management of computing and communications. From the 1960s onwards firms have made great use of computers to store and process information. The rôle of the systems analyst has been to record the information sets and flows which exist in firms, and to propose and supervise the implementation of revisions to these.

4.6. Formal techniques for undertaking the tasks of systems analysis and design have been used extensively. Within sufficiently large organisations the techniques are set down as standard procedures and document structures. In the UK the National Computing Centre (NCC) developed at an early stage a formal set of procedures and documentation standards which have been widely used. The British Standards Institute also established a formal methodology (BS 5515), as did corporations such as International Business Machines (IBM). More recently, formal procedures based upon the structured systems analysis and design method (SSADM) have been adopted, and following on from this, object-oriented systems analysis and design. One feature these methods have in common, is that they reject informal narrative, (i.e. the anecdotal evidence referred to by economists) in favour of highly formalised data and procedure descriptions, using tightly defined terms. This is partly the result of the close association of the task with computer software development, which imposes its own formal logic structures upon information processing. It is also in part the result of pragmatic considerations to do with organising and documenting complex processes. The requirement for a highly structured approach arises because of the complexity of the information processing tasks being modified, because of the need for different people at different times to understand the systems, and frequently because of the importance of the systems concerned to the firms and major effects of errors and inaccuracies.

4.7. The form taken by a structured system documentation is briefly as follows. The information system is broadly divided into operational areas (eg production planning, purchasing, design). The data used by the firm in this operational area is then described as a set of files. Each file consists of a set of records, or linked data items. For example, within the operational area *purchasing*, files may exist representing *outstanding orders*, *suppliers*, and *requisitions*. Each record contains a set of linked data items known as fields, and each field is defined by a set of attributes such as type (eg money, text), maximum and minimum value, membership of another file set, etc. For example a record from the *order* file of a *purchasing* system might contain the fields *supplier name*, *item ordered*, *quantity*, *price*, and *delivery date*, each of these fields having a specific definition.

4.8. The procedures used by the firm in each operational area are similarly broken down into sub-systems, processes, and individual procedures, with sets of input and output data associated with each level. An example, again taken from a purchasing system might be the placing of a purchase order, which would have as input a requisition record and a supplier file and produce as output an order record. Thus all the elements of the purchasing decision are considered in a formal fashion using specifically identified data items and procedures. It is clear that such an analysis of business decision making procedures could be useful when developing a micro-economic model of the firm which includes as a major element the internal behavioural activities.

4.9. The data collection methods used in business systems analysis are also worth consideration with respect to the present task. The structured interview is the prime tool used to gain the necessary information on data files, flows and decisions. These interviews are supplemented by examination of any existing formal data sets, (eg. historic transaction files, existing reference data files). Simple observation of the processes as they occur is also a useful technique. To be successful a comprehensive set of interviews cross-relating all inputs and outputs is necessary.

4.10. This cross-checking will also show up inaccuracies and subjective responses. The jobs of interview subjects may frequently be changed as a result of the work and they therefore have a direct personal interest in the outcome of the interview. As a result they will often attempt to influence the outcome. Academic research is much less likely to have any direct effect on the interview subjects. Nevertheless, subjective influences are likely to affect responses when questions are asked concerning how business is or should be conducted. Research has been done into interviewing techniques where subjective responses are expected and this is referred to below in chapter 5.

4.11. The analytical element of the systems analyst's task therefore, involves the investigation and formal documentation of the firm's information processing procedures. This process uses standardised techniques most of which have parallels in the data acquisition techniques adopted in academic research into behavioural topics. The contribution of this work to the present investigation of behavioural factors governing decision making within firms is substantial. Subsequent to spending time purely in systems analysis, a period was spent as a data processing manager responsible for managing both current information processing tasks and the work of several teams of systems analysts. Then the author founded his own company. This company has continued successfully for a further ten years, and at the time of writing has a workforce of ten advising on and implementing new information systems. The client base of the author's company includes a wide range of firms, principally in the north of Scotland.

Personal entrepreneurial practice.

4.12. The background of ten successful years owning and directing a business as ones sole source of income has considerable relevance to the present work. The venture has provided first hand experience of the entrepreneurial rôle, and the behavioural decision making processes involved in being an entrepreneur. This is a non-trivial consideration. Understanding the factors governing risk taking behaviour is greatly improved if, for a period of several years, one's livelihood is daily placed at risk. As a further help to understanding of the entrepreneurial function, the company's customers have provided an extensive informal empirical base from which to draw evidence. Repeated direct contact with the founders of small entrepreneurial firms through business associations and as customers and suppliers took place over an extended period. This has provided, and continues to provide, valuable analytical insights into the formal characteristics of the group and the modelling and prediction of their behaviour patterns.

4.13. This research aims to represent the flexible behaviour of a typical small firm. In developing the model, reference has been repeatedly been made to the general base of knowledge about the operation of firms. In common with academic research, extended experience of fieldwork, in addition to providing the substantive data, also produces an expert knowledge base. This expert knowledge base is not necessarily consciously structured, but is able to provide examples, precedents and decision rules about the decision making behaviour of the firms studied. Inconsistencies which might otherwise be present in the model can be highlighted by placing it in the context of a specific company known to the researcher, and considering what the outcome of such a situation might be. Similarly, gaps in the model may be supplemented by selecting attributes from example firms relevant to the particular behavioural aspect. In this way useful tests that the model was reasonably representative were able to be undertaken throughout the development process.

4.14. To summarise, the first element of the empirical base consists of the authors knowledge of the operations and environment of business enterprises both large and small. This has been gained over a twenty year period investigating the firms' information flows. These investigations were undertaken in a formal analytical manner, interviewing both the principals and staff of the companies, and documenting key elements in the successful running of the companies. Formal methodologies established by the British Standards Institute (BS 5515), NCC, and IBM were used. In addition to formal investigations made into the behaviour of other firms, participation in the authors own firm took place, giving valuable information on behavioural perceptions and motivation.

The firms encountered during the industrial experience.

4.15. Turning now to the nature of the firms studied, the following paragraphs discuss the observations which were made during the last ten year period. The sample selection over the period was governed by commercial considerations rather than an *a priori* intention to study the companies as a group. Around 250 businesses were investigated, most of them located in the north of Scotland. The length of time spent with each one varied greatly, from a single half day to repeated visits extending over several years. Apart from the location element, two principal categories of commercial circumstances can be distinguished which led to their inclusion in the client list. The first of these categories relates to information technology changes affecting all or many firms within an industry. These changes affect firms in a single relatively homogenous industrial sector, and they occur during a definite time period. The second category relates to periods of rapid change or stress which occur in the client firms. Such firms then resort to changes in internal systems as a response. Changes in the second category may affect individual firms or many firms in a sector.

4.16. The first general category of contact with firms arises as a result of a technological change in the information processing facilities available to the particular industrial sector. Thus in the early 1980s the sudden availability of estimating software able to handle the complex engineering bids common in the oil industry led to work with a series of companies in this sector. Slightly later, the ability to calculate rapidly salmon growth rates, and thus profitability forecasts, from feed ratios, led to contact with most of the larger fish farming operations and several individual fish farms. Similar technological developments specific to particular industrial and commercial sectors occur at the rate of one or two per year. From an information gathering point of view, there are three aspects to this type of company contact. Firstly there is the simple knowledge to be gained from examining the firm's operations. Secondly there is the comparative knowledge to be gained through investigating a group of similar firms which operate in the same narrow sector at the same time. The contact arises as they introduce the same change to their systems and has provided excellent opportunities for observing and analysing behavioural differences occurring where most exogenous factors are the same. Thirdly there is the direct experience of flexibility resulting from the constantly changing environment facing the company supplying the expertise. The periodic changes in technology affecting the client firms mean that each year presents a substantially different market place to the advising firm with changes in factor and product markets, and in commercial mores. The types of contract, methods of negotiation, and operating modes, employed by a vehicle dealer introducing a customer prospecting system, are substantially different from those employed by a fish processor introducing a vessel payment system, and differ again from those employed by a lawyer introducing a property register. Different methods of trading are appropriate to these different markets. As the introduction of new systems to such groups of clients peaks and then subsides, considerable flexibility is required of the firm advising on the introduction of the new systems. This flexibility requirement applies to both aspects of flexibility as discussed later in this study. That is to say, the firm is required to respond quickly to external change on the one hand, but is also required to keep alternative options open because of unknown but frequent future changes.

4.17. The second class of circumstances, which have led to the involvement of the author with firms, relates to periods of rapid change or stress in individual firms or groups of firms. These firms, faced with a set of changed circumstances, make alterations to their internal systems as a response. The occurrence of the circumstances promoting change varies. Some are developmental, reflecting a discontinuity in the smooth growth of the firm. This in turn is frequently brought about by step functions present in factor supply. This is the case especially if the structure of factor supply is broad enough to include management skills and marketing expertise. Others are not developmental, but result from exogenous shocks. Some examples of empirical observations made over the period of industrial experience may serve to illustrate such circumstances. One describes the development of financial reporting systems in a small start-up company. Another describes the action taken by firms experiencing a demand shock.

4.18. A small company in the early stages of development will initially place a relatively low priority in the allocation of resources to income and expenditure analysis. Management and staff time will preferably be spent on marketing and producing. These are vital activities which cannot be postponed, in comparison with monitoring the financial performance of the firm, which can be largely ignored in the very short run. Similarly capital at the outset is allocated to productive assets directed to producing more immediate returns than information processing equipment. As time passes, ad hoc systems for accounting analysis develop to meet specific external requirements such as statutory returns or lenders information demands. The tasks are carried out by directors, by external accountants, or by staff whose principal duties lie elsewhere. As the firm grows, however, a break point develops, usually as a result of the principals of the firm perceiving the need for feedback from their activities. If the firm is growing, competing demands on key individuals time will lead to a breakdown of the ad hoc systems. The process of changing to a fully functioning internal financial reporting system is not gradual. It is not accompanied by a smoothly increasing consumption of some factor inputs, and a gradual downward movement of the firm's average and marginal cost functions. It is a sudden change, frequently prompted by external factors whose timing is specific to the company, such as a tax break or a change in personnel. Additionally, because one change to the internal systems is taking place, the firm will often opt to implement other changes at the same time. The pressure for the change builds up over a period of time but the change itself forms a discontinuity in the development of the firm. Examples or the foregoing were regularly encountered throughout the period.

4.19. When firms experience a sudden increase in demand, they do not necessarily recognise either its duration or its scale immediately. Sales enquiry levels, and order acceptances are the main sources of information on demand which the firms are able to observe. These may continually fluctuate in a minor way, so that a short term fluctuation is indistinguishable from a permanent shift. The firm may tentatively issue quotations at a higher price in order to ascertain the scale of the change. An iterative process over a number of deals may be necessary to obtain sufficient information to justify a new base price. The firm may not change price but rather simply increase the number of quotations in response to the increased enquiry levels. This will then result in an increased number of order acceptances. Thus some time will have passed before the decision makers in the firm clearly recognise the change. More time may pass before the decision makers recognise the change as a permanent one. At this point a change in capacity may be indicated to handle the additional throughput profitably. Such a capacity change will require additional risk capital, and depending upon circumstances further information gathering will be necessary before action can be taken. A break point will again develop where the firm has to make a large change in throughput in order to catch up. Changes in capacity frequently involve changes in the information systems used by the firm to monitor and control them. In addition, information processing is increasingly an integral part of the production process, especially in service oriented companies. Thus, in some service sectors (eg contract labour supply in the oil industry, legal services) the information handling system is itself the production process.

Empirical evidence on flexibility from industrial experience.

4.20. The final area where the author's industrial experience has direct empirical relevance to the present research, lies in the observation of the various aspects of flexibility itself. Flexibility involves response to change; flexibility involves maintaining open options;

and flexibility is important at the periphery. The following paragraphs discuss these three aspects of flexibility in the context of the empirical observations gained from the industrial experience.

Flexibility involves response to change.

4.21. The introduction of new computer systems involves change, and as a result many opportunities existed for observation of behavioural response to change. In some cases the introduction of computerised procedures was itself the change engendering responses, in many others it was the response to other changes. As an example of the former, the development and widespread adoption of computer aided design in engineering was observed at first hand, as was the introduction of computer based job scheduling techniques to deal with any demand for more frequent production changes. Such changes are not restricted to small firms being brought within the ambit of computerised operations for the first time through cost reduction. Large firms which have utilised computer procedures over several decades are equally subject to technological shocks. It was thus possible to observe such technological shocks affecting the production control procedure of a nuclear power plant and a paper mill operated by a multi-national. It was also possible to observe these technological shocks simultaneously affecting several small independent engineering workshops, and small printing companies.

4.22. The computer industry itself has been undergoing continuous change throughout the period. The significance of these changes, viewed from within the industry, is not limited to the technical aspects, though these are the predominant source of change. Of equal significance to the participants, are the accompanying marketing and organisational changes which occur each time a new hardware or software development opens up a new market. The initial expectation when setting up the company was for a firm employing two or three people over a three to five year period. The firm would engage in the introduction of computers to a market created through sudden changes in the price structure of accounting and estimating systems. This change occurred immediately prior to the date the company commenced operations. What has enabled the company to trade at a higher level over a much longer period has been profits earned from the subsequent series of technological developments. These profits have been earned by the ability of the company to adapt its operations rapidly to make profitable use of each change as it arose.

Flexibility involves maintaining open options.

4.23. That is to say, flexibility involves keeping open alternative courses of action, under conditions of imperfect information, which can be implemented when additional information on future events is available. This aspect of flexibility, formally documented by Mandelbaum and Buzacott (1990), has been considered in detail in Chapter 3. A number of opportunities arose to observe such flexibility in action. However, it is less easy to categorise the episodes contributing to this area of flexibility experience. This is because maintaining options open is usually highly specific to the individual circumstance of the company, its production factors, and its potential output markets. Also it has to be clearly identifiable as a behavioural choice made by the company, rather than a set of externally generated circumstances presenting alternatives. There is one set which is clearly distinguishable, and that is the set of small trading groups of companies. These make useful cases for study because comparisons can be made between these multiple product firms, and their single product competitors. Such small groups of companies were regularly observed, operating in the same markets as individual firms. It was possible to see how the owners, by spreading their operations over different products and markets, achieved not only economies of scope in terms of their cost functions, but increased flexibility of action in the event of shocks occurring in one part of their operations. This may simply be viewed as a another way of describing a risk spreading structure. That is to say the participants are adopting the strategy of operating several firms as a defence against any one of them experiencing setbacks. However, the participants also evinced rather more positive strategic motives for a small group structure. This was that it increased the opportunities for exploiting market changes. Instances of firms adopting such strategies were encountered, and include both commonly occurring combinations of activities, and unusual small groups set up to meet highly individual situations.

4.24. For example, the author encountered on perhaps a dozen occasions small groups of companies combining three or four activities drawn from the set public works contractor, road transport company, farm, garage, and house builder. What was notable about such groupings was not necessarily the economies of scope which they could realise. Economies of scope clearly existed, but were not of such magnitude as to prevent competitors without such economies from trading. These small groups were, and still are, operating in markets where many rivals in their output markets are single product firms. Therefore they are not gaining an overwhelming long term cost advantage sufficient to drive their rivals from the market. The interesting aspect from the point of view of the present investigation was the variety of the options open to such small groups, and the speed with which these options could be implemented, in the event of fluctuations in factor and product markets. The dynamic considerations of adjustment to changed circumstances might be of more strategic significance in such cases than the static cost factors. The implication of this would be that they should have greater longevity but not necessarily greater profits. No formal measurements were made to test this. However, these effects were observed when significant upward and downward shocks occurred in their markets.

4.25. Both short term and long term shocks can be handled within such groups. Short term seasonal shifts in labour requirements for the farm business can be met from other parts of the group, for instance. Shocks with longer term effects, such as changes in asset values and/or overall demand levels associated with house building and agriculture are more difficult to handle for a single product firm operating only in that market. This is not to say that the small group structure gives a long-term cost based economic advantage. That may or may not be the case. The important benefit to be highlighted here, is that the necessary adjustment to sudden change can be smoothed because of the wider range of options available. During a long stable period, the group's single product rivals may threaten its success. (eg rival farming enterprises may drive up prices in factor markets, rival transport companies may undercut prices in product markets).

4.26. The second example is rather more individual. The owner manager of a firm operating in a highly volatile labour subcontracting business, and with management skills specific to the oil industry, developed with great success, from scratch, two additional businesses. The second company within the group developed a tourism related project, and the third a high-technology engineering product. Whilst risk spreading and cost savings may have played some part, dynamic demand fluctuations were of more significance in determining the particular structure. Being able to cope with sudden short-term cash inputs, through building tourist accommodation, was only one of several innovative flexibility strategies employed by the companies.

4.27. Strategies were consciously employed within the author's firm to maintain open options at a cost, rather than pursuing the static profit maximising course of action. However, it should be said that this arose from prior formal study of Bayesian approaches to decision making.

Flexibility is important at the periphery.

4.28. The term *periphery* is used in the sense of firms not being in the mainstream of a particular industry or market. This peripherality may take several forms. The most obvious one is being at a much greater geographical distance from a market than the majority of participants. However the analysis used here would extend the definition, to include as peripheral, firms where other non-spatial features are outlying. New entrants to an industry, firms with the smallest production plants, firms whose products are more differentiated than the norm, and firms with problems, all fall within this category. Such firms may be a fruitful source of flexible responses. Many firms falling within the broadly defined *peripheral* category, were encountered. Many firms serving a market outwith the north of Scotland tended to be spatially peripheral with respect to their output markets, with one or two exceptions like distilleries. Local businesses, competing with non-local firms in the local market tend to be peripheral with respect to their factor markets, and to their size. Flexibility as a survival strategy has relevance to these firms. Observations were made of the use of information processing to compete with larger and more centrally based companies. In these, and in other peripheral companies, including his own, the author has been able to observe flexibility.

4.29. To summarise, the nature of the firms studied, and the observations which were possible, have enabled the author effectively to undertake a wide ranging review of virtually all types of business operating in the north of Scotland over a ten year period. The nature of the data collected on individual companies was not *a priori* designed to provide an empirical base. However, the interview and data collection formats largely followed the standards established for systems analysis by the British Standards Institute, (BS 5515), the National Computing Centre, and IBM, modified by the author. They necessarily investigated the behavioural patterns established within different companies, and covered all activities from marketing through to product research, rather than, for instance, the more restricted set of formal accounting procedures. Furthermore, the observations were made at times of change within the firms, and directly concerned their behavioural responses. This was supplemented over the same period by personal experience gained directing a firm subject to technology and demand shocks. Such an empirical base provides a powerful source from which to create a behavioural model of flexibility in the firm.

4.30. Criticism may be made of the method. It might be thought that evidence of firm behaviour collected in this way runs the danger of becoming anecdotal, thereby failing to meet rigorous quantitative criteria, and therefore being unsuitable for use as a basis for confirming or extending theory. As against this there are also good reasons for valuing such data more highly than that gathered by disinterested formal data collection methods. The greater depth of qualitative investigation one is able to conduct under commercial, as opposed to academic conditions is one such reason. The motivation to collect and to provide the significant data items, being guided by strong commercial pressures, is substantial. This is particularly the case from the point of view of the participants providing the information in a commercial context, who by contrast generally feel they may gain little specific benefit from providing data for an academic data survey. The commercial method does not, however, provide quantitative data in a form which is immediately suitable for academic analysis. This is a situation which is frequently encountered in the social sciences. To meet this shortcoming, the empirical base for the model was extended through the medium of a new specially designed survey, discussed in the following chapter 5.

Summary

4.31. After first outlining the empirical content of the research, this chapter has examined the empirical and methodological significance for the project of the author's extensive industrial experience. It has established firstly that the data were neither informal nor capriciously selected. Observations were undertaken according to a formal schema. The sample was large and able to be structured with reference to its flexibility and behavioural characteristics. The depth of study was greater than could be undertaken in an academic context, without loss of motivation for seeking accuracy and avoiding bias. It is complemented by the second empirical source employed in the project, i.e. the new survey. This is discussed in the next chapter. The survey has been designed specifically for the project, and readily lends itself to statistical interpretation, thus complementing the more general, and less measurable, nature of the industrial data source.

Chapter 5 Survey Design.

Introduction.

5.1 The empirical base of this part of the project is the survey of small firms undertaken in the second half of 1990. Three key aims led to a new instrument, specially designed to elicit information on flexibility. These three aims were:

1. to obtain dynamic data
2. to obtain data on objective events rather than subjective opinions
3. to explore the possibilities for automating the design and data analysis.

The need to obtain dynamic data arises from the nature of flexibility, and in particular that aspect of flexibility which relates to speed of response. The need to obtain data on objective events rather than subjective opinions arises from several sources. Firstly, the survey is intended to complement, rather than add to, the prior practical field experience, which involved extensive qualitative enquiries into the views of entrepreneurs on their decision processes. Secondly, the author, having himself been a respondent to a number of surveys, both commercial and academic, was particularly aware of subjective prejudices which might influence the response. Thirdly, and most importantly, the event itself, i.e. the entrepreneurial decision, is to a large extent, the unit of study. J. R. Commons (1934), proposed the use of the transaction as the unit of analysis. Herbert Simon (1957) has proposed the decision premise, and Oliver Williamson (1979) developed extensively the use of transactions as the principal unit of analysis. The entrepreneurial decision is closely linked to contracting and to transactions. The need to obtain data on objective events was therefore a consideration in the empirical design. The wish to make maximum use of the recent (in 1989) general purpose personal computer software arose because of the target sample size which, at 50 companies, would represent a considerable task for an unaided single-handed investigation. Computer resources, on the other hand, were readily available. In designing the empirical instrument, the following attributes required defining: (1) the nature and size of the sample; (2) the survey techniques to be used; and (3) the data items to be observed and wording of individual questions. These items are dealt with in turn below.

The nature and size of the sample

5.2 To provide a consistent base for inter-firm comparisons, it was preferable to restrict the sample to a single industry at the outset. Although the sampling was restricted as a result, the object of this was to remove variation in the data caused by industry differences, and thus highlight the behavioural flexibility issues. This methodology also reflects the recent shift in emphasis in industrial economics, favouring intra-industry analysis over inter-industry analysis.

5.3 The criteria for industry selection were:

The target industry should be undergoing change external to the individual firms.

The industry should contain a sufficient number of firms for large sample statistic theory to be relevant.

The internal systems used by the firms should already be known to the researcher

Research access should be possible

At the outset, it was also the intention to include two groups of companies, drawn from different economies, with the intention of identifying any differences in flexibility strategies. Several industries appeared to meet these criteria, including oil related engineering, sectors of the print industry, the fish processing industry, and the computer industry. Initial investigative steps were taken with each of these industries, including obtaining lists of firms and setting up outline computer models. Homogeneity of the firms within the lists was the next measure used to select an industry. The oil related engineering industry and the computer industries were judged to be less homogenous in terms of the size, spatial distribution, and product mix of the firms to which research access would be possible.

5.4 Further investigation was therefore made into the print industry and into fish processing. In the case of the print industry, the desired criteria were met as follows. The industry was facing considerable shocks of a technological nature in its production processes. Typesetting and other pre-print processes were being deskilled and costs were being dramatically reduced as a result of developments in electronic text handling and laser typesetters. Additional to, though connected with, this technology shock, were the shocks which had occurred because of substantial reductions in the power of organised labour. This reduction progressed through different sectors of the industry at different rates. Many small and medium sized printing firms existed, so that a sizeable sample could be collected and analysed. Adequate knowledge of the behavioural processes existed as a result of the two years the author spent in systems analysis with a Swedish printing company which was introducing new technology. Research access appeared practicable both in the UK industry and in either Sweden or West Germany.

5.5 Fish processing met the criteria as follows. Shocks appeared to be occurring which affected production, supply, and demand functions. Technology shocks had affected the industry with the introduction of more sophisticated weighing, size grading and slicing plant, the use of specialised trucks able to transport live fish long distances, and the use of microcomputers to handle complex settlement contracts and accounting systems. Supply shocks were occurring as a result of fish conservation regulation and natural causes. A major demand shock had occurred as a result of the accession of Spain to the European Economic Community. The target industry clearly appeared to be undergoing change external to the individual firms. Regarding need to get an adequate sample size, the Highlands and Islands Fish Processors Training Association alone provided a sufficiently large membership list. The Portuguese Institute of Fish Processing indicated that a sufficiently large sample set of firms was obtainable, and confirmed that technology changes were present in the Portuguese industry. These were related to the changes from canning to freezing technology. A substantial E.E.C. funded conversion program was being administered by the Institute. With reference to the third criterion, that sufficient knowledge for building the model existed, fish processing had substantial advantages from the author's standpoint. Over the three years prior to commencement of the project, the author had introduced new production control systems to several fish processing concerns. Development and introduction of these production control systems involved working closely with the companies over an extended period of months in each case. The systems were being introduced to cope with rapidly increasing demand accompanied by frequent supply shocks, at a time when the industry in the north of Scotland was expanding. In addition the author had had involvement over a longer period with the accounting and production processes of other firms in the industry.

5.6 On balance, the judgement was made that fish processing would be the final choice of industry in which to conduct the survey. Fish processing therefore provides the parameters of the specific model constructed. This supplements the more general behavioural rules studied in the more widely based prior industrial experience. The value of obtaining the parameters from two groups of firms in two separate economies was also reviewed, but difficulties of conducting the fieldwork in two different fields proved insurmountable. The resulting decision was that satisfactory evidence on appropriate parameters could be obtainable from a single industry. Intra-industry analysis is now becoming the dominant methodology in industrial research. The sample of firms to which the survey would be applied was therefore drawn from the fish processing industry in Scotland.

5.7 A list of 137 fish processing companies was provided by the training association and a further 70 were provided by the Scottish Council for Development and Industry, of which the author's company was a member. The former companies were located throughout the Highlands and Islands, and were classified by the association into location and product type as follows:

Location	**Shellfish**	**Other**
Argyll	11	26
Caithness and Sutherland	4	6
Inverness and Nairn	1	7
Lochaber	6	6
Moray, Badenoch, and Strathspey		4
Orkney	6	8
Ross-shire	5	10
Skye and Lochalsh	2	3
Western Isles	12	20
Total	47	90

The latter companies were unclassified by location or product type. 19 firms were common to both lists.

The survey techniques to be used.

5.8 Several alternative data collection options were then evaluated, details of which are given below in paragraphs 5.21 - 5.24. A questionnaire was settled on, the design of which is discussed below in paragraphs 5.9 - 5.20. The following procedure was adopted for completion of the questionnaire. The names, addresses, telephone numbers, and contact names of the firms were provided and these were then entered in a computer file. Five firms to test the questionnaire were selected from the list at random using random numbers generated by software (Microsoft Excel). These five firms randomly selected from the list were supplemented by two further firms whose owners were known to the author. The purpose of including these additional firms was to gain direct feedback from them on the methodology. These firms were known to be willing to spend some time giving their views on the questionnaire design. The main conclusion drawn from the pilot study was that a greater completion rate and a shorter timescale would be achieved if the firms were offered a choice of completion method. Minor changes to the questions were also made. A telephone call was made to each firm, to the contact named in the training association list. After establishing that he was the appropriate person, i.e. the principal decision taker, the project was described and the contact asked if he would like to participate. No *quid pro quo* was offered to the executive, other than the opportunity to have his views on how he took decisions registered. The participants were then offered the choice of a visit or a questionnaire forwarded by post. In the case of non-response from the postal questionnaire a follow-up call was made, offering a questionnaire conducted by telephone, or a site visit. The questionnaire introduction repeated the general description of the project and the reasons for requesting the participant's help. The introduction also indicated that the questions could and should be answered quickly. The principal purpose of this was to discourage putting it on one side to complete later (or possibly never). The final questionnaire design is shown at appendix 1. Selection of the sample proper used the random software function to select from the computer list. The process followed was to select twenty firms at random every three or four weeks and continue until a sufficient number of responses, (more than 50) were received. In all, attempts were made to contact 120 firms, from whom 54 responses received.

The wording of individual questions.

5.9 The questionnaire is shown at appendix 1. Topics for the questionnaire are set out in five separate sections. The introductory section covers general identification and data to position the firm in its industry context. The name of the respondent, the company concerned, the respondents position in it, the industry and date were entered prior to presenting questionnaire. The first question the participant was required to answer was to list the firm's major enterprises/profit centres, with space for three. This confirmed the initial information provided by the training organisation on whether the firm was a shellfish processor or not. It also established whether the firm was also involved in activities other than fish processing. Lastly, for those engaged solely in fish processing, the question gave an insight into the internal subdivisions the respondents used to control the business. The company size was then requested. The markets in which the firm operates were then entered, again with space for up to three entries. This question provided information on the degree to which the firms operated in more than one market. The principal activities undertaken by the firm were then entered. This gave information on how to classify the firms activities, as seen from the point of view of the person actually controlling them. It also gave an indication of the vertical integration of the firm.

5.10 Thus the first section of the questionnaire contained straightforward, non-contentious questions designed to start the response process easily. Also, the three questions 1.5, 1.7, and 1.8 asked the firm to identify and subdivide aspects of their business. In each case they were asked to estimate the importance of each subdivision as a percentage. In addition to the actual data gathered, these questions introduced quantitative responses as early as possible.

Section 2 of the questionnaire.

5.11 The second section directly raises the issue of unexpected external changes. Question 2.1 (a) asks "Was there any unexpected major change in demand for any product group?" The object here is to get the respondent to think directly about specific events which have actually occurred, involving demand shocks, rather than enquiring about his opinions. Having got the respondent to focus upon a particular real event, there follows a series of highly specific questions concerning the event. The object is to improve accuracy of response by focusing upon real events. This follows the techniques established in applied psychology for obtaining accurate responses from individuals who may themselves have opinions on the questionnaire topics. The theoretical background to this style of questioning is discussed in detail in paragraphs 5.27 - 5.32 below. Question 2.1 (b) asks whether demand increased or decreased on that particular occasion, and question 2.1 (c) asks when the event occurred. Only after the focus has been placed upon a particular event in this way, is the question asked at 2.1 (d) "What action was taken in response?" The point here is that, if he had been simply asked "what do you do when demand changes suddenly?" the response might be coloured by personal views on what *should* be done. The next question asks "How soon afterwards was the decision taken?" This provides an ordinal response based upon an actual event. Question 2.1 (f) "At what level was the decision taken?" is principally intended to confirm that the respondent is in fact the principal decision maker in the firm, i.e. that the questionnaire has been directed to the right person. Question 2.1 (g) "In response to what specific information?" was the decision taken. The respondent is being prompted to suggest the sources of information he uses when taking decisions in response to demand shocks, but he is being asked in the specific context of a decision he has actually taken. The next two questions are probing to find other courses of action which the respondent might have taken in response to the demand shock. These questions are less likely to be readily recalled, but still add to the data on responses to demand shocks. Finally another quantitative question is asked on the length of time between the taking of the decision and its implementation.

5.12 The innovative style and structure of question 2.1 is designed to get a full and accurate description of the decision process. The structure is especially designed to minimise the problems of objectivity present in a behavioural survey. Closed questions, i.e. questions with a very limited range of possible answers, are asked first in order to obtain a specific instance of an appropriate decision. Open questions, where the answers are not so restricted, are introduced only when the respondent has a clear focus on a specific decision. These open questions are asked about the observation inputs to the decision (question 2.1 g), the action outputs (questions 2.1 d and 2.1 h), and the lags involved (questions 2.1 e and 2.1 j).

5.13 This structure was then repeated for further types of external shock in the remainder of section 2. The respondent was asked in 2.2 (a) if any unexpected major change in raw material supply occurred. The questions first focus on a particular event and then obtain the data on the decision. This process is repeated in questions 2.3 (a - j), which address labour supply shocks, and questions 2.4 (a - j) which address technology shocks. The use of these four sets of questions in section 2 thus provides up to four detailed records of individual decisions taken by the respondent.

5.14 The coding of the responses to these questions for subsequent analysis took advantage of the common data record structure which resulted from the question structure. The individual decisions were coded in terms of input, output, and time taken. The sheet used to codify the questionnaire results is shown at appendix 2. The input, i.e. the sources of information requested in questions 2.1 (g), 2.2 (g) 2.3 (g) and 2.4 (g) were coded into five information source types. The decision outputs, i.e. the actions requested in questions 2.1 (d) , 2.2 (d), 2.3 (d) and 2.4 (d) were coded into 12 different action types. The time periods, which were measured as ordinal values in each of the subsections of section 2, were standardised, from the diverse units used by the respondents, into a standard time unit of days. Other questions from section two were coded using simple numeric categories, e.g. 2.1 (a) "Was there any unexpected change in demand for any product group?" was coded thus: 1 = yes, 2 = no. This is detailed the right hand column of the coding sheet shown at appendix 1.

Section 3 of the questionnaire.

5.15 The third section of the questionnaire is designed to obtain information on the observations the entrepreneur makes in the control of the company. Cyert and DeGroot (1987 chapter 3) describe the management of the firm as a control mechanism which compares target results with actual performance. This principle is operationalised in the present model. In addition to the final target and actual variables described by Cyert and Degroot, there are intermediate variables used in practice by firms. These variables are used in combination as inputs to decisions. Thus the items in listed in questions 3.1 (a) to 3.1 (z) are items which the entrepreneur might use to control firm performance as described by Cyert and DeGroot (1987 page 31). The list was drawn up using the experience of the author in designing business information and decision support systems. Sales quantity is an easily obtained figure which is a useful guide to short term performance in an industry where input and output prices fluctuate in tandem in the short term. Sales value and gross profit may also be used as a short term measure, but are also likely to take longer to acquire. Raw material quantity is a useful proxy for short term performance in an industry where access to a fluctuating supply is prevalent. New order value and new order quantity are useful indicators of future performance in the short term. Outstanding order quantity, stock quantity, stock value, and production quantity, are useful indicators of the internal performance of the company in matching production to demand. Material costs provide short term data for altering prices and output levels. Labour costs, plant costs, and overhead costs provide longer term information. The firm's estimates of future market size, sales, profits and technology developments are derived from a variety of observations the firm makes about its external environment, and then used to make (usually longer term) decisions. Observations on industry output prices, material prices, labour rates, and profitability are also used as inputs to decisions. Net profit before tax, net profit after tax, net worth, and return on capital employed are the key performance criteria for any S.E.F. However, they are usually highly retrospective and therefore less useful, as decision inputs, in a fluctuating environment.

5.16 The respondent is asked to identify the most important figures (question 3.2), and to state the frequency of observation of all 26 items (questions 3.1 a-z). The response to question 3.2 is liable to subjectivity bias, in that it measures opinion, rather than potentially verifiable fact, but can still give an indication of the key areas of control. Questions 3.1 a-z, which measure the frequency with which observations are made, are more likely to be matters of record. Coding of section 3 is effected by a simple 1 - 5 category code for each of the five frequency categories, and entered on page 2 of the coding sheet shown at appendix 2.

Section 4 of the questionnaire.

5.17 In section 2, as described above. each sub-section took a particular exogenous change , and then worked through an actual example collecting data on the resulting decision and action. The fourth section of the questionnaire approaches the same events but from another direction. Each subsection of section 4 selects a particular type of action, and then works back, through the decision to take that action, to the original exogenous changes which prompted the decision. Question 4.1 (a) focuses on an event thus "When was the decision taken to start this particular enterprise?". Question 4.1 (b) probes for the preceding events which prompted the decision. The respondent is then asked to select observations which may have affected the decision. The selection is made from the 26 items previously listed in section 3. Questions 4.1 (d) and 4.1 (e) then collect data on the timing of the event and the decision implementation lag. The procedure followed is similar to that of section 2.

5.18 Pricing is addressed by the questions in sub-section 4.2. The respondent is asked in question 4.2 (a) to focus on the last price change action he took. The events preceding the action are then prompted for, followed by a request to list the observations contributing to the decision. After entering details of the decision timings, the respondent is then asked two further questions, firstly on the frequency of price changes, and secondly on the causes of price changes in general. The question on frequency of action, question 4.2 (f), is equivalent to the frequency of observation questions in sub-section 3.1. Although not related to specific events, the frequency is verifiable and less likely to be biased by opinion. This, however, cannot be said of question 4.2 (g), which is not related to a specific event nor verifiable, and thus has scope for subjective bias. Nevertheless, the question was included as a supplement to the data on decision inputs. Further sub-sections in the fourth section follow the same pattern, as the pricing decision subsection. They collect data on specific actions which have taken place in the firm, and their causes. They cover actions on marketing, plant change, output level, and staff hours and numbers. There is thus the potential to document a further seven actual decisions in section 4 of the questionnaire. Some of these decisions may be the same as the four decisions documented in section two. This redundancy is considered to be a benefit to the accuracy of a behavioural questionnaire. The coding of section 4 follows a similar format to that of section 2, using the same categories for information sources and action codes (see Appendix 2).

Section 5 of the questionnaire.

5.19 The fifth and final section directly addresses flexibility in plant and staff transfer between different products. The focus is again placed upon actual events rather than general views. The respondents are asked to identify the different uses to which the plant was put at question 5.1 (a), and to quantify them as a percentage of total usage. Data on the decision timings are entered at questions 5.1 (b) and 5.1 (c). Then two questions are asked which are designed to collect data on transaction costs and flexibility. The respondent is asked at question 5.1 (d) how his plant is funded, and at question 5.1 (e) whether the decision is affected by the ability to change plant. The subsection on staffing flexibility follows the same pattern. The questions in section 5 are coded in a similar fashion to the previous section. The codes used are given in the right hand column of coding sheet shown at appendix 2.

The questionnaire - some general points.

5.20 Considerable effort has been made to meet the business executive half-way in the terminology used, and in selecting data items with which he is likely to be familiar rather than their economic theory equivalents or derivatives. Conciseness of question has been attempted to minimise the time to complete the questionnaire, and hopefully to maximise the response rate and to enhance follow-up opportunities. The primary role of the questionnaire is to collect data upon which the behavioural model can be grounded. A secondary rôle is that the data acquired can be used to refine and test the model. This is an iterative process, involving careful parameter modification in the light of different results. The development of the model as a result of the comparison with the data collected on the questionnaires is a valid method, because the changes are to the parameters of the functions contained in the model, rather than changes to the structure of the model itself. In summary, the survey was undertaken to provide parameters for the model. An original instrument design was evolved for the project. It contained features specifically aimed at problems arising in behavioural research where the views of the subject may introduce bias. The development of the survey was not a straightforward task. Several alternative approaches were considered and rejected. The author's experience as a participant himself in a number of surveys led to an emphasis on actual events rather than subjective views. Some of the issues arising during the design process are detailed below.

Alternative survey techniques considered.

5.21 Several alternative data collection options exist which could be applied to the fish processing industry, ranging from published figures at one extreme to participant observation at the other. Successful examples of the former technique being applied in the small firms research area include David Birch (1979) in the USA and David Storey (1981) in the UK. Both of these researchers derived their findings largely from data which had first been drawn from the firms for other purposes. Active participation in the target firms has been documented as a research method by Body and Lewis (1986).

5.22 Several available sets of data already existed relating to the fish processors being analysed. Data on raw fish prices are collected daily. Producer levies based upon production quantities by individual firms are recorded and may be available for research purposes. Employment and turnover figures are collected by government agencies. Such statistics might therefore be useful. However, the usefulness of such figures would be restricted to monitoring only some of the exogenous changes occurring, and only some of the responses. Whilst fluctuations in employment rates might be able to be linked to price and quantity changes, the behavioural mechanisms through which the link is operationalised would not be observed. Also, periodic aggregation of the figures may smooth individual decision break points, and miss significant evidence on response timing. The time taken to respond to change is judged to be a key component in the model, a component for which parameters are required. Readily available statistics were therefore rejected as a source of parameters for a behavioural model.

5.23 An action research route was also considered. This would involve detailed work with a small number of companies over an extended period. Gibb and Scott (1986), investigating growth mechanisms in small, owner-managed firms, participated in the firms' activities themselves. They played an advisory rôle in the decision making process of firms facing change. Their objective was to observe how the firms coped with change, and to understand the behavioural processes involved. However, their approach is more of a model for the primary empirical base of the present research, ie the industrial experience. The arguments against using such an approach for the purpose of providing empirical parameters are given above in paragraph 5.1. It is worthy of note that the research carried out by Gibb and Scott on sixteen firms incorporated a quid pro quo of free advice and association with grant giving bodies in order to motivate the firms to provide information. This may possibly cause undesirable observational bias. The individual respondent may wish to present a particular image to a grant giving body or those associated with it. Moreover, firms with a greater requirement for advice or financial assistance may be more prominent in such a sample of firms, whilst firms with lesser requirements for advice or finance may not be represented. The technique of becoming very closely involved with the firms was therefore not used to provide the parameters.

5.24 Intermediate techniques between these two extremes were then evaluated. The following alternatives existed: a case study approach; a semi-structured interview approach using an administered questionnaire; a self-administered questionnaire; or combinations of these methods. The case study approach, widely used in more behaviourally oriented disciplines such as marketing and sociology, was rejected as being too similar to the method already used to gain the bulk of the knowledge base. Between the semi-structured interview and the self administered questionnaire there was less to choose. If the survey objective had been to gain familiarity with the behavioural processes, as is usually the case with the semi-structured interview, then that method might have greater attractions. However, the familiarity with the processes was already present. Furthermore, the greater demands upon the target firms made by an interview may introduce unmeasurable bias between firms willing to participate and firms unwilling to participate. It was decided to design a questionnaire which could be used either by direct administration on the participants premises, or as a self-administered postal questionnaire, and let the firm choose the mode of completion. Presenting the self-administered questionnaire as an alternative in the event of time objections being raised to an interview should ensure a better response rate than either of the methods used on their own.

The use to which the instrument may be put.

5.25 The principal aim of the questionnaire was to provide parameters for the model. The ideas on the structure of the behavioural mechanisms were already present and based upon other empirical sources. To obtain knowledge of the relevant parameters the survey was designed to acquire three basic classes of data: (1) identification and classification data suitable for categorising the firms into groups which may have a bearing on their behaviour; (2) data on the information processes used by the decision makers in the firm. The object of gathering this information was to suggest reasonable values for modelling individual behaviour; (3) data on exogenous shocks and the responses to them. The information from this is used to suggest the form of different types of shock incorporated into the model. It is also used to set parameters controlling the response times of policy variables (i.e. lags between exogenous shock and resulting behavioural change).

5.26 Whilst designed for application to a particular industry, the survey contains no questions which could only relate to fish processing. The particular model, based on the data collected, is intended to be specific to the industry, but the methodology is not. Thus different values for parameters drawn from a different industry could be acquired using a similar instrument, and a similar modelling method. If, in the future, the opportunity arises to conduct the survey into another industry, then the experience of constructing the model reported on in this thesis would be beneficial. The identification and classification items collect general data on the industry, principal enterprises of the firm, markets and production processes. The data sought on the information processes present in the company refer to what information variables the decision takers monitor, and how these input items are related to output policy variables. For example does the decision maker monitor competitors prices, and if they change, does this affect his own pricing? The third class of data observed through the survey concerns the frequency with which input variables are monitored and used in decisions, and the length of time taken between input change and output response.

Some general points on the style of individual questions.

5.27 The questionnaire is reproduced in Appendix 1 to the thesis. Several general points can be made about the style of the questions and the structure of the document. Two points are concerned with avoiding bias introduced by the subjective views of the participants. The first of these is redundancy. A conscious aim has been to build a certain amount of redundancy into the survey structure. Data on events categorised by input changes in the second section is to a degree common to data collected in the fourth section, which discusses events categorised by output decision. These events may be the same, and appear as answers once in each section. The second general point is the adoption of techniques from personnel interviewing to improve accuracy. A third general point concerns the open nature of many of the questions. This is largely to ensure that the responses are not conditioned by the restriction of responses to predetermined choices.

5.28 The questions themselves are constructed to elicit from decision makers the circumstances affecting and/or prompting past key decisions. This method is put forward for several reasons. Firstly, it enables the research to make some estimate of the frequency of certain decision types, and perhaps to draw inferences about the lags involved or their perceived importance. Secondly, where several similar firms are studied, similar decisions taking place at the same time may provide a stronger indication of causation. Thirdly, by reducing dependence on hypothetical decisions, the questions have more limited scope for idealised responses.

5.29 The following example may serve to illustrate the last point. Suppose an executive is asked to consider whether he would raise prices when faced with a postulated increase in demand, or take some alternative action such as expanding output at increased cost. In responding to a hypothetical question such as this he may consider other issues as well as the substantive one. Does he wish to be seen as a positive, expansion-minded leader of a growing business? Is charging a higher price for the same item consistent with his current aims? It is difficult to put such normative matters to the back of the mind when asked for *general* views about how decisions are *usually* taken. Such sets of decision making principles will inevitably be coloured by value judgements. On the other hand, when asked the direct question "Was demand increasing when you last raised your price?, or "did you turn down any low margin orders last time the factory was working at capacity? the answer is less a matter of opinion or intent, and more likely to be a matter of record. Selective recall may still play a major part, of course, where the topic is not a matter of record.

5.30 Concentrating upon past decisions, it may be argued, reduces the validity of the conclusion in a rapidly developing industry or firm. Similarly, the absence of appropriate decisions in the recent past, to which the executive can refer, may mean significant gaps in the data. In these circumstances, however, the subjective general views of the executive will be equally flawed, though this will be less apparent. Essentially, such conditions mean that the industry or firm is acting under increased uncertainty, an external factor affecting the validity of the model, irrespective of empirical methods.

5.31 A further significant thread running through the questions is the emphasis on collecting data on changes which have occurred. This is partly a reflection of the dynamic nature of the model itself. More importantly, however, by intentionally concentrating upon critical events in the recent history of the firms the more significant strategic and control functions will be identified. This technique is adopted from the discipline of management psychology, where the approach is used in personnel interviewing to aid prediction of individuals future performance. In essence the technique is to ask the interviewee to identify the most significant events, and then to concentrate upon the factual elements associated with these, and the decision or reaction of the interviewee to these elements. The first advantage that this approach gives is that the salience of particular factors is not predetermined by the question format, it is the target firm which decides which factors are the most important. The second advantage arises from the avoidance of speculative responses as detailed in the preceding paragraph. Lastly, the technique enables specific ordinal data on timing of actual events to be obtained, providing a sounder statistical base.

5.32 Much of the approach described in the preceding four paragraphs is derived from the field of applied psychology. Endel Tulving (1983) makes a division of memory into episodic and semantic categories. As described by Colin Ingleton (1988) the episodic memory stores records of events consisting of the following fields:

time(year, month, day, hour);
place;
people involved;
sequence of events(start, middle, end);
behaviour(what actually happened).

More effective interviewing (i.e. more accurate recall) occurs when people are asked to remember specific episodes. Similar observations are made by Wernimont and Campbell (1968), in comparing memories of events on the one hand, with perceptions of status, on the other. These expositions are aimed at the personnel interview. The author of the present thesis received training at Edinburgh University in the practical application of the interview techniques several years ago. Since then it has been successfully applied by the author for other purposes similar to the present behavioural study.

Chapter 6 The Behavioural Model.

Introduction.

6.1 This chapter, and the succeeding three chapters, describe and evaluate the grounded behavioural model developed for the research. The present chapter is divided into two sections. The first section describes the foundations which underpin the model. This section covers the approach taken, the assumptions in the model, and the scope of the model. The second section provides an outline of the overall structure of the model. It delineates the individual components of the computer implementation, and shows how they are related. The succeeding chapters develop the analysis as follows. In Chapter 7 there is an description of the development process and the series of prior computer models from which the final version was synthesised. Reference is made to possible further extensions of the model and additional applications of the method. In chapter 8 a more detailed description is provided. The technical format of each of the component parts of the computer model is then discussed. Chapter 9 considers the application of the model. Following Paul Samuelson's (1983) guidelines for the evaluation of dynamic models, the effects of various changes in the exogenous variables and the model parameters are examined. These are compared to the body of empirical knowledge. Finally, the results of the model are evaluated for choice flexibility and response flexibility.

The foundations of the model

Theoretical Approach.

6.2 Herbert Simon (1962,1982) provides the source from which the theoretical approach proceeds. Richard Cyert and James March (1963), and Richard Cyert and Morris DeGroot (1987) provide the decision control model structure from which the computer model is developed. The S.E.F. is considered to be a complex system as described by Simon (1982). In order to model the behaviour of the S.E.F., it is necessary to break down its structure into a hierarchy of loosely coupled sub-systems. These sub-systems contain variables and functional relationships which are more closely connected within subsystems than between them. The distinction between this hierarchy and Oliver Williamson's (1975) hierarchy is noted below. The development of Simon's work into the systems analysis approach employed in the present model has been conducted by several authors (P. Courtois 1985, Schaer and Mellor 1988, Coad and Yourdon 1990). They describe an approach to the representation of complex information processing structures. The general approach is known as object oriented systems design. It closely follows Herbert Simon's (1982) hierarchy of nearly decomposable sub-systems. Thus each component subsystem is relatively self contained, and able to be analysed relatively independently. Again following Herbert Simon (1982), the number of types of subsystems which make up a whole information structure is small. The whole structure is defined by the way in which a relatively small number of types of sub-system are combined.[1]

6.3 Applied to the present topic, the firm or industry modelling task may be viewed as an exercise in representing a complex information processing structure. It requires to be broken down into nearly decomposable subsystems representing information processing elements of the firm which can be described independently. This approach is to be distinguished from the hierarchical analysis employed by Oliver Williamson (1975), which is also derived from Herbert Simon's analysis of complex systems. Oliver Williamson presents a hierarchical structure based upon the human participants in an organisation. The organisational and motivational structures are the basis of the latter hierarchy, which is widely recognised in current economic theory. It has superiors and subordinates linked by formal and informal contracts. In contrast, the hierarchy being considered here is applied to classes of information processing structures.

6.4 The principal class of information processing structure considered in this report is the S.E.F. itself. The group of S.E.F.s which share a set of product markets form a higher class of information processing structure which may be defined as an industry. This study is primarily directed at modelling behaviour at the level of the S.E.F. and below. The behavioural model structure used by Richard Cyert and Morris DeGroot describes a firm where a sequential control process determines the outcome of such decisions as price and output determination, and plant selection. Cyert and DeGroot's (1987 pp 27-40) "behavioral and control theory of the firm" sets out the basic framework. The firm develops a plan, establishes targets, compares actuals with results, and executes control actions. The model described in this research is a derivative of Cyert and DeGroot's model. It is firstly made more specific to the S.E.F.and secondly to the fish processing industry. This enables the model to be grounded in empirical knowledge gained through direct observation of the firms being modelled.

6.5 Decomposing the S.E.F. into information processing subsystems uses the components of the firm described by Michael Porter(1980) following Christensen, Andrews and Bower(1973). Although Porter's analysis is directed at large companies rather than S.E.F.s, the format he follows has proved useful in the present analysis.

Porter divides the firm into a class of sub-systems such as sales, manufacturing, distribution, etc. Within the large corporations considered by Porter, these sub-systems will generally represent actual administrative divisions staffed by specific teams. Within the S.E.F. however, it is unlikely that all Porter's subdivisions will be found as formal administrative structures. Nevertheless, even in the one man business, activities relating to sales may be distinguished from activities relating to manufacturing, or from activities relating to distribution. When viewing these activities as information processes, the distinction between Porter's large corporations, and S.E.F.s is much less apparent. Again taking the example of a one man business, it is possible to conceive of competing information processes relating to sales or manufacturing being resolved through the individuals decision making process. This contrasts with an analysis using an principal/agent or contractual type of hierarchy. The latter analysis is less clear in a one or two man business because the smallest unit of analysis is the individual to whom the contract or relationship applies. Viewing the S.E.F. as an information structure requires less adjustment for firm size because the smallest unit of analysis can be the individual decisions. Decisions, and their associated information inputs and outputs, are common to all sizes of firm. This is not to say that small firms do not have unique characteristics which distinguish them from large corporations. The point is that analyses such as Porter's, derived from a corporate empirical base, can be applied to small firms viewed as information processors. Thus Porter's subdivisions form a class of information processing objects. These subdivisions are recognised within the firms and are used by entrepreneurs to describe their own behaviour.

Assumptions - the model

6.6 The model assumes that there is a set of endogenous variables which describe factor prices and quantities, end-product prices, production technology, production quantity, and plant capacity. The values of these endogenous variables can be changed by the entrepreneur. It is assumed that there is a smaller set of endogenous variables which the entrepreneur uses to control the company. This second set of endogenous variable are denoted target variables. The distinction is made in order to describe the difference between, on the one hand, a firm which sets a price and takes the resulting quantity sold, and on the other hand, a firm which makes a quantity available, and takes the resulting price. In both cases, price and quantity are endogenous, but in the first case, that of the price setting firm, price is the policy variable, and in the second case quantity is the policy variable. Changes in these target variables operate through the set of linked functions to produce change in the entire set of endogenous variables. These include variables such as profit and net worth. The model further assumes that the entrepreneur is motivated to choose values which will maximise a particular variable, such as profit or net worth. This is to be distinguished from a simple profit maximisation model, and from a satisficing model. It differs from a simple profit maximising model because of behavioural considerations. Firstly, the entrepreneur selects a course which moves towards, but does not necessarily reach, the target maximum values. Secondly discontinuities in the model mean that even in stable conditions movement around an optimum may occur. Thirdly, the motivation to maximise is constrained by the information available to the entrepreneur. The motivation of the model is to be contrasted with a satisficing model, where optimising actions cease once a particular level of the relevant variable is achieved. The set of possible solutions for the model as a whole is constrained by functions such as product demand, technology, and factor supply, which contain exogenous variables.

6.7 The mechanisms by which the entrepreneur observes values of variables and sets the policy variables are denoted behavioural functions. Behavioural functions are evaluated as decisions. The price and quantity decision in traditional marginal analysis gives a simple route to the profit maximising values. To model this as a behavioural decision, however, it is necessary to take into account the information available to the decision maker. He is not able to observe marginal cost and revenue directly. The behavioural decision model therefore uses only observed variables as input to decision functions.

6.8 The nature of these behavioural functions, i.e. the way they map input variables to output variables, reflects the internal administrative organisation of the firm, as well as the technology employed by the firm. In the present behavioural model, the firm is not regarded as simply a production function reflecting largely technological relationships. It is a set of interrelated functions covering technology, information channels, and expectations. Thus a firm may ~~changes~~ the profile of its outputs by modifying its contracts and internal incentives, as well as by choosing a particular technological solution. The model represents these two varieties of change separately. This distinction is made for three reasons. Firstly, technology based production function changes are more likely to be industry specific because of their nature. Exceptions to this do occur in the real world. That is to say, changes occur such as the adoption of new transport, communications, or data processing technology, which simultaneously affect all industry. Secondly, and much more importantly, organisational structures which have the ability to change quickly are the essence of behavioural flexibility. A change in organisational structure is a second order change which may affect the firm's ability to adopt first order technology changes. Thirdly, the view of the firm as an information processing structure means that the two types of change occur within two different classes of object. Technology change occurs within the plant financing and the manufacturing sub-systems only. Organisational or contractual change can occur within any sub-system or in the structure as a whole. This distinction between technology change versus organisational change refers to the nature of the change within the S.E.F. It does not refer to the external variable shock which prompts the change. That is to say a technology shock may induce either an organisational or a technology change within the S.E.F.

6.9 It is assumed that, under conditions of perfect information, a single valued static solution would exist. That is to say, for a given set of values taken by the exogenous variables and instantly observed by the decision taker, there exists a single set of policy variable values which will map to a maximum profit. This assumption also implies a single valued dynamic solution, i.e. for a series of values taken over a time period by the exogenous variables, a single corresponding series of policy variable values exist which will maximise the present value of the total profit stream. The model considers the case where the entrepreneur acts under conditions of less than perfect information. It is assumed that the entrepreneur is unable to directly observe the exogenous variables or the maximand. It is assumed that he may only observe a restricted set of variables. A dynamic assumption is made that there is a lag between observations of variables and the evaluation of the behavioural function, i.e. the decision. A further lag is assumed between the decision point and the change to the policy variable. Individual lags exist specific to each variable observed or changed. Expectations are modelled though the mechanism of a vector of expected future values for observed variables. Finally, assumptions are made about specific behavioural rules in individual operational areas such as production or sales. These assumptions are noted below within the descriptions of the individual modules.

The scope of the model

6.10 The model primarily aims to describe the activities of an individual firm using parameters drawn from the fish processing industry. Production levels, output pricing and factor input levels and pricing are modelled in the short term. Selection by the individual firm of a production technology are modelled in the longer term. The principal use of the model is to show the variation in the effects of exogenous shocks when different behavioural parameters exist.

6.11 The model is constructed so that the behavioural parameters can be set to zero. The function optimised in the model is the net present value of the profit stream. If the behavioural parameters are set to zero, the model approximates a static model whose optimal solution equates marginal revenues and marginal costs. By setting the behavioural parameters to non-zero values, the model still uses the net present value of the profit stream as the function to be optimised. Additional constraints on the profit function are produced by the non-zero behavioural variables. In the first case, with zero behavioural parameters, the effect of exogenous shocks only shows the new optimal solution which the firm must achieve. The use of the behavioural elements enables the model to track the route to an optimal position. It also enables dynamic situations to be modelled where the frequency of the exogenous change is less than the response time to achieve the optimum. In these situations a profit maximising stasis is never attained, but the model can nevertheless compare the relative profitability of different firm strategies.

Outline description of the model.

6.12 The model consists of four principal sections, each of which has links to the other three. These sections are shown schematically below:

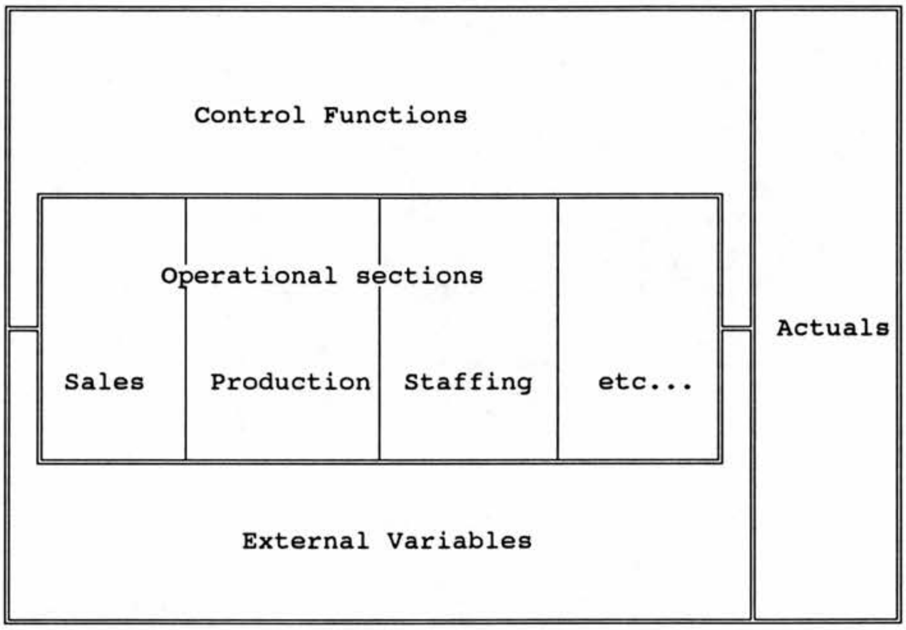


Figure 6.1. Model structure

The control process - setting targets.

6.13 The model is an adaptive control model which incorporates uncertainty, learning, and sequential decision processes. Such a model has been outlined by

Cyert and DeGroot (1987) in their application of Bayesian decision analysis to firm theory. The present model differs from Cyert and Degroot's firstly in that it is specifically related to a set of small entrepreneurial firms, and secondly in that the focus is flexibility. Cyert and DeGroot's model is principally concerned with a large, decentralised corporation (1987, p 28). Their use of the model is to explore the behavioural processes employed by the firm to cope with uncertainty. However, the essential mechanisms being considered are the same. Although management in fish processing S.E.F.s may not be decentralised and do not work solely to a set of monthly accounts, as is described in the Cyert and DeGroot model, the problems addressed by the decision makers are the same. Furthermore, Cyert and DeGroot's model is directly concerned with responses to uncertainty, and this is intimately related to the entrepreneurial flexibility issues considered here. As in the case of Richard Porter's (1980) exposition, Richard Cyert and Morris DeGroot's (1987) study has in practice proved a useful source to draw upon for the model's control mechanisms. Thus the S.E.F. first develops a plan. This involves making observations upon three sets of variables. These are: (1) conditions inside the firm; (2) conditions in the industry, and in rival firms; and (3) conditions in the economy as a whole (Cyert and DeGroot 1987, p 29). The observations upon all three of these sets are represented by variables contained in the control section. They are chosen to be representative of the observations used by the fish processing firms studied by the author. The same set of variables, with minor adjustments, is also presented in the survey questionnaire. Question 3.1 asks the respondent to identify the frequency of observations of these variables. Seven questions in Section 4 of the questionnaire ask the respondents to relate changes they have made to changes in these observations. A list of the variables used in the control section to represent these observable variables is as follows in figure 6.2:

The observation variables are represented in the computer model by single values for each time period. The setting of these values includes lags and error terms as discussed in paragraph 6.16 below.

Sales quantity
Sales value
Gross profit
Raw material quantity
New order value
Outstanding order value
Outstanding order quantity
Stock quantity
Stock value
Production quantities
Material costs
Labour costs
Plant costs
Overhead costs
Competitors or market prices
Estimates of future market size
Estimates of future sales
Estimates of future profits
Estimates of tech developments
Industry material prices
Industry or competitor profits
Industry labour rates
Net profit before tax
Net profit after tax
Net worth

Figure 6.2

6.14 Following Holt, Modigliani, Muth, and Simon (1960), Cyert and Degroot postulate that management selects certain key variables whose actual values during the year reflect the progress of the firm. These key variables are denoted target variables. Within the present model, the S.E.F.s goals are represented by specific values taken by these target variables, against which observations of actual performance are measured. The target variables are contained in the control section of the model. Information on which variables were used by S.E.F.s was gathered in section 3 of the questionnaire. Question 3.2 asked the respondent to select and rank the three most important observations of performance from the set provided. The goals are represented in the control section of the model by the following target variables:

Production Capacity
Production Quantity
Product Price
Material Price
Labour Cost
External Finance Amount
Gross Profit
Net Profit before tax

Figure 6.3

The target variables used differ from those used by Cyert and DeGroot (1987, page 30). The difference reflects the type of firm under consideration. The fieldwork undertaken amongst S.E.F.s provided the list used in the present model, whereas the model of Cyert and DeGroot addresses large corporations, and used different target variables suitable for this type of firm. Thus, the return on stockholder's equity is a key target variable for a publicly quoted company where ownership and management are separate. In the environment of the owner managed fish processing firm, however, net profit before tax is used more widely as a long term target, and variables such as earnings per share usually not even calculated. Each target variable is represented in the model by three values per time period. These values are the goal value, the actual value observed, and the result value, i.e. the ratio of actual to goal.

The control process - evaluating performance.

6.15 Having established a plan, and set targets, the company then makes observations in order to make comparisons in the target variables between the goal vale and the achieved value. In Cyert and DeGroot's model the comparison is made once per month. In the present model it is possible to adjust the frequency of the comparison in accordance with the empirical results. The key point is that different variables may be used as targets as the company considers different time periods. Thus net profit after tax over the firms lifetime may be a conscious target for the owner of a fish processing firm. Over a smaller number of years, however, he may equate this to a combination of plant capacity and net profit before tax. During the course of a year, more readily observable variables are used such as gross profit or sales and purchase prices may be used. On a day to day basis, the key target variable used by the fish processor is the production quantity.

6.16 The mechanisms by which this dynamic evaluation process is implemented in the model are (1) the observation variables are changed subject to lags and errors; (2) the actual values of the target variables are set to reflect the new observations; (3) the differences between the goal and actual values of the target variables are assigned to a result value of the target variable. There are three sets of parameters associated with this evaluation mechanism. These are (1) the magnitude of the lags associated with observations, (2) the magnitude of errors associated with the observations, and (3) the range of acceptable variation between goal and actual values of the target variable. The process by which performance is evaluated in the control section of the model is considered in more detail below.

6.17 Changing the observation variables is accomplished in the control section as follows. Each variable is represented either by a function which takes its value directly from an exogenous variable, in the external section of the model, or by a function dependent upon endogenous variables in one or other of the operational sections. Values assigned to the variables representing these observations are subject to lags estimated from the empirical work. The evaluation of the variables in the model also incorporates an error term reflecting the accuracy with which the firm is actually able to make observations. Estimates of the accuracy with which firms are able to observe their surroundings were not made in the survey questionnaire because of practical difficulties in framing appropriate questions: if the entrepreneurs were aware of such inaccuracies they would correct them. The empirical work done prior to the survey indicated that such observational inaccuracies on the part of the firms may be substantial. The observations made by the firms are a form of information gathering which cannot be undertaken without incurring a cost. Economising actions will take place on this activity. Excluding observation errors from the model would mean less realism. Giving such errors a rigorous treatment would require the modelling of information gathering costs. The present empirical work does not provide a base for this. Random variables are instead included to represent observational errors, and their effects are governed by coefficients entered into the model as parameters. Thus a firm with low information gathering costs can be modelled by setting the parameters so as to give less weight to stochastic variation in the evaluation of the above observation variables.

6.18 Setting of the actual value of the target variable from the observation is accomplished simply by equating its value to the observation value. No lag and no error term are included. The lags and error terms already included in the observation variables are sufficient to model any additional delay or errors occurring in the transmission of the information within the firm from operational section to decision maker. Comparison between goal and actual is then effected. The resulting value is set to the difference in the actual value as a percentage of the goal value, provided that it exceeds a given parameter value. This means that the model is able to reflect the situation in which there is a difference between goal and actual, but the firm attributes that change to random or transient factors not requiring control action (Cyert and Degroot 1987 p 32).

The control process - taking action

6.19 If the results of the comparison are within the tolerance specified by the parameters then no control action takes place. Otherwise the firm takes action, and this can be modelled using the Cyert and Degroot (1987) framework, with modifications to reflect the S.E.F., and fish processing. On failing to meet targets the firm institutes a search activity to select an appropriate response. The responses enumerated by Cyert and DeGroot are apart from price change, corporate strategic actions which are inappropriate to the present set of firms. However, there are a wide range of strategic and tactical responses which even a small company can make. Some of these could be represented by changes in the parameters controlling the model, i.e. a change to the fundamental nature of the company equivalent to the change of management action suggested by Cyert and DeGroot. Others, such as price change, can be implemented simply by allowing feedback to the target variables. This latter mechanism is implemented in the present model. It is effected through the operational sections. Within these sections, for example finance, observations are made of current and past values and used to set expectations of future trading conditions. These expectations are then used to allocate the revised goals values to the target variables.

6.20 The effect of an external shock on the system is shown schematically below in figure 6.4.

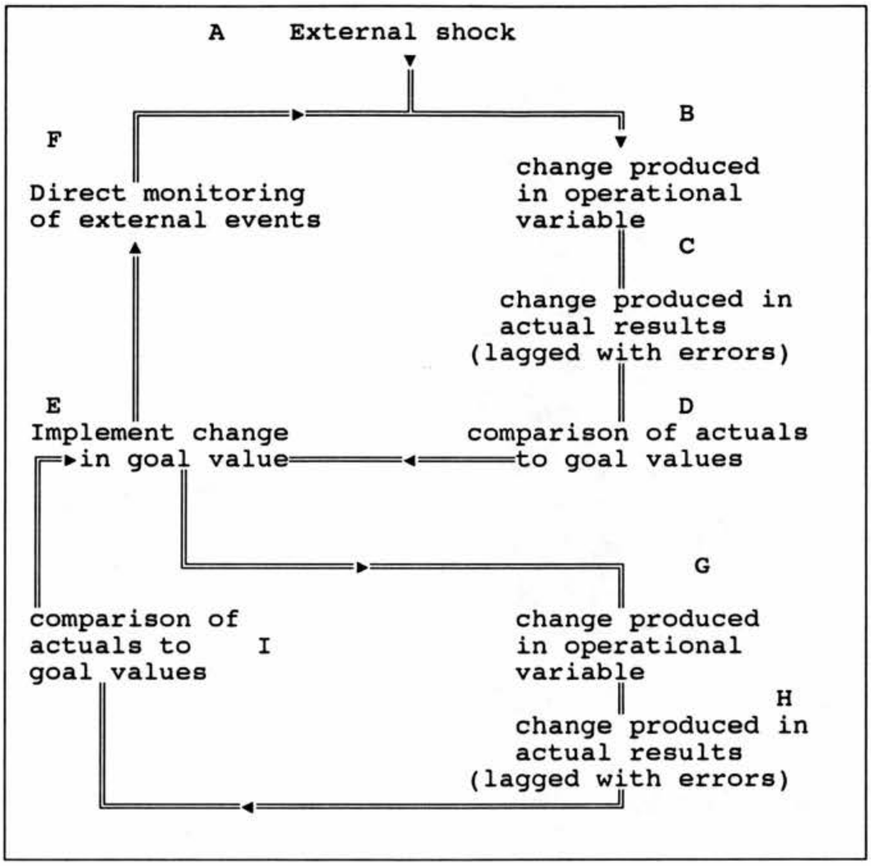


Figure 6.4

This illustrates the sequence of events taking place subsequent to an external shock, and shows how control is effected through two feedback loops. The events progress as follows. The occurrence of direct monitoring of external events (F) and an external shock (A) cause the model to produce a change in an operational variable (B) which affects the actual results of the firm (C). The firm compares the actual results with its goals (D), and amends its goals (E), to reflect the new external circumstances. The firm continues to monitor exogenous variables (F) and produce further changes in goals. The changed goals also produce a change in the operation of the firm (G) with consequent changes in the actual results (H), and the comparison with goals (I). Because of the lags and errors further change is produced in the goal values. The control system is analogous to that of a marksman taking successive shots at a moving target. Two feedback loops are involved, one to account for the rate of movement in the target, and one to correct for errors in aiming.

6.21 The operational sections of the model are largely derived from the type of model firms use themselves to monitor and predict their own performance. They contain fairly determinate data linking physical flows and levels within the firm, together with behavioural mechanisms. They are the functional sections of industrial firms documented in Michael Porter's *Competitive Strategy*

(1980 pp xvi-xviii) A full list of the operational sections is as follows:

Sales
Manufacturing
Labour
Purchasing
Distribution
Product line
Marketing
Finance
R & D

Figure 6.5

Of these the distribution section and the R & D section are included only for further development of the model and have no effect on its current performance. Research and Development was not found to be a significant element of the fish processor's activity. The activity is instead carried out by equipment suppliers and hence exogenous to the model. Distribution of finished product is also treated as exogenous to the model. Fish processing firms do sometimes have separate distribution departments. In two cases studied the S.E.F. was a small group in which transport formed a larger part than fish processing. However, changes in this aspect were not identified by the firms as being distinct from technology or market changes.

6.22 The four sections comprising sales, manufacturing, labour, and purchasing together provide the key operational elements of the model. These sections form a group within the computer model, and the structure of the spreadsheet representation of each of the four sections is similar. They each combine a short term plan, (e.g. a sales or production plan for the period) with exogenous variables (e.g. those representing product demand or production technology) to produce an actual result (e.g. sales price achieved or production quantity). The short term plans are based upon one or more of the target variables and upon the observation variables contained in the control section. The remaining sections from Porter's subdivisions are product line, marketing, and finance. These elements form a second group whose effects are longer term. They are concerned with the estimating of future trading conditions, technology, and other exogenous variables, and the selection of appropriate manufacturing capacity, markets, and external finance levels. Each of the operational sections can on its own represent a self-contained part of the firm, meeting Herbert Simon's description of nearly-decomposable sub-systems. (e.g.

the sales section can represent a sales planning and price setting model with exogenous production costs and quantity.)

The control process - the external environment, recording results and modifying the environment.

6.23 The remaining elements of the model are the exogenous variables section and the actuals section. The exogenous variables section describes items such as product demand, factor supply, and production technology, which are considered in this model to be beyond the direct and conscious influence of the firm. The variables provide input to the rest of the model in two distinct ways. Firstly, through use of the observation variables, a lagged and error adjusted value is passed to the control section. Secondly, the operational sections take their input directly from the exogenous section when evaluating the actual results. An example follows to illustrate the process. Taking product demand, this is represented in the exogenous section by three variables linking the total revenue and quantity of each of ten products over 50 time periods. At a single time period, the demand for a single product, is represented in the model by three values. These reflect the behavioural measurements the entrepreneur is able to make. He cannot observe the function throughout its range. However, he can easily observe the total revenue at the present output level. If recent changes in price and output have taken place, he can, with a little more difficulty, also calculate the difference resulting from changes around the present output level. He may also, by comparing the effects of different changes, be able to estimate the cumulative effects of changes in output and price on total revenue, again in the restricted area around present trading levels. These three observations are the total revenue level, and the first and second derivatives of total revenue, with respect to quantity. At a particular time period, the entrepreneur is thus represented as observing three aspects of price. These are the total income he is receiving from a product at present sales levels, the rate at which the total income changes as quantity sold changes, and the rate at which income change effects themselves are changing as quantity changes. The entrepreneur does not observe these directly but subject to two modifications: (1) The time period is shifted one or more time periods back to represent the lag in observation. (2) An error term is introduced to represent observational errors. The demand function observed by the entrepreneur is then combined with other observations to formulate, amongst other things, a production quantity. This production quantity is passed to the sales section. The exogenous variables representing demand in the current period are also passed unmodified to the sales section, to form the actual demand function experienced that period. The value of the actual production quantity is presented as an argument to this demand function, which can then be solved for price. Thus price is determined through a planned price and production quantity generating an actual production quantity. This actual production quantity in turn generates an actual price. The exogenous variables are used twice, once in generating the plan, with delays and errors, and once in determining the actual result. The above example used the sales section to illustrate how the exogenous variables are used. The other operational sections follow a similar process to determine other endogenous values such as production quantity, plant capacity, market, and product type.

6.24 The results for the current period are passed back to the control section from the individual operational sections. Additionally the values as they are generated for each period are successively transferred to the actuals section of the model. This represents the history of the firms performance, much as the audited accounts might in the real world. The rôle of the actuals section could be extended to model the effect of the firm's action on its environment. This would be done by relating the values of particular exogenous variables to the values of appropriate endogenous variables. For example the product demand parameters could be modified by the the production quantity placed on the market by the firm. Relating exogenous to endogenous variables in this way reduces the number of genuinely exogenous variables in the model. This path has not been followed because of the dearth of empirical data on interfirm effects, as opposed to intrafirm effects. This completes the outline description of the model. There follows a more detailed description of the computer implementation in chapter 8, but first the report turns to the development process, which is described in the next chapter.

1. The object-oriented analysis methodology is directed towards software representation of complex systems. It is a recent development drawing its immediate source from object oriented programming. Object-oriented programming, i.e. the use of a complex systems approach to the software itself, has been one of the most important developments in recent years in the field of software design. The use of the C++ programming language as a vehicle for this is documented by Bjarne Stroustrup(1986,1987). Rather than decomposing a complex software structure in terms of procedures only, the object-oriented programming approach has subsystems in the form of objects which contain data structures, and their related processes. Examples of widely used object-oriented implementations include the Microsoft Windows, Unix X-windows, IBM's OS2, and Apple's MacApp

Chapter 7 Modelling Methodology.

Introduction

7.1. Chapters 4 and 5 highlighted some innovative methods in data collection and questionnaire design. The research project also has some innovative features in its application of computer software to the behavioural model. The objective of the computing exercise was to establish that computer software could be used to represent the behavioural flexibility described in part 2 of the thesis, i.e. to establish that the behavioural model was computable. The computer techniques are based upon the control systems used by the firms themselves. Clear visual representation of the model is obtained through the use of current windows-based software. The survey results are processed using the same type of software. This chapter describes the software development approach adopted, and how it was arrived at. Details of proprietary products used in the research are listed at Appendix 5. Appendix 4 provides detailed listings of the models written for the research. Chapter 1 has noted the advantages in the use of a spreadsheet format to represent the behaviour of firms. These are: the extensive use of such software by the firms themselves, the ease with which non-linear relationships can be set up, and the representational form of the software.

Software Development - the choice of approach.

7.2. It is worthwhile, at the outset, sounding a note of caution concerning computer representation. Richard Cyert (1988) notes that the advantage of computer simulation over mathematical modelling is that more complex relations can be developed in the simulation. However, he goes on to point out, (Cyert 1988 p 215)

"Because of the power of the computer it is possible to make a simulation nearly as complex as the real world. As one would expect, such models become as difficult to analyse as the real world and, consequently, are of little explanatory value."

The point is an important one, and particularly relevant to the present project where a wealth of empirical detail was available and a considerable range of existing software arising from the author's prior involvement writing control software for fish processing companies. In addition to the use of a spreadsheet to give clarity, the development process adopted in the present research used incremental methods and object-oriented design to minimise these problems. That is to say, small working computer models were first written and then developed by adding additional detail in order to build up complexity. This contrasts with a more rigid approach which might, for example, list all the variables and functions required first and then implement them in software in a single step. As a result of this approach, individual subsystems (for example the sales department), can be separately modelled. The vehicle used to implement the software, is a proprietary software package, Microsoft Excel (see Appendix 5). The package runs on personal computers using the Microsoft Windows (see Appendix 5) operating environment. The results of this choice have led to an effective and readily demonstrable modelling process. It is worthwhile detailing the course leading to this particular software choice.

7.3. The development of the software was undertaken in the following stages. Firstly a review of available modelling software took place. The next stage was to develop highly determinate sections of the software incorporating as much as possible of the known technological relationships present within the firms. Following this comes the third stage where the software has added to it those policy variables and interdependencies which are more organisational, behaviourally oriented features. The distinction between these two stages is not a clear dividing line, reflecting the difference between what is known and what is postulated. It is merely a convenient and practical project development milestone. The next stage was to draw the sections together. Finally the data collected from the field was used both to refine and test the software.

7.4. The review of suitable software covered the following five alternative approaches.

1. Use a simple spreadsheet package to set up the relationships combined with a database to store successive trials.
2. Write from scratch totally project specific software using widely available compiler/operating system combination.
3. Use a simulation package such as are used in control applications.
4. Use artificial intelligence software to develop rules and apply data to them.
5. Use a complex integrated spreadsheet linking a series of sub-models.

The following criteria were used to select the most suitable approach.

1. The skills required to use the software should be already available or easy to acquire within the project timetable.
2. The software should be capable of handling at least five hundred time periods for each variable. This would be sufficient for a ten year model with a resolution of one working week at fifty weeks to the year, or a two year model with a resolution of one working day.
3. A graphics presentation mode should be available.

This is desirable both for ease of development and modification, (i.e. relationships are more readily seen and identified), and to provide continuity with more traditional economic analysis.

4. There should be a sufficient range of maths functions and facilities available.

5. To provide a useful example for other projects to follow, the cost should be reasonable.

6. The software should be able to run on the equipment available to the research project. This consists of a dedicated IBM PS/2 P70, with 4 megabytes of memory and 60 megabytes of disk storage. At the time the choice was made, 1988-9, it was more common in social science research to use mainframe packages with unintelligent terminals or alternatively to use less powerful PC technology. This might have limited the projects transferability. However, the pace of technological change in this area and the wider availability of more powerful workstations has removed this limitation within the project's lifetime.

7. The software should be able to run using a Unix or MSDos operating system. This constraint ensures that exchange of data, wider circulation of the software, and transfer to other hardware are possible.

7.5. A spreadsheet is a computer software package which enables the user to represent relationships and data in the form of cells organised into rows and columns, rather like the large tabular sheets used in the past by accountants to prepare company financial forecasts. An example is shown at figure 7.1. The key feature is that the value held in one cell can be made a function of the values in other cells, which themselves may be either a simple value or a function dependant on other cells. Immediate recalculation of the entire set of cells occurs each time the data is changed. This produces a powerful modelling facility, easily learnt and with broad application. Limitations in simple spreadsheets occur as the complexity of the model increases. The recalculation needs to be controlled to prevent unnecessary time being spent recalculating sections of the model where no change has occurred. (For example the recalculation of a firm's production function when changes relating to the demand end are made.) There are further limitations to the complexity of model able to be handled. These relate to technical issues involving memory usage, together with the manageability of large models in a single matrix.

	Quant	M Rev	Cost	T Rev	Cost	Profit	Target		
	1.00	10.00	5.50	10.00	5.50	4.50	10.00	Income Function	2
Single product/	2.00	7.20	4.20	17.20	9.70	7.50	17.20	Cost Function	2
single period	3.00	5.23	3.80	22.43	13.50	8.93	22.43		
model	4.00	3.98	3.77	26.41	17.27	9.14	26.41		
	5.00	3.01	3.80	29.42	21.07	8.35	29.42		
	6.00	2.22	3.85	31.64	24.92	6.72	31.64		
	7.00	1.55	3.95	33.19	28.87	4.32	33.19		
	8.00	0.97	4.05	34.16	32.92	1.24	None		
	9.00	0.60	4.70	34.76	37.62	-2.86	None		
	10.00	0.40	5.90	35.16	43.52	-8.36	None		
Maximise Profit	4.00	3.98	3.77	26.41	17.27	9.14			
Maximise Sales	7.00	1.55	3.95	33.19	28.87	4.32	33.19	Acceptable rate	10%

Figure 7.1

These limitations can to an extent be resolved by the use of, say a database to store and retrieve sections of data for summary on a spreadsheet.

7.6. The use of totally project specific software, i.e. programs written specifically to process the project data, was an attractive proposition from several points of view. Functions could be incorporated to reflect precisely the required nuances of the model. Dedicated modelling compilers existed which could provide the specific language constructs. These would, however, introduce restrictions in the form of computer model specific and compiler specific skills, thus limiting transferability. Alternatively, using a general purpose compiler such as "C" would mean that both in development and dissemination fewer technical limitations will affect the performance and use of the software. The one overriding factor, however, which precluded this approach was resource requirement. To achieve a comparable result to a package approach requires an effort several thousand times greater than with a package approach.

7.7. Simulation and control packages exist which will monitor external inputs and respond to variations in a predetermined way. They are used to control physical processes connected to the computer hardware. They generally handle large numbers of external variables over a given repeated cycle. In some respects the firm model may be looked at as a complex set of control loops, and this is the general theoretical approach taken here, following Cyert and De Groot (1987). Two drawbacks exist with this approach, however. Firstly the software is not as widely available and documented as financial modelling software. Secondly since it is not designed directly for modelling non-physical processes it does not provide the same level of appropriate functions built in.

7.8. Artificial intelligence software, though then still largely in an initial acceptance stage, at first sight appeared relevant to the task. However such software aims more at deriving the relationships and repeating them when presented with further data. They are intended for complex, but much more determinate applications. In the future there may well be scope for this approach but their present use would be limited to minor but detailed aspects of the totality of the firm model.

7.9. The most obvious solution was that being used by the more advanced companies themselves, the use of complex integrated spreadsheets. These software packages were increasingly being used where large and complex management control systems were required. Over and above the capabilities describes for spreadsheets above, these packages have programming capability, enabling project specific procedures to be incorporated. (specifically, the macro capability is used to control the stepping of the software through sets of time periods) Further, the linking of multiple datasets enables breaking down of the model into demand function, production function et cetera without limiting their interrelatedness. The graphic and other presentational aspects are suitable to the task, as are the software development facilities. To confirm the selection a simple single product static firm model was developed. The software uses step functions for marginal revenue and costs. These are selectable from a set of alternatives. Output levels reflecting profit maximisation are chosen by the software, which will also maximise sales subject to a minimum rate of gross profit.

7.10. The technique used to develop the relatively fixed functions is based upon production and performance models used by companies themselves. In general these tend to be plant or company specific, so a generalising task exists to, for example, bring prices and volumes to a common base. Sections from the software used by Cyert in 1963 have also been incorporated in the framework, both as a test for developing the dynamic aspects of the software, and as a start point for some of the functions.

7.11. Consideration was also given at this stage to the selection of the time period to be used on the models. The basic time unit chosen for the model is the week. It possesses the advantages of a day resolution without the disadvantages. Several years can be modelled without undue resource demands. For simplicity a fifty week year is used. Taking into account variability in plant holidays and shutdown periods, this is not a drawback.

Software development - the spreadsheet structure

7.12. The use of a spreadsheet approach enables the software to follow by a more modern route the course first taken by the Austrian writers on economic matters, and to combine with it the procedural computer modelling approach adopted by Cyert & March (1963 pp 150-160). The tabular presentations of Carl Menger (1871 *Grundsätze der Volkswirthschaftslehre*), provide a useful basic format for the present software. The iterative procedures documented by Richard Cyert (1963) provide the basis for the dynamics of the software. Richard Cyert (1963) uses limit variables based upon previous experience to control the dynamic progress of software. The present software uses a similar approach. However, a vastly increased variable space is available, in comparison with Richard Cyert's original computer resources. As a result a much more complex model and behaviourally rich model has been possible, with multiple products and factors, more behavioural limits and greater control over dynamic lags. The computer model contains many step functions and break points. As with the frequent allusions to specific practical decisions presented by Menger, this attribute of the computer model is considered important for realism. Equally importantly, step functions and non-continuous variables are there because the essence of the topic is how particular economic agents react to sudden, generally unexpected change. The work on marginal utility led by Carl Menger, relied heavily on the discrete choices faced by individual economic agents.

The methodology allows for the extensive use of step functions to link the various factors within the firm. This also applies to the dynamic content of the software. Functional relationships may be linked to specific time periods within the software in a non-continuous fashion. Thus, in modelling responsiveness to change in demand, the sales section incorporates a series of discrete values representing sales in previous periods. Responsiveness is modelled by varying the weight used for the latest time period.

Software development - the process.

7.13. The present software has been derived from several sources and preceding software versions. These are shown diagrammatically below in figure 7.2. Two sets of pre-existing software formed the start point for the software development proper. These were (1) software written by the author over a period of several years to aid fish processors to control their businesses, and (2) the software used by Cyert and March for "A Behavioural Theory of the firm". For the fish processors, several different software methods had been used over a dozen or so companies. In particular, in the two years prior to the research, similar sets of spreadsheet based reporting systems had been implemented in six companies. Of the six, two were salmon processors and four shellfish processors.

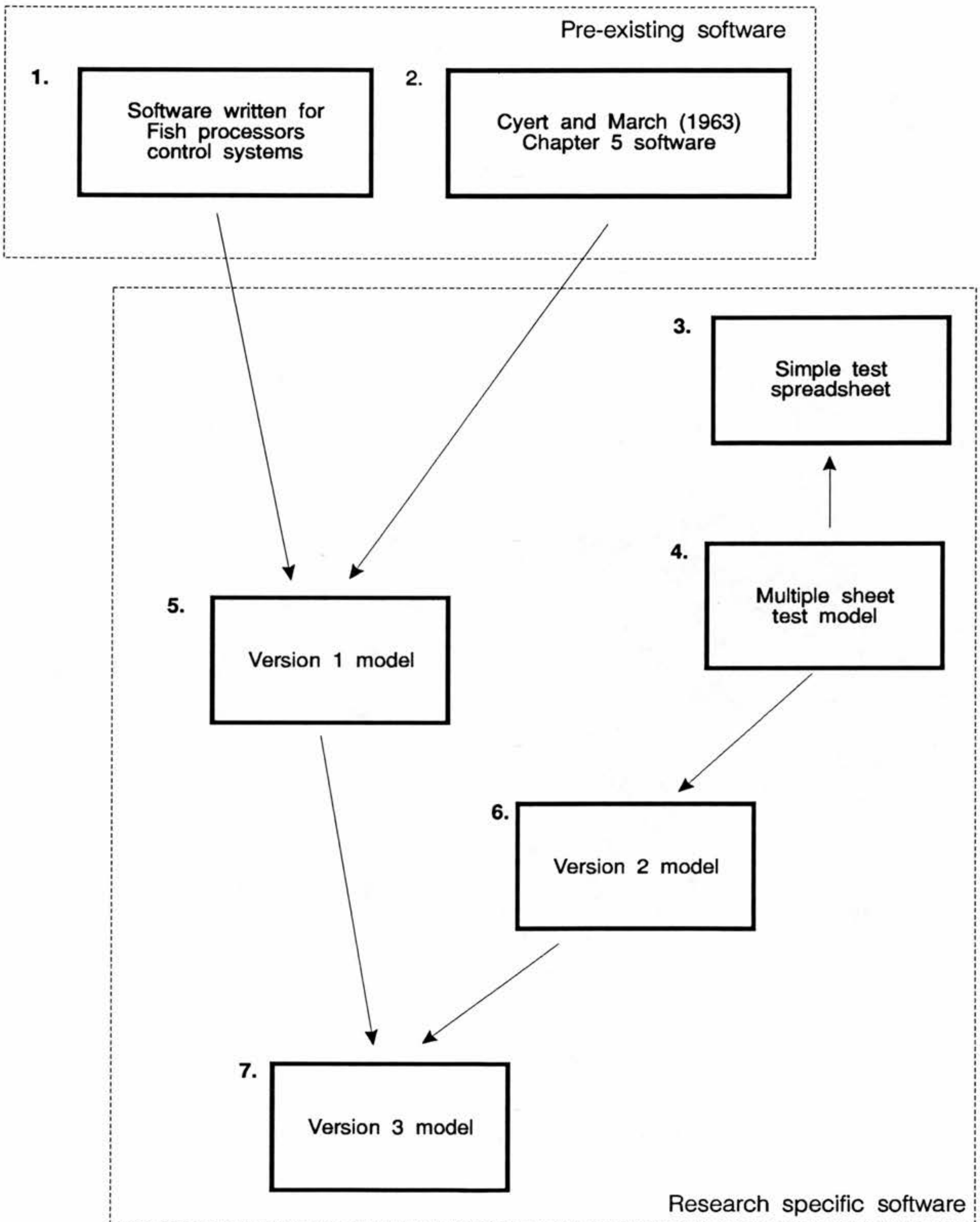

Pre-existing software
1.
Software written for Fish processors control systems
2.
Cyert and March (1963) Chapter 5 software
3.
Simple test spreadsheet
4.
Multiple sheet test model
5.
Version 1 model
6.
Version 2 model
7.
Version 3 model
Research specific software

Figure 7.2

The software was written by the author in 1986, initially for two companies, and used the proprietary packages Lotus-123 and Paradox (see Appendix 5) as the base package. The spreadsheets modelled details of the companies production schedules, raw material purchases, sales, and stocks. Their purpose was to give the company summarised data on the key performance variables in the company and to provide a production and sales planning mechanism. Contemporaneous work in Iceland, but using project specific Fortran code, has been documented by P Jensson (1988). The spreadsheets developed for the firms provided a working set of routines, able to represent a substantial part of the firms' behaviour, onto which could be built mechanisms for generating the exogenous variables and other modelling elements.

7.14. The software used by Cyert and March for "A Behavioural Theory of the firm" is extensively documented in chapters 7, 8 and 9 pp. 128 - 252. The source code listing provided in the Appendix to chapter 8, pp. 183 - 236 cannot be implemented directly on a current computer system, but the code was sufficiently clear to enable a spreadsheet version to be used as a trial development exercise. The two principal contributions of the Cyert and March computer program to the present computer software, however, were (1) the use of monitor variables in determining the output decision, and (2) the iteration process used to move from one period to the next. These were incorporated into the initial version of the firm model.

7.15. The first version of the behavioural model is listed at appendix 4. First the spreadsheets used in the firms themselves were generalised, i.e. all price and quantity units were standardised, and details specific to any particular firm were removed. Then a spreadsheet containing exogenous variables was added, to replace the figures entered daily by the firms. Then a control section was added containing the target variables, and a section added to step through one, or a series of, time periods, following Cyert & March (1963 pp 159 - 165). The stock section used by the firms was removed and stock levels were incorporated into the production section of the software. This was necessary because the detailed records kept by the firms themselves on individual stock lines added little to the behavioural model. An actuals section was added to record the progress of the software through a fifty period iteration. The control section was then modified and observation and goal variables grouped into three types in order to investigate the ability of the software to represent short, medium, and long term decisions, and hence Bo Carlsson's (1989) flexibility categories.

7.16. This completed the first version of the software. Its close connection with the planning processes used by the fish processors resulted in this first version of the software representing the processors behaviour well. When changes were made to external variables, the control system produced changes to output and price values successively over a number of periods, eventually reaching a new stable position. Parameters could be set in the software which enabled it to ignore minor fluctuations in exogenous variables. Parameters could also be set to adjust the size of change made to output or prices, thus controlling the responsiveness of the software to sudden change. Low values of change resulted in a long period of adjustment, and high values resulted in a divergent non-stable model. Thus far the software performed well and its behaviour appeared typical of the firms it aimed to represent. The software was less useful in one respect, however. Although representative, it was difficult to analyse because of its complexity. It was therefore decided to develop a second version, less closely linked to the original firms' software.

7.17. The second version of the software, (see Appendix 4) was derived from the initial trial spreadsheets written to test the suitability of the method. In this version the firm had a much more limited set of options.

It could choose from five separate technology functions, five factor supply functions, and five product demand functions. One of each function was chosen and observed by taking a random sample of the values of each function, in each period. A single parameter could be set which controlled the size of the sample. The technology functions could be set to represent more or less flexible plants following Stigler (1939), i.e. they could be set to have unit cost curves with more or less flexibility. Alternatively, the technology functions could be set to represent economies of scale, i.e. with unit cost curve whose convexity remained constant and whose minima reduced as output range reduced. Exogenous shocks could be modelled by making changes to the demand or supply functions. The software did not progress using a set of targets and compare these with actuals. Instead, over a number of periods, it built up a table of observed inputs, outputs, and profit levels. From this table, which represented its experience, it selected the input and output values which produced the most profit. This model could be more easily analysed. The software adjusted in fewer periods if a flexible technology function was chosen. It adjusted more quickly if the size of sample in the observations was increased. The ease of analysis, however, was achieved at the expense of a loss of behavioural detail, so that the software had no special relevance to fish processing. It was therefore decided to combine the two approaches, into a third and final version. The detailed target variables and control system of the original software were retained, and joined with the system of selecting from alternative factor supply, product demand, and technology functions used in the second version.

Chapter 8 Computer Implementation.

Detailed description of the model.

8.1 The computer implementation of the model has been effected through the use of linked spreadsheets each representing a relatively self-contained set of variables. The particular software system used is the proprietary product Excel licensed by Microsoft Corporation. The software is amongst the most widely used spreadsheet systems, with implementations on both IBM PS/2 and Apple MacIntosh computers. The development process and reasons for arriving at this representation have been described in chapter 7, which also outlines the general spreadsheet methodology. The sections of the model are identified below.

control.xls	the control section of the model
distrib.xls	
exogen.xls	the sheet containing values for all the exogenous variables
firm.xlm	procedure sheet for stepping from one period to the next
firm.xlw	linking file to load the separate sections required for the fish processing model
labour.xls	the operational section determining labour hours and cost

manuf.xls	the operational section which determines current production and stock levels
marketng.xls	the section which selects product markets
plantfin.xls	the section which determines plant capacity and cost
prodline.xls	the section which selects factor markets
purchase.xls	the operational section which determines the raw material factor price and quantity
res&dev.xls	
sales.xls	the section which determines the product price in a period
salesexp.xls	
summary.xls	documentation sheet describing links between sections

Descriptions of these individual sections are given below.

	A	B	K	L	U	V	AE	AF	AO	AP	AY
1	Demand	c		m		C					
2	t	1	10	1	10	1	10				
3	-24	5.00	5.00	-5.00	-5.00	0.00	0.00				
26	-1	5.00	5.00	-5.00	-5.00	0.00	0.00				
27	0	5.00	5.00	-5.00	-5.00	0.00	0.00				
28	1	5.00	5.00	-5.00	-5.00	0.00	0.00				
50	23	5.00	5.00	-5.00	-5.00	0.00	0.00				
51	Supply	c		m		C					
52	t	1	10	1	10	1	10				
53	-24	0.00	0.00	4.00	4.00	1.00	1.00				
76	-1	0.00	0.00	4.00	4.00	1.00	1.00				
77	0	0.00	0.00	4.00	4.00	1.00	1.00				
78	1	0.00	0.00	4.00	4.00	1.00	1.00				
100	23	0.00	0.00	4.00	4.00	1.00	1.00				
101	Labour	c		m		C					
102	t	1	10	1	10	1	10				
103	-24	0.50	0.50	0.20	0.20	1.00	1.00				
126	-1	0.50	0.50	0.20	0.20	1.00	1.00				
127	0	0.50	0.50	0.20	0.20	1.00	1.00				
128	1	0.50	0.50	0.20	0.20	1.00	1.00				
150	23	0.50	0.50	0.20	0.20	1.00	1.00				
151	Plant	Capacity		Range		Cost		Labour req'd		Mat'l req'd	
152	t	1	10	1	10	1	10	1	10	1	10
153	-24	0.50	19.22	0.36	0.36	0.10	1.45	0.75	0.75	1.10	1.10
176	-1	0.50	19.22	0.36	0.36	0.10	1.45	0.75	0.75	1.10	1.10
177	0	0.50	19.22	0.36	0.36	0.10	1.45	0.75	0.75	1.10	1.10
178	1	0.50	19.22	0.36	0.36	0.10	1.45	0.75	0.75	1.10	1.10
200	23	0.50	19.22	0.36	0.36	0.10	1.45	0.75	0.75	1.10	1.10

Figure 8.1

8.2 Description of the exogenous section.

Figure 8.1 shows a condensed print of the values held in the exogenous section. It has been condensed by omitting from the print rows representing time periods -23 to -2, and +2 to +22. Columns representing products 2 to 9 have also been omitted in order to condense the print. Figure 8.2 shows part of the demand section without any rows or columns omitted. There are four parts to the exogenous sheet. These are the variables describing product demand, raw material supply, labour supply, and the input and output coefficients characterising different types of plant. The first three parts have similar structure and the following description of the demand variables may also be applied to the material and labour supply variables.

8.3 Three variables, c, m, and C are used to define demand in time period t. The values t may take have a range of -24 to +23. Ten products are represented. For each product a separate set of c, m, and C are held for each time period. Thus, referring to figure 8.2, the variable c for the fifth product in time period t = -7 is represented by the value in cell **F20**. The variable m for the same product and period is represented by the value in cell **P20**. The variable C for the same product and period is represented by the value in cell **Z20**. The three variables together describe the demand conditions experienced by the firm for product 5 at present levels of trading. The variables are not intended to represent the demand conditions for the product across its entire range from zero quantity through to infinite quantity. They represent only those values of the demand variables which are in the vicinity of present levels of trading. This is firstly because the extremes of the demand related variables, when output is zero, or infinite, or close to the levels, are not areas of interest to the present study.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	U	V	W	X	Y	Z
1	Demand	c										m						C				
2	t	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	10	1	2	3	4	5
3	-24	5.00	5.00	4.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-4.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
4	-23	5.00	5.00	4.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-4.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
5	-22	5.00	5.00	4.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-4.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
6	-21	5.00	5.00	4.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-4.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
7	-20	5.00	5.00	4.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-4.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
8	-19	5.00	6.00	4.75	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-4.50	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
9	-18	5.00	7.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
10	-17	5.00	8.00	5.25	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-5.50	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
11	-16	5.00	9.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
12	-15	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
13	-14	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
14	-13	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
15	-12	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
16	-11	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
17	-10	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
18	-9	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
19	-8	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
20	-7	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
21	-6	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.10	0.00	0.00
22	-5	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
23	-4	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
24	-3	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
25	-2	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
26	-1	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
27	0	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
28	1	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
29	2	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
30	3	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
31	4	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
32	5	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
33	6	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
34	7	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
35	8	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
36	9	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
37	10	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
38	11	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
39	12	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
40	13	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
41	14	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
42	15	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
43	16	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
44	17	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00
45	18	5.00	5.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-5.00	-5.00	-6.00	-5.00	-5.00	-5.00	0.00	0.00	0.00	0.00	0.00

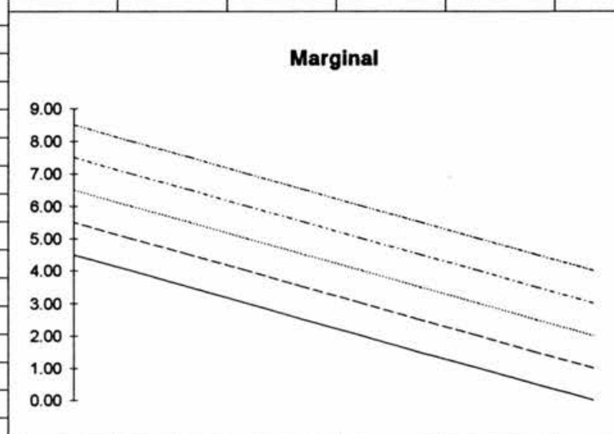
Figure 8.2

Secondly, it is because behaviourally, the firm tends to evaluate the effect of changes from the present state, rather than deriving its plans and observations from first principles covering the whole spectrum of options. This is an economic way for the firm to behave and also means that the demand conditions can be represented in the model with less variables.

8.4 The three variables defining the demand conditions for each product, at each time period, operate as follows: Variable *c* represents the rate at which total income increases as quantity sold increases, i.e. the basic price obtained at the lower end of the present trading range. Variable *m* represents an incremental change in revenue as total quantity moves up from the lower end of the present trading range. The price at the lowest quantity $q_{\underline{0}}$ in the trading range is set to *c*. The price at the next quantity step up, $q_{\underline{1}}$, is set to $c + m$. At $q_{\underline{2}}$ the price is $c + 2m$, and so on. The total revenue is calculated at each step by adding the price to the total revenue at the previous step, using *C* as the initial total revenue at the lowest quantity, $q_{\underline{0}}$.

Within the EXOGEN.XLS spreadsheet, the 1,550 cells from **A1** to **AE50** define the external demand conditions facing the firm over a time span. Each set of three variables from this area can be expanded to produce a series of stepped evaluations of total revenue for given quantity steps. This is illustrated by the spreadsheet EXOGRPH.XLS, shown in figure 8.3 and figure 8.4. The marginal revenue and total revenue equations above are evaluated as step functions in columns **F** to **O**. Product quantity is represented by the ten cells **F1** to **O1**. These step in ten discrete intervals from 0 to 1 representing the present trading range. EXOGRPH.XLS enables a graphical representation of different demand functions to be generated. In figure 8.3, five groups of the three variables c, m, and C are shown in cells **C2** to **E6**. The group in cells **C2** to **E2** defines the demand function for product 2, period t = -20. The marginal revenue is represented in cells **F2** to **O2**, and the total revenue in cells **F28** to **O28**.

	A	B	C	D	E	F	G	H	M	N	O
1	Product	Period	c	m	C	0.10	0.20	0.30	0.80	0.90	1.00
2	2	-20	5.00	-5.00	0.00	4.50	4.00	3.50	1.00	0.50	0.00
3	2	-19	6.00	-5.00	0.00	5.50	5.00	4.50	2.00	1.50	1.00
4	2	-18	7.00	-5.00	0.00	6.50	6.00	5.50	3.00	2.50	2.00
5	2	-17	8.00	-5.00	0.00	7.50	7.00	6.50	4.00	3.50	3.00
6	2	-16	9.00	-5.00	0.00	8.50	8.00	7.50	5.00	4.50	4.00



	A	B	C	D	E	F	G	H	M	N	O
27						0.10	0.20	0.30	0.80	0.90	1.00
28						4.50	8.50	12.00	22.00	22.50	22.50
29						5.50	10.50	15.00	30.00	31.50	32.50
30						6.50	12.50	18.00	38.00	40.50	42.50
31						7.50	14.50	21.00	46.00	49.50	52.50
32						8.50	16.50	24.00	54.00	58.50	62.50

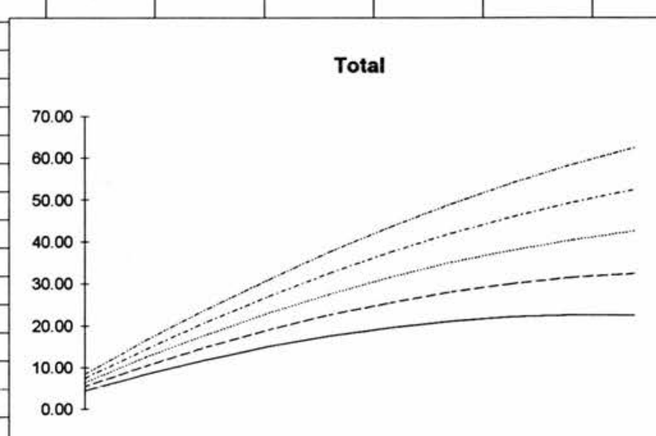
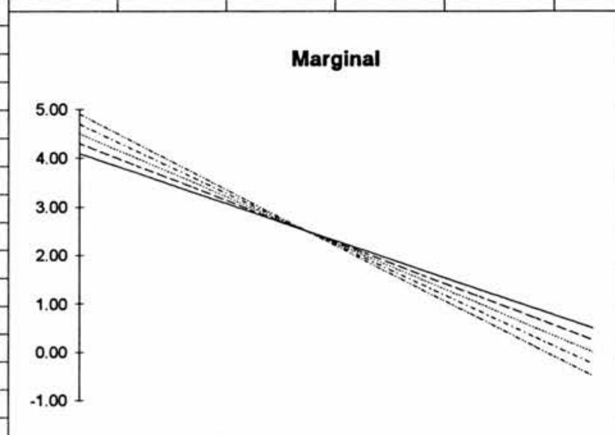


Figure 8.3

These are plotted, against quantity on the horizontal axis, in the two graphs in figure 8.3. The values for the first demand function (in this case product 2, period t = -20), are shown by a solid line. This shows, in this particular example, the marginal revenue falling at a constant rate over the present trading range, as quantity supplied increases. Columns **I** to **L** are present in the sheet but not shown in figure 8.3. Values of the three variables c, m, and C, are shown for the four subsequent periods for product 2 in the example shown. The step functions are evaluated for these values and the results depicted on the graphs. Rows **3** to **6** are shown on the marginal graph as successively higher parallel lines. This shows the demand level rising with no change in the slope of the marginal revenue curve. The effect on the total revenue is shown by the equivalent lines rising more steeply.

8.5 Figure 8.4 shows the sheet EXOGRPH.XLS with a different set of demand defining variables. These represent the demand for product three in the five successive periods t = -20 to t = - 16. Figure 8.2 has these, and the values used in the previous example highlighted.

	A	B	C	D	E	F	G	H	M	N	O
1	Product	Period	c	m	C	0.10	0.20	0.30	0.80	0.90	1.00
2	3	-20	4.50	-4.00	0.00	4.10	3.70	3.30	1.30	0.90	0.50
3	3	-19	4.75	-4.50	0.00	4.30	3.85	3.40	1.15	0.70	0.25
4	3	-18	5.00	-5.00	0.00	4.50	4.00	3.50	1.00	0.50	0.00
5	3	-17	5.25	-5.50	0.00	4.70	4.15	3.60	0.85	0.30	-0.25
6	3	-16	5.50	-6.00	0.00	4.90	4.30	3.70	0.70	0.10	-0.50



	F	G	H	M	N	O
27	0.10	0.20	0.30	0.80	0.90	1.00
28	4.10	7.80	11.10	21.60	22.50	23.00
29	4.30	8.15	11.55	21.80	22.50	22.75
30	4.50	8.50	12.00	22.00	22.50	22.50
31	4.70	8.85	12.45	22.20	22.50	22.25
32	4.90	9.20	12.90	22.40	22.50	22.00

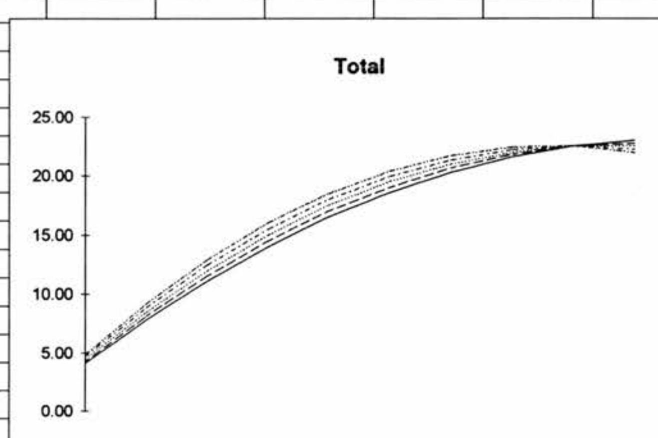


Figure 8.4

The changes in the variable represent a rise in demand to a new permanent level. The rise is spread over five periods. It is accompanied by an increase in the steepness of the downward slope on the marginal revenue with respect to quantity. i.e. demand is increasing but becoming more elastic over the present trading range. The graphs depicted in figure 8.4 show this for the marginal revenue curve and the effect on the total revenue, with a decrease at the upper end of the quantity range where reduced price has cancelled out the increase due to quantity. (see figure 8.4 cells **O5-O6** and **N32-O33**)

8.6 The supply conditions experienced by the firm are represented in EXOGEN.XLS using the same format for the variables. Variables c, m, and C are included in the sheet for ten raw material factors and ten labour supply factors. The technological environment facing the firm is also represented by EXOGEN.XLS (see figure 8.1 cells **A151** to **AY200**). The variables representing technology are organised as follows: Five variables define the input and output characteristics of a type of plant at a particular time period. There are ten types of plant in the sheet and 48 time periods.

	A	B	K	L	U	V	AE
1							
2	**Decision implementation lags**						
3	Product quant change lead tim	5.000					
4	Raw mat price change lead tim	1.000					
5	Product price change lead time	5.000					
6	Wage rate change lead time	60.000					
7	Staffing change lead time	20.000					
8	Hours change lead time	60.000					
9	Plant change lead time	240.000					
10	Product change lead time	20.000					
11	**Observation lags**						
12	Sales quantity	5.000					
13	Sales value	5.000					
14	Gross profit	5.000					
15	Raw material quantity	1.000					
16	New order value	5.000					
17	Outstanding order value	5.000					
18	Outstanding order quantity	5.000					
19	Stock quantity	5.000					
20	Stock value	5.000					
21	Production quantities	1.000					
22	Material costs	5.000					
23	Labour costs	5.000					
24	Plant costs	60.000					
25	Overhead costs	60.000					
26	Competitors or market prices	5.000					
27	Estimates of future market size	240.000					
28	Estimates of future sales	60.000					
29	Estimates of future profits	60.000					
30	Estimates of tech development	240.000					
31	Industry material prices	5.000					
32	Industry or competitor profits	240.000					
33	Industry labour rates	20.000					
34	Net profit before tax	60.000					
35	Net profit after tax	240.000					
36	Net worth	240.000					
37		Goal values		Actual Values		Difference	
38	**Target variables**	1	10	1	10	1	10
39	Plant capacity	1.125		1.125		0%	
40	Production quantity	0.750		0.765		2%	
41	Product price	23.333		24.055		3%	
42	Material price	14.000		14.894		6%	
43	Staff numbers	10.000		10.000		0%	
44	Finance	40.000		42.000		5%	
45	Gross profit	7.000		7.008		0%	
46	Net profit before tax	6.375		5.650		-11%	

Figure 8.5

The first two variables concern the output of the plant. These are the maximum capacity, and the production range over which the firm would normally consider processing. The remaining three variables are concerned with inputs. These are the capital cost of the plant, the labour required per unit of output, and the material required per unit of output. Within the production range considered by the firm the input ratios for material and labour are considered constant. This is a simplifying assumption in the model. The firms may also make this simplifying assumption when taking production decisions.

The control section.

8.7 The control section (CONTROL.XLS) of the computer model is shown in figure 8.5 and figure 8.6. It consists of three separate parts. These are the lag values used in the dynamic process, the target variables, used by the firm to measure progress and prompt action, and the observations made by the firm. The lags are used by the process which steps from period to period. In respect of the observation lags, each observation variable with lag *l* is set to the actual value *l* periods prior to the current period t=0. The values transferred are held in the exogenous sheet and the actual sheet. The decision implementation lags are treated differently. Each time a decision change is made, e.g. a change in plant or entry to a new market, the effect of the change on the rest of the model is delayed for the number of time periods specified in the lag. This is effected by setting a counter to the value of the lag variable at the time of the change, decrementing the counter each period, and changing the variable when the counter reaches zero. An example of this is shown in cells B54 to B57 of the PLANTFIN.XLS sheet in figure 8.10.

8.8 The values assigned to the lags are based upon the empirical work. Firstly, internal reporting cycles were defined during the detailed interviews conducted in the first part of the empirical survey. Thus weekly sales, purchases and labour cost reports were required by the fish processors, whereas plant costs, overhead costs, and profitability was only reported in the firms on a monthly or quarterly basis. Sales levels, i.e. the volumes of transactions for goods delivered and invoiced, and order levels, i.e. contracts for future sales, were not generally distinguished, the terms being used interchangeably. This is probably because of the short delivery time between order placement and completion of sale, which itself occurs because of the short life of processed fish. Outstanding orders were therefore not extensively measured by the firms. One exception to this occurs in salmon processing where the processor is integrated back to the producing fish farms. In this case outstanding orders are significant because there is a stock of non-deteriorating raw material from which the farm can select size grades in advance. Processed quantities and stock quantities were also reviewed together by the processors. The reasons were similarly related to the rapid deterioration of the fresh product. The empirical survey provided confirmation of these lags. For example, of 54 respondents one third monitored sales value daily, 55% monitored sales value weekly and the remainder 11% monitored sales value monthly. Of the same respondents, none monitored net profit daily or weekly, 59% monitored net profit monthly, 15% quarterly, and 26% annually.

8.9 The time base used in the computer model can be varied in the model to reflect the different orders of magnitude for different types of decisions. For example a monthly or quarterly time base is used for modelling plant change decisions whilst a daily time base is used for modelling manufacturing decisions. This was found preferable in practice to an earlier version of the model which only allowed certain variables to be evaluated at fixed intervals.

8.10 The part of the control section containing the target variables is also shown in figure 8.5. A goal value, an actual value, and the percentage difference are held for each target variable. The values in the goal column, are derived from the planned levels established in other sections of the model. For example, the plant capacity is determined in part of the finance section (PLANTFIN.XLS, see below). The other sections which establish the target values derive them using functions of observation variables. This follows Cyert and DeGroot's (1987) model structure. These observation variables are lagged and contain error terms.

	A	B	K	L	U	V	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
47		c		m		C		Error term			Error rang	c	m	C		
48	**Observations**	1	10	1	10	1	10									
49	Sales quantity					1.000		0.054	0.425	0.942	2.00%	0.000	0.000	1.009	i	m
50	Sales value	5.000	5.000	-5.00	-5.00	0.00	0.00	0.294	0.327	0.862	2.00%	4.979	-4.983	0.000	e	m
51	Gross profit					7.008		0.358	0.665	0.009	2.00%	0.000	0.000	7.070	i	f
52	Raw material quantity					0.631		0.259	0.402	0.926	2.00%	0.000	0.000	0.637	i	p
53	New order value							0.956	0.798	0.163	2.00%	0.000	0.000	0.000	i	m
54	Outstanding order value							0.711	0.157	0.441	2.00%	0.000	0.000	0.000	i	m
55	Outstanding order quantity							0.443	0.192	0.306	2.00%	0.000	0.000	0.000	i	m
56	Stock quantity					0.020		0.413	0.014	0.347	2.00%	0.000	0.000	0.020	i	p
57	Stock value							0.802	0.334	0.719	2.00%	0.000	0.000	0.000	i	p
58	Production quantities					0.765		0.318	0.041	0.526	2.00%	0.000	0.000	0.772	i	p
59	Material costs	0.000	0.000	4.000	4.000	1.000	1.000	0.308	0.703	0.863	2.00%	0.000	4.016	1.007	e	p
60	Labour costs	0.250	0.000	0.000	0.000	1.000	1.000	0.072	0.248	0.575	2.00%	0.248	0.000	1.002	e	l
61	Plant costs	0.000	0.000	0.000	0.000	1.000	1.000	0.510	0.166	0.667	2.00%	0.000	0.000	1.003	e	t
62	Overhead costs	0.000	0.000	0.000	0.000	1.000	0.000	0.878	0.414	0.101	2.00%	0.000	0.000	1.009	i	f
63	Competitors or market price	5.000	5.000	-5.00	-5.00	0.00	0.00	0.555	0.686	0.501	2.00%	5.006	-5.019	0.000	s	m
64	Estimates of future market size					1.000		0.507	0.761	0.421	2.00%	0.000	0.000	0.998	s	m
65	Estimates of future sales					1.000		0.487	0.966	0.397	2.00%	0.000	0.000	0.998	s	m
66	Estimates of future profits					1.000		0.503	0.914	0.680	2.00%	0.000	0.000	1.004	s	m
67	Estimates of tech developments					1.000		0.062	0.268	0.867	2.00%	0.000	0.000	1.007	s	t
68	Industry material prices	0.000	0.000	4.000	4.000	1.000	1.000	0.528	0.809	0.271	2.00%	0.000	4.025	0.995	s	p
69	Industry or competitor profitability					1.000	1.000	0.141	0.923	0.170	2.00%	0.000	0.000	0.993	s	m
70	Industry labour rates	0.000	0.000	0.000	0.000	1.000	1.000	0.603	0.016	0.045	2.00%	0.000	0.000	0.991	s	p
71	Net profit before tax					5.650		0.217	0.796	0.744	2.00%	0.000	0.000	5.700	i	f
72	Net profit after tax							0.951	0.754	0.570	2.00%	0.000	0.000	0.000	s	f
73	Net worth							0.273	0.162	0.069	2.00%	0.000	0.000	0.000	i	f
74	Finance costs	0.200				0.500					0.020	0.198	0.000	0.504	s	f

Figure 8.6

The actual values of the target variables contained in the control section are also established in other sections of the model. The other sections which establish the actual values derive them using functions of exogenous variables and other actual values. These are derived without lags but may contain stochastic terms. The result of this target variable mechanism is that goal and actual will vary as a result of three separate circumstances. These are: (1) the actual will differ from the target where there is a significant dynamic change in an exogenous variable and a significant lag in the corresponding observation; (2) the actual will differ from the target where there is a significant error term in the observation variable from which the target is derived; and (3) a stochastic variation in the actual value of the target.[1] Whether or not these changes and error terms are significant depends upon the step functions contained in the model. For example, a 5% random error or a one week delay in the measurement of material costs may result in a planned level of production one step different than that which would otherwise occur. The planned output price would also be different from that which would otherwise occur. These planned values would be set in the goal column of the target variables in the control section, cells **B40** and **B41**. Using these planned values in the manufacturing section will produce an actual output level. Again a significant variation may result in a stepped change in the actual production. This actual quantity produced will also contain a stochastic term. Actual quantity produced is used to evaluate the actual price achieved, again with the addition of a stochastic term. These actual values for production quantity and product price are transferred to the actual column of the target variable, cells **L40** and **L41**. Thus the computer model is able to reproduce variations between targets and results in a way which follows Cyert's approach and which is grounded in a specific empirical case, that of the small fish processing firm.

8.11 The variation between goal and actual is calculated as a percentage in cells **V39** to **V46** of CONTROL.XLS. This provides a basis for the model to determine changes in targets or other endogenous variables. In Cyert and DeGroot's (1987) model, the vector W_j, which represents the actual values in month j, is compared to the vector t_j, which represents the vector of corresponding target values. All values of W_j, must exceed all values of t_j, for the firm to be meeting its targets. If the firm is not meeting its targets, it initiates a search action to determine the reasons. If the deficiency is "due to random factors that are essentially transient in nature" no action will be taken. The present model effects this by checking if each differences is within a specified tolerance. If it is, no action is taken. A range of control actions commonly taken if the firm does not meet its target is also specified by

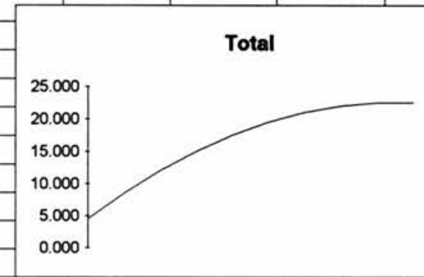
Cyert and DeGroot(1987). These are: (1) price change; (2) mergers and acquisitions (3) contraction; (4) selling parts of the firm; and (5) changing management. The present computer model has a different set of actions. These are: (1) change market, (2) change plant, (3) change factor source. They differ from Cyert and Degroot's actions because the present model addresses S.E.F.s and because implementing Cyert and Degroot's actions would widen the scope of the model into areas which are not supported by the empirical work.

8.12 The third part of the control section is shown in figure 8.6. It contains the observations, together with the transformations made upon them to adjust fro error terms. Observations are either scalar variables, for example stock quantity, or they are represented by three values, as described for the demand related variables in paragraph 8.4 above. The values are assigned taking into account lags as described above. The error terms are introduced by calculating a random number for each term of an observation. This is scaled to be within a specified range. Thus the firms observation on labour costs has two lagged components, represented in cells **B60** and **V60** to which error terms varying randomly from -1% to +1% are added. The results are held in cells **AJ60** and **AK60**. These modified values are then used in the planning calculations in the sales and other sheets. Two columns to the right of the values categorise the abbreviation variables. The first set of categories specifies whether the variable observed is exogenous (e), endogenous (i), or a variable estimated by the firm (s). This last category could have subjective probabilities assigned to alternative values. The alternatives could then be evaluated in the planning calculations. The computer model does not take this analysis further because of the difficulties in getting an empirical base. The second categorisation of observations concerns the scope of the particular observed variable. The variable may be applicable to the firm (f), the product (p), the market (m), the labour type (l), or the plant type (t).

The sales, purchasing and staff sections

8.13 The sales section, SALES.XLS, is illustrated in figure 8.7. There are two parts to the sales section, the planned sales and the actual sales. The planned sales calculation takes the observation variables and derives expected income and cost functions. The functions are calculated taking into consideration other variables such as competitors or market prices. The empirical work indicated that some fish processors actively use competitors prices or industry material prices as a guide to setting their own prices. These may also be indicated by the survey (question 3.1, o), where around a third of respondents measured competitors or market prices once or more per week The functions use as a base the lagged demand and supply observations from the control section, and modify them with a weighted adjustment for the other variables The result is shown graphically in the lower of the insets in figure 8.7.

1	**Actual**												
2		c	m	C	Marginal with respect to quantity					Total			
3	Demand	5.000	-5.000	0.000	4.500	4.000	3.500	0.500	0.000	4.500	8.500	12.000	22.000
4	quantity			0.250	0.100	0.200	0.300	0.900	1.000	0.350	0.450	0.550	1.050
5	Production quantity	0.765											
6	Quantity sold	0.733											
7	Income	17.571											
8	Price achieved	23.985											
9													
10													
11	Stochastic term	5%											
12		0.036											
13		0.581											
14													
15													
16													
17													
18	**Planned**												
19				C	Marginal with respect to quantity					Total			
20	Income			0.000	4.500	4.000	3.500	0.500	0.000	4.500	8.500	12.000	22.000
21	Cost			4.000	0.625	1.025	1.425	3.825	4.225	4.625	5.650	7.075	20.200
22	Quantity	0.750		0.250	0.100	0.200	0.300	0.900	1.000	0.350	0.450	0.550	1.050
23	Net profit	6.375								-0.125	2.850	4.925	1.800
24	Product price	23.333								12.857	18.889	21.818	20.952
25	**Observations**	c	m	C									
27	Sales value	5.000	-5.000	0.000									
36	Material costs	0.000	4.000	1.000									
37	Labour costs	0.250	0.000	1.000									
38	Plant costs	0.000	0.000	1.000									
39	Overhead costs	0.000	0.000	1.000									
40	Competitors or market prices	5.000	-5.000	0.000									
45	Industry material prices	0.000	4.000	1.000									
47	Industry labour rates	0.000	0.000	1.000									
77													
78													
79													
80													
81													
82													
83													
84	Experience weight	c	m	C	Marginal					Total			
85	30%	5.000	-5.000	0.000	4.500	4.000	3.500	0.500	0.000	4.500	8.500	12.000	22.000
86	10%	0.000	4.000	1.000	0.400	0.800	1.200	3.600	4.000	1.400	2.200	3.400	15.400
87	10%	0.225	0.000	1.000	0.225	0.225	0.225	0.225	0.225	1.225	1.450	1.675	2.800
88		0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000
89		0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000
90		5.000	-5.000	0.000									



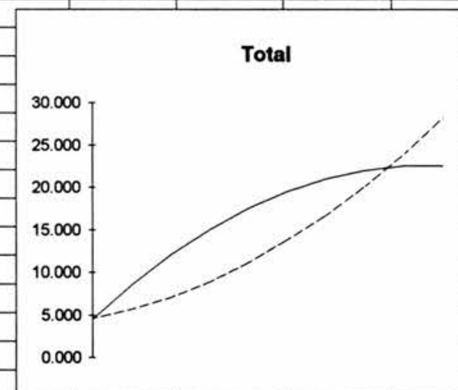


Figure 8.7

Planned total costs are subtracted from planned total income for each quantity level and the resulting net value shown in cells **O23** to **X23**. (Note: the columns between column **G** and column **M**, and between column **Q** and column **V** are omitted to fit the illustration to a single page.) A maximum is then evaluated, cell **B23** and used as an argument to look up the corresponding quantity and product price. These two values are then passed back to the control section as goal values for the corresponding target variables.

8.14 The actuals part of the sales section creates a demand function from the exogenous variables describing demand. No lags or error terms are involved. The actual production quantity calculated in the manufacturing section is used to look up the nearest step in the total revenue row, cells **O3** to **X3**. This value, cell **B7** is used to calculate the price achieved. Both the actual price achieved, and the actual quantity sold, are modified by a stochastic term and then passed to the actuals section of the computer model.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**Actual**																
2		c	m	C	Marginal with respect to quantity										Total		
3	Supply cost	0.000	4.000	1.000	0.400	0.800	1.200	1.600	2.000	2.400	2.800	3.200	3.600	4.000	1.400	2.200	3.400
4					0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000	0.100	0.200	0.300
5	Material quantity	0.631															
6	Total cost	9.400															
7	Price paid	14.894															
8																	
9																	
10	Stochastic term	0%															
11		0.005															
12																	
13																	
14																	
15																	
16																	
17																	
18	**Planned**																
19				C	Marginal with respect to quantity										Total		
20	Income			0.000	4.500	4.000	3.500	3.000	2.500	2.000	1.500	1.000	0.500	0.000	4.500	8.500	12.000
21	Cost			2.000	0.625	1.025	1.425	1.825	2.225	2.625	3.025	3.425	3.825	4.225	2.625	3.650	5.075
22	Quantity	0.500		0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000	0.100	0.200	0.300
23	Gross profit	8.375													1.875	4.850	6.925
24	Material price	14.000													14.000	11.000	11.333
25	**Observations**	c	m	C	Experi	c	m	C	Marginal								
27	Sales value	5.000	-5.000	0.000	10%	5.000	-5.000	0.000	4.500	4.000	3.500	3.000	2.500	2.000	1.500	1.000	0.500
36	Material costs	0.000	4.000	1.000	10%	0.000	4.000	1.000	0.400	0.800	1.200	1.600	2.000	2.400	2.800	3.200	3.600
37	Labour costs	0.250	0.000	1.000	10%	0.225	0.000	1.000	0.225	0.225	0.225	0.225	0.225	0.225	0.225	0.225	0.225
38	Plant costs	0.000	0.000	1.000					0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	Overhead costs	0.000	0.000	1.000					0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	Competitors or market prices	5.000	-5.000	0.000													
45	Industry material prices	0.000	4.000	1.000													
47	Industry labour rates	0.000	0.000	1.000													

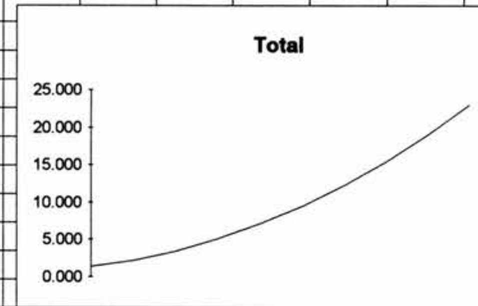


Figure 8.8.

8.15 The purchase section, PURCHASE.XLS, is illustrated in figure 8.8. It has a similar format to the sales section. The planned material purchase calculation takes the same observation variables and derives expected income and cost functions. These are then used to set a planned material price, which is passed back to the control section as a target value. The actual price is calculated directly from the endogenously generated supply curve, using the material quantity calculated in the manufacturing section. Labour use is calculated in a similar section. Alternative models for the labour supply calculation may be constructed to reflect the three different payroll regimes encountered during the empirical work. These were (1) fixed hourly rate with variable hours (2) fixed weekly wage with productivity bonus (3) piece work payments by weight and size of fish processed. All incorporated the ability to vary wage costs proportionate to production. This might occur to a greater or lesser extent in individual companies. A straight line function with constant slope is used to represent this in the computer model.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Production range											
2	Quantity	0.765	0.805	0.845	0.885	0.925	0.965	1.005	1.045	1.085	1.125		
3	Labour required	0.574	0.604	0.634	0.664	0.694	0.724	0.754	0.784	0.814	0.844		
4	Material required	0.631	0.664	0.697	0.730	0.763	0.796	0.829	0.862	0.895	0.928		
5													
6	Planned sales quantity	0.750											
7	Planned production quantity	0.750											
8	Quantity actually produced	0.765											
9	Stock bf	0.000											
10	Available for sale	0.765											
11	Actual sales quantity	0.746											
12	Stock cf	0.019											
13													
14													
15	**Technology constants**	3											
16	Plant capacity	1.125											
17	Production range	0.360											
18	Plant cost	0.400											
19	Labour requirement	0.750											
20	Material requirement	1.100											
21													
22	**Stochastic term**	0%											
23		0.578											

Figure 8.9.

The plant selection and manufacturing section.

8.16 The manufacturing section MANUF.XLS, contains the cells which set the production level, consequently determining product and factor prices and quantities. A diagram showing the structure of the manufacturing section, with the values of a typical set of variables is given at figure 8.9. The inputs to the manufacturing section come from the control section, providing planned sales quantity and the exogenous section providing the technological coefficients which determine the factor input quantities. The choice of plant (cell **B15**) is determined by part of the finance section, PLANTFIN.XLS. This in turn determines which coefficients, held in cells **B16** to **B20**, are used. An adjustment is first made to the planned sales quantity to allow for opening stock. This is then used as an argument to lookup the corresponding factor inputs. The stepped nature of the function generates an adjusted production quantity, which is then modified by a stochastic term. The resulting actual production quantity is added to the opening stock to produce the sales quantity used in the actual sales calculation.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Planned plant**												
2	Income	28.250	28.250	53.675	48.025	36.725	25.425	8.475	8.475	8.475	8.475		
3	Finance costs	0.700	0.900	1.300	1.500	1.900	2.100	2.500	2.500	2.500	2.500		
4	Net Income	27.550	27.350	52.375	46.525	34.825	23.325	5.975	5.975	5.975	5.975		
5													
6	Optimum	52.375											
7	Plant type	3											
8	Capacity available	1.125											
9	Output range	0.360											
10	Cost	0.400											
11	Labour required	0.750											
12	Material required	1.100											
13													
14		Basic			Adjusted for estimates								
15	**Observations**	c	m	C	c	m	C						
16	Sales quantity	0.000	0.000	1.000									
17	Sales value	5.000	-5.000	0.000	5.000	-5.000	0.000	5.000	4.500	4.000	3.500	3.000	2.500
31	Estimates of future market size	0.000	0.000	1.000									
32	Estimates of future sales	0.000	0.000	1.000									
33	Estimates of future profits	0.000	0.000	1.000									
34	Estimates of tech developments	0.000	0.000	1.000									
38	Net profit before tax	0.000	0.000	5.650			5.650						
41	Finance costs	0.200	0.000	0.500	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
43	Cost	0.100		0.000	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
44	Quantity	0.500		0.000	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
46	Plant type	1	2	3	4	5	6	7	8	9	10		
47	Capacity available	0.500	0.750	1.125	1.688	2.531	3.797	5.695	8.543	12.814	19.222		
48	Output range	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360		
49	Cost	0.100	0.250	0.400	0.550	0.700	0.850	1.000	1.150	1.300	1.450		
50	Labour required	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750		
51	Material required	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100		
52													
53	**Actual Plant**												
54	Previous	3											
55	Lead time	240											
56	Unexpired lead time	0											
57	Current plant	3											
58	Capacity available	1.125											
59	Output range	0.360											
60	Cost	0.400											
61	Labour required	0.750											
62	Material required	1.100											

Figure 8.10.

The actual sales quantity returned by the sales section is used to calculate a closing stock for use in the next periods calculation.

8.17 The choice of plant is determined in the PLANTFIN.XLS sheet, illustrated in figure 8.10. This follows a similar procedure to the sales section in deriving a plan. Variables estimated by the firm are used to project expected returns from different plant types and an optimum chosen. This section could be modified to produce alternatives based upon subjective probabilities and several options considered rather than a single sheet. Empirical data on the subjective probabilities was not gathered in the initial phase, nor were questions formulated for this in the questionnaire. Because the optimum plant cannot be installed immediately, a lag is introduced in the actual section of PLANTFIN.XLS, cells **B54** to **B57**. The lead time is set from the value held in the control section. When the plant requirement changes, a counter is initialised to this value in cell **B56**. The counter is reduced by one each period until the lead time expires, when the optimum plant type is substituted in the actual plant type, thus changing the manufacturing coefficients. The same procedure is used to determine market changes, using the sheet MARKET.XLS, and factor market changes, using the sheet PRODLINE.XLS

Recording the results and stepping through the time periods.

8.18 The contents of the control model observations for each period are logged in the actuals file ACTUALS.XLS. This enables lagged endogenous variable to be evaluated from previous observations. This recording function models a major part of the finance function identified by Michael Porter (1980). The remaining part of the finance function is the determination of funding requirements. In the present model this is evaluated in the PLANTFIN.XLS sheet described above. The mechanism for stepping through the periods is accomplished either by use of the macro sheet FIRM.XLM, or by making the changes through the keyboard and then recalculating the sheets.

Conclusion

8.19 The principal aim of the latter part of this chapter is to demonstrate the computability of the behavioural model proposed. To achieve this aim examples from the set of software tools developed during the project have been used. Many more sheets were developed during the course of the project as described in chapter 7. The behavioural rules adopted by S.E.F.s in practice are highly complex. This complexity cannot easily be reduced to simpler structures, without loss of realism. However the use by the firms themselves of similar techniques in parts of their business indicates that the behavioural model is capable of being represented in software. The above examples confirm this. The results of applying the behavioural model to fish processing S.E.F.s and the implications for flexibility are considered in the ensuing two chapters.

Notes:

1. A fourth reason for the difference between goal and actual might also be that the internal measurement of the actual might include an error term, i.e. poor internal reporting. This is not explicitly modelled. The effect would be similar to the stochastic term added to the evaluation of the actual value.

Chapter 9 Linking the Survey Data to the Model.

Introduction.

9.1 Following on from the description of the survey in chapter 5, and the description of the model in chapters 6-8, the present chapter discusses the links between the two. Specifically, it explains how one goes from the survey data to the model, and includes comment on the more salient survey responses. The results of the survey are given in full in Appendix 3, with summary statistics. The design of the model, drawn as it is from the work described in chapter 4, is implicitly grounded in empirical experience. A rather more explicit grounding of the model in the empirical data provided by the survey is given in the following pages.

9.2 Why was the survey necessary? Knowledge of the behavioural processes was already available in sufficient detail to construct a model of the firm. The aim of the survey was to provide a specific empirical focus upon a single industry, and, if possible, to provide quantitative data to supplement the qualitative data gained from direct experience. The present chapter addresses the way in which the survey data is used to modify the structure of the model and to provide reasonable values for parameters contained in the model.

The procedure followed in the chapter is to select the key questions from the survey questionnaire, comment directly upon the responses, and show how they are incorporated into the model. The key questions in this context address the observations used to control the firm, the types of action taken in response to exogenous change, and the speed with which such actions were taken.

Relating the model to the survey data.

9.3 Linking the model to the results from the survey took place via three separate paths. Firstly the results from section 3 of the questionnaire determined which of the observation variables should be used in the model for initiating action. Secondly the timing data from sections 2, 3, 4, and 5 provided reasonable values with which to set the lags in the model. Thirdly, the survey results from sections 2, 4, and 5, describing which actions resulted from which responses, enabled corresponding relationships to be implemented in the model. Each of these links between the survey results and the model is now considered in turn.

9.4 Section 3 of the questionnaire listed 26 possible observation variables, which form the input to the control model as described by Cyert and DeGroot (1987 p 31). These same variables are included in the control section of the model. The set of variables as a whole was selected and incorporated in the model based upon the industrial experience. However, it is clear that not all of these observations will be given equal importance by the entrepreneur, either when assessing the performance of the company as a whole, or when deciding upon a response to a particular change. Part of the survey was designed to assist with the selection of key variables for inclusion in the control section of the model.

Key observation variables identified by the survey.

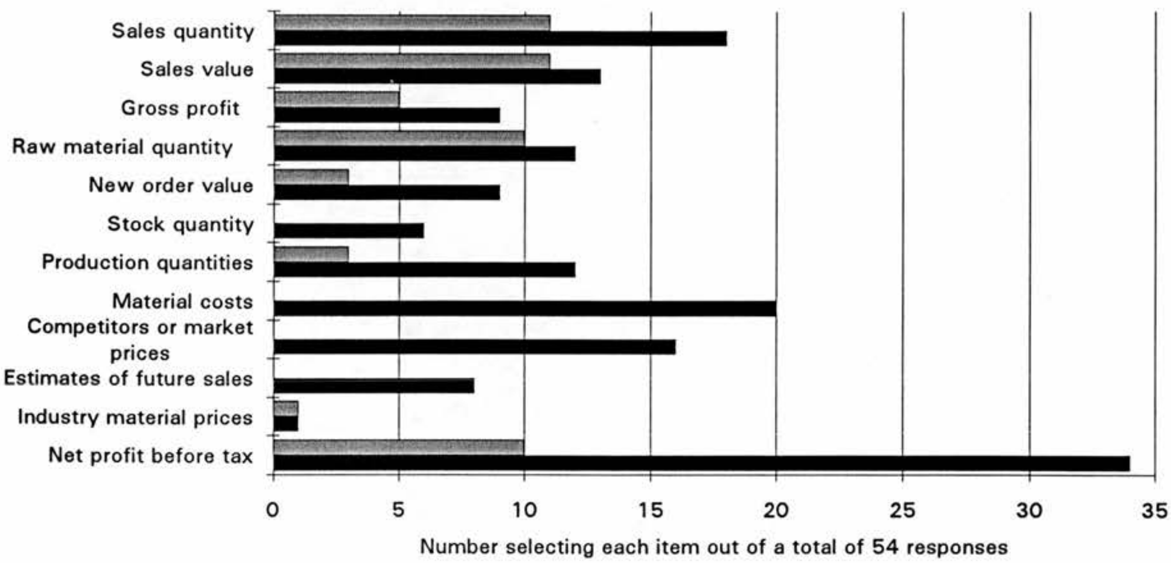


Figure 9.1

All the observations variables are likely to be used by the firms, but some, such as net profit, will more usually be used to initiate general action to change the operations of the firm, whilst others, such as stock quantity, will more usually be used for specific action in a particular operational area. It is also possible that there will be variation between entrepreneurs in different industries in the use of these variables to control their firms. Question 3.2 of the survey questionnaire asks the respondent to identify the three most important, out of 26 possible observation variables, so that the responses can be used as a basis for selecting the control variables in the model. Figure 9.1, depicting the results of question 3.2, thus shows why particular variables such as net profit, sales quantity and value, and material price, are used in the control section, whilst other variables such as stock and wage levels, are used for specific operational decisions in the subsidiary sections.

The figure is constructed as follows. 12 key observation variables are represented. These were selected from the list of 26 variables by the respondents. In order for a variable to appear in the chart at least one respondent has included that variable in his list of the three most important observations he makes. The other 14 variables are not shown as they were not included by any respondent in his list of the three most important observations. Each of the variables is represented by two horizontal bars. All variables mentioned by the respondents in their answers to question 3.2. are shown. The uppermost bar, shown shaded, represents the number of participants entering that variable as their first choice, i.e. the single most important observation variable. The lower bar shown against each variable represents the number of participants who included the variable in any position in their choice of the three most important items with no weighting to reflect rank. Of the 54 participants, all entered a first choice and a second choice, and 50 entered a third choice.

9.5 As might be expected, net profit was the variable most frequently included by the respondents in their list of three key observations. 34 respondents (64% of the sample) considered net profit to be one of their three most important direct observations. The response also usefully highlights the behavioural issues. Firstly, if the firms are all intended profit maximisers, why was the response for net profit not 100%? I.e. why did the firms not rate net profit as their most important observation. The answer lies in the difference between their observed net profit at any point, and the true net profit at that same point. They do not all regard net profit as a key observation because they are aware of the errors which may be present, and of the delay in measuring net profit. By improving their accounting methods they could improve the accuracy or timeliness of the observation, but only at a cost, and some of the firms prefer to use other variables as a proxy for profit. Variation in behavioural factors between firms results in similar variation in their assessment of the importance of net profit observation. Hence 64% did include net profit in the list and 36% did not.

The figure of 64% of respondents for net profit compared with 38% for material costs, which was the second most common choice. This is a more interesting result. It reflects one of the key variability elements in the fish processor's environment - raw material supply fluctuation. Variation in supply, caused by natural factors and by the regulatory regime, mean that constant monitoring of raw material costs are considered by the participants to be their second most important observation after net profit.[1] The third most commonly included variable in the list of three was sales quantity. 34% of respondents include sales quantity in their list, and this variable, jointly with sales value, was ranked first in the list by 20% of respondents. Like the result for net profit, this result is probably less

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1 In the same way that farmers often begin a conversation with a discussion of the weather, it is commonplace for conversations in fish processing to begin with comments on raw material availability and quality.

remarkable. In many industries, including fish processing, sales volume is a good immediate dynamic approximation for net profit. Behavioural considerations to do with accounting methods mean that the sales figures can be quickly calculated, on a daily or weekly basis, whereas it is rare for net profit to be available at less than a monthly frequency.

9.6 Based on the results of question 3.2, therefore, it is possible to select a list of observations which the entrepreneurs themselves regard as the most important. These are then used as the basis for model design. Following the control loop diagram shown in chapter 6, figure 6.4, these variables are the key observations used to initiate a change (i.e. node D in figure 6.4). In order to link the model to the specific decision behaviour in the fish processing sample the responses must be incorporated into the spreadsheets. Therefore the results from question 3.2 of the survey results are used to provide the basis for the subset of key observation variables which are incorporated in cells A39 - AE46 of the control section spreadsheet (see chapter 8 figure 8.5). The three additional variables included in this section, plant capacity, staff numbers, and total finance, are assumed in the model to be accurately known at all times to the decision maker, rather than observed at specific intervals and subject to observation errors.

The remainder of the observation variables are used in the more specific operational decisions and are held in cells A48 - AE74 of the control section spreadsheet (shown in chapter 8, figure 8.6.). Thus the particular types of observations used by the fish processing decision makers in the sample, are carried through to the structure of the model.

9.7 The survey also provided the basis for the lag values used in the model. The frequencies of observation entered by the participants in response to question 3.1 (a - z), provide the observation lag values used in cells B12 - B36 of the control section spreadsheet. (shown in chapter 8 figure 8.5). The frequencies reported by the survey participants for all 26 observation variables are shown at Appendix 3 paras 3:1:1 to 3:1:26.

Time taken to implement decisions.

(a) Price change — Question 4.2 (e)

Decision time in days		Number of responses	%
1		48	89%
3		2	4%
365		4	7%
	total	54	100%

(b) Market change — Question 4.3 (e)

Decision time in days		Number of responses	%
1		8	31%
7		2	8%
14		3	12%
30		7	27%
122		2	8%
183		2	8%
243		2	8%
	total	26	100%

(c) Capacity change — Question 4.4 (e)

Decision time in days		Number of responses	%
1		5	19%
183 (6 months)		17	63%
274 (9 months)		1	4%
1825 (5 years)		2	7%
3650 (10 years)		2	7%
	total	27	100%

(d) Output change — Question 4.5 (e)

Decision time in days		Number of responses	%
1		43	88%
7		6	12%
	total	49	100%

(e) Hours change — Question 4.6 (e)

Decision time in days		Number of responses	%
7		2	33%
30		2	33%
365		2	33%
	total	6	100%

(f) Staffing change — Question 4.7 (e)

Decision time in days		Number of responses	%
1		25	46%
7		20	37%
14		4	7%
21		2	4%
30		3	6%
	total	54	100%

Figure 9.2

The frequency values considered in question 3.1 were requested directly in the survey questionnaire and the modal values for these observation lags could therefore be transferred straight into the spreadsheet. The implementation lags, e.g. the lead time to acquire and install new plant, or the time taken to investigate and exploit a new market or product, were also measured in the questionnaire. Typical values for actual decisions taken can be estimated from the responses to section 4. Implementation times for the most recent occurrences of particular actions were requested in questions 4.2 (e), 4.3 (e), 4.4 (e), 4.5 (e), 4.6 (e) and 4.7 (e). Figure 9.2 above shows the times taken to implement changes by the sample firms.

9.8 The results shown are notable for the short decision implementation times which the firms are able to achieve. The time taken to implement a price change decision is shown at (a) in Figure 9.2. The overwhelming majority of price changes (48, out of 54 reported, 89%) were carried out within a day. Fish processors do not work from documented output prices as is common in many industries. Such prices take time to change and are only suitable where stability in the market exists. Similarly the output changes shown at (d) in the figure, were generally accomplished within a day (43 out of 49 respondents, 88%). This again reflects an industry able to make rapid changes to its output levels to meet exogenous fluctuations. Staffing changes, shown at (f) in the figure, were reported as being implemented generally within a week of the decision with just under half of the reported decisions being implemented on a daily basis, reflecting both considerable use of casual labour, and possibly also the ready availability of new recruits. The reported staff change responses do, however, still seem rather short when compared with the industrial experience. This may be explained by the presence of firms who have a very stable or slowly growing workforce where only disciplinary decisions and hiring decisions were recorded. Plant changes, shown at (c) in Figure 9.2, took six months to implement in 17 cases out of 27 reported, i.e. 63%. This result is entirely as expected given the physical delivery and installation tasks involved. Decisions on markets, shown at (b) in the figure, were implemented in a month in 7 out of 26 cases reported - 27%. Again this delay is of the expected magnitude, given the information acquisition and administrative time necessary to establish the firm in new markets. In both plant and marketing categories some firms reported being able to implement changes on a daily basis, which was unexpected. This, however may be caused by a misinterpretation of the questions. That is to say the firms may be changing between existing markets or plant on a daily basis.

9.9 The results were used in the model as follows. No lags were implemented in the model for product price change, and product quantity change. That is to say, when the operational spreadsheets SALES.XLS, and MANUF.XLS changed as a result of exogenous variable changes, the new values for product price and quantity were used directly to recalculate the control spreadsheet values for the next period. Lags were implemented for PLANTFIN.XLS, MARKETNG.XLS, and LABOUR.XLS in the form of values which were decremented each period by the procedure sheet FIRM.XLM. That is to say, the new values for capacity, market, and staff numbers were not used to recalculate the control sheet until a number of periods had passed. Chapter 8, Figure 8.10, shows the entries for the plant change lag calculation in cells A54 - B56. The actual values used for these lags were set within the range indicated by the survey results. Lastly, the survey results indicated that changing staff hours was not an option widely used by the sample, and so the provision for recalculating the staff hours, and the consequent effects on production levels and costs, in MANUF.XLS was removed.

Actions resulting from different types of shock

(a) **Demand shock**	Question 2.1 (d)	
Resulting action	Number of responses	%
Price change	11	24%
Market change	4	9%
Output change	13	28%
Factor price change	6	13%
Supply change	12	26%
total	46	100%

(b) **Supply shock**	Question 2.2 (d)	
Resulting action	Number of responses	%
Price change	2	4%
Output change	16	34%
Factor price change	8	17%
Supply change	21	45%
total	47	100%

(c) **Labour shock**	Question 2.3 (d)	
Resulting action	Number of responses	%
Staff change	4	27%
Wage change	11	73%
total	15	100%

(d) **Technology shock**	Question 2.4 (d)	
Resulting action	Number of responses	%
Plant change	13	87%
Factor price change	2	13%
total	15	100%

Figure 9.3

9.10 Questions in the survey from sections 2 and 4, were used to investigate which actions resulted from which responses. Given a particular external shock, the respondents were asked to say what action they took, in section 2, whilst in section 4 they were given a particular type of action and asked to identify the exogenous change which prompted it. This enabled corresponding relationships to be tested and implemented in the model. The questions were put in a way which required the respondents first to isolate actual instances of decisions, and then to detail the connections between the external changes and the resulting actions. In section 2 the key questions to be analysed are 2.1 (d), 2.2 (d), 2.3 (d) and 2.4 (d), all of which requested this type of information. The responses are shown in Figure 9.3.

The general response of the sampled firms, when faced with an exogenous shock, as shown by these results, is to take action directly upon that part of the business most closely related to the exogenous shock. This is most clearly shown in labour changes, shown at Figure 9.3 (c), where all the staff related shocks resulted in staff related responses, and in technology changes, shown at Figure 5.3 (d) where only 13% of responses were not directly plant related. Similarly, 45% of supply shocks, shown at figure 9.3 ((b), produced action to change source of supply and 17% action to change supply price. However, a third of the firms changed product quantity and 4% made product price changes. Changes in demand, shown at figure 9.3 (a) resulted in actions less closely related to the source of the shock. Change of supply source and price between them took a 39% share of responses. Output quantity and price changes took an unsurprising 28% and 24% respectively. However, in only 9% of cases where the firm was faced with a demand shock, did it respond by seeking to change its output market. This compares with 45% of cases of a supply shock prompting a factor market change. One inference which could be drawn is that there is more stochastic variation between sources of supply than there is between product markets. As a result, an alert firm has a greater chance of improving its position by changing its factor market position than by changing its product market position. Others might offer alternative behavioural explanations for product marketing getting a low rating. It might be indicative that the industry as a whole is not as active in seeking new markets, as a response to external changes, as it might or should be.

9.11 The results from this section of the survey can be incorporated in the model by the contents of a list held in the procedure sheet (FIRM.XLM). The list is used to determine which of the operational spreadsheets are loaded and recalculated in response to each of the four types of exogenous shock.

9.12 The route from the survey questionnaire to the model has been described in the foregoing paragraphs as a logical progression from empirical source to behavioural model. In practice the linkage was rather more complex. Some of the survey results confirmed structures and values that were already in the model as a result of the original industrial experience sources. Other results seemed to contradict this empirical experience and prompted changes to the model. Yet other results were used to fill in gaps, or to suggest suitable parameter values. Some of the questions did not produce a sufficiently wide response to justify linkage to the model. There were some questions where the responses were less precise than expected. In spite of the deliberate emphasis upon specific events, respondents sometimes reported their experiences as opinions instead of factual recollections, and such opinions are hard to incorporate into a model. In other cases the emphasis of the model had shifted (notably by becoming more focused) between administration of the questionnaire and implementation of the model, making some responses redundant to the modelling process.. Nevertheless, on balance, the survey was able to provide valuable direct and indirect empirical support to the model in a way which would have been impossible with only the industrial experience.

9.13 The present chapter has set out the relationship between the survey and the model, by examination of the results of the questionnaire responses, and relating these to the structure of the model and the settings of its parameters. It has also highlighted some interesting data on the particular importance placed by firms on action and observations in raw material markets. The prior existence of empirical knowledge, and of versions of the model itself meant that the survey results could be used to confirm the nature of the behavioural model and make it more specific to an industry exhibiting change. The next chapter takes this checking process further and analyses the behaviour of the model itself.

Chapter 10 Comparative Dynamics of the Model.

Introduction.

10.1 This chapter evaluates the behaviour of the model presented in chapters 6 - 8 and analyses the results of the model. Paul Samuelson's (1983) Foundations of Economic Analysis provides an agenda for analysing the behaviour of dynamic models. *Comparative dynamics*, as described by Samuelson, requires the consideration of three types of change to a dynamic system. These are (1) a change in the initial conditions of the system; (2) a change in some force acting upon the system; and (3) a change in the internal parameters of the system. Samuelson then goes on to say: *"The rich variety of forms which the change in data may take is matched by the numerous ways in which we can choose to describe the 'resulting effects on the behaviour of the system'."* (Samuelson 1983 page 353). This is a key point in the evaluation of a dynamic model: it is even more so when the model is behaviourally based. An exhaustive audit of all the possibilities of the model would be too protracted and difficult to define. It is necessary to restrict the evaluation of the model to the examination of specific attributes rather than attempt a comprehensive performance check. Considering Samuelson's list of changes further, the first of these categories of change is principally relevant to the dynamic stability

of the system. A change in the initial conditions of a stable system should not produce any alteration in the behaviour of the system given a sufficiently long time period. The present research does not address an environment where sufficiently long periods without change occur in practice. Nor is the issue of stability of interest per se. The route taken from one state to a stable state may be of interest. However, the issue of stability of the model does not arise empirically, and therefore changes to the initial conditions of the model do not form part of this grounded evaluation.
Samuelson's second type of change, a change in some force acting upon the system, is directly relevant to the evaluation of the present model. Technology shocks, supply shocks, and demand changes, have all affected the behaviour of the S.E.F.s studied in the empirical work. The models ability to reflect their response to these changes is important, and forms the subject matter of the present chapter. The third change put forward by Samuelson is a change in the internal parameters of the system. What is of specific interest to the present study are those parameters which might be related to the flexibility of the S.E.F. Samuelson's third category therefore provides the basis for the next chapter. It considers what internal firm parameters are associated with flexible behaviour.

10.2 In summary, the assessment of the model in these two chapters is based upon Samuelson's (1983) agenda for assessing comparative dynamic models. The present chapter looks at the system's reaction to some specific exogenous changes, and considers how the model is used to explore flexibility. The complexity of the behavioural model under consideration means that the thesis does not have a single sharply focused hypothesis which can be directly subjected to a straightforward empirical verification. Rather it has to do with exploring possibilities and scenario analysis. A variety of exogenous shocks can be applied to the model and the output traces how adaptive mechanisms in the firm are used to deal with these shocks.

The response of the S.E.F. to exogenous shocks.

10.3 In examining the response of the S.E.F. to exogenous shocks, the procedure followed was to select three different types of shock and examine the changes which might occur in the firm's choice of output, product, plant and market. These three types of shock are a technology shock, a demand shock, and a material supply shock. The effect of the shock is traced through the firm's decision process as specified in the model, and related to the empirical experience.

Technology shocks

10.4 The first type of shock considered is a technology shock. Instances of such shocks were encountered during both parts of the empirical work (e.g. the proposed E.E.C. hygiene regulations, which represent an upward shift in plant costs, and the introduction of wet fish slicing machines, which reduce costs at higher capacities). The new E.E.C hygiene regulations to be implemented within the near future concern the layout of the factory, and type of equipment used, as well as the procedures to be followed by the operators. In many case a complete change of factory layout is required in order to separate operations on unprocessed and processed material. The regulations were announced during the empirical work and became mandatory two years later. This produces an upward shift in the cost across all plant capacities, and a possible relative increase at smaller plant sizes. The mandatory nature and scale of the change had a major effect on the investment decisions of fish processors. The wet fish slicing equipment on the other hand, is not a mandatory change. It is a technologically advanced machine which provides an option for the fish processing firm handling salmon. It requires a much lower labour input per unit of product. Set up time and throughput necessitate operating at higher volumes. Other considerations for the firm introducing the equipment relate to different labour types required and different labour payment schemes. This compares with the existing labour intensive salmon processing operations. The technology shock is modelled as a change in the sets of exogenous variables describing plant cost, and factor coefficients relating to a particular plant type. The application of the model proceeds as follows.

10.5 Firstly one or more of the variables in the external section representing plant cost is changed. There are three such variables: the plant cost level C, the first of cost derivative with respect to capacity c, and the second derivative of cost with respect to plant capacity m. Thus the shock can be an overall shift in the cost of all types of plant regardless of capacity. It could be a shift in the relative costs of large capacity plants compared to small capacity plants, that is to say economies of scale are present. Lastly, it could be a shift in rate at which relative plant cost savings are made as capacity increases, i.e. economies of scale occur at an accelerating rate.

10.6 A behavioural lag then occurs which represents the time between the change taking place and the time at which it is observed. Taking each of the above examples, the plant regulatory change and the wet fish slicing machine, in the first case the observation lag might represent the time before the entrepreneur is notified of the new regulations. Members of trade associations may receive earlier notification when legislation is in prospect, some companies may not have the technical expertise to assess the impact of the change, and yet others may simply keep abreast of the industry press. In the case of the wet fish processing machine, the company may get its information on new plant costs and characteristics from a variety of sources. They may receive marketing literature from the plant supplier; they may be visited by a salesperson; they may see the equipment in use elsewhere, or may hire staff who have done so. One of the commonest ways for suppliers to disseminate information about such changes is the industry exhibition. Thus the interval between visits to exhibitions of new plant designs might be the significant lag in observing plant cost changes. There is, then, a lag which varies from company to company in observing the change. Information from the empirical survey indicated that this lag could be quite substantial. 44 out of 54 respondents said that they monitored technology developments, and of these 50% used monthly monitoring, 45.45% used quarterly monitoring, and 4.55% used yearly monitoring. When asked about specific technology shocks, however, no respondent was able to give a definite answer on how long it took them to become aware of the change in technology. This, combined with evidence from the industrial experience (i.e. some clients aware of changes before others) indicated that 1 - 6 months was a reasonable, though not precise, estimate of this lag).

10.7 Once the change in the plant options open to the firm has occurred, the next event has to do with whether the firm is meeting its current set of targets. If it is, as described by Cyert and DeGroot (1987), ie. all the actual values are more then the goal values, the firm will take no action. Using the examples above, this is best illustrated by the wet fish slicing machine, which may be of no immediate interest to the firm because it is currently trading profitably and does not wish to increase reliance on external funds to purchase new equipment. In the case of the hygiene regulations, it is necessary to introduce a new target variable which has the logical value TRUE if the firm expects to meeting its statutory obligations, and, of course, a goal value of TRUE. On the other hand, if the firm is not meeting its current set of targets, then it will initiate a search activity to determine what changes to make to bring the actuals towards the goal values.

10.8 In practice, the S.E.F. would probably consider a wide range of options simultaneously. Opportunities to address new markets may be opened up by the different cost profile presented by a change of plant. Labour requirements may cause the company to change location. Finance requirements may even cause a change in company ownership. All of these examples are directly drawn from the empirical work. For the purposes of the present evaluation, however only the plant change option is considered here. This may still result in no action by the firm. The introduction of the wet fish slicing machine may

10.9 Thus the next stage in the modelling of the technology shock is for the firm to reassess its optimum plant in the light of observed exogenous changes combined with a failure to meet targets. The plant capacity change decision module. This module may be used to recalculate the plant planning decision automatically through the use of the FIRM.XLM macro sheet, or it may simply be invoked by loading it and the control sheet from disk after changing the exogenous variables. This plant capacity sheet forms part of the finance section of the model. Using all of Porter's categories the product line section, or the marketing section might also be invoked, i.e. the firm should also re-evaluate whether to continue with the product. Tracing the subsequent effects would, however, be complex. For simplicity of analysis, this is not done here. In practice a further lag may also occur at this stage whilst the firm, having observed the change, gathers supplementary information. It may go through a Bayesian process of evaluating subjective probabilities concerning, for example, future plant price reductions, second hand asset values, or other similar judgements. These elements are not directly represented in the computer sheets described in the previous chapter, but nevertheless form part of the overall schema proposed for the model and could be implemented using similar techniques.

10.10 The firm may seek information on the new plant by observing how a competitor performs with it, and implement the plant change only when the risk factor is reduced and the competitor is clearly seen to be benefitting. The empirical survey indicated that 51 of 54 respondents monitored their competitors and of these 30% did so quarterly and 70% annually. The invocation of the decision module in that case would thus be expected to take 6 - 18 months from the shock occurring. When it does eventually occur, the result of recalculating the optimum plant may or may not result in a decision to change plant, depending upon the other firm circumstances.

10.11 For example, if the new plant, moves the firm upwards in output to a position on its demand curve where it needs to seek new markets or accept declining prices. The stepped nature of the plant cost function means that such a firm is not at a static equilibrium point, and it is worth examining how in practice the firm may move to a new optimum position. If new markets are available with

higher demand, then other firms may enter them using the new plant, and compete in the present market also. The empirical work encountered examples of this where firms were able to install new equipment at the same time as entering European markets. The higher prices obtainable in the new market enabled them to use higher capacity plant with a lower costs. This could also be applied to supplying the existing market. However, for this to occur requires that the conditions determining the particular optimum remain in force long enough for the plant to be decided upon, installed, and for the competitive industry effects to filter through. Such stable conditions were not encountered during the empirical work.

10.12 In terms of the computer implementation, the evaluation proceeds as follows. The revisions to estimated future net revenue arising from exogenous cost changes then feed back as input to the control section. An information search then takes place on the other inputs to the plant capacity decision module. A lag occurs in the estimating of these inputs. The empirical evidence from the survey is not appropriate to this lag as the information search is prompted by the change, rather than a simple frequency as implied in the survey.

Depending upon the outcome of this information search, a further iteration of the plant capacity decision module is executed. (e.g. the regulatory change might be expected to increase the market available by eliminating rivals). A new plant capacity is then selected. Then a lag occurs because of the physical lead time to install the plant, and finally the plant is installed. Two other outcomes are also possible: the firm may withdraw from that product or the firm may make no change. In the case where the firm withdraws from the product market the model as presently constructed does nothing further. It would be feasible to construct a sheet such that the plant information, along with the market estimates for that product, would be retained for review. Then recalculation of the optimum, and possible re-entry, as happens in the real world, could be modelled. In the case where no change to the plant capacity is made following the technology shock, there may still be change in the behaviour of the firm because of the technology shock. Firstly, provided that the technology shock is permanent future plant decisions will occur periodically. This can be modelled by re-invoking the plant decision module. If other changes in the inputs to this section have occurred then the outcome may change. Secondly, external industry effects may occur. For example, new entrants may occur following the introduction of a lower cost plant option.This may be modelled by changes to the demand variables, for example, making the general output price level c, a function of the average material costs and plant costs contained in the exogenous section, representing the effect of rivals reduced costs on the competitive price. Endogenous market and sales expectations could be similarly changed by linking their values inversely to input cost levels.

10.13 Diagrammatically, the shock is modelled as shown In figure 10.1 below. At point A in the schema shown the technology shock occurs. E.g. the new wet fish slicing machine is launched by the manufacturer, or the regulation requiring fish processors to adhere to new hygiene standards by December 1992 is made law. This is represented by changes in values describing the plant options in the exogenous sheet. Point A represents the delay occurring as the information is disseminated

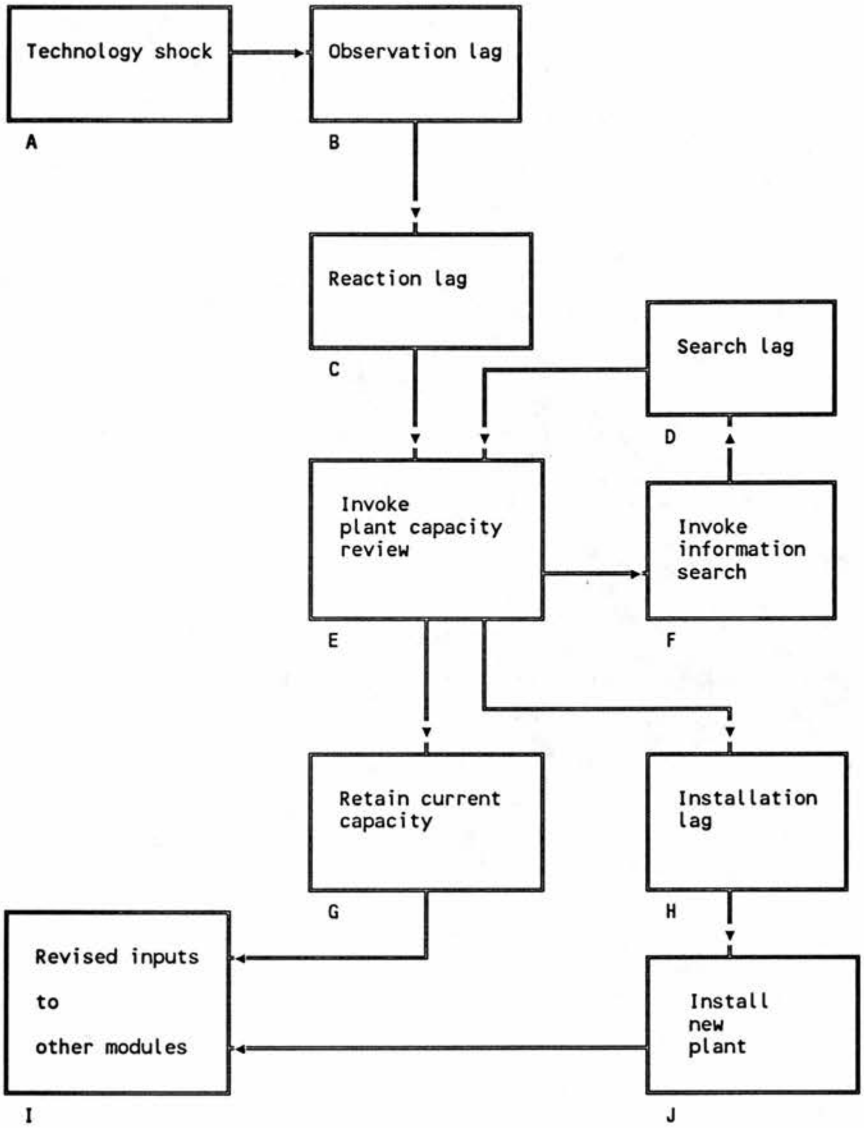

Technology shock
A
Observation lag
B
Reaction lag
C
Search lag
D
Invoke plant capacity review
E
Invoke information search
F
Retain current capacity
G
Installation lag
H
Revised inputs to other modules
I
Install new plant
J

Figure 10.1.

through the firms. Several weeks or months is a reasonable estimate of this lag. In the real world this may be delays from the source of the information, who will frequently be selective in the order of their approaches to firms with information (machinery suppliers approaching the best prospects first, government departments approaching special interest groups etc.). It may also be delays engendered by the firm itself in seeking out information, frequently because of information gathering costs (e.g. shortage of entrepreneurial time to monitor product launches or attend trade associations). Point B is represented in the computer implementation by the lagged link between the cells in the exogenous section representing plant, and the cells in the control section representing observations on plant. Once the firm has the information a lag occurs whilst the effect, if any, on the firm's ability to meet its targets is assessed. It also reflects the time taken to assess which sphere of action may produce the best movement towards firm goals. For example, an S.E.F. in fish processing faced with classification of his product as perishable may choose to use his trade association to press for its reclassification as preserved so as to reduce the impact on his plant costs of the new regulation. Such a response will involve a delay, whether successful or not.

Similarly, the S.E.F. decision taker may not believe the claims made on behalf of the newly available fish slicing machine. He may delay his evaluation until the supplier has evidence from a given number of installations in other firms. This process of assessing the relevance and effects of the change is represented in the control section of model by the comparison of goal and actual values of the target variables. A lag is not implemented in the sheets described in chapter 5 to retain clarity, and because it is subsumed by the observation lags.

10.14 Point E is then reached and the firm makes an evaluation of its existing plant and the alternatives now open to it. The firm may adopt a number of strategies for comparing possible plant purchases. It may ask the manufacturer for performance figures from other customers, i.e. the firm's rivals. It may make extensive forecasts of its future markets and factor costs, as well as the plant performance. This will happen particularly if bank or equity funding is required. Points D and F in the diagram illustrate the sequence of events. Such an equipment purchase decision may typically take several months, or even years, of iterating through points D, E, and F in the diagram. The computer model implements this procedure through the PLANTFIN.XLS sheet. If the review of plant recommends a change then a further lag, point H on the diagram is encountered. For many plant changes in fish processing this may not only involve physical plant manufacture and installation delays, but also planning and other institutionally engendered delays. The model represents this process through the installation lead time calculation in PLANTFIN.XLS. Alternatively, the plant capacity review may be discontinued with no decision to change plant. This is represented by point G on the diagram. Finally the effect of the technology shock is fully absorbed and the resulting plant characteristics such as factor coefficients passed to other sections of the model. In practice, that is to say, the firm might now have a new fish slicing machine in a factory meeting current regulations, probably some two and a half years after their first impact on the firms environment. Future results and decisions of the firm will reflect the changed labour requirements, finished product capacity and costs.

10.15 These results compare favourably with what may be expected to happen in a representative fish processing firm. The new E.E.C. hygiene regulations (Council Directive 91/493/EEC 11th July 1991) will undoubtedly cause some smaller processors to withdraw from the market, having evaluated the options for financing new plant. Some others, after considerable deliberation on future market prospects, financing options, and risk, will re-equip their factories. Examples of both types exist in the empirical data set. Two of the larger firms relocated their factories from more remote locations on the west coast to larger premises meeting the new regulations on the east coast. Labour supply considerations resulting from their increased capacity played a strong part in the decision to relocate, prompted by the regulatory change. The cost reductions from technological developments are also reasonably representative, though it is difficult to distinguish individual empirical examples in the author's current industrial experience. This is because of masking of the technological effects by the dominant demand fall. The behavioural computer model shows how the representative fish processing firm might respond to technology shocks and, in particular, the mechanisms by which this response proceeds.

Demand shocks

10.16 The second type of change to the forces acting upon the system is a demand shock. This is used to evaluate the models dynamic properties in a similar way to the technology shock dealt with above. Diagrammatically, the shock is modelled as shown below in figure 10.2:

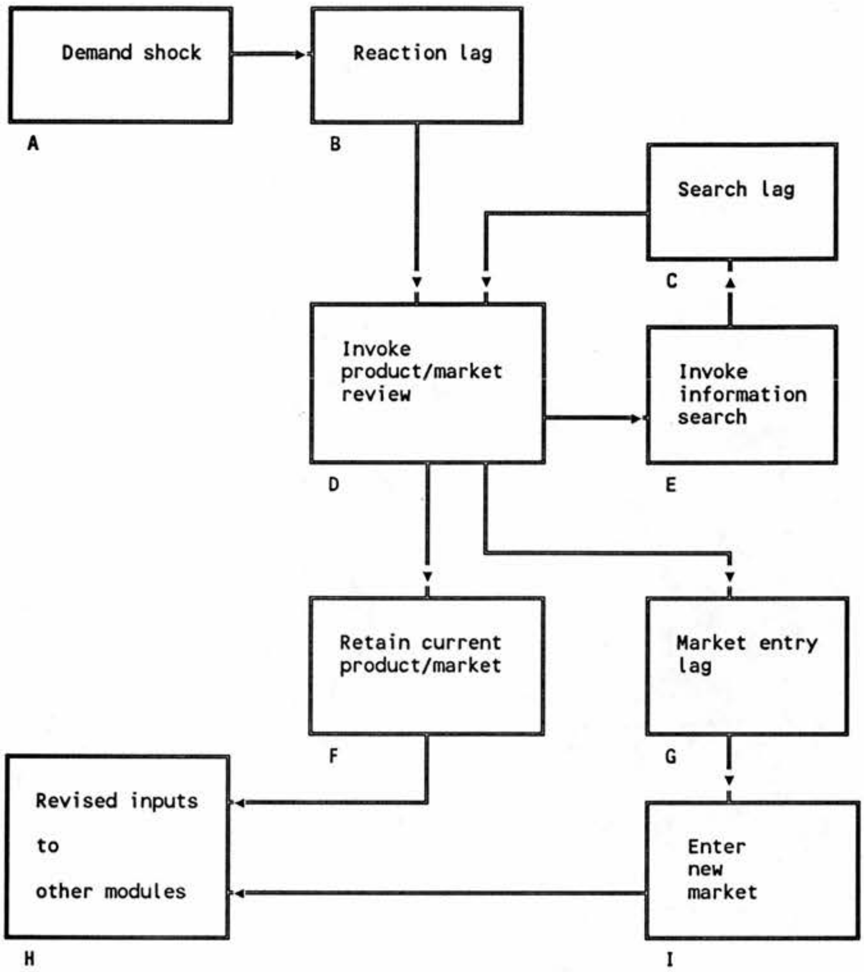

Demand shock
A
Reaction lag
B
Search lag
C
Invoke product/market review
D
Invoke information search
E
Retain current product/market
F
Market entry lag
G
Revised inputs to other modules
H
Enter new market
I

Figure 10.2.

10.17 At point A the change in demand for the firms product changes. This may take a variety of forms. Two examples will be used to ground the process empirically, and illustrate how it may be represented in the behavioural model. One of these refers to an increase in the demand for a product and the other to a decrease. The first example is that occurring in the market for processed prawns. Nephrops Norvegicus, the Norway Lobster, is variously sold as prawns, scampi, etc., chilled or frozen, peeled or shell-on. It formed the principal product group of many of the firms studied, comprising over half the fish processing clients and 31 of the 54 survey respondents. Improvements in chilled transport facilities have enabled continental buyers to enter the market for chilled fresh product. This has resulted in a rise in the price of the chilled fresh product. The second example is the fall in demand for processed salmon experienced by those firms producing salmon based products. Around one third of the firms studied were salmon processors, including 15 of the survey respondents. The general price fall experienced is the result of a large increase in the production of farmed salmon during the last decade, both in the UK and Norway. The demand shock is modelled as a change in the three exogenous variables describing product demand. The subsequent information flow through the model follows.

10.18 Firstly at point A in the figure, the variables in the external section representing the demand for a product are changed. There are three such variables: the income level, the first derivative of income with respect to quantity, i.e. the price level, and the second derivative of income with respect to quantity sold i.e. the rate of change of price as quantity changes. A lag, point B in figure 2, follows whilst the firm acquires the information about demand for its product. The situation is a little different from that of a technology shock. Here the delay in gaining information is more related to sampling and interpretation difficulties. Prices fluctuate frequently over time and between buyers. The firm may make offers of a quantity of chilled prawns at a particular price to a buyer, and receive a binary response - yes or no. If it is no, the firm will probably repeat the offer to further buyers. The firm's sample of buyers is limited by several factors: the geographic area it is able to distribute to, the knowledge of buyer contacts, and the time period before the product deteriorates. Faced with a series of no's, it may lower its price or choose to freeze the prawns for sale later at the lower price obtaining for frozen product. This process. Faced with a series of yes's, it may try a higher price the next period, or it may regard the result as a transient fluctuation. Faced with a series of no's the salmon processor may decide to reduce price. If he is integrated backwards and owns a fish farm, he may simply defer harvesting, allowing the fish to grow on. The prawn processor faced with a further set of yes's may propose a further rise. Where the sales force are separate from the directors, delay is possible in internal communications. A number of periods may pass before the firm has made a sufficiently large number of offers at higher prices, and had them accepted, to be convinced that a general price shift has occurred. At this point, other observations which the firm is able to make may well be observed by the firm. In particular, gross profit targets may be exceeded, and the firm may investigate the cause.

10.19 Thus a behavioural lag occurs which represents the time between the demand change taking place and the time at which a response is mooted. This might be represented by the frequency with which new prices are struck with buyers, provided that the entrepreneur is able to distinguish between permanent demand shifts and random fluctuations, and provided that the price information reaches the entrepreneur from the sales force. Information from the empirical survey indicated that this lag would generally be fairly short in these circumstances. Of 54 respondents, 33% said that they monitored demand daily, 56% weekly, and 11% monthly monitoring. When asked in the survey about specific demand shocks, of 46 respondents 45% said they were able to take a decision within 7 days and 73% within a month. The industrial experience indicates that it is commonplace for processed fish prices to be struck by firms on a daily basis. These data indicate that 7 days was a reasonable estimate of this lag.

10.20 Having established that a demand shift has occurred, the firm then responds to the effects of this by considering alternative markets or products. In reality, the firm is likely to take a broader approach and review all aspects of its business when any exogenous change of a sufficient magnitude changes affects its targets. This is also possible to emulate in the model by invoking all the planning sections to establish new targets. For the sake of clarity, only review of the product and market is considered here. The firm will investigate alternative product and market combinations, represented by D in figure 2. In the computer representation, this process is represented by recalculating a sheet selecting the product and market, based upon expectations of product market demand, factor supply and manufacturing performance. The process follows a similar route to the plant selection decision. The prawn processing firm, observing high gross profits arising from trading with its present customer set, will seek information on other customer sets who may provide similar profits. For instance they may consider selling to an additional country. They may also consider selling a similar product, such as velvet crabs, through the existing customer channel. A cost of entering each market is incurred, similar to the plant acquisition cost. Different markets for the same product, or for different products, have the same representation in the model. This is partly reflected in the behaviour of the firms. Within broad limits established by the manufacturing technology, adding a product such as velvet crab or scallops to say a Spanish market, involves a similar planning exercise to adding a French customer base. Start-up costs and running costs have to be evaluated, potential demand estimated, and factor supply assessed. Points C and E in diagram 2 detail this process. It is an iterative process, perhaps involving several blind alleys before a change is made, signified by point G. Alternatively, the firm may cease its search for different markets and or products, shown at point F. Amongst the salmon processors examples occurred both of firms who sought new markets in response to price change, and of firms who changed product, for example from smoked salmon to gravad lax, or marinated salmon. The success of these particular changes, which depended upon the firms' market and cost expectations being met, was not measured.

Supply shocks

10.21 The modelling of a supply shock follows a similar path to the two previous evaluation exercises. A change in the exogenous variables describing supply occurs. This is followed by a behavioural lag whilst the firm gets and assesses information on the change. An iterative process then occurs whilst the firm decides what action to take in the light of the supply change. This consists of getting information about expected demand, supply and manufacturing, and making forecasts based on alternative product or market. The firm may then change or add products or markets in its attempt to meet new targets, or it may accept the effects produced by the exogenous supply change. Supply shocks encountered in the empirical work included severe reductions in the Nephrops catch in spring 1989. After an initial period assessing supply conditions, several firms turned to processing other products. Other firms estimated the shortage to be transient, reduced production, and took no permanent action.

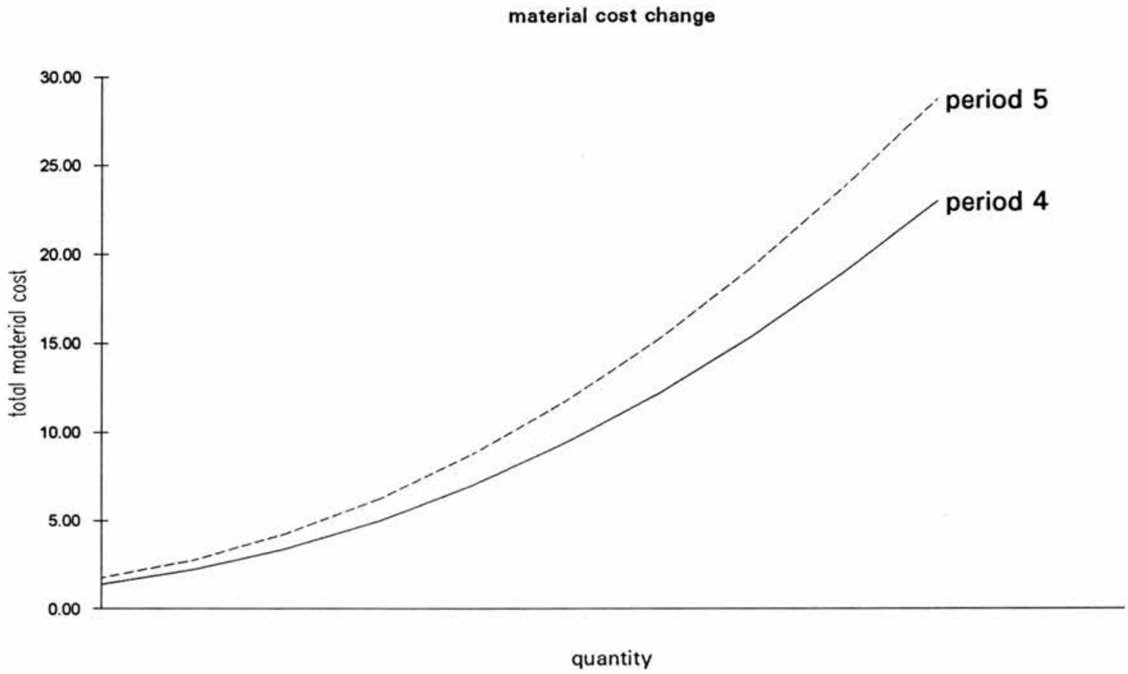
Model results illustrating flexibility.

10.22 Direct analysis of the "results" of model, i.e. comparison of the output of the model compared to the actual behaviour of the real world firm being modelled has to overcome two practical problems. The first of these arises from the large number of different tests which could be applied, following Simon (1983). This is particularly important since experience with using the model has shown that small changes to the parameters or structure of the model produce substantial changes in its performance. This is not unexpected and is also found in the practical use of macroeconomic models (for example MICRO-QMED, Matti Viren 1990) To overcome this practical analysis problem, the results evaluation takes the form of example tests. Each of these tests uses a specific set of exogenous values matched to the parameter values or structural modification being analysed. The second practical problem concerns the validity criteria to be used. A error statistic is not a meaningful choice, given the behavioural nature of the data. Instead the criterion used is the subjective similarity between the model output and the behaviour of a typical fish processor. The model is valid if it appears to behave like a small fish processing firm. The extensions to the micro-economic analysis of flexibility, discussed in chapter 3, identified two components of a flexible strategy: choice flexibility and response flexibility. The purpose of the following examples is to demonstrate how the computer model can be used to illustrate these two components of flexibility, by setting values in the exogenous variables to represent a shock, and by applying different values to the behavioural parameters which control the way the model reacts.

An illustration of choice flexibility.

10.23 The first two sets of output from the model illustrate choice flexibility. A supply shock for the raw material factor market 1 is entered into the model at time period 5. This is achieved by changing part of the array of supply variables held in EXOGEN.XLS. The array of cells B53 - AE100 hold these values for periods -24 to +23 for ten possible supply sources. The values held in column L53 to L100 give the change in total material cost for supply source 1 as quantity changes. The change in supply conditions is effected by increasing from 4 to 5 the value in cell L82 and subsequent cells through to L100, period 23. This represents an increase in the price of raw material throughout the observed quantity range, which becomes greater as quantity rises. This might illustrate the supply at a port where fish is still available at the bottom of the observed quantity range, but because of poor landings, becomes much more expensive as quantity increases.

10.24 It should be noted that in this example, and in the example which follows, the shock examined is a single permanent change to the supply situation facing the firm. A permanent change is used in order to clarify the analysis, in the same way as a ceteris paribus assumption may be used. The model can also be used to represent the more complex situations experienced in practice, and it is worth while, before analysing the present example, to give this some consideration. Though useful analytically, a single permanent exogenous shock is not necessarily the norm in practice. Shocks may be of a transient nature. In the present example, rather than all periods from period 1 onwards being changed, only periods 1 to 12 might be changed. This would represent a shock which lasts for just twelve periods. The distinction between a permanent exogenous change, and a transient one is, of course highly significant for the firm's proposed course of action. The firm does not know at the outset that a shock has occurred. When it has made a sufficient number of observations to establish this fact, it still does not know whether the shock is permanent or not, and must continue to make observations to establish this. A certain inertia may be useful to the firm in the face of such transient changes. The permanence of any change made in response to an observed exogenous shock is also a significant issue.



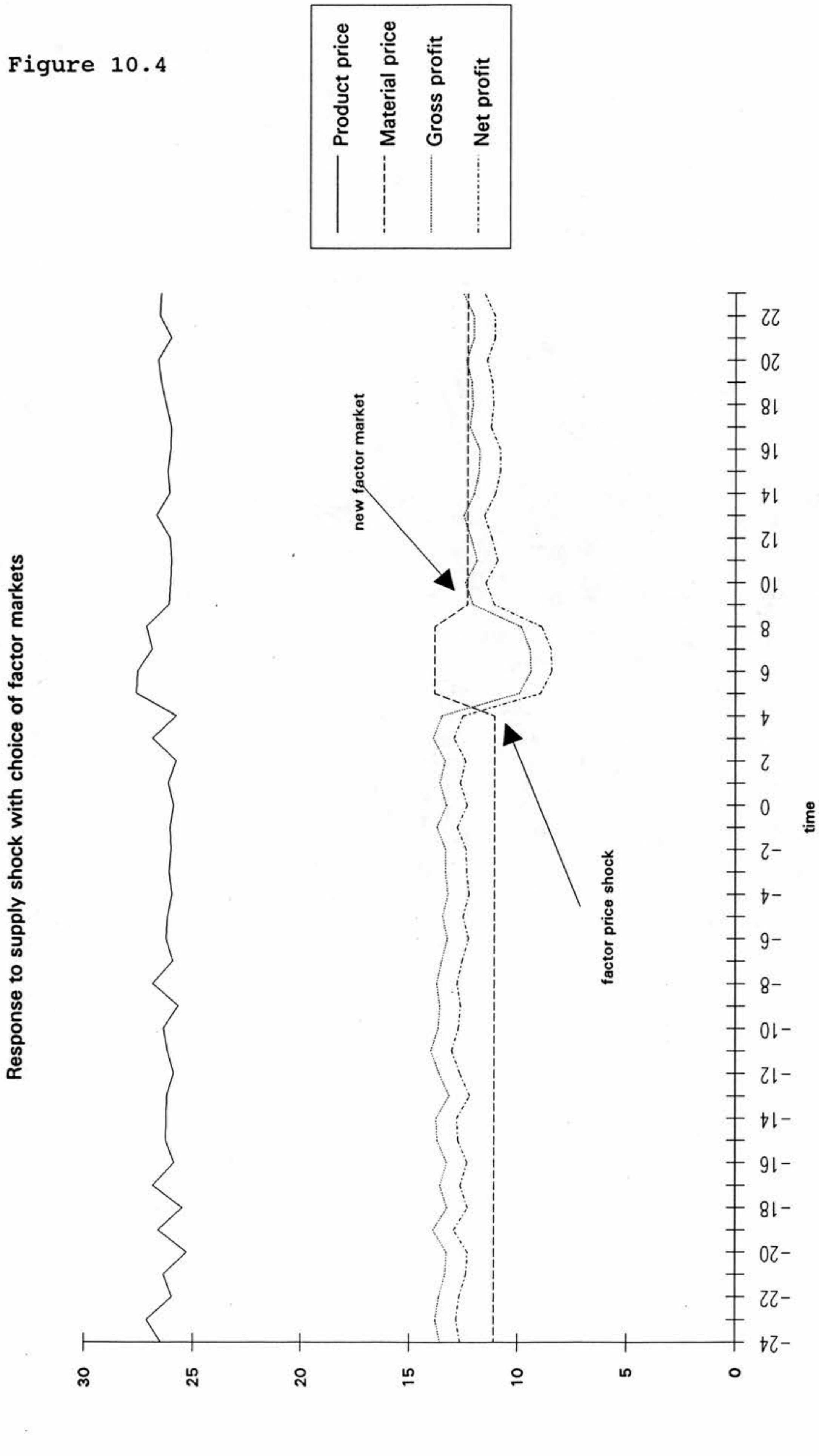
	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
/	m	material source									C	material source								
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1	4.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.00	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
2	4.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.00	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
3	4.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.00	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
4	4.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.00	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
5	5.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.25	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
6	5.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.25	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
7	5.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.25	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
8	5.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.25	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
9	5.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.25	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
0	5.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.25	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
1	5.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.25	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01
2	5.00	4.45	4.90	5.35	5.80	6.25	6.70	7.15	7.60	8.05	1.25	1.11	1.23	1.34	1.45	1.56	1.68	1.79	1.90	2.01

Figure 10.3

The values held in column L53 to L100 represent the total material cost at the base of the observed range for product 1. A 25% increase is also made to the values in cells V82 to V100. These changes represent a overall upward shift in the price paid for material from source 1, throughout the quantity range. which is greater at the top ofthe quantity range. The shift occurs at period 5 and is sustained thereafter. Figure 10.3 illustrates this, showing an extract from the relevant part of EXOGEN.XLS and a graph showing the shape of the total material cost curve at period 4, before the change, and period 5, after the change.

10.25 Two firms are considered. The first firm has a wider choice of factor markets to choose from, representing choice flexibility. This choice is given effect by the range of values entered in the cells of EXOGEN.XLS, which represent the observed supply variables for factor markets 2 to 10. These are held in M53 - M100, and W53 - AE100. For example the variation in values in cells M78 to U78, and W78 to AE78, represent the supply costs varying between different sources in period 1.

Figure 10.4


Response to supply shock with choice of factor markets
Product price
Material price
Gross profit
Net profit
new factor market
factor price shock
time
-24
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22
0
5
10
15
20
25
30

This might represent, in the real world, a fish processor who maintains a buying presence at several different ports, thus providing greater supply flexibility, at a cost of increased administration overheads. The output from the model for the flexible firm, i.e. the firm which provided itself with a choice of sources for its material, is shown in figure 10.4. Figure 10.4 shows, in the form of a graph with time on the horizontal axis, and monetary value on the vertical axis, the values of four variables over time periods -24 to + 23. Although not strictly in the same scale on the vertical axis, for comparison purposes unit product price and unit material price are shown on the same graph as total gross profit and net profit. Prior to period 5 the values output from the model are subject to fluctuations arising from the various observational and random error terms in the model. The supply shock occurs at period 5, shown by an increase in the unit price the firm pays for material, noted by the arrow. At the same time the quantity produced reduces, as the firm adjusts to the new supply situation. This is reflected on the graph by a small increase in the product price obtained, which occurs as a result of the smaller output. As a result of the changes the gross profit falls. This change occurring in the gross profit exceeds the tolerance parameter and the factor market choice is recalculated.

This is effected by entering a value in an array which governs the range of response actions in the sheet FIRM.XLM. A delay occurs reflecting the lag in implementing the change to the new material source. During this delay output price remains higher, and gross profit and net profit remain lower, with fluctuations due to the stochastic functions in the model. After 4 periods the new material source is selected, noted by the second arrow. The material price drops following the change and a small decrease in unit product price occurs, reflecting a small increase in output. The total gross profit rises and the net profit rises. The gross profit target is amended using the new material factor market variables. Thereafter the resulting gross profit is sufficiently close to the target value and no further changes are made. The only variation is that resulting from the stochastic functions.

10.26 The second firm has a narrower range of factor markets to choose from. This is represented by entering the same values in eight of the ten factor market ranges in the exogenous variables representing supply sources. Figure 10.5 below shows the relevant section of EXOGEN.XLS.

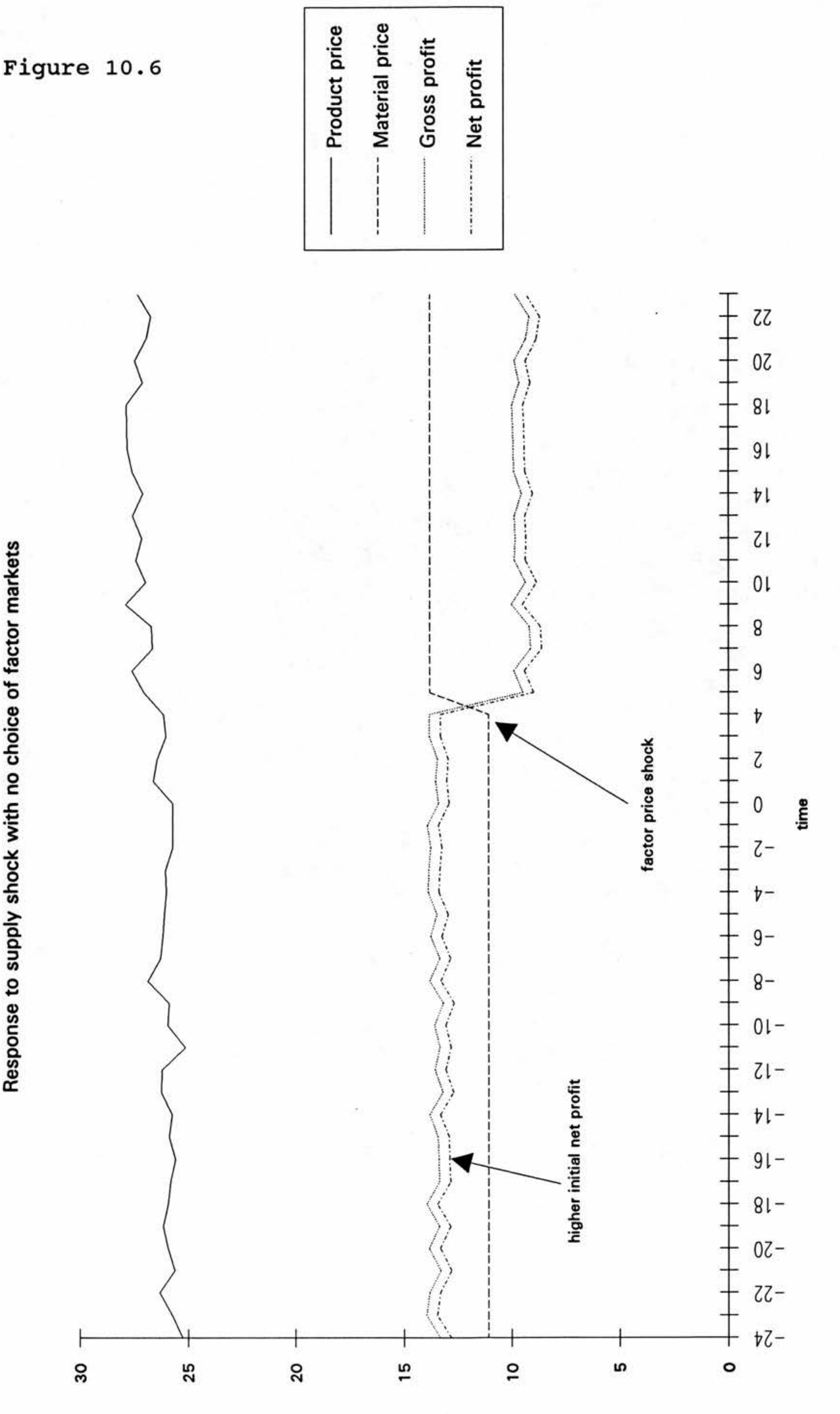
The supply shock in material source 1 is entered identically to that in figure 10.3, i.e. the entries in column L82 to L100 and V82 to V100 are increased by 25%. The smaller choice of material sources available to the firm is effected by entering identical values in the columns M53 to U100 and W53 to AE100, representing the supply conditions for material sources 2 to 10. In the real world this might mean that the fish processing firm does not maintain a buying presence at other ports, but is simply aware that another, higher cost, material source exists.

Figure 10.5

	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1	4.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.00	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
2	4.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.00	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
3	4.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.00	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
4	4.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.00	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
5	5.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.00	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
6	5.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.25	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
7	5.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.25	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
8	5.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.25	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
9	5.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.25	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
0	5.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.25	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
1	5.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.25	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01
2	5.00	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	8.05	1.25	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	2.01

Figure 10.5

Figure 10.6


Response to supply shock with no choice of factor markets
Product price
Material price
Gross profit
Net profit
factor price shock
higher initial net profit
time

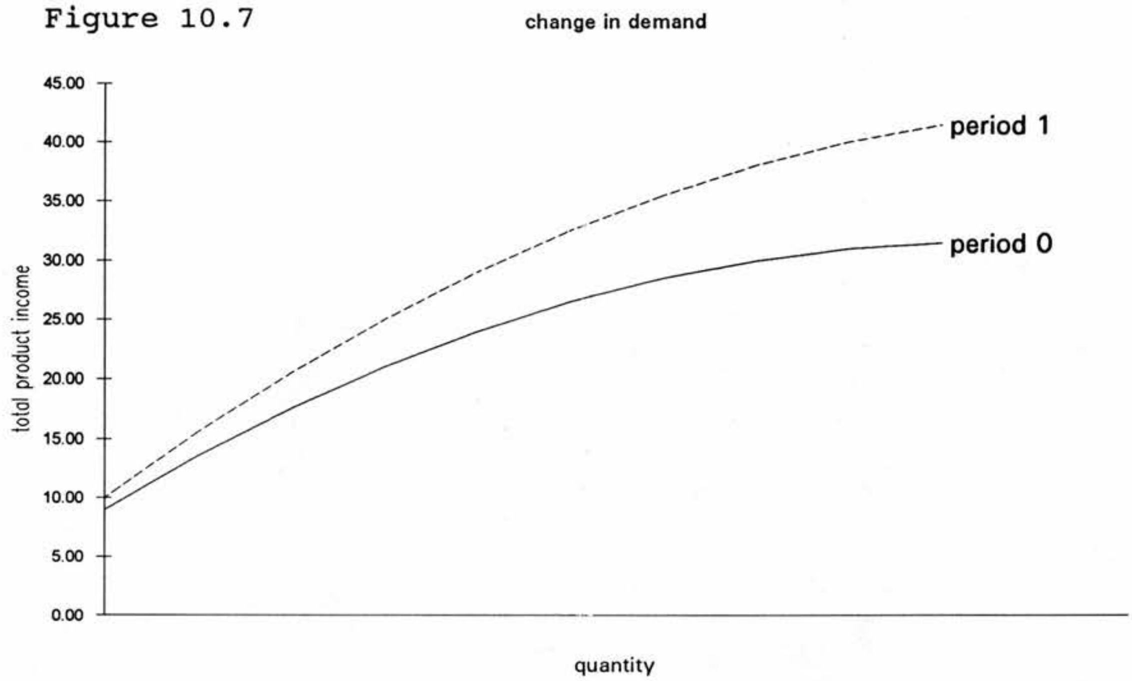
To reflect the lower costs of operating in a smaller number of factor markets the overhead cost is reduced. This is done by a change to a coefficient in the control section CONTROL.XLS.

10.27 The output from the model for the inflexible firm, which has not provided itself with a choice of sources for its material, but instead has lowered its observation overheads, is shown in figure 10.6. As in the previous case, Figure 10.6 shows, in the form of a graph with time on the horizontal axis, and monetary value on the vertical axis, the values of the four variables over time periods -24 to + 23. For comparison purposes, unit product price and unit material price are shown on the same graph as total gross profit and net profit. The values prior to period 5 output from the model are subject to similar fluctuations arising from the various observational and random error terms in the model. However, because the less flexible firm has lower overhead costs, its net profit is higher, i.e. nearer to the gross profit, than the previous example. The increase in the unit price the firm pays for material, noted by the arrow, again occurs at period 5. The reduction in quantity produced also occurs, as the firm adjusts to the new supply situation. This is shown on the graph as a small increase in the product price obtained. As a result of the change the gross profit falls. This change occurring in the gross profit exceeds the tolerance parameter and the factor market choice is recalculated. No alternative exists which would result in a lowering of material cost within the present observation range. therefore no further change takes place and the firm continues at the lower net profit level.

An illustration of response flexibility.

10.28 The next two sets of output from the model illustrate response flexibility. A demand shock for product market 1 is entered into the model at time period 1. This is given effect by changing part of the array of demand variables held in EXOGEN.XLS. The array of cells B3 - AE50 hold these values for periods -24 to +23 for ten possible product markets. The values held in column B3 to B50 give the price for product market 1 at the base of the quantity range. The demand shock is effected by increasing from 5.5 to 6.50 the value in cells B27 - B50. This represents a permanent rise at all levels above the base of the observed quantity range.

Figure 10.7



	A	B	K	L	U	V	AE
1	Demand	c		m		C	
2	t	1	10	1	10	1	10
3	-24	5.50	5.00	-5.00	-5.00	4.00	0.00
26	-1	5.50	5.00	-5.00	-5.00	4.00	0.00
27	0	5.50	5.00	-5.00	-5.00	4.00	0.00
28	1	6.50	5.00	-5.00	-5.00	4.00	0.00
29	2	6.50	5.00	-5.00	-5.00	4.00	0.00
30	3	6.50	5.00	-5.00	-5.00	4.00	0.00
31	4	6.50	5.00	-5.00	-5.00	4.00	0.00
32	5	6.50	5.00	-5.00	-5.00	4.00	0.00
33	6	6.50	5.00	-5.00	-5.00	4.00	0.00
34	7	6.50	5.00	-5.00	-5.00	4.00	0.00
35	8	6.50	5.00	-5.00	-5.00	4.00	0.00
36	9	6.50	5.00	-5.00	-5.00	4.00	0.00
37	10	6.50	5.00	-5.00	-5.00	4.00	0.00
38	11	6.50	5.00	-5.00	-5.00	4.00	0.00
39	12	6.50	5.00	-5.00	-5.00	4.00	0.00

Figure 10.8

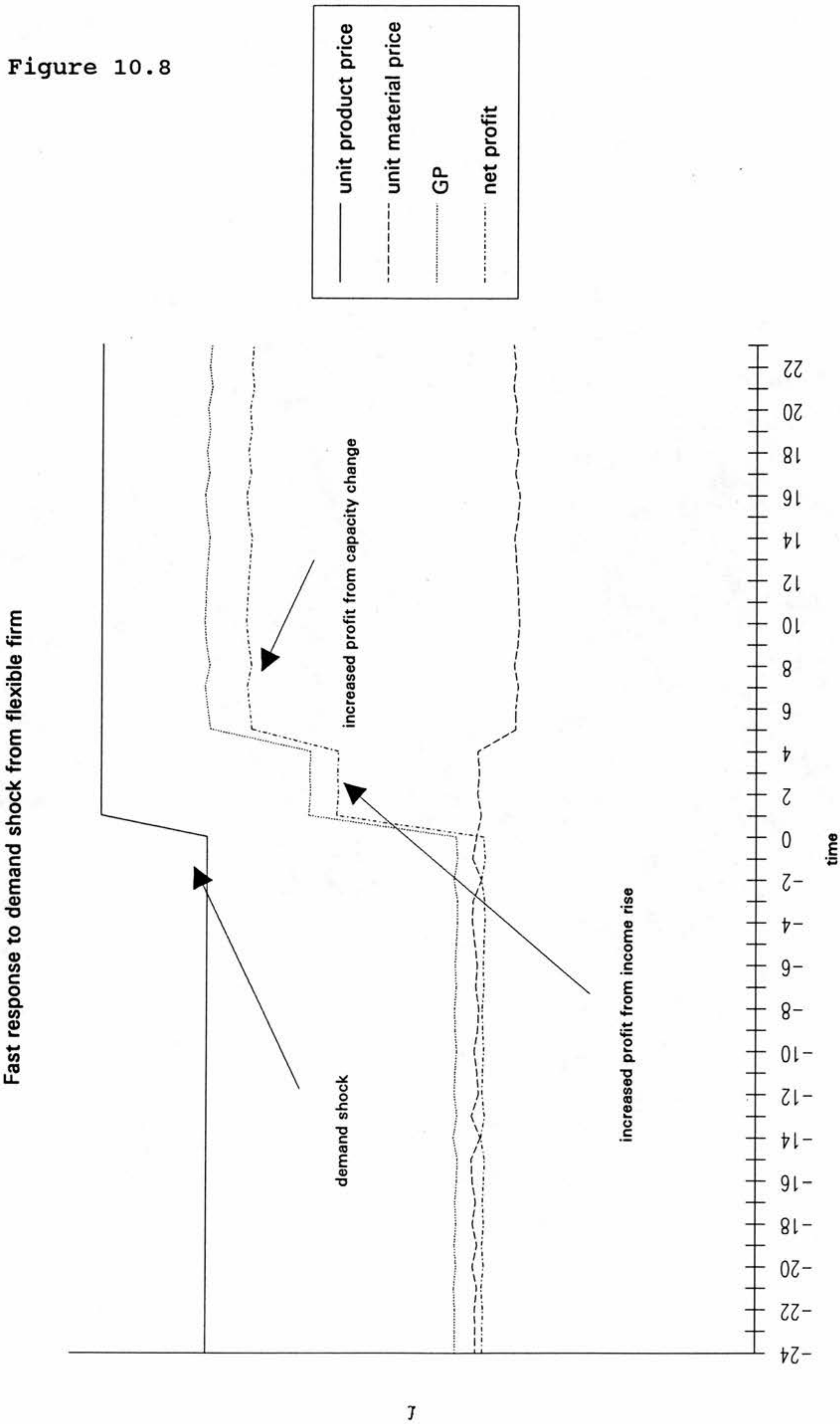
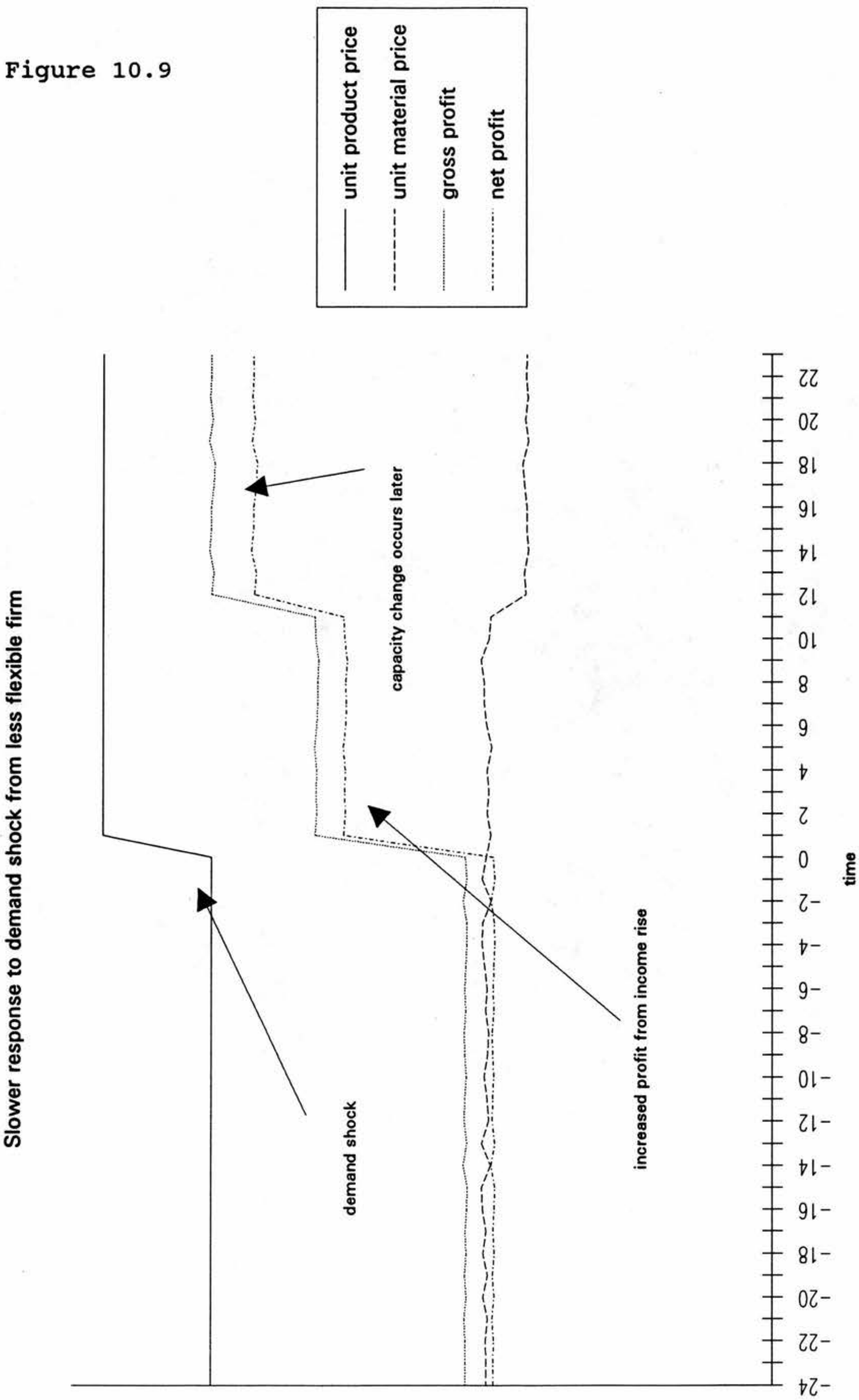

Fast response to demand shock from flexible firm
unit product price
unit material price
GP
net profit
increased profit from capacity change
increased profit from income rise
demand shock
time
-24
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22

Figure 10.9


Slower response to demand shock from less flexible firm
unit product price
unit material price
gross profit
net profit
capacity change occurs later
increased profit from income rise
demand shock
time
-24
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22

10.29 Two firms are again considered. The first firm is able to change its plant in four periods, whilst the second firm takes eleven. The lead time to change plant is entered into cell B55 of PLANTFIN.XLS. Figure 10.8 shows the output for the first firm, and figure 10.9 shows the output for the second firm. Product price falls at period 5 and the firm makes increased profits from the higher product price, and a small increase in output. A small reduction in the material price occurs as output increases. The resulting change occurring in the output exceeds the tolerance parameter and the factor plant capacity choice is recalculated. An increase in capacity occurs as a result. The increase in capacity is selected after four periods in the case of the first firm, and eleven periods in the case of the second firm. The capacity and output levels assume new values in subsequent periods. The resulting values are sufficiently close to the target values and no further changes are made.

10.30 The same example can be extended to show the effects of a transient, rather than a permanent demand shock, in a flexible and an inflexible firm. Figures 10.10 and 10.11 illustrate this.

Figure 10.10

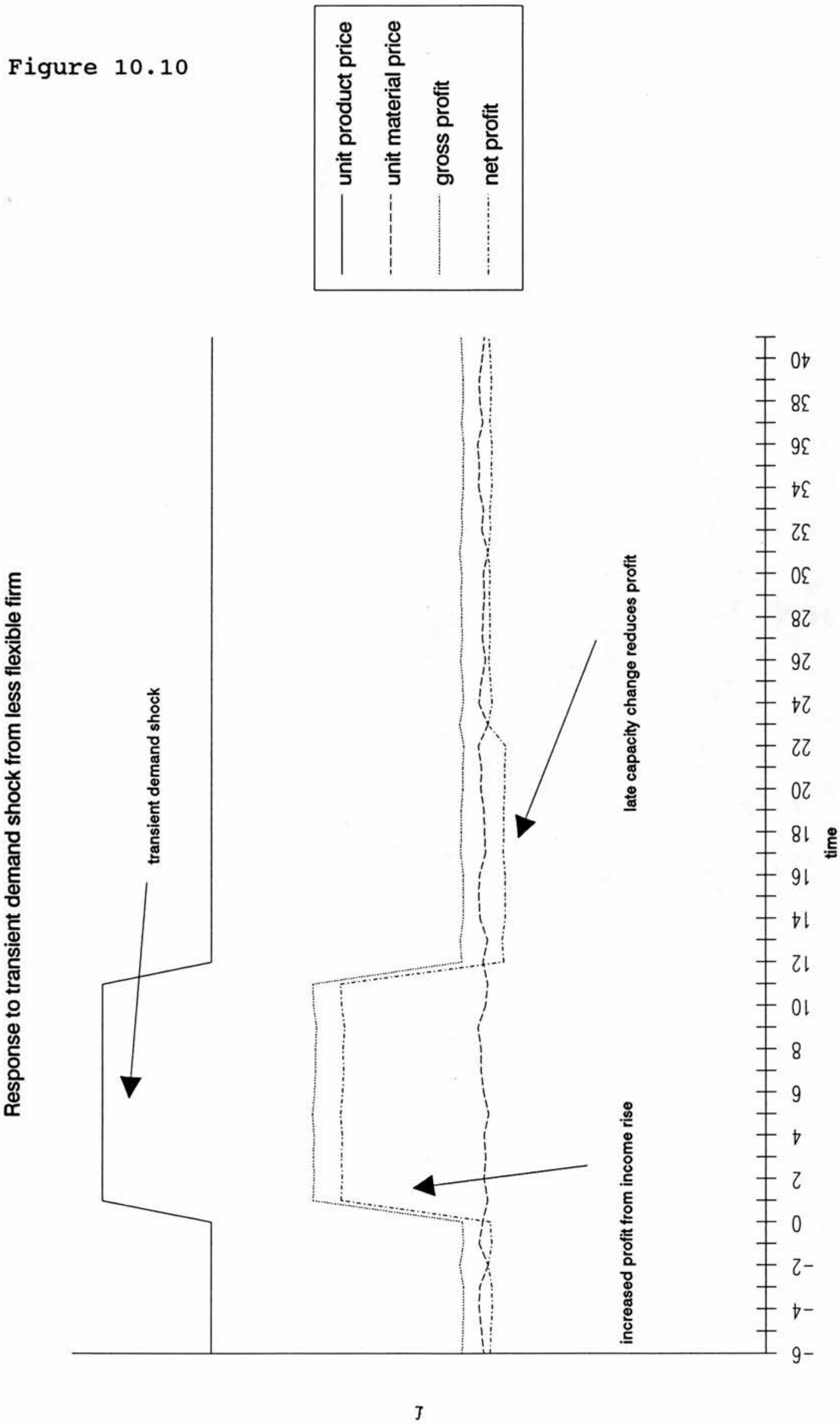
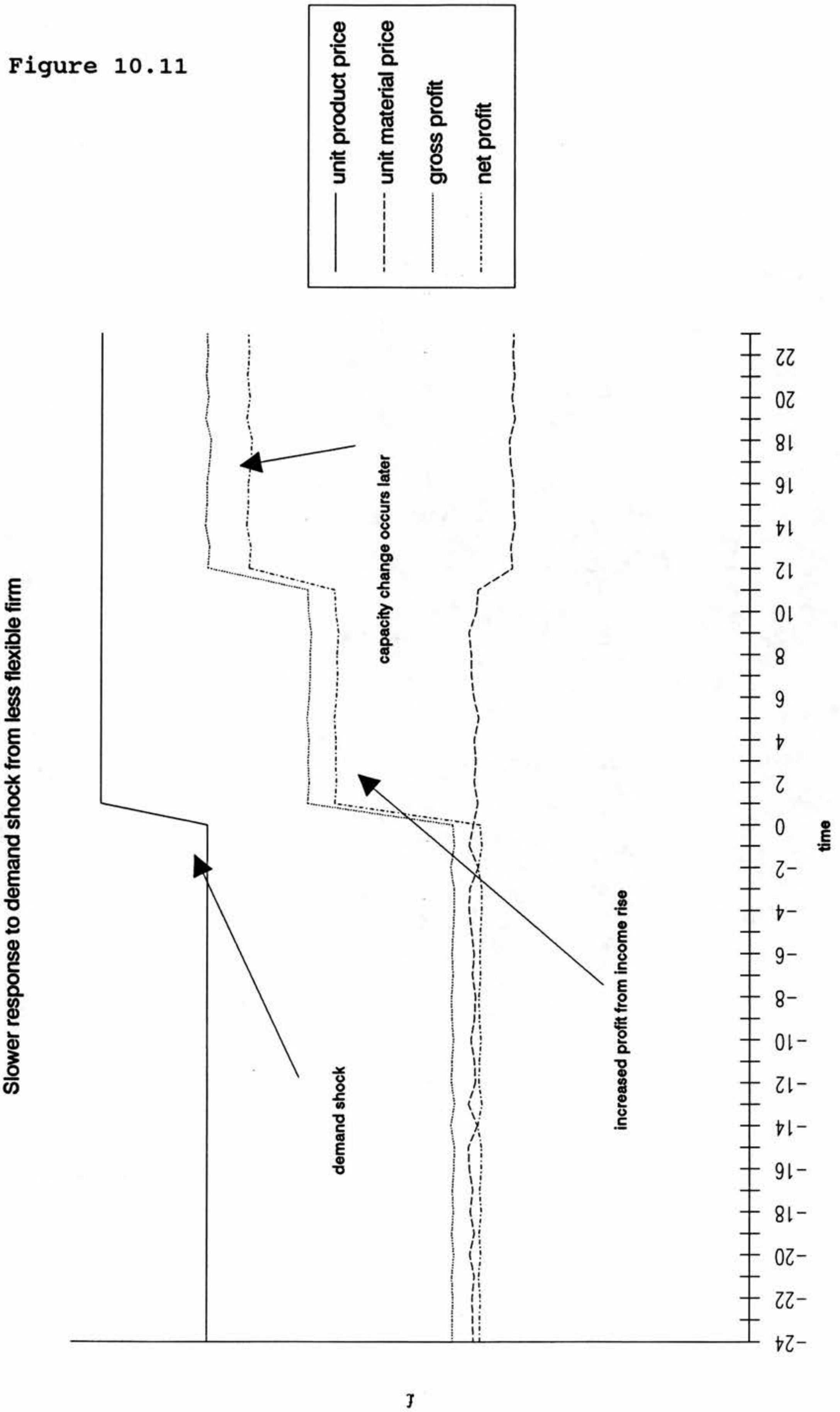

Response to transient demand shock from less flexible firm
unit product price
unit material price
gross profit
net profit
transient demand shock
late capacity change reduces profit
increased profit from income rise
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
time
£

Figure 10.10 illustrates the same demand shock experienced by a flexible firm, but this time the level of demand as reflected by the unit product price returns to its original level at period 12. During periods 1 to 11, the firm follows the same course. It is not aware that the shock is transient and so behaves identically. In period 12 demand reverts to the original level and the immediate response is for output, and variable costs to do the same. Because the firm has adjusted its plant to reflect the upward shift in demand, it now has excess capacity. The net profit is therefore lower than before the demand shock. However, the flexible firm adjusts its capacity back to the original level within a short time, and from period 17 onwards is once again operating at a stable optimum position. It should be noted that the plant change lag in the model does not change according to whether capacity is increased or decreased. This may not be altogether representative or the real position. George Stigler (1939) points out that costs of changing plant may depend upon what particular plant is currently installed. This point can be extended. The lead time to replace or modify plant will depend upon what the plant is currently. More particularly, when a reduction in plant capacity is required, the lead time may be more than that when an increase is required. Output will fall, but a variety of behavioural factors are likely to delay capcity reduction.

Figure 10.11


Slower response to demand shock from less flexible firm
unit product price
unit material price
gross profit
net profit
capacity change occurs later
demand shock
increased profit from income rise
£
time
-24
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22

The case of the inflexible firm responding to a transient demand shock is illustrated in figure 10.11. The same demand changes occur, but because the firm is slow to change plant, it is unable to benefit at all from the opportunity to increase capacity. Similarly, because it takes longer to reduce capacity, following the reversion of demand to its original level, the net profit remains lower for longer, and the firm does not return to the optimum position until period 22.

Conclusion.

10.31 The object of this chapter has been to assess the dynamic model using a method proposed by Paul Samuelson. Its aim has been to show that an empirically grounded behavioural model of a fish processor, based upon Herbert Simon and Richard Cyert's theories may be formally described and may be represented by a set of computer software. The chapter has been concerned with showing that changes to the forces acting upon the firm can be represented in the model and made to follow closely the behaviour of the firms themselves, thus grounding the model firmly in specific industrial experience. This has been achieved by selecting individual exogenous changes and tracing through the detailed path. Other behavioural aspects, may be fitted into the same framework, although not explicitly modelled in the sheets illustrated. The complexity of behavioural systems highlighted by Herbert Simon, and the complexity of dynamic models highlighted by Paul Samuelson, can be represented using the representational methods described in chapters 6 - 8, and can be grounded in empirical experience using the empirical methods described in chapters 4 and 5. Samuelson has said, in the work referred to at the start of this chapter, (Samuelson 1983 page 353), there are numerous ways in which we can choose to describe the results of the behaviour of a dynamic system. As noted in chapter 7 above, Cyert states that difficulties in the analysis of software results increase greatly as complexity is introduced (Cyert 1988 p 215). Samuelson's agenda for the analysis of the model has therefore been followed through the use of a series of examples.

PART IV
CONCLUSION

Chapter 11 Conclusions.

Introduction.

11.1. What are the conclusions to be drawn from the research? This chapter endeavours to evaluate and summarise the findings of the project. The three contributions made by the research are: *(1) New insights into flexibility within the firm; (2) Verification of the usefulness of the behavioural model as a method for representing the complexity in firms; (3) Development of innovative but highly practical procedures for data gathering and representation.*

11.2. Several general themes running through the research have also hopefully contributed to its value, and it is worthwhile giving them brief consideration in this introductory section, before proceeding to a fuller analysis of the three principal results. The first of these general themes has been the desire for interchange between different fields of knowledge. Much value can be gained by placing formal experience gained in the business field into the domain of economics, and vice versa. This is not simply a matter of empiricism, or merely a transfer of passive data to be analysed. Economics has frequently found common ground with the physical sciences at a theoretical level, for example in Alfred Marshall (1890) and Herbert Simon (1962).

Economics has shared methodological approaches with other social sciences, for example Gavin Reid (1986). The frequently sophisticated methods used both for gathering and interpreting information in business may similarly contribute to economic methodology. The second general theme running through the research is its emphasis on small firms. Their variety, innovativeness, or contribution to the economy as a whole has not been the explicit object of study in this research, but these attributes are certainly buttressed by the research. The enthusiasm of Michael Porter (1983, 1985), or Peters and Waterman (1982) for the contribution which corporate business makes to broader economic activity, is clear throughout their work. In the same way, the present work is underpinned throughout by a confidence in the importance of the workings of small business for the economy in general. The last general theme which has been present throughout the research is the relevance of economic principles not just to the general set of firms as a whole, nor even to the Marshallian representative firm, but directly to each individual firm in its day to day operations. The process of abstraction, so necessary to the formulation of concise theory, should not deter economists from putting forward individual and specific applications of theory, to complement the contribution of economics on a wider scale.

New insights into flexibility in the firm have been gained.

11.3. Turning now to the first of the three specific conclusions to be drawn from the research, it is appropriate to ask why flexibility is important. Firstly, what does flexibility mean. It means the ability to adapt to change. More specifically, it is the ability to seek out a niche market *before* competitors, the ability to adopt technical innovations quickly, the ability to accommodate surplus or shortage more profitably. In short flexibility is the ability to recognise external changes and exploit them more quickly than competitors.

In my view, flexibility is important because it is to a degree a measure of the dynamics of firm growth and decline, which are themselves driven by change. Without change, there is no dynamic behaviour, and without dynamic behaviour, there is no flexibility. "*All is flux, nothing remains the same*" [1] as much typifies the individual small firm's behaviour as the somewhat contrary "*Natura non facit saltum*" [2] typifies the behaviour of the generality of firms. In a stable environment, the ability to mould the organisation into a

1 Heraclitus of Ephesus c. 540 - 475 BC

2 Alfred Marshall 1842 - 1924

form which maximises a particular function, be it profit or some other measure, requires only that the firm is able to take account of stable exogenous variables. The values of such stable variables can be repeatedly observed, providing the basis for minimising, by an iterative procedure, the divergence between optimum value of the function, and the actual value achieved by the firm. In a changing environment, the optimum in one period may differ greatly from the optimum in the next. The notion of a divergence between a single period optimum and a multi-period optimum becomes less important than the ability to adjust from period to period. Maximising by the choice of a function which is a time series replaces maximising by the choice of a variable over a single period. Effects such as economies of scale are subsumed under a more comprehensive notion of economies of fit incorporating flexibility. Size of plant may be the key decision in one group of firms, representing economies of scale. In a different environment, a second group of firms may be faced with product combination as the key decision, representing economies of scope. In yet another environment, a third group of firms may have as their key feature the ability to adapt, representing flexibility economies. External change is important, and flexibility measures how well firms adapt to change. Flexibility is what distinguishes the optimal firm in a stable environment from the optimum firm in a changing environment. Firms are subject to many changes in today's industrial economies. Flexibility, the measure of adaption to change, is thus at the heart of current industrial economics.

11.4. If flexibility is important, how can it be analysed? Theorists in the past have interpreted flexibility as a sort of dynamic choice. They have represented flexibility in terms of a set of alternative options which the firm can take up once it has observed the exogenous change. Thus Stigler (1939), considers as relatively flexible the plant for which one *could* choose from a wide range of outputs rather than a narrow range, without detriment to "tolerable efficiency". Mandelbaum and Buzacott (1990) consider a strategy flexible if it produces a wide, rather than a narrow set of options for the firm to choose from subsequently. What this research would suggest is that the choice element is only one of two essential flexibility characteristics. The other, is the speed with which the choice can be implemented, and it is of equal importance. Furthermore, behavioral components which contribute to this speed of response in turn are important. A plant which can operate with tolerable efficiency over a wider output range *is* flexible, but *only if* the change from one output level to the next can be accomplished at the same rate as the exogenous change itself, *and only if* the change is observed promptly.

11.5. Setting temporarily on one side the behavioural aspect of the firm, and examining flexibility from other theoretical perspectives, the research has presented several alternative views. Taking a marginalist perspective, it has put forward the view that flexibility may be represented by the ratio of variable factor costs to fixed factor costs present in any particular production process. It has shown that flexibility of production may be represented in a similar way to scale of production when analysing the long term. Lastly, it has noted that some of the economies of scope realised by having alternative products are also flexibility features. They are examples of choice flexibility. The research has also viewed flexibility from a transaction cost perspective. In the same way that markets and contracts may be used as alternative means of economising on transaction costs, determining which activities are internal to the firm and which external, so too flexibility may be implemented through the choice of transacting method. Contracts may provide different degrees of flexibility to the firm, as well as different levels of flexibility. Therefore their choice of contract, and through this the scope of activities of the firm, may be determined by considerations of flexibility.

11.6. Returning to the behavioural context, the research puts forward three parameters of flexibility which can be observed in the firm's behaviour. These parameters are: (1) the existence and magnitude of behavioural lags; (2) the accuracy of information gathering and expectations; and (3) the appropriateness of responses to change. The existence and magnitude of behavioural lags determine the rate of response to exogenous change. The frequency of observation of performance in relation to targets involves one such behavioural response. The small firm which monitors its profits yearly is becoming rare. Monthly or quarterly financial statements will identify required adjustments more quickly. Direct observation of the exogenous variables themselves involves another behavioural lag. More frequent checks on price levels in product and factor markets clearly fall into this category. Less obviously, the frequency of assessment of technological changes, and monitoring of supplier, customer and competitor performance will also affect the speed with which significant exogenous shocks may be recognised. With Stigler (1939), this research recognises that flexibility has a cost. The more stable the environment, the less is there a requirement for rapid adjustment, and the more efficient is the firm with minimal observation costs. Put another way, the more changeable the environment, the more justifiable are the increased costs of more frequent observation. The speed with which decisions are implemented involves another behavioural lag. The speed with which decisions are implemented, setting aside physical constraints, depends upon the organisational structure. The size of the firm, or more specifically the length of the control loop which links observation to decision, and decision to action, is a key element here. A second element is the extent to which, following the analysis of Harold Demsetz (1988), the decision implementation is capable of being motivated by a co-operative team structure. This may be the source of a widely encountered view, which is difficult to explain in any other terms, that small owner-managed firms are more flexible, or "quicker on their feet", etc, than larger enterprises like publicly quoted corporations.

11.7. It is not surprising that the accuracy of information gathering and expectations should have a major rôle to play as a parameter for flexibility, given the importance which the economics of information has for industrial economics as a whole. The key point for the analysis of flexibility is that, whatever the general significance of the costs of information to the firm, that significance is greater when there is greater fluctuation in the firm's environment. For example, if information asymmetry is an important determinant of industry structure, then it will be more important in an industry subject to exogenous change. If a firm's expectations are an important determinant of its price and output, then that importance is enhanced in a changeable environment. As with the frequency of observation, achieving accuracy is not done without cost. The same economising process will be followed, and frequent change will be better handled by those firms willing and able to incur the higher costs of achieving accuracy in information gathering and forecasting. The same general points can be made concerning the third parameter of behavioural flexibility, the appropriateness of response. It is almost self-evident that the firm will acquire resources of judgement and skill in the same way that it acquires any other factor. But with flexibility come specific resources of judgement and skill attuned to the particular exogenous changes and their effects on the firm. Although not directly measured by the empirical survey, the entrepreneurial skills exhibited by the fish processing owner managers were qualitatively different from those in, for example, engineering or tourism. Some part of that qualitative difference can be attributed to the need for constant adjustment of prices, output, and factor inputs, etc, in order to cope with exogenous shocks.

The usefulness of the behavioural model has been verified as a method for representing the complexity in firms.

11.8. *"if the world of competition is very complicated, then excesses of simplification are to be avoided. Industrial economics has simply moved beyond an 'oversimplification' threshold"* Oliver Williamson (1990 p. xv) In economic theory there is a trade-off between conciseness of theoretical representation, and depth of application. What Oliver Williamson is saying, in his introduction to the collection of papers on industrial organisation, is that simple, concise, and perhaps more elegant, models are of less value, because there is a requirement to apply the conclusions of such models at a deeper, more specific level. A requirement for complex solutions implies complex problem statements. Milton Friedman (1953) states that detailed empirical assumptions are not necessary for a valid theory. Provided that the predictive power of the theory is acceptable, the theory is valid. However, if the theory is required to make predictions at a lower level than the whole economy, or major sectors, then the behavioural approach can be justified, not merely because of its empirical assumptions, but because of the detailed intra-industry predictive ability required of the theory. As Porter (1980, 1985) has demonstrated, there is a need for industrial economics to be applied to complex intra-industry, and in some cases, single firm problems. At this level of complexity the marginalist model can offer more limited general predictions about behaviour external to the firm. The behavioural model, although less concise and elegant, can explain and predict the behaviour of the specific mechanisms which policy is required to address.

11.9. The present research has demonstrated the value of the behavioural model in representing the complex issues involved with flexibility. It has considered flexibility in behaviouralist terms, and it has also contrasted this with the marginalist analysis of Stigler. If validity of theory is measured by predictive ability, then the practical value of the flexibility predictions of the two approaches should be compared. A model based upon relative convexity of unit cost curves needs considerable interpretive processing before its predictions can be applied to individual cases. The predictions of the behavioural model of flexibility, expressed in terms of speed of response, frequency of observation, etc, can, on the other hand be directly applied. This is not to undervalue the application which marginal models may have to *some* aspects of individual firm activity, notably economies of scale, which may be readily applied directly. Rather, this thesis would argue that both approaches are justifiable, but in different applications. In the present research, which endeavours to make predictions at an intra-industry and individual firm level, the behavioural model has been demonstrated to have advantages. In particular, the research demonstrates the use of computer techniques to overcome the inherent complexity of a behavioural analysis. It shows how one might use the resulting model to explore possible responses of firms to exogenous shocks, and to investigate and explain the variety of behaviour exhibited by relatively small groups of firms in the face of common external influences.

Innovative but highly practical procedures for gathering data and representation have been used.

11.10. "*We know of no obviously optimal procedure for gathering information that exists inside firms or inside consumers' heads. Nevertheless, this is the kind of information that economists desire and that computer models can readily handle*" K J Cohen and R M Cyert (1961). These optimistic closing comments, reprinted as the final appendix of Richard Cyert and James March's (1963) "Behavioural Theory of the Firm" were written within two decades of the introduction of general purpose digital computers. The three subsequent decades have seen a phenomenal growth in the power and availability of computer resources. The desire of economists for behavioural information has also increased, as evidenced by the quotation from Oliver Williamson referred to in paragraph 10.8 above. Whether the increased supply of computer resources and the increased demand from economists for data handling, has been matched by a similar increase in the use of computers for economic theory purposes, is not a question this research can answer. However, the project has itself made use of the available technology throughout. The computer use covered the entire gamut of research activity, from the detailed time scheduling of the research, through the survey documentation, distribution, and analysis, to the report production. The computer skills used were available at no pecuniary cost. Also available were business skills in information gathering, gained from formal training and extensive experience. The project was an exercise in applying the author's computer and business interviewing skills, for no other reasons than to solve the practical and substantial personal resource problems encountered. A fortunate by-product of this necessity, has been the resulting innovative aspects of the methodology. These are: firstly, systems of linked spreadsheets used as a behavioural modelling tool; and secondly, survey techniques designed to minimise subjective bias based upon management interviewing principles. The spreadsheet approach enabled close empirical links to be established both at the practical level and at the conceptual level. Existing firm's spreadsheets could contribute directly to the model. Because of the spreadsheet approach, it was not necessary for the form of model to be highly abstracted away from the information systems used by the firms themselves. These two features should be sufficient to justify the inclusion of advanced spreadsheet techniques in the methodological toolkit of the industrial economist. The benefits gained from the questionnaire style are aimed at securing data at the microanalytic level. This follows Herbert Simon's (1984) reasoning that improved data resolution is preferable to greater statistical sophistication as a means of eliminating the effects of error.

Summary.

11.11. In summary, the research set out to analyse flexibility in the industrial economics domain. Subsidiary aims were to establish the relevance of the behavioural model to the analysis of flexibility, and to present the model in a computable form. The research task sought out a suitable empirical source for flexibility, and established from this source the grounding of a behavioural economic analysis. This economic analysis gave useful insights into the nature of flexible behaviour and showed how it may be categorised and described. Lastly the research task enabled the testing of two innovative research methods. The value of the findings is to be measured by their contribution to knowledge in industrial economics, by their contribution

to knowledge within the firms themselves, and by their contribution to the author's knowledge.

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Appendix 1. the survey questionnaire.

Industrial Organisation Survey.

s questionnaire is designed to obtain data on the decision making methods and the information you have used whilst forming a senior executive role within a business The data will be used solely for the purposes of academic research, and dentification data will be used other than to control the documents. Your responses will contribute to a research project g undertaken at Edinburgh University. The aim is to improve our knowledge of how companies such as yours actually orm in the real world. This will in turn enable those not directly involved with your industry to make better informed gements about its performance.

questions are intended to be answered quickly. Your co-operation is vital to the success of the project and the few minutes kes to complete the form will be much appreciated.

ction 1

General Data.

1.1 Name of respondent

1.2 Company concerned and position

1.3 Industry 1.4 Period of analysis *Sept 88 - Sept 90*

1.5 Major enterprises/ profit centres

A. % by value:

B. % by value:

C. % by value:

1.6 Company size

Markets.

1.7 Where were your main markets for your principal enterprise:

(a) % by value:

(b) % by value:

(c) % by value:

Activities.

1.8 What principal activities were involved:

(a) % by no. of staff
% by value of fixed assets (plant buildings & equipment) used

(b) % by no. of staff
% by value of fixed assets used

(c) % by no. of staff
% by value of fixed assets used

ction 2 Unexpected external changes.

Demand shocks during the last two years:

(a) Was there any unexpected major change in demand for any product group?

(b) Did demand increase or a decrease

(c) When did this occur?

(d) What action was taken in response?

(e) How soon afterwards was the decision taken?

(f) At what level was the decision taken?

(g) In response to what specific information?

(h) What other options were considered?

(i) Why were these rejected?

(j) How long did it take from decision to fully changed operation?

Raw material supply shocks during the last two years:

(a) Was there any unexpected major change in raw material supply for any product group?

(b) Did supply increase or decrease

(c) When did this occur?

(d) What action was taken in response?

(e) How soon afterwards was the decision taken?

(f) At what level was the decision taken?

(g) In response to what specific information?

(h) What other options were considered?

(i) Why were these rejected?

(j) How long did it take from decision to fully changed operation?

3 Labour supply shocks during the last two years:

(a) Was there any unexpected major changes in labour availability for any process?

(b) Did labour availability increase or decrease.

(c) When did this occur?

(d) What action was taken in response?

(e) How soon afterwards was the decision taken?

(f) At what level was the decision taken?

(g) In response to what specific information?

(h) What other options were considered?

(i) Why were these rejected?

(j) How long did it take from decision to fully changed operation?

4 Technology shocks during the last two years:

(a) Did any major technology changes occur in the last two years? (eg new processes, machine designs, transportation systems)

(b) What was the nature of the change

(c) When did this occur?

(d) What action was taken in response?

(e) How soon afterwards was the decision taken?

(f) At what level was the decision taken?

(g) In response to what specific information?

(h) What other options were considered?

(i) Why were these rejected?

(j) How long did it take from decision to fully changed operation?

ction 3 **What information did you obtain or use during the last 2 years?**

circle frequency as appropriate

(a)	Sales quantity	daily weekly monthly quarterly annually
(b)	Sales value	daily weekly monthly quarterly annually
(c)	Gross profit	daily weekly monthly quarterly annually
(d)	Raw material quantity	daily weekly monthly quarterly annually
(e)	New order value	daily weekly monthly quarterly annually
(f)	Outstanding order value	daily weekly monthly quarterly annually
(g)	Outstanding order quantity	daily weekly monthly quarterly annually
(h)	Stock quantity	daily weekly monthly quarterly annually
(i)	Stock value	daily weekly monthly quarterly annually
(j)	Production quantities	daily weekly monthly quarterly annually
(k)	Material costs	daily weekly monthly quarterly annually
(l)	Labour costs	daily weekly monthly quarterly annually
(m)	Plant costs	daily weekly monthly quarterly annually
(n)	Overhead costs	daily weekly monthly quarterly annually
(o)	Competitors or market prices	daily weekly monthly quarterly annually
(p)	Estimates of future market size	daily weekly monthly quarterly annually
(q)	Estimates of future sales	daily weekly monthly quarterly annually
(r)	Estimates of future profits	daily weekly monthly quarterly annually
(s)	Estimates of technology developments	daily weekly monthly quarterly annually
(t)	Industry material prices	daily weekly monthly quarterly annually
(u)	Industry or competitor profitability	daily weekly monthly quarterly annually
(v)	Industry labour rates	daily weekly monthly quarterly annually
(w)	Net profit before tax	daily weekly monthly quarterly annually
(x)	Net profit after tax	daily weekly monthly quarterly annually
(y)	Net worth	daily weekly monthly quarterly annually
(z)	Return on capital employed	daily weekly monthly quarterly annually

Which are the three most important figures you use daily, weekly, monthly, quarterly or annually; place the figures 1, 2, 3 against the circles above.

ction 4 *(completed for the principal enterprise)*

1 Enterprise selection decisions.

(a) When was the decision taken to start this particular enterprise?

(b) What events prompted the decision?

(c) What specific data did you have available? (Enter references from section 3 above)

(d) When did the events prompting the decision occur?

(e) How long did it take from decision to full operation?

2 Pricing decisions

(a) When was the last decision taken to change the price levels for this enterprise?

(b) What events prompted the decision?

(c) What specific data did you have available? (Enter references from section 3 above)

(d) When did the events prompting the decision occur?

(e) How long did it take from decision to implementation of the change?

(f) How often were price levels reviewed?

Hourly Daily Weekly Monthly

(g) What have been the principal reasons for changes in price levels

i. Demand fluctuations

ii. Raw material supply fluctuations

iii. Production capacity changes

iv. Changes in marketing effort

3 Marketing decisions

(eg advertising spend, number of sales staff)

(a) When was the last decision taken to change the marketing effort?

(b) What events prompted the decision?

(c) What specific data did you have available? (Enter references from section 3 above)

(d) When did the events prompting the decision occur?

(e) How long did it take from decision to implementation of the change?

(f) How often was the level of marketing effort reviewed?

Hourly Daily Weekly Monthly

(g) What were the principal reasons for changes in marketing effort

i. Demand fluctuations

ii. Raw material supply fluctuations

iii. Production capacity changes

4 Physical capacity change decisions

(e.g. buildings, process plant)

(a) When was the last decision taken to change the capacity for this process?

(b) What events prompted the decision?

(c) What specific data did you have available? (Enter references from section 3 above)

(d) When did the events prompting the decision occur?

(e) How long did it take from decision to implementation of the change?

(f) How often was the physical capacity reviewed?
Hourly Daily Weekly Monthly

.5 Product quantity decisions

(a) When was the last decision taken to change the amount produced by this enterprise?

(b) What events prompted the decision?

(c) What specific data did you have available? (Enter references from section 3 above)

(d) When did the events prompting the decision occur?

(e) How long did it take from decision to implementation of the change?

(f) How often was production quantity reviewed?

Hourly Daily Weekly Monthly

(g) What is the current output of the enterprise expressed as a percentage of the maximum capacity?

(h) For how long has the enterprise been running at that level?

(i) What is the lowest output the enterprise has run at during the last two years, excluding holidays etc?

(j) What is the highest output the enterprise has run at during the last two years, excluding holidays etc?

(k) What have the principal reasons been for changes in production levels

i. Demand fluctuations

ii. Raw material supply fluctuations

iii. Staff availability

iv. Plant down-time

6 Staff hours

(a) When was the last decision taken to change the staff hours?

(b) What events prompted the decision?

(c) What specific data did you have available? (Enter references from section 3 above)

(d) When did the events prompting the decision occur?

(e) How long did it take from decision to implementation of the change?

(f) How often were staff hours reviewed?

Hourly Daily Weekly Monthly

.7 Staff numbers

(a) When was the last decision taken to change the staff numbers?

(b) What events prompted the decision?

(c) What specific data did you have available? (Enter references from section 3 above)

(d) When did the events prompting the decision occur?

(e) How long did it take from decision to implementation of the change?

(f) What is the current staffing of the enterprise.

(g) For how long has the enterprise operated at that staff level.

(h) What is the lowest staffing level for the enterprise during the last two years, excluding holidays etc.

(i) What is the highest staffing level for the enterprise during the last two years, excluding holidays etc.

(j) How often were staff numbers reviewed?

Hourly Daily Weekly Monthly

ection 5 *(completed for the principal production activity)*

.1 Asset flexibility.

(a) Has the same plant been used for different products during the last two years?

If so what were they i. % of total output during that period?

ii. % of total output during that period?

iii. % of total output during that period?

iv. % of total output during that period?

(b) When was the last decision taken to change the type of product produced by this process?

(c) How long did it take from decision to implementation of the change?

(d) How are your production assets funded? (eg purchase, lease, short term hire)

(e) Is ability to change plant a significant factor in your choice of financing even if it increases your plant costs?

.2 Staffing flexibility.

(a) Have the same staff been used for different tasks during the last two years?

If so what were they i. % of total output during that period?

ii. % of total output during that period?

iii. % of total output during that period?

iv. % of total output during that period?

(b) When was the last decision taken to change the tasks undertaken by one or more staff?

(c) How long did it take from decision to implementation of the change?

(d) How are your staff paid? (eg fixed hourly rate, piece work, profit bonus)

(e) Is ability to change staff tasks a significant factor in your staffing plan even if it increases your staff costs?

Appendix 2 Questionnaire Response Coding

1:1	Communication purposes only
1:2	Check to ensure right respondent
1:3	Possible future use
1:4	Possible future use
1:5	1 = Fish Processing only, 2 = Main enterprise, 3 = Secondary enterprise
1:6	1 = uses Turnover, 2 = uses Employment, 3 = uses Small, medium, large
1:7	1 = local, 2 = UK, 3 = export, 4 = mixed
1:8	1 = differentiated by process, 2 = differentiated by product, 3 = not differentiate
2:1:1	1 = yes, 2 = no
2:1:2	1 = increase, 2 = decrease, 3 = both
2:1:3	Month No, September 1988 = 1
2:1:4	Action code
2:1:5	days, week = 7, year = 365, month = year/12, immediate = 1
2:1:6	1 = self, 2 = below, 3 = above
2:1:7	Source code
2:1:8	Action code
2:1:9	Source code
2:1:10	days, week = 7, year = 365, month = year/12, immediate = 1
2:2:1	1 = yes, 2 = no
2:2:2	1 = increase, 2 = decrease, 3 = both
2:2:3	Month No, September 1988 = 1
2:2:4	Action code
2:2:5	days, week = 7, year = 365, month = year/12, immediate = 1
2:2:6	1 = self, 2 = below, 3 = above
2:2:7	Source code
2:2:8	Action code
2:2:9	Source code
2:2:10	days, week = 7, year = 365, month = year/12, immediate = 1
2:3:1	1 = yes, 2 = no
2:3:2	1 = increase, 2 = decrease, 3 = both
2:3:3	Month No, September 1988 = 1
2:3:4	Action code
2:3:5	days, week = 7, year = 365, month = year/12, immediate = 1
2:3:6	1 = self, 2 = below, 3 = above
2:3:7	Source code
2:3:8	Action code
2:3:9	Source code
2:3:10	days, week = 7, year = 365, month = year/12, immediate = 1
2:4:1	1 = yes, 2 = no
2:4:2	1 = cost, 2 = product differentiation, 3 = both
2:4:3	Month No, September 1988 = 1
2:4:4	Action code
2:4:5	days, week = 7, year = 365, month = year/12, immediate = 1
2:4:6	1 = self, 2 = below, 3 = above
2:4:7	Source code
2:4:8	Action code
2:4:9	Source code
2:4:10	days, week = 7, year = 365, month = year/12, immediate = 1

Actions		
	1 = change enterprise	7 = change staff numbers
	2 = change price	8 = supply price
	3 = change marketing effort	9 = stock
	4 = capacity	10 = change supply source
	5 = quantity	11 = change wages
	6 = hours	12 = product type

Sources	
	1 = demand
	2 = supply
	3 = labour
	4 = technology
	5 = regulation

3:1:1	Sales quantity
3:1:2	Sales value
3:1:3	Gross profit

3:1:4	Raw material quantity
3:1:5	New order value
3:1:6	Outstanding order value
3:1:7	Outstanding order quantity
3:1:8	Stock quantity
3:1:9	Stock value
3:1:10	Production quantities
3:1:11	Material costs
3:1:12	Labour costs
3:1:13	Plant costs
3:1:14	Overhead costs
3:1:15	Competitors or market prices
3:1:16	Estimates of future market size
3:1:17	Estimates of future sales
3:1:18	Estimates of future profits
3:1:19	Estimates of technology developments
3:1:20	Industry material prices
3:1:21	Industry or competitor profitability
3:1:22	Industry labour rates
3:1:23	Net profit before tax
3:1:24	Net profit after tax
3:1:25	Net worth
3:1:26	Return on capital employed
3:2:1	Importance 1
3:2:2	Importance 2
3:2:3	Importance 3
4:1:1	Relative month no
4:1:2	Source code
4:1:3:1	Reference
4:1:3:2	Reference
4:1:3:3	Reference
4:1:4	Relative month no
4:1:5	days, week = 7, year = 365, month = year/12, immediate = 1
4:2:1	Relative day no
4:2:2	Source code
4:2:3:1	Reference
4:2:3:2	Reference
4:2:3:3	Reference
4:2:4	Relative day no
4:2:5	days, week = 7, year = 365, month = year/12, immediate = 1
4:2:6	1 = hourly, 2 = daily, 3 = weekly, 4 = monthly
4:2:7	1 = demand, 2 = supply, 3 = production capacity, 4 = marketing effort
4:3:1	Relative day no
4:3:2	Source code
4:3:3:1	Reference
4:3:3:2	Reference
4:3:3:3	Reference
4:3:4	Relative day no
4:3:5	days, week = 7, year = 365, month = year/12, immediate = 1
4:3:6	1 = hourly, 2 = daily, 3 = weekly, 4 = monthly
4:3:7	1 = demand, 2 = supply, 3 = production capacity
4:4:1	Relative day no
4:4:2	Source code
4:4:3:1	Reference
4:4:3:2	Reference
4:4:3:3	Reference
4:4:4	Relative day no

4:4:5	days, week = 7,year = 365,month = year/12,immediate = 1
4:4:6	1 = hourly,2 = daily,3 = weekly,4 = monthly
4:5:1	Relative day no
4:5:2	Source code
4:5:3:1	Reference
4:5:3:2	Reference
4:5:3:3	Reference
4:5:4	Relative day no
4:5:5	days, week = 7,year = 365,month = year/12,immediate = 1
4:5:6	1 = hourly,2 = daily,3 = weekly,4 = monthly
4:5:7	percentage
4:5:8	days, week = 7,year = 365,month = year/12,immediate = 1
4:5:9	percentage
4:5:10	percentage
4:5:11	1 = demand,2 = supply,3 = staffavailability,4 = plant down time
4:6:1	Relative day no
4:6:2	Source code
4:6:3:1	Reference
4:6:3:2	Reference
4:6:3:3	Reference
4:6:4	Relative day no
4:6:5	days, week = 7,year = 365,month = year/12,immediate = 1
4:6:6	1 = hourly,2 = daily,3 = weekly,4 = monthly
4:7:1	Relative day no
4:7:2	Source code
4:7:3:1	Reference
4:7:3:2	Reference
4:7:3:3	Reference
4:7:4	Relative day no
4:7:5	days, week = 7,year = 365,month = year/12,immediate = 1
4:7:6	staff numbers
4:7:7	days, week = 7,year = 365,month = year/12,immediate = 1
4:7:8	numbers
4:7:9	numbers
4:7:10	1 = hourly,2 = daily,3 = weekly,4 = monthly
5:1:1	1 = no,2 = 75%to 50%,3 = 50%or less for main usage
5:2:2	Relative day no
5:2:3	days, week = 7,year = 365,month = year/12,immediate = 1
5:2:4	1 = purchased,2 = leased,3 = hired
5:2:5	1 = yes,2 = no
5:1:1	1 = no,2 = 75%to 50%,3 = 50%or less for main usage
5:2:2	Relative day no
5:2:3	days, week = 7,year = 365,month = year/12,immediate = 1
5:2:4	1 = fixed rate,2 = piecework,3 = fixed + bonus
5:2:5	1 = yes,2 = no
6	Survey type 1 = on-site,2 = post

Appendix 3 Coded Questionnaire Responses

1:1																																				
1:2																																				
1:3																																				
1:4																																				
1:5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1:6	4	4	3	1	1	1	3	3	2	3	3	1	1	3	2	1	3	4	1	1	1	1	3	2	1	4	1	3	4	3	1	4	2	1	3	1
1:7	2	2	3	4	3	4	3	3	3	2	4	4	4	3	4	4	4	2	4	3	4	4	2	3	4	2	4	2	2	4	4	2	2	4	3	4
1:8	1	1	1	2	1	3	1	1	1	3	1	1	2	1	1	1	1	1	2	3	1	1	3	1	1	1	1	3	1	1	2	1	1	3	1	3
2:1:1	1	1	1	1	1	1	1	1	1	1	•	1	1	•	•	1	1	•	1	1	1	1	1	1	1	•	1	1	•	1	1	•	1	1	1	1
2:1:2	2	2	3	3	3	3	1	1	2	1	•	1	3	•	•	3	3	•	3	1	2	3	1	3	3	•	3	1	•	2	3	•	2	2	3	3
2:1:3	5	4	•	12	•	12	12	12	5	13	•	13	12	•	•	12	•	•	12	12	4	•	13	13	•	•	•	13	•	5	•	•	6	5	24	•
2:1:4	3	8	5	8	5	8	5	5	8	2	•	2	10	•	•	2	10	•	10	3	8	10	2	5	2	•	2	2	•	10	10	•	10	10	5	10
2:1:5	30	30	1	7	1	7	30	91	30	61	•	61	7	•	•	183	91	•	3	61	30	14	61	30	5	•	5	1	•	30	91	•	7	30	5	91
2:1:6	1	1	1	1	1	1	1	1	1	1	•	1	1	•	•	1	1	•	1	1	1	1	1	1	2	•	2	1	•	1	1	•	1	1	1	1
2:1:7	1	1	1	1	1	1	1	1	1	1	•	1	1	•	•	1	1	•	1	1	1	1	1	1	1	•	1	1	•	2	1	•	1	2	1	1
2:1:8	•	•	•	•	•	•	•	2	•	•	•	•	•	•	•	5	5	•	8	•	•	5	•	2	•	•	•	•	•	•	5	•	5	•	•	5
2:1:9	•	•	•	•	•	•	•	1	•	•	•	•	•	•	•	3	•	•	•	•	•	•	•	1	•	•	•	•	•	•	•	•	•	•	•	•
2:1:10	30	30	1	1	1	1	3	1	30	14	•	7	7	•	•	1	91	•	3	61	30	14	14	1	1	•	1	1	•	30	91	•	21	30	1	91
2:2:1	1	1	1	1	1	1	1	1	1	1	•	1	1	1	1	1	1	1	1	1	1	1	•	1	1	•	1	1	•	1	1	•	•	1	1	1
2:2:2	2	2	3	2	1	2	3	3	1	3	•	3	2	1	3	2	3	1	2	2	3	2	•	3	1	•	1	1	•	3	2	•	•	2	2	2
2:2:3	4	18	14	•	13	•	12	14	12	13	•	12	7	13	12	4	•	14	15	6	•	4	•	12	•	•	•	12	•	13	6	•	•	5	7	4
2:2:4	8	10	5	8	5	8	10	5	10	10	•	5	10	5	10	8	2	5	10	10	5	8	•	5	5	•	5	10	•	5	8	•	•	10	10	8
2:2:5	14	7	30	1	1	1	30	30	7	91	•	7	30	1	30	14	1	7	7	7	1	14	•	7	1	•	1	7	•	7	7	•	•	30	30	14
2:2:6	1	1	1	1	1	1	1	1	1	1	•	1	1	1	1	1	1	1	1	1	1	1	•	1	1	•	1	1	•	1	1	•	•	1	1	1
2:2:7	2	2	2	2	2	2	2	2	2	2	•	2	2	2	2	2	2	•	2	2	2	2	•	2	2	•	2	2	•	2	2	•	•	2	2	2
2:2:8	10	•	10	•	2	•	•	10	•	•	•	12	•	2	•	10	5	•	•	8	•	10	•	12	5	•	5	•	•	10	10	•	•	•	•	10
2:2:9	•	•	2	•	1	•	•	2	•	•	•	1	•	1	•	•	2	•	•	1	•	•	•	1	2	•	2	•	•	2	•	•	•	•	•	•
2:2:10	7	7	30	1	1	1	7	30	30	30	•	1	30	1	7	7	1	7	7	30	1	7	•	1	1	•	1	30	•	1	7	•	•	30	30	7
2:3:1	2	1	1	2	1	2	2	1	2	•	•	2	2	2	2	1	1	•	2	1	2	2	•	2	2	•	2	2	•	1	2	•	1	1	2	2
2:3:2	•	2	2	•	2	•	•	2	•	•	•	•	•	•	•	2	2	•	•	2	•	•	•	•	•	•	•	•	•	2	•	•	2	2	•	•
2:3:3	•	18	15	•	18	•	•	18	•	•	•	•	•	•	•	16	16	•	•	15	•	•	•	•	•	•	•	•	•	15	•	•	18	15	•	•
2:3:4	•	11	11	•	7	•	•	11	•	•	•	•	•	•	•	11	16	•	•	11	•	•	•	•	•	•	•	•	•	11	•	•	7	11	•	•
2:3:5	•	91	1	•	30	•	•	91	•	•	•	•	•	•	•	1	1	•	•	1	•	•	•	•	•	•	•	•	•	1	•	•	30	1	•	•
2:3:6	•	1	1	•	1	•	•	1	•	•	•	•	•	•	•	1	1	•	•	1	•	•	•	•	•	•	•	•	•	1	•	•	1	1	•	•
2:3:7	•	3	3	•	3	•	•	3	•	•	•	•	•	•	•	3	3	•	•	3	•	•	•	•	•	•	•	•	•	3	•	•	3	3	•	•
2:3:8	•	7	•	•	•	•	•	7	•	•	•	•	•	•	•	7	7	•	•	•	•	•	•	•	•	•	•	•	•	7	•	•	•	•	•	•
2:3:9	•	3	•	•	•	•	•	3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
2:3:10	•	7	1	•	30	•	•	7	•	•	•	•	•	•	•	1	1	•	•	1	•	•	•	•	•	•	•	•	•	1	•	•	30	1	•	•
2:4:1	•	•	1	2	2	2	1	1	•	1	1	•	2	•	•	1	1	2	1	•	1	•	•	1	2	1	2	2	•	1	•	•	1	•	2	•
2:4:2	•	•	3	•	•	•	3	1	•	1	1	•	•	•	•	1	3	•	2	•	3	•	•	3	•	1	•	•	•	1	•	•	3	•	•	•
2:4:3	•	•	18	•	•	•	18	18	•	15	18	•	•	•	•	15	12	•	24	•	12	•	•	12	•	15	•	•	•	18	•	•	18	•	•	•
2:4:4	•	•	•	•	•	•	•	•	•	4	4	•	•	•	•	4	4	•	8	•	4	•	•	4	•	4	•	•	•	4	•	•	•	•	•	•
2:4:5	•	•	•	•	•	•	•	•	•	183	91	•	•	•	•	183	61	•	7	•	61	•	•	61	•	183	•	•	•	91	•	•	•	•	•	•
2:4:6	•	•	•	•	•	•	•	•	•	1	1	•	•	•	•	1	1	•	1	•	1	•	•	1	•	1	•	•	•	1	•	•	•	•	•	•
2:4:7	•	•	•	•	•	•	•	•	•	5	5	•	•	•	•	5	4	•	1	•	4	•	•	4	•	5	•	•	•	5	•	•	•	•	•	•
2:4:8	•	•	4	•	•	•	4	4	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	4	•	•	•
2:4:9	4	4	•	•	•	•	•	•	•	•	•	4	•	•	4	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
2:4:10	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	30	•	7	•	30	•	•	30	•	•	•	•	•	•	•	•	•	•	•	•
3:1:1	2	2	1	2	2	2	1	1	2	3	1	1	2	1	2	2	1	1	1	2	2	1	1	1	3	1	3	1	1	2	1	2	3	2	2	2
3:1:2	2	2	1	2	2	2	1	1	2	3	2	1	2	1	2	2	1	2	2	2	2	1	1	1	3	2	3	1	1	2	1	2	3	2	2	2
3:1:3	3	3	2	2	2	2	3	3	3	3	4	3	2	3	3	2	2	4	2	4	3	3	4	3	3	4	3	3	3	3	3	4	3	3	3	3

3:1:4	1	1	1	2	2	2	1	1	1	2	4	1	2	1	2	2	1	5	1	1	1	1	5	1	3	5	3	1	5	1	1	5	1	1	1	1
3:1:5	2	2	1	2	1	2	1	1	2	2	1	2	2	2	1	1	1	1	2	2	2	2	1	1	4	1	4	1	1	2	1	1	2	2	2	2
3:1:6	2	2	1	1	2	1	1	1	2	2	1	2	1	2	2	2	1	1	1	1	2	2	1	1	4	1	4	1	1	1	1	1	2	2	1	2
3:1:7	•	•	1	1	2	1	1	•	2	2	1	2	1	2	2	2	1	•	1	1	2	2	•	1	4	•	4	•	1	1	•	•	2	2	1	•
3:1:8	2	2	1	1	2	1	1	1	2	1	1	1	1	2	2	2	1	1	1	2	2	2	1	1	3	1	3	1	1	2	1	1	2	2	1	2
3:1:9	2	2	3	2	3	2	3	3	2	2	2	3	2	2	3	3	3	1	2	2	2	2	1	3	3	1	3	3	3	2	3	1	2	2	2	2
3:1:10	1	1	1	2	2	2	1	1	1	2	1	1	1	1	2	2	1	1	2	1	1	1	1	1	3	1	3	1	1	1	1	1	1	1	1	1
3:1:11	2	2	1	3	2	3	1	1	2	1	1	1	3	2	3	2	1	1	3	3	2	2	1	1	4	1	4	1	3	2	1	1	2	2	3	2
3:1:12	5	5	3	2	3	2	4	3	5	4	2	4	3	5	4	3	3	2	2	3	5	5	2	4	4	2	4	3	2	3	3	2	3	3	3	5
3:1:13	5	5	3	3	4	3	4	3	3	4	5	3	4	5	5	4	3	4	3	3	3	5	5	4	4	4	4	3	4	3	3	5	3	3	4	5
3:1:14	4	4	3	2	4	2	3	3	3	4	4	3	4	4	5	4	3	4	2	3	3	4	5	3	4	4	4	3	5	3	3	4	3	3	4	4
3:1:15	3	3	4	1	2	1	3	•	2	3	3	4	1	3	3	2	4	3	1	3	2	3	3	3	4	3	4	•	3	4	•	3	2	3	2	3
3:1:16	5	5	4	4	5	4	3	3	5	4	5	4	4	5	5	5	4	5	3	5	5	5	5	3	4	5	4	3	4	5	3	5	4	5	3	5
3:1:17	5	5	4	4	5	4	3	3	5	4	5	4	4	5	5	5	4	5	4	5	5	5	5	3	4	5	4	3	4	5	3	5	4	5	4	5
3:1:18	5	5	4	4	5	4	3	3	5	5	5	4	4	5	5	5	4	5	4	5	5	5	5	3	5	5	5	3	4	5	3	5	4	5	4	5
3:1:19	3	3	3	4	4	4	•	•	3	5	4	3	4	3	4	4	3	3	•	3	3	3	4	•	4	3	4	•	4	3	•	4	3	3	•	3
3:1:20	1	1	4	2	2	2	3	2	2	2	2	4	3	3	4	2	4	5	3	2	2	3	4	3	4	5	4	2	2	2	2	5	2	2	2	1
3:1:21	5	5	4	5	5	5	4	4	5	5	4	4	5	5	5	5	4	•	5	5	5	5	4	4	5	•	5	4	5	5	4	•	5	5	5	5
3:1:22	5	5	4	5	5	5	4	4	5	5	5	4	5	5	5	5	4	3	5	5	5	5	3	4	5	3	5	4	4	5	4	5	5	5	5	5
3:1:23	3	3	3	3	5	3	3	3	3	4	5	4	5	5	3	5	3	5	3	3	3	5	5	3	3	5	3	3	5	3	3	5	4	3	3	3
3:1:24	3	3	4	5	5	5	4	3	3	5	5	4	5	5	5	5	4	5	5	3	3	5	5	4	4	5	4	3	5	3	3	5	5	3	5	3
3:1:25	3	3	4	5	5	5	4	3	3	5	5	4	5	5	5	5	4	5	3	3	3	5	5	4	5	5	5	3	5	3	3	5	5	3	3	3
3:1:26	4	4	4	4	5	4	4	3	4	5	5	4	5	•	5	5	4	5	4	5	4	•	5	4	5	5	5	3	5	5	3	5	5	5	5	4
3:2:1	23	23	10	2	3	2	2	1	23	4	20	1	3	4	2	3	10	5	2	2	23	4	2	2	4	5	4	1	1	4	1	5	23	23	1	23
3:2:2	15	15	1	11	23	11	5	17	11	23	1	23	8	11	4	23	1	1	11	23	11	11	11	5	23	1	23	17	5	23	17	1	10	15	8	15
3:2:3	11	11	17	3	11	3	23	23	15	2	•	8	15	15	23	11	17	11	3	10	15	15	5	23	10	11	10	23	•	10	23	•	15	10	15	11
4:1:1	42	60	48	60	60	60	48	42	•	42	36	52	36	48	52	60	24	144	48	•	60	18	42	24	240	60	240	96	48	36	•	144	52	960	36	•
4:1:2	1	1	1	1	•	1	1	1	•	1	1	2	2	2	2	1	1	2	2	•	2	1	1	1	2	1	2	•	2	1	•	2	2	•	1	•
4:1:3:1	17	21	16	1	•	1	16	16	•	17	24	21	16	16	21	21	17	18	16	•	18	18	17	17	•	21	•	•	16	24	•	18	21	•	16	•
4:1:3:2	•	16	18	16	•	16	18	21	•	•	•	16	17	17	16	16	•	•	17	•	•	17	•	•	•	16	•	•	17	•	•	•	16	•	17	•
4:1:3:3	•	•	21	18	•	18	21	•	•	•	•	•	18	•	•	•	•	•	18	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	18	•
4:1:4	•	•	60	20	•	20	60	42	•	•	60	60	60	•	60	•	36	•	120	•	•	•	•	36	252	•	252	•	•	60	•	•	60	•	60	•
4:1:5	183	365	183	183	183	183	183	183	•	183	183	365	30	183	365	274	274	365	365	•	183	183	183	274	730	365	730	365	183	183	•	365	365	•	274	•
4:2:1	1	1	7	1	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21	1	21	1	1	1	1	1	7	1	1	1
4:2:2	1	1	1	1	2	1	1	1	1	2	1	1	1	2	1	2	1	2	1	1	1	1	2	1	•	2	•	1	2	1	2	2	2	1	1	1
4:2:3:1	15	2	2	2	2	2	2	2	15	15	1	2	5	11	2	11	1	11	5	15	15	15	15	2	1	11	1	1	11	1	11	11	2	15	2	15
4:2:3:2	•	•	1	15	10	15	•	•	•	•	15	•	1	15	•	•	11	•	1	•	•	•	•	•	2	•	2	15	15	15	15	•	10	•	•	•
4:2:3:3	•	•	11	5	11	5	•	•	•	•	•	•	•	•	•	•	3	•	•	•	•	•	•	•	3	•	3	•	•	•	•	•	11	•	•	•
4:2:4	1	1	7	1	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	61	1	61	1	1	1	1	1	7	1	1	1
4:2:5	1	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	365	1	365	1	1	1	1	1	3	1	1	1
4:2:6	1	2	2	1	3	1	2	2	1	1	2	2	1	1	2	1	2	2	1	2	1	1	1	2	4	1	4	2	1	2	1	2	3	1	2	1
4:2:7	1	1	1	1	2	1	1	1	1	2	1	1	1	2	1	2	2	2	1	1	1	1	2	1	2	2	2	1	2	1	2	2	2	1	1	1
4:3:1		365	•	183	•	183	365	183	•	•	•	183	61	•	183	61	183	30	122	•	•	•	•	183	•	61	•	•	•	•	•	30	365	•	365	•
4:3:2		2	•	1	•	4	2	4	•	•	•	2	2	•	2	2	1	3	1	•	•	•	•	1	•	2	•	•	•	•	•	3	1	•	2	•
4:3:3:1		16	•	16	•	16	•	16	•	•	•	16	•	•	16	•	16	14	16	•	•	•	•	16	•	•	•	•	•	•	•	14	1	•	•	•
4:3:3:2		17	•	17	•	•	•	•	•	•	•	•	•	•	•	•	17	•	17	•	•	•	•	•	•	•	•	•	•	•	•	•	2	•	•	•
4:3:3:3		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	3	•	•	•
4:3:4		1095	•	1095	•	304	365	304	•	•	•	183	•	•	183	•	1095	•	1460	•	•	•	•	183	•	•	•	•	•	•	•	•	365	•	365	•
4:3:5		122	•	183	•	1	30	1	•	•	•	1	14	•	1	14	183	30	243	•	•	•	•	7	•	14	•	•	•	•	•	30	30	•	1	•
4:3:6		4	•	5	•	•	5	•	•	•	•	5	•	•	5	•	5	4	4	•	•	•	•	•	•	•	•	•	•	•	•	4	•	•	•	•
4:3:7		1	•	1	•	3	3	3	•	•	•	1	3	•	1	3	1	3	3	•	•	•	•	3	•	3	•	•	•	•	•	3	1	•	3	•
4:4:1		•	•	548	•	183	183	183	365	•	•	•	183	•	608	•	•	•	730	365	•	•	•	608	•	365	•	365	365	•	456	•	•	608	183	608
4:4:2		•	•	1	•	1	1	1	5	•	•	•	1	•	5	•	•	•	2	5	•	•	•	5	•	2	•	2	2	•	1	•	•	5	1	5
4:4:3:1		•	•	16	•	16	16	16	•	•	•	•	16	•	•	•	•	•	16	•	•	•	•	•	•	11	•	11	11	•	10	•	•	•	16	•
4:4:3:2		•	•	17	•	•	•	•	•	•	•	•	•	•	•	•	•	•	17	•	•	•	•	•	•	5	•	5	17	•	16	•	•	•	•	•
4:4:3:3		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4:4:4		•	•	•	•	365	365	365	730	•	•	•	365	•	730	•	•	•	•	730	•	•	•	730	•	365	•	365	365	•	•	•	•	730	365	730

4:4:5		•	•	1825	•	183	183	183	183	•	•	•	183	•	183	•	•	•	3650	183	•	•	•	183	•	1	•	1	1	•	183	•	•	183	183	183
4:4:6		4	•	4	•	•	•	•	•	•	•	•	•	•	•	•	•	•	4	•	•	•	•	•	•	4	•	4	4	•	•	•	•	•	•	•
4:5:1		1	1	1	1	7	5	7	2	183	183	•	183	•	7	183	1	•	7	1	7	1	183	183	1	183	1	1	•	183	1	•	7	1	•	1
4:5:2		1	1	1	2	1	1	1	1	1	1	•	1	•	2	1	1	•	1	2	1	1	1	1	2	1	2	1	•	1	1	•	2	1	•	1
4:5:3:1		15	1	5	4	5	5	5	1	1	1	•	1	•	4	1	5	•	15	4	5	2	1	1	11	1	11	1	•	1	2	•	4	1	•	2
4:5:3:2		•	•	•	•	•	•	•	•	•	•	•	•	•	1	•	•	•	•	•	•	•	•	•	19	•	19	11	•	•	•	•	•	•	•	•
4:5:3:3		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	6	•	6	4	•	•	•	•	•	•	•	•
4:5:4		1	1	1	1	7	7	7	1	365	183	7	183	•	7	183	1	•	7	1	7	1	365	183	1	183	1	1	•	183	1	•	7	1	7	1
4:5:5		1	1	1	1	1	1	1	1	7	1	1	7	•	1	7	1	•	1	1	1	1	7	7	1	7	1	1	•	1	1	•	1	1	1	1
4:5:6		2	1	2	1	3	3	3	1	4	4	3	4	•	1	4	2	•	2	2	2	1	4	4	1	4	1	1	•	4	1	•	1	1	3	1
4:5:7		75	60	90	60	50	90	50	60	100	100	80	100	•	90	100	90	•	70	50	75	•	100	100	75	100	75	75	•	100	70	•	80	60	50	70
4:5:8		1095	91	21	30	365	183	365	91	183	183	183	183	•	61	183	21	•	61	91	30	•	183	183	•	183	•	183	•	183	61	•	7	91	183	61
4:5:9		75	•	75	60	25	50	25	•	80	75	30	60	•	10	60	75	•	40	50	50	•	80	60	40	60	40	50	•	75	•	•	40	•	25	•
4:5:10		75	•	100	100	60	90	60	•	100	100	90	100	•	100	100	100	•	85	60	100	•	100	100	100	100	100	90	•	100	•	•	100	•	90	•
4:5:11		2	1	1	2	1	1	1	1	1	2	1	1	•	2	1	1	•	2	1	2	1	1	1	2	1	2	2	•	2	1	•	2	1	1	1
4:6:1	•	•	•	•	•	•	•	•	•	•	183	•	456	122	•	•	•	•	395	•	•	•	•	•	1440	•	1440	•	122	183	•	•	•	•	•	•
4:6:2	•	•	•	•	•	•	•	•	•	•	4	•	3	3	•	•	•	•	3	•	•	•	•	•	3	•	3	•	3	4	•	•	•	•	•	•
4:6:3:1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	12	•	12	•	•	•	•	•	•	•	•	•
4:6:3:2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	2	•	2	•	•	•	•	•	•	•	•	•
4:6:3:3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	3	•	3	•	•	•	•	•	•	•	•	•
4:6:4	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4:6:5	•	•	•	•	•	•	•	•	•	•	30	•	•	7	•	•	•	•	•	•	•	•	•	•	365	•	365	•	7	30	•	•	•	•	•	•
4:6:6	•	•	•	•	•	•	•	•	•	•	•	•	4	•	•	•	•	•	4	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4:7:1	1	1	1	1	7	183	30	183	1	7	7	183	4	4	183	3	183	7	1	1	1	1	7	61	1	3	1	7	4	1	1	3	30	183	3	1
4:7:2	1	1	1	2	2	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	2	2	1	2	1	1	1	1	1	1
4:7:3:1	•	•	•	4	4	1	1	1	•	4	16	1	17	17	1	17	1	4	4	•	•	•	17	10	4	17	4	4	17	•	•	5	1	•	17	•
4:7:3:2	•	•	•	•	1	•	•	10	•	2	•	•	•	•	•	•	10	1	8	•	•	•	•	1	12	•	12	2	•	•	•	16	•	•	•	•
4:7:3:3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	3	•	3	•	•	•	•	•	•	•	•	•
4:7:4	1	1	1	1	7	183	30	183	1	7	7	183	7	7	183	7	183	7	1	1	•	1	7	61	1	7	1	7	7	1	1	7	30	183	7	1
4:7:5	7	7	7	1	7	30	7	14	7	7	1	30	1	1	30	1	14	7	1	7	21	7	1	1	1	1	1	7	1	1	7	1	7	7	1	7
4:7:6	11	15	•	25	12	13	12	9	11	15	8	13	6	6	13	7	9	12	35	15	10	12	5	10	•	7	•	15	6	23	•	7	12	30	7	•
4:7:7	•	•	•	2	7	•	30	183	•	7	548	•	365	365	•	730	183	7	1	•	•	•	183	91	•	730	•	7	365	1	•	183	30	91	730	•
4:7:8	•	•	•	10	6	•	9	7	•	6	6	•	6	6	•	5	7	6	15	•	•	•	5	•	•	5	•	6	6	6	•	5	9	10	5	•
4:7:9	•	•	•	35	18	•	12	9	•	21	8	•	8	8	•	8	9	18	42	•	•	•	8	10	•	8	•	21	8	29	•	10	12	30	8	•
4:7:10	•	•	•	2	2	4	4	4	•	2	2	4	2	2	4	2	4	2	2	•	•	•	2	4	2	2	2	2	2	2	•	2	4	3	2	•
5:1:1	1	1	2	2	•	1	1	1	1	1	1	1	1	2	2	2	1	2	2	1	1	•	1	2	2	1	2	2	1	1	•	1	1	1	2	•
5:2:2	•	•	425	30	•	•	•	•	•	•	•	•	•	1	1	365	•	1	425	•	•	•	•	30	1	•	30	7	•	•	•	•	•	•	1	•
5:2:3	•	•	61	7	•	•	•	•	•	•	•	•	•	1	1	30	•	1	61	•	•	•	•	7	1	•	7	7	•	•	•	•	•	•	1	•
5:2:4	•	•	4	4	•	•	•	•	•	•	•	•	•	4	1	4	•	4	4	•	•	•	•	4	4	•	4	4	•	•	•	•	•	•	4	•
5:2:5	•	•	1	1	•	1	•	•	•	•	•	•	1	1	1	1	•	1	1	•	•	•	•	1	1	•	1	1	•	•	•	•	•	•	1	•
5:1:1	1	1	•	•	•	•	2	2	1	1	1	2	•	2	2	•	1	2	•	1	1	•	1	•	2	1	•	2	1	1	•	1	1	1	2	•
5:2:2	•	•	365	•	•	•	•	•	•	•	•	•	•	1	1	•	•	1	365	•	•	•	•	•	1	•	•	7	•	•	•	•	•	•	1	•
5:2:3	•	•	1	•	•	•	•	•	•	•	•	•	•	1	1	•	•	1	1	•	•	•	•	•	1	•	•	7	•	•	•	•	•	•	1	•
5:2:4	3	3	3	3	•	3	1	1	3	1	1	1	3	4	2	4	3	4	3	3	3	•	1	3	4	1	3	2	3	1	•	1	3	3	4	•
5:2:5	1	1	1	1	•	1	1	1	1	•	•	1	1	1	1	1	1	1	1	1	1	•	•	1	1	•	1	1	1	•	•	•	1	1	1	•
6	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	1	1	1	1	2	1	2	2	1	1	1	1	1	1	2	2	1

																		Communication purposes only
																		Check to ensure right respondent
																		Possible future use
																		Possible future use
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1 = Fish Processing only, 2 = Main enterprise, 3 = Secondary enterprise
1	2	2	1	3	1	3	2	2	1	1	2	1	2	4	1	4	1	1 = uses Turnover, 2 = uses Employment, 3 = uses Small, medium, large
3	3	3	4	3	4	3	2	4	3	4	3	3	4	2	4	2	4	1 = local, 2 = UK, 3 = export, 4 = mixed
1	1	1	3	1	2	1	1	1	1	2	1	1	3	1	1	1	2	1 = differentiated by process, 2 = differentiated by product, 3 = not differentiated
1	1	1	1	1	1	1	1	1	•	1	1	1	1	1	1	1	1	1 = yes, 2 = no
3	1	3	2	1	1	3	2	3	•	1	1	3	2	1	1	1	3	1 = increase, 2 = decrease, 3 = both
12	13	•	6	13	3	12	5	24	•	3	12	13	4	12	13	12	12	Month No, September 1988 = 1
10	2	5	10	2	5	2	3	5	•	5	3	5	8	5	2	5	10	Action code
3	1	1	7	1	3	183	30	5	•	3	61	30	30	91	1	30	7	days, week = 7, year = 365, month = year/12, immediate = 1
1	1	1	1	1	1	1	1	1	•	1	1	1	1	1	1	1	1	1 = self, 2 = below, 3 = above
1	1	1	1	1	1	1	1	1	•	1	1	1	1	1	1	1	1	Source code
8	•	•	5	•	•	5	•	•	•	•	•	2	•	2	•	•	•	Action code
•	•	•	•	•	•	3	•	•	•	•	•	1	•	1	•	•	•	Source code
3	1	1	21	1	1	1	30	1	•	1	61	1	30	1	1	3	7	days, week = 7, year = 365, month = year/12, immediate = 1
1	1	1	1	1	1	1	1	1	1	1	•	1	1	1	1	1	1	1 = yes, 2 = no
2	1	2	1	1	1	3	2	3	2	1	•	3	2	2	3	2	2	1 = increase, 2 = decrease, 3 = both
15	13	5	12	13	14	13	7	•	18	12	•	13	6	6	•	7	18	Month No, September 1988 = 1
10	5	10	10	5	5	5	10	5	10	10	•	10	8	10	2	10	10	Action code
7	7	30		7	7	7	30	1	7		•	91	7	7	1	30	7	days, week = 7, year = 365, month = year/12, immediate = 1
1	1	1	1	1	1	1	1	1	1	1	•	1	1	1	1	1	1	1 = self, 2 = below, 3 = above
2	2	2	2	2	•	2	2	2	2	2	•	2	2	2	2	2	2	Source code
•	•	•	•	•	•	10	•	•	•	•	•	•	10	8	5	•	•	Action code
•	•	•	•	•	•	2	•	•	•	•	•	•	•	1	2	•	•	Source code
7	7	30		7	7	1	30	1	7		•	30	7	30	1	30	7	days, week = 7, year = 365, month = year/12, immediate = 1
2	2	1	2	2	2	2	1	2	1	1	2	2	1	1	2	2	2	1 = yes, 2 = no
•	•	2	•	•	•	•	2	•	2	2	•	•	2	2	•	•	•	1 = increase, 2 = decrease, 3 = both
•	•	18	•	•	•	•	15	•	15	18	•	•	16	18	•	•	•	Month No, September 1988 = 1
•	•	7	•	•	•	•	11	•	11	7	•	•	11	11	•	•	•	Action code
•	•	30	•	•	•	•	1	•	1	91	•	•	1	91	•	•	•	days, week = 7, year = 365, month = year/12, immediate = 1
•	•	1	•	•	•	•	1	•	1	1	•	•	1	1	•	•	•	1 = self, 2 = below, 3 = above
•	•	3	•	•	•	•	3	•	3	3	•	•	3	3	•	•	•	Source code
•	•	•	•	•	•	•	7	•	•	7	•	•	7	7	•	•	•	Action code
•	•	•	•	•	•	•	•	•	•	3	•	•	•	3	•	•	•	Source code
•	•	30	•	•	•	•	1	•	1	7	•	•	1	7	•	•	•	days, week = 7, year = 365, month = year/12, immediate = 1
1	1	2	•	1	2	•	•	2	•	1	1	1	•	1	2	1	2	1 = yes, 2 = no
2	1	•	•	1	•	•	•	•	•	1	1	3	•	1	•	3	•	1 = cost, 2 = product differentiation, 3 = both
24	15	•	•	15	•	•	•	•	•	15	15	12	•	18	•	18	•	Month No, September 1988 = 1
8	4	•	•	4	•	•	•	•	•	4	4	4	•	•	•	•	•	Action code
7	183	•	•	183	•	•	•	•	•	183	183	61	•	•	•	•	•	days, week = 7, year = 365, month = year/12, immediate = 1
1	1	•	•	1	•	•	•	•	•	1	1	1	•	•	•	•	•	1 = self, 2 = below, 3 = above
1	4	•	•	4	•	•	•	•	•	5	5	4	•	•	•	•	•	Source code
•	•	•	•	•	•	•	•	•	•	•	•	•	•	4	•	4	•	Action code
•	•	•	•	•	•	4	•	•	4	•	•	•	•	•	•	•	•	Source code
7	183	•	•	183	•	•	•	•	•	•	•	30	•	•	•	•	•	days, week = 7, year = 365, month = year/12, immediate = 1
1	2	1	2	2	2	1	2	2	2	1	2	1	3	1	3	1	2	Sales quantity
2	2	1	2	2	2	1	2	2	2	1	2	1	3	1	3	1	2	Sales value
2	2	3	3	2	3	3	4	3	2	3	3	2	3	3	3	3	2	Gross profit

1	2	1	1	2	2	1	2	1	2	5	1	1	1	1	2	1	2	Raw material quantity
2	1	1	2	1	1	1	2	2	1	1	2	1	2	2	2	1	2	New order value
1	2	2	1	2	2	2	2	1	2	1	2	1	2	2	2	1	1	Outstanding order value
1	2	2	1	2	2	2	2	1	2	1	2	1	2	2	2	1	1	Outstanding order quantity
1	2	1	2	2	2	1	2	1	2	1	2	1	2	1	1	1	1	Stock quantity
2	3	3	2	3	3	3	2	2	3	3	2	3	2	3	2	3	2	Stock value
2	2	1	1	2	2	1	1	1	2	1	1	1	1	1	2	1	1	Production quantities
3	2	1	2	2	3	1	3	3	2	3	2	1	2	1	1	1	3	Material costs
2	2	3	3	2	4	3	4	3	3	2	3	3	3	4	4	4	3	Labour costs
3	4	4	3	4	5	4	3	4	4	4	3	3	3	3	4	4	4	Plant costs
2	4	4	3	4	5	4	3	4	4	5	3	3	3	3	4	3	4	Overhead costs
1	2	4	4	2	3	4	4	2	2	3	3	4	2	4	3	3	1	Competitors or market prices
3	5	3	5	5	5	3	5	3	5	4	5	4	4	4	4	3	4	Estimates of future market size
4	5	3	5	5	5	3	5	4	5	4	5	4	4	4	4	3	4	Estimates of future sales
4	5	3	5	5	5	3	5	4	5	4	5	4	4	4	5	3	4	Estimates of future profits
•	4	4	3	4	4	4	3	•	4	4	3	3	3	3	5	•	4	Estimates of technology developments
3	2	3	2	2	4	3	2	2	2	2	2	4	2	4	2	3	3	Industry material prices
5	5	4	5	5	5	4	5	5	5	5	5	4	5	4	5	4	5	Industry or competitor profitability
5	5	4	5	5	5	4	5	5	5	4	5	4	5	4	5	4	5	Industry labour rates
3	3	4	3	3	3	4	3	3	5	5	3	3	4	4	4	3	5	Net profit before tax
5	4	4	3	4	5	4	3	5	5	5	3	4	5	4	5	4	5	Net profit after tax
3	5	4	3	5	5	4	3	3	5	5	3	4	5	4	5	4	5	Net worth
4	5	4	5	5	5	4	5	5	5	5	5	4	5	4	5	4	5	Return on capital employed
2	4	1	4	4	2	1	23	1	3	1	23	10	23	1	4	2	3	Importance 1
11	11	17	23	11	4	17	15	8	23	5	15	1	10	23	23	5	8	Importance 2
3	23	23	10	23	23	23	11	15	11	•	10	17	15	8	2	23	15	Importance 3
48	•	60	•	•	•	60	240	36	60	•	144	24	800	42	96	48	36	Relative month no
2	•	•	•	•	•	2	•	1	2	•	2	1	•	1	•	1	2	Source code
16	•	•	•	•	•	18	•	16	18	•	18	17	•	16	•	16	16	Reference
17	•	•	•	•	•	•	•	17	•	•	•	•	•	21	•	18	17	Reference
18	•	•	•	•	•	•	•	18	•	•	•	•	•	•	•	21	18	Reference
120	•	•	•	•	•	•	•	60	•	•	•	36	•	42	•	60	60	Relative month no
365	•	183	•	•	183	183	•	274	365	183	183	274	•	183	365	183	30	days, week = 7,year = 365,month = year/12,immediate = 1
1	183	1	1	183	7	1	1	1	1	1	1	1	1	1	1	1	1	Relative day no
1	1	2	1	1	1	1	1	1	1	2	1	1	1	2	1	2	1	Source code
5	2	11	15	2	2	2	15	2	2	11	15	2	15	15	1	11	5	Reference
1	•	15	•	•	1	•	•	•	•	15	•	•	•	•	11	•	1	Reference
•	•	•	•	•	11	•	•	•	•	•	•	•	•	•	3	•	•	Reference
1	•	1	1	•	7	1	1	1	1	1	1	1	1	1	1	1	1	Relative day no
1	365	1	1	365	1	1	1	1	1	1	1	1	1	1	1	1	1	days, week = 7,year = 365,month = year/12,immediate = 1
1	5	1	2	5	2	2	1	2	2	1	1	2	1	1	2	2	1	1 = hourly,2 = daily,3 = weekly,4 = monthly
1	1	2	1	1	1	1	2	1	1	2	1	1	1	2	2	2	1	1 = demand,2 = supply,3 = production capacity,4 = marketing effort
122	365	•	•	365	•	365	•	•	365	•	•	183	•	183	•	365	365	Relative day no
1	1	•	•	2	•	2	•	•	2	•	•	1	•	4	•	2	2	Source code
16	1	•	•	•	•	•	•	•	•	•	•	16	•	16	•	•	16	Reference
17	2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	17	Reference
•	3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Reference
1460	365	•	•	365	•	365	•	•	365	•	•	183	•	304	•	365	1095	Relative day no
243	30	•	•	30	•	1	•	•	1	•	•	7	•	1	•	30	122	days, week = 7,year = 365,month = year/12,immediate = 1
4	•	•	•	5	•	•	•	•	•	•	•	•	•	•	•	5	4	1 = hourly,2 = daily,3 = weekly,4 = monthly
3	1	•	•	3	•	3	•	•	3	•	•	3	•	3	•	3	1	1 = demand,2 = supply,3 = production capacity
730	•	365	365	183	•	456	183	1095	1095	365	•	•	91	456	•	548	•	Relative day no
2	•	2	5	1	•	1	5	2	2	2	•	•	5	1	•	1	•	Source code
16	•	11	•	16	•	10	•	16	16	11	•	•	•	10	•	16	•	Reference
17	•	17	•	•	•	16	•	17	17	5	•	•	•	16	•	17	•	Reference
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Reference
•	•	365	730	365	•	•	730	•	•	365	•	•	730	•	•	•	•	Relative day no

3650	•	1	183	183	•	183	274	•	•	1	•	•	183	183	•	1826	•						days, week = 7,year = 365,month = year/12,immediate = 1
4	•	4	•	•	•	•	•	4	4	4	•	•	•	•	•	4	4						1 = hourly,2 = daily,3 = weekly,4 = monthly
7	7	1	7	5	7	•	1	7	1	7	1	•	1	7	1	5	1						Relative day no
1	2	2	1	1	2	•	1	1	1	2	1	•	2	1	1	1	1						Source code
15	4	4	1	5	4	•	1	5	1	4	2	•	4	5	1	5	15						Reference
•	•	•	•	•	1	•	•	•	11	1	•	•	•	•	11	•	•						Reference
•	•	•	•	•	•	•	•	•	4	•	•	•	•	•	4	•	•						Reference
7	7	1	1	7	7	7	1	7	1	7	1	7	1	7	1	7	1						Relative day no
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						days, week = 7,year = 365,month = year/12,immediate = 1
2	1	1	2	3	1	3	1	2	1	1	1	3	2	3	1	3	2						1 = hourly,2 = daily,3 = weekly,4 = monthly
70	80	60	60	90	90	50	60	75	75	90	•	75	75	50	75	90	75						percentage
61	7	30	30	183	61	183	91	30	183	61	•	365	61	365	183	183	1095						days, week = 7,year = 365,month = year/12,immediate = 1
40	40	60	•	50	10	25	•	50	50	10	•	50	•	25	50	50	75						percentage
85	100	100	•	90	100	90	•	100	90	100	•	100	•	60	90	90	75						percentage
2	2	2	1	1	2	1	1	2	2	2	1	1	1	1	2	1	2						1 = demand,2 = supply,3 = staffavailability,4 = plant down time
395	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	456						Relative day no
3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	3						Source code
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•						Reference
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•						Reference
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•						Reference
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•						Relative day no
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•						days, week = 7,year = 365,month = year/12,immediate = 1
4	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	4						1 = hourly,2 = daily,3 = weekly,4 = monthly
1	1	7	14	14	1	14	1	1	14	1	1	61	30	183	7	30	1						Relative day no
1	2	2	1	1	2	1	1	2	1	2	1	1	1	1	2	1	1						Source code
4	4	4	•	1	•	1	•	5	1	•	•	10	•	1	4	1	1						Reference
8	1	1	•	•	•	•	•	4	•	•	•	1	•	10	2	•	5						Reference
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•						Reference
1	1	7	14	30	1	30	•	1	30	1	1	61	30	183	7	30	1						Relative day no
1	1	7	14	1	1	1	21	1	1	1	7	1	7	14	7	7	1						days, week = 7,year = 365,month = year/12,immediate = 1
35	10	12	22	10	23	10	10	32	10	23	12	10	25	9	15	12	33						staff numbers
1	1	7	•	•	1	•	•	1	•	1	•	91	•	183	7	30	1						days, week = 7,year = 365,month = year/12,immediate = 1
15	8	6	•	•	6	•	•	10	•	6	•	•	•	7	6	9	16						numbers
42	10	18	•	•	29	•	•	32	•	29	•	10	•	9	21	12	37						numbers
2	2	2	•	2	2	2	•	2	2	2	•	4	•	4	2	4	2						1 = hourly,2 = daily,3 = weekly,4 = monthly
2	2	•	1	2	2	1	1	1	1	2	•	1	1	1	2	1	2						1 = no,2 = 75%to 50%,3 = 50%or less for main usage
1	1	•	•	365	1	•	•	•	•	365	•	•	•	•	7	•	365						Relative day no
1	1	•	•	30	1	•	•	•	•	30	•	•	•	•	7	•	30						days, week = 7,year = 365,month = year/12,immediate = 1
1	1	•	•	4	4	•	•	•	•	4	•	•	•	•	4	•	4						1 = purchased,2 = leased,3 = hired
1	1	•	•	1	1	•	•	1	1	1	•	•	•	•	1	•	1						1 = yes,2 = no
2	2	•	1	•	2	1	1	•	•	•	•	1	1	2	2	2	•						1 = no,2 = 75%to 50%,3 = 50%or less for main usage
1	1	•	•	•	1	•	•	•	•	•	•	•	•	•	7	•	•						Relative day no
1	1	•	•	•	1	•	•	•	•	•	•	•	•	•	7	•	•						days, week = 7,year = 365,month = year/12,immediate = 1
2	2	•	3	4	4	3	3	3	3	4	•	2	3	1	2	1	4						1 = fixed rate,2 = piecework,3 = fixed + bonus
1	1	•	1	1	1	1	1	1	1	1	•	3	1	1	1	1	1						1 = yes,2 = no
2	1	2	1	2	1	2	1	1	2	1	2	1	1	2	2	2	1						Survey type 1 = on-site,2 = post

1:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	54	54	100.00	100.00
N=	54			

1:6	COUNT	CUMCNT	PERCENT	CUMPCT
1	23	23	42.59	42.59
2	10	33	18.52	61.11
3	13	46	24.07	85.19
4	8	54	14.81	100.00
N=	54			

1:7	COUNT	CUMCNT	PERCENT	CUMPCT
2	13	13	24.07	24.07
3	17	30	31.48	55.56
4	24	54	44.44	100.00
N=	54			

1:8	COUNT	CUMCNT	PERCENT	CUMPCT
1	38	38	70.37	70.37
2	7	45	12.96	83.33
3	9	54	16.67	100.00
N=	54			

2:1:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	46	46	100.00	100.00
N=	46			
*=	8			

2:1:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	15	15	32.61	32.61
2	10	25	21.74	54.35
3	21	46	45.65	100.00
N=	46			
*=	8			

2:1:3	COUNT	CUMCNT	PERCENT	CUMPCT
3	2	2	5.41	5.41
4	3	5	8.11	13.51
5	5	10	13.51	27.03
6	2	12	5.41	32.43
12	14	26	37.84	70.27
13	9	35	24.32	94.59
24	2	37	5.41	100.00
N=	37			
*=	17			

2:1:4	COUNT	CUMCNT	PERCENT	CUMPCT
2	11	11	23.91	23.91
3	4	15	8.70	32.61
5	13	28	28.26	60.87
8	6	34	13.04	73.91
10	12	46	26.09	100.00
N=	46			
*=	8			

2:1:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	7	7	15.22	15.22
3	4	11	8.70	23.91
5	4	15	8.70	32.61
7	6	21	13.04	45.65
14	1	22	2.17	47.83
30	12	34	26.09	73.91
61	5	39	10.87	84.78
91	5	44	10.87	95.65
183	2	46	4.35	100.00
N=	46			
*=	8			

2:1:6	COUNT	CUMCNT	PERCENT	CUMPCT
1	44	44	95.65	95.65
2	2	46	4.35	100.00
N=	46			
*=	8			

2:1:7	COUNT	CUMCNT	PERCENT	CUMPCT
1	44	44	95.65	95.65
2	2	46	4.35	100.00
N=	46			
*=	8			

2:1:8	COUNT	CUMCNT	PERCENT	CUMPCT
2	4	4	28.57	28.57
5	8	12	57.14	85.71
8	2	14	14.29	100.00
N=	14			
*=	37			

2:1:9	COUNT	CUMCNT	PERCENT	CUMPCT
1	4	4	66.67	66.67
3	2	6	33.33	100.00
N=	6			
*=	45			

2:1:10	COUNT	CUMCNT	PERCENT	CUMPCT
1	21	21	45.65	45.65
3	4	25	8.70	54.35
7	3	28	6.52	60.87
14	3	31	6.52	67.39
21	2	33	4.35	71.74
30	8	41	17.39	89.13
61	2	43	4.35	93.48
91	3	46	6.52	100.00
N=	46			
*=	8			

2:2:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	47	47	100.00	100.00
N=	47			
*=	7			

2:2:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	12	12	25.53	25.53
2	21	33	44.68	70.21
3	14	47	29.79	100.00
N=	47			
*=	7			

2:2:3	COUNT	CUMCNT	PERCENT	CUMPCT
4	4	4	10.26	10.26
5	2	6	5.13	15.38
6	4	10	10.26	25.64
7	4	14	10.26	35.90
12	8	22	20.51	56.41
13	8	30	20.51	76.92
14	4	34	10.26	87.18
15	2	36	5.13	92.31
18	3	39	7.69	100.00
N=	39			
*=	15			

2:2:4	COUNT	CUMCNT	PERCENT	CUMPCT
2	2	2	4.26	4.26
5	16	18	34.04	38.30
8	8	26	17.02	55.32
10	21	47	44.68	100.00
N=	47			
*=	7			

2:2:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	10	10	22.22	22.22
7	19	29	42.22	64.44
14	4	33	8.89	73.33
30	10	43	22.22	95.56
91	2	45	4.44	100.00
N=	45			
*=	9			

2:2:6	COUNT	CUMCNT	PERCENT	CUMPCT
1	47	47	100.00	100.00
N=	47			
*=	7			

2:2:7	COUNT	CUMCNT	PERCENT	CUMPCT
2	45	45	100.00	100.00
N=	45			
*=	9			

2:2:8	COUNT	CUMCNT	PERCENT	CUMPCT
2	2	2	10.00	10.00
5	4	6	20.00	30.00
8	2	8	10.00	40.00
10	10	18	50.00	90.00
12	2	20	10.00	100.00
N=	20			
*=	32			

2:2:9	COUNT	CUMCNT	PERCENT	CUMPCT
1	6	6	42.86	42.86
2	8	14	57.14	100.00
N=	14			
*=	38			

2:2:10	COUNT	CUMCNT	PERCENT	CUMPCT
1	14	14	31.11	31.11
7	17	31	37.78	68.89
30	14	45	31.11	100.00
N=	45			
*=	9			

2:3:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	16	16	34.04	34.04
2	31	47	65.96	100.00
N=	47			
*=	7			

2:3:2	COUNT	CUMCNT	PERCENT	CUMPCT
2	16	16	100.00	100.00
N=	16			
*=	35			

2:3:3	COUNT	CUMCNT	PERCENT	CUMPCT
15	6	6	37.50	37.50
16	3	9	18.75	56.25
18	7	16	43.75	100.00
N=	16			
*=	35			

2:3:4	COUNT	CUMCNT	PERCENT	CUMPCT
7	4	4	25.00	25.00
11	11	15	68.75	93.75
16	1	16	6.25	100.00
N=	16			
*=	35			

2:3:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	9	9	56.25	56.25
30	3	12	18.75	75.00
91	4	16	25.00	100.00
N=	16			
*=	35			

2:3:6	COUNT	CUMCNT	PERCENT	CUMPCT
1	16	16	100.00	100.00
N=	16			
*=	35			

2:3:7	COUNT	CUMCNT	PERCENT	CUMPCT
3	16	16	100.00	100.00
N=	16			
*=	35			

2:3:8	COUNT	CUMCNT	PERCENT	CUMPCT
7	9	9	100.00	100.00
N=	9			
*=	42			

2:3:9	COUNT	CUMCNT	PERCENT	CUMPCT
3	4	4	100.00	100.00
N=	4			
*=	47			

2:3:10	COUNT	CUMCNT	PERCENT	CUMPCT
1	9	9	56.25	56.25
7	4	13	25.00	81.25
30	3	16	18.75	100.00
N=	16			
*=	35			

2:4:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	21	21	60.00	60.00
2	14	35	40.00	100.00
N=	35			
*=	19			

2:4:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	11	11	52.38	52.38
2	2	13	9.52	61.90
3	8	21	38.10	100.00
N=	21			
*=	32			

2:4:3	COUNT	CUMCNT	PERCENT	CUMPCT
12	4	4	19.05	19.05
15	7	11	33.33	52.38
18	8	19	38.10	90.48
24	2	21	9.52	100.00
N=	21			
*=	32			

2:4:4	COUNT	CUMCNT	PERCENT	CUMPCT
4	13	13	86.67	86.67
8	2	15	13.33	100.00
N=	15			
*=	34			

2:4:5	COUNT	CUMCNT	PERCENT	CUMPCT
7	2	2	13.33	13.33
61	4	6	26.67	40.00
91	2	8	13.33	53.33
183	7	15	46.67	100.00
N=	15			
*=	34			

2:4:6	COUNT	CUMCNT	PERCENT	CUMPCT
1	15	15	100.00	100.00
N=	15			
*=	34			

2:4:7	COUNT	CUMCNT	PERCENT	CUMPCT
1	2	2	13.33	13.33
4	6	8	40.00	53.33
5	7	15	46.67	100.00
N=	15			
*=	34			

2:4:8	COUNT	CUMCNT	PERCENT	CUMPCT
4	6	6	100.00	100.00
N=	6			
*=	47			

2:4:9	COUNT	CUMCNT	PERCENT	CUMPCT
4	6	6	100.00	100.00
N=	6			
*=	40			

2:4:10	COUNT	CUMCNT	PERCENT	CUMPCT
7	2	2	25.00	25.00
30	4	6	50.00	75.00
183	2	8	25.00	100.00
N=	8			
*=	41			

3:1:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	23	23	42.59	42.59
2	25	48	46.30	88.89
3	6	54	11.11	100.00
N=	54			

3:1:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	18	18	33.33	33.33
2	30	48	55.56	88.89
3	6	54	11.11	100.00
N=	54			

3:1:3	COUNT	CUMCNT	PERCENT	CUMPCT
2	14	14	25.93	25.93
3	33	47	61.11	87.04
4	7	54	12.96	100.00
N=	54			

3:1:4	COUNT	CUMCNT	PERCENT	CUMPCT
1	31	31	57.41	57.41
2	14	45	25.93	83.33
3	2	47	3.70	87.04
4	1	48	1.85	88.89
5	6	54	11.11	100.00
N=	54			

3:1:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	25	25	46.30	46.30
2	27	52	50.00	96.30
4	2	54	3.70	100.00
N=	54			

3:1:6	COUNT	CUMCNT	PERCENT	CUMPCT
1	27	27	50.00	50.00
2	25	52	46.30	96.30
4	2	54	3.70	100.00
N=	54			

3:1:7	COUNT	CUMCNT	PERCENT	CUMPCT
1	20	20	45.45	45.45
2	22	42	50.00	95.45
4	2	44	4.55	100.00
N=	44			
*=	10			

3:1:8	COUNT	CUMCNT	PERCENT	CUMPCT
1	30	30	55.56	55.56
2	22	52	40.74	96.30
3	2	54	3.70	100.00
N=	54			

3:1:9	COUNT	CUMCNT	PERCENT	CUMPCT
1	4	4	7.41	7.41
2	26	30	48.15	55.56
3	24	54	44.44	100.00
N=	54			

3:1:10	COUNT	CUMCNT	PERCENT	CUMPCT
1	39	39	72.22	72.22
2	13	52	24.07	96.30
3	2	54	3.70	100.00
N=	54			

3:1:11	COUNT	CUMCNT	PERCENT	CUMPCT
1	20	20	37.04	37.04
2	18	38	33.33	70.37
3	14	52	25.93	96.30
4	2	54	3.70	100.00
N=	54			

3:1:12	COUNT	CUMCNT	PERCENT	CUMPCT
2	13	13	24.07	24.07
3	22	35	40.74	64.81
4	12	47	22.22	87.04
5	7	54	12.96	100.00
N=	54			

3:1:13	COUNT	CUMCNT	PERCENT	CUMPCT
3	22	22	40.74	40.74
4	22	44	40.74	81.48
5	10	54	18.52	100.00
N=	54			

3:1:14	COUNT	CUMCNT	PERCENT	CUMPCT
2	4	4	7.41	7.41
3	21	25	38.89	46.30
4	24	49	44.44	90.74
5	5	54	9.26	100.00
N=	54			

3:1:15	COUNT	CUMCNT	PERCENT	CUMPCT
1	6	6	11.76	11.76
2	11	17	21.57	33.33
3	22	39	43.14	76.47
4	12	51	23.53	100.00
N=	51			
*=	3			

3:1:16	COUNT	CUMCNT	PERCENT	CUMPCT
3	12	12	22.22	22.22
4	17	29	31.48	53.70
5	25	54	46.30	100.00
N=	54			

3:1:17	COUNT	CUMCNT	PERCENT	CUMPCT
3	8	8	14.81	14.81
4	21	29	38.89	53.70
5	25	54	46.30	100.00
N=	54			

3:1:18	COUNT	CUMCNT	PERCENT	CUMPCT
3	8	8	14.81	14.81
4	17	25	31.48	46.30
5	29	54	53.70	100.00
N=	54			

3:1:19	COUNT	CUMCNT	PERCENT	CUMPCT
3	22	22	50.00	50.00
4	20	42	45.45	95.45
5	2	44	4.55	100.00
N=	44			
*=	10			

3:1:20	COUNT	CUMCNT	PERCENT	CUMPCT
1	3	3	5.56	5.56
2	27	30	50.00	55.56
3	11	41	20.37	75.93
4	10	51	18.52	94.44
5	3	54	5.56	100.00
N=	54			

3:1:21	COUNT	CUMCNT	PERCENT	CUMPCT
4	15	15	29.41	29.41
5	36	51	70.59	100.00
N=	51			
*=	3			

3:1:22	COUNT	CUMCNT	PERCENT	CUMPCT
3	3	3	5.56	5.56
4	15	18	27.78	33.33
5	36	54	66.67	100.00
N=	54			

3:1:23	COUNT	CUMCNT	PERCENT	CUMPCT
3	32	32	59.26	59.26
4	8	40	14.81	74.07
5	14	54	25.93	100.00
N=	54			

3:1:24	COUNT	CUMCNT	PERCENT	CUMPCT
3	14	14	25.93	25.93
4	14	28	25.93	51.85
5	26	54	48.15	100.00
N=	54			

3:1:25	COUNT	CUMCNT	PERCENT	CUMPCT
3	18	18	33.33	33.33
4	10	28	18.52	51.85
5	26	54	48.15	100.00
N=	54			

3:1:26	COUNT	CUMCNT	PERCENT	CUMPCT
3	3	3	5.77	5.77
4	19	22	36.54	42.31
5	30	52	57.69	100.00
N=	52			
*=	2			

3:2:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	11	11	20.37	20.37
2	11	22	20.37	40.74
3	5	27	9.26	50.00
4	10	37	18.52	68.52
5	3	40	5.56	74.07
10	3	43	5.56	79.63
20	1	44	1.85	81.48
23	10	54	18.52	100.00
N=	54			

3:2:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	7	7	12.96	12.96
4	2	9	3.70	16.67
5	5	14	9.26	25.93
8	4	18	7.41	33.33
10	2	20	3.70	37.04
11	11	31	20.37	57.41
15	6	37	11.11	68.52
17	5	42	9.26	77.78
23	12	54	22.22	100.00
N=	54			

3:2:3	COUNT	CUMCNT	PERCENT	CUMPCT
2	2	2	4.00	4.00
3	4	6	8.00	12.00
5	1	7	2.00	14.00
8	2	9	4.00	18.00
10	7	16	14.00	32.00
11	9	25	18.00	50.00
15	10	35	20.00	70.00
17	3	38	6.00	76.00
23	12	50	24.00	100.00
N=	50			
*=	4			

4:1:1	COUNT	CUMCNT	PERCENT	CUMPCT
18	1	1	2.22	2.22
24	3	4	6.67	8.89
36	6	10	13.33	22.22
42	5	15	11.11	33.33
48	7	22	15.56	48.89
52	3	25	6.67	55.56
60	10	35	22.22	77.78
96	2	37	4.44	82.22
144	3	40	6.67	88.89
240	3	43	6.67	95.56
800	1	44	2.22	97.78
960	1	45	2.22	100.00
N=	45			
*=	9			

4:1:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	21	21	55.26	55.26
2	17	38	44.74	100.00
N=	38			
*=	16			

41:3:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	2	2	5.56	5.56
16	13	15	36.11	41.67
17	6	21	16.67	58.33
18	7	28	19.44	77.78
21	6	34	16.67	94.44
24	2	36	5.56	100.00
N=	36			
*=	18			

41:3:2	COUNT	CUMCNT	PERCENT	CUMPCT
16	8	8	36.36	36.36
17	9	17	40.91	77.27
18	3	20	13.64	90.91
21	2	22	9.09	100.00
N=	22			
*=	32			

41:3:3	COUNT	CUMCNT	PERCENT	CUMPCT
18	8	8	72.73	72.73
21	3	11	27.27	100.00
N=	11			
*=	43			

4:1:4	COUNT	CUMCNT	PERCENT	CUMPCT
20	2	2	8.70	8.70
36	3	5	13.04	21.74
42	2	7	8.70	30.43
60	12	19	52.17	82.61
120	2	21	8.70	91.30
252	2	23	8.70	100.00
N=	23			
*=	31			

4:1:5	COUNT	CUMCNT	PERCENT	CUMPCT
30	2	2	4.55	4.55
183	22	24	50.00	54.55
274	6	30	13.64	68.18
365	12	42	27.27	95.45
730	2	44	4.55	100.00
N=	44			
*=	10			

4:2:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	46	46	85.19	85.19
7	4	50	7.41	92.59
21	2	52	3.70	96.30
183	2	54	3.70	100.00
N=	54			

4:2:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	37	37	71.15	71.15
2	15	52	28.85	100.00
N=	52			
*=	2			

4:2:3:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	7	7	12.96	12.96
2	19	26	35.19	48.15
5	4	30	7.41	55.56
11	10	40	18.52	74.07
15	14	54	25.93	100.00
N=	54			

4:2:3:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	6	6	27.27	27.27
2	2	8	9.09	36.36
10	2	10	9.09	45.45
11	2	12	9.09	54.55
15	10	22	45.45	100.00
N=	22			
*=	32			

4:2:3:3	COUNT	CUMCNT	PERCENT	CUMPCT
3	4	4	40.00	40.00
5	2	6	20.00	60.00
11	4	10	40.00	100.00
N=	10			
*=	42			

4:2:4	COUNT	CUMCNT	PERCENT	CUMPCT
1	46	46	88.46	88.46
7	4	50	7.69	96.15
61	2	52	3.85	100.00
N=	52			
*=	2			

4:2:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	48	48	88.89	88.89
3	2	50	3.70	92.59
365	4	54	7.41	100.00
N=	54			

4:2:6	COUNT	CUMCNT	PERCENT	CUMPCT
1	25	25	46.30	46.30
2	23	48	42.59	88.89
3	2	50	3.70	92.59
4	2	52	3.70	96.30
5	2	54	3.70	100.00
N=	54			

4:2:7	COUNT	CUMCNT	PERCENT	CUMPCT
1	34	34	62.96	62.96
2	20	54	37.04	100.00
N=	54			

4:3:1	COUNT	CUMCNT	PERCENT	CUMPCT
30	2	2	7.69	7.69
61	3	5	11.54	19.23
122	2	7	7.69	26.92
183	9	16	34.62	61.54
365	10	26	38.46	100.00
N=	26			
*=	28			

4:3:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	8	8	30.77	30.77
2	13	21	50.00	80.77
3	2	23	7.69	88.46
4	3	26	11.54	100.00
N=	26			
*=	28			

4:3:3:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	2	2	11.76	11.76
14	2	4	11.76	23.53
16	13	17	76.47	100.00
N=	17			
*=	37			

4:3:3:2	COUNT	CUMCNT	PERCENT	CUMPCT
2	2	2	25.00	25.00
17	6	8	75.00	100.00
N=	8			
*=	46			

4:3:3:3	COUNT	CUMCNT	PERCENT	CUMPCT
3	2	2	100.00	100.00
N=	2			
*=	36			

4:3:4	COUNT	CUMCNT	PERCENT	CUMPCT
183	4	4	19.05	19.05
304	3	7	14.29	33.33
365	8	15	38.10	71.43
1095	4	19	19.05	90.48
1460	2	21	9.52	100.00
N=	21			
*=	33			

4:3:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	8	8	30.77	30.77
7	2	10	7.69	38.46
14	3	13	11.54	50.00
30	7	20	26.92	76.92
122	2	22	7.69	84.62
183	2	24	7.69	92.31
243	2	26	7.69	100.00
N=	26			
*=	28			

4:3:6	COUNT	CUMCNT	PERCENT	CUMPCT
4	6	6	46.15	46.15
5	7	13	53.85	100.00
N=	13			
*=	41			

4:3:7	COUNT	CUMCNT	PERCENT	CUMPCT
1	8	8	30.77	30.77
3	18	26	69.23	100.00
N=	26			
*=	28			

4:4:1	COUNT	CUMCNT	PERCENT	CUMPCT
91	1	1	3.45	3.45
183	7	8	24.14	27.59
365	8	16	27.59	55.17
456	3	19	10.34	65.52
548	2	21	6.90	72.41
608	4	25	13.79	86.21
730	2	27	6.90	93.10
1095	2	29	6.90	100.00
N=	29			
*=	24			

4:4:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	11	11	37.93	37.93
2	9	20	31.03	68.97
5	9	29	31.03	100.00
N=	29			
*=	24			

4:4:3:1	COUNT	CUMCNT	PERCENT	CUMPCT
10	3	3	15.00	15.00
11	5	8	25.00	40.00
16	12	20	60.00	100.00
N=	20			
*=	33			

4:4:3:2	COUNT	CUMCNT	PERCENT	CUMPCT
5	3	3	21.43	21.43
16	3	6	21.43	42.86
17	8	14	57.14	100.00
N=	14			
*=	39			

4:4:4	COUNT	CUMCNT	PERCENT	CUMPCT
365	11	11	55.00	55.00
730	9	20	45.00	100.00
N=	20			
*=	30			

4:4:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	5	5	18.52	18.52
183	17	22	62.96	81.48
274	1	23	3.70	85.19
1825	2	25	7.41	92.59
3650	2	27	7.41	100.00
N=	27			
*=	26			

4:4:6	COUNT	CUMCNT	PERCENT	CUMPCT
4	13	13	100.00	100.00
N=	13			
*=	41			

4:5:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	20	20	44.44	44.44
2	1	21	2.22	46.67
5	3	24	6.67	53.33
7	13	37	28.89	82.22
183	8	45	17.78	100.00
N=	45			
*=	9			

4:5:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	34	34	75.56	75.56
2	11	45	24.44	100.00
N=	45			
*=	9			

4:5:3:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	16	16	35.56	35.56
2	4	20	8.89	44.44
4	9	29	20.00	64.44
5	10	39	22.22	86.67
11	2	41	4.44	91.11
15	4	45	8.89	100.00
N=	45			
*=	9			

4:5:3:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	3	3	37.50	37.50
11	3	6	37.50	75.00
19	2	8	25.00	100.00
N=	8			
*=	44			

4:5:3:3	COUNT	CUMCNT	PERCENT	CUMPCT
4	3	3	60.00	60.00
6	2	5	40.00	100.00
N=	5			
*=	47			

4:5:4	COUNT	CUMCNT	PERCENT	CUMPCT
1	22	22	44.90	44.90
7	19	41	38.78	83.67
183	6	47	12.24	95.92
365	2	49	4.08	100.00
N=	49			
*=	5			

4:5:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	43	43	87.76	87.76
7	6	49	12.24	100.00
N=	49			
*=	5			

4:5:6	COUNT	CUMCNT	PERCENT	CUMPCT
1	20	20	40.82	40.82
2	11	31	22.45	63.27
3	10	41	20.41	83.67
4	8	49	16.33	100.00
N=	49			
*=	5			

4:5:7	COUNT	CUMCNT	PERCENT	CUMPCT
50	6	6	12.77	12.77
60	7	13	14.89	27.66
70	4	17	8.51	36.17
75	11	28	23.40	59.57
80	3	31	6.38	65.96
90	8	39	17.02	82.98
100	8	47	17.02	100.00
N=	47			
*=	7			

4:5:8	COUNT	CUMCNT	PERCENT	CUMPCT
7	2	2	4.44	4.44
21	2	4	4.44	8.89
30	5	9	11.11	20.00
61	8	17	17.78	37.78
91	5	22	11.11	48.89
183	17	39	37.78	86.67
365	4	43	8.89	95.56
1095	2	45	4.44	100.00
N=	45			
*=	9			

4:5:9	COUNT	CUMCNT	PERCENT	CUMPCT
10	3	3	7.69	7.69
25	5	8	12.82	20.51
30	1	9	2.56	23.08
40	6	15	15.38	38.46
50	10	25	25.64	64.10
60	6	31	15.38	79.49
75	6	37	15.38	94.87
80	2	39	5.13	100.00
N=	39			
*=	15			

4:5:10	COUNT	CUMCNT	PERCENT	CUMPCT
60	4	4	10.26	10.26
75	2	6	5.13	15.38
85	2	8	5.13	20.51
90	9	17	23.08	43.59
100	22	39	56.41	100.00
N=	39			
*=	15			

4:5:11	COUNT	CUMCNT	PERCENT	CUMPCT
1	29	29	59.18	59.18
2	20	49	40.82	100.00
N=	49			
*=	5			

4:6:1	COUNT	CUMCNT	PERCENT	CUMPCT
122	2	2	20.00	20.00
183	2	4	20.00	40.00
395	2	6	20.00	60.00
456	2	8	20.00	80.00
1440	2	10	20.00	100.00
N=	10			
*=	44			

4:6:2	COUNT	CUMCNT	PERCENT	CUMPCT
3	8	8	80.00	80.00
4	2	10	20.00	100.00
N=	10			
*=	44			

4:6:3:1	COUNT	CUMCNT	PERCENT	CUMPCT
12	2	2	100.00	100.00
N=	2			
*=	25			

4:6:3:2	COUNT	CUMCNT	PERCENT	CUMPCT
2	2	2	100.00	100.00
N=	2			
*=	25			

4:6:3:3	COUNT	CUMCNT	PERCENT	CUMPCT
3	2	2	100.00	100.00
N=	2			
*=	25			

4:6:5	COUNT	CUMCNT	PERCENT	CUMPCT
7	2	2	33.33	33.33
30	2	4	33.33	66.67
365	2	6	33.33	100.00
N=	6			
*=	24			

4:6:6	COUNT	CUMCNT	PERCENT	CUMPCT
4	4	4	100.00	100.00
N=	4			
*=	50			

4:7:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	22	22	40.74	40.74
3	4	26	7.41	48.15
4	3	29	5.56	53.70
7	8	37	14.81	68.52
14	4	41	7.41	75.93
30	4	45	7.41	83.33
61	2	47	3.70	87.04
183	7	54	12.96	100.00
N=	54			

4:7:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	40	40	74.07	74.07
2	14	54	25.93	100.00
N=	54			

4:7:3:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	13	13	35.14	35.14
4	12	25	32.43	67.57
5	2	27	5.41	72.97
10	2	29	5.41	78.38
16	1	30	2.70	81.08
17	7	37	18.92	100.00
N=	37			
*=	17			

4:7:3:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	6	6	31.58	31.58
2	3	9	15.79	47.37
4	1	10	5.26	52.63
5	1	11	5.26	57.89
8	2	13	10.53	68.42
10	3	16	15.79	84.21
12	2	18	10.53	94.74
16	1	19	5.26	100.00
N=	19			
*=	35			

4:7:3:3	COUNT	CUMCNT	PERCENT	CUMPCT
3	2	2	100.00	100.00
N=	2			
*=	25			

4:7:4	COUNT	CUMCNT	PERCENT	CUMPCT
1	20	20	38.46	38.46
7	15	35	28.85	67.31
14	1	36	1.92	69.23
30	7	43	13.46	82.69
61	2	45	3.85	86.54
183	7	52	13.46	100.00
N=	52			
*=	2			

4:7:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	25	25	46.30	46.30
7	20	45	37.04	83.33
14	4	49	7.41	90.74
21	2	51	3.70	94.44
30	3	54	5.56	100.00
N=	54			

4:7:6	COUNT	CUMCNT	PERCENT	CUMPCT
5	1	1	2.04	2.04
6	3	4	6.12	8.16
7	4	8	8.16	16.33
8	1	9	2.04	18.37
9	3	12	6.12	24.49
10	8	20	16.33	40.82
11	2	22	4.08	44.90
12	8	30	16.33	61.22
13	3	33	6.12	67.35
15	5	38	10.20	77.55
22	1	39	2.04	79.59
23	3	42	6.12	85.71
25	2	44	4.08	89.80
30	1	45	2.04	91.84
32	1	46	2.04	93.88
33	1	47	2.04	95.92
35	2	49	4.08	100.00
N=	49			
*=	5			

4:7:7	COUNT	CUMCNT	PERCENT	CUMPCT
1	8	8	24.24	24.24
2	1	9	3.03	27.27
7	6	15	18.18	45.45
30	3	18	9.09	54.55
91	3	21	9.09	63.64
183	5	26	15.15	78.79
365	3	29	9.09	87.88
548	1	30	3.03	90.91
730	3	33	9.09	100.00
N=	33			
*=	21			

4:7:8	COUNT	CUMCNT	PERCENT	CUMPCT
5	5	5	16.13	16.13
6	13	18	41.94	58.06
7	3	21	9.68	67.74
8	1	22	3.23	70.97
9	3	25	9.68	80.65
10	3	28	9.68	90.32
15	2	30	6.45	96.77
16	1	31	3.23	100.00
N=	31			
*=	23			

4:7:9	COUNT	CUMCNT	PERCENT	CUMPCT
8	8	8	24.24	24.24
9	3	11	9.09	33.33
10	4	15	12.12	45.45
12	3	18	9.09	54.55
18	3	21	9.09	63.64
21	3	24	9.09	72.73
29	3	27	9.09	81.82
30	1	28	3.03	84.85
32	1	29	3.03	87.88
35	1	30	3.03	90.91
37	1	31	3.03	93.94
42	2	33	6.06	100.00
N=	33			
*=	21			

4:7:10	COUNT	CUMCNT	PERCENT	CUMPCT
2	29	29	70.73	70.73
3	1	30	2.44	73.17
4	11	41	26.83	100.00
N=	41			
*=	13			

5:1:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	29	29	60.42	60.42
2	19	48	39.58	100.00
N=	48			
*=	6			

5:1:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	8	8	42.11	42.11
7	2	10	10.53	52.63
30	3	13	15.79	68.42
365	4	17	21.05	89.47
425	2	19	10.53	100.00
N=	19			
*=	35			

5:1:3	COUNT	CUMCNT	PERCENT	CUMPCT
1	8	8	42.11	42.11
7	5	13	26.32	68.42
30	4	17	21.05	89.47
61	2	19	10.53	100.00
N=	19			
*=	35			

5:1:4	COUNT	CUMCNT	PERCENT	CUMPCT
1	3	3	15.79	15.79
4	16	19	84.21	100.00
N=	19			
*=	35			

5:1:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	23	23	100.00	100.00
N=	23			
*=	31			

5:2:1	COUNT	CUMCNT	PERCENT	CUMPCT
1	20	20	57.14	57.14
2	15	35	42.86	100.00
N=	35			
*=	18			

5:2:2	COUNT	CUMCNT	PERCENT	CUMPCT
1	8	8	66.67	66.67
7	2	10	16.67	83.33
365	2	12	16.67	100.00
N=	12			
*=	40			

5:2:3	COUNT	CUMCNT	PERCENT	CUMPCT
1	10	10	83.33	83.33
7	2	12	16.67	100.00
N=	12			
*=	40			

5:2:4	COUNT	CUMCNT	PERCENT	CUMPCT
1	11	11	22.92	22.92
2	6	17	12.50	35.42
3	22	39	45.83	81.25
4	9	48	18.75	100.00
N=	48			
*=	6			

5:2:5	COUNT	CUMCNT	PERCENT	CUMPCT
1	41	41	97.62	97.62
3	1	42	2.38	100.00
N=	42			
*=	12			

6	COUNT	CUMCNT	PERCENT	CUMPCT
1	30	30	55.56	55.56
2	24	54	44.44	100.00
N=	54			

	N	N*	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
1:5	54	0	1.0000	1.0000	1.0000	0.0000	0.0000
1:6	54	0	2.111	2.000	2.063	1.127	0.153
1:7	54	0	3.204	3.000	3.229	0.810	0.110
1:8	54	0	1.463	1.000	1.396	0.770	0.105
2:1:1	46	8	1.0000	1.0000	1.0000	0.0000	0.0000
2:1:2	46	8	2.130	2.000	2.143	0.885	0.130
2:1:3	37	17	10.486	12.000	10.121	4.953	0.814
2:1:4	46	8	5.804	5.000	5.786	3.124	0.461
2:1:5	46	8	34.37	30.00	28.88	43.23	6.37
2:1:6	46	8	1.0435	1.0000	1.0000	0.2062	0.0304
2:1:7	46	8	1.0435	1.0000	1.0000	0.2062	0.0304
2:1:8	14	37	4.571	5.000	4.500	1.989	0.532
2:1:9	6	45	1.667	1.000	1.667	1.033	0.422
2:1:10	46	8	16.80	3.00	14.02	25.02	3.69
2:2:1	47	7	1.0000	1.0000	1.0000	0.0000	0.0000
2:2:2	47	7	2.043	2.000	2.047	0.751	0.109
2:2:3	39	15	10.718	12.000	10.686	4.242	0.679
2:2:4	47	7	7.617	8.000	7.767	2.524	0.368
2:2:5	45	9	15.13	7.00	12.12	19.65	2.93
2:2:6	47	7	1.0000	1.0000	1.0000	0.0000	0.0000
2:2:7	45	9	2.0000	2.0000	2.0000	0.0000	0.0000
2:2:8	20	32	8.200	10.000	8.333	3.071	0.687
2:2:9	14	38	1.571	2.000	1.583	0.514	0.137
2:2:10	45	9	12.29	7.00	11.98	12.29	1.83
2:3:1	47	7	1.6596	2.0000	1.6744	0.4790	0.0699
2:3:2	16	35	2.0000	2.0000	2.0000	0.0000	0.0000
2:3:3	16	35	16.500	16.000	16.500	1.414	0.354
2:3:4	16	35	10.312	11.000	10.143	2.330	0.583
2:3:5	16	35	28.94	1.00	26.50	38.67	9.67
2:3:6	16	35	1.0000	1.0000	1.0000	0.0000	0.0000
2:3:7	16	35	3.0000	3.0000	3.0000	0.0000	0.0000
2:3:8	9	42	7.0000	7.0000	7.0000	0.0000	0.0000
2:3:9	4	47	3.0000	3.0000	3.0000	0.0000	0.0000
2:3:10	16	35	7.94	1.00	6.86	11.25	2.81
2:4:1	35	19	1.4000	1.0000	1.3871	0.4971	0.0840
2:4:2	21	32	1.857	1.000	1.842	0.964	0.210
2:4:3	21	32	16.429	15.000	16.263	3.370	0.735
2:4:4	15	34	4.533	4.000	4.308	1.407	0.363
2:4:5	15	34	114.7	91.0	117.8	70.0	18.1
2:4:6	15	34	1.0000	1.0000	1.0000	0.0000	0.0000
2:4:7	15	34	4.067	4.000	4.231	1.335	0.345
2:4:8	6	47	4.0000	4.0000	4.0000	0.0000	0.0000
2:4:9	6	40	4.0000	4.0000	4.0000	0.0000	0.0000
2:4:10	8	41	62.5	30.0	62.5	75.0	26.5

	MIN	MAX	Q1	Q3
1:5	1.0000	1.0000	1.0000	1.0000
1:6	1.000	4.000	1.000	3.000
1:7	2.000	4.000	2.750	4.000
1:8	1.000	3.000	1.000	2.000
2:1:1	1.0000	1.0000	1.0000	1.0000
2:1:2	1.000	3.000	1.000	3.000
2:1:3	3.000	24.000	5.000	13.000
2:1:4	2.000	10.000	2.750	10.000
2:1:5	1.00	183.00	4.50	61.00
2:1:6	1.0000	2.0000	1.0000	1.0000
2:1:7	1.0000	2.0000	1.0000	1.0000
2:1:8	2.000	8.000	2.000	5.000
2:1:9	1.000	3.000	1.000	3.000
2:1:10	1.00	91.00	1.00	30.00
2:2:1	1.0000	1.0000	1.0000	1.0000
2:2:2	1.000	3.000	1.000	3.000
2:2:3	4.000	18.000	6.000	13.000
2:2:4	2.000	10.000	5.000	10.000
2:2:5	1.00	91.00	7.00	30.00
2:2:6	1.0000	1.0000	1.0000	1.0000
2:2:7	2.0000	2.0000	2.0000	2.0000
2:2:8	2.000	12.000	5.000	10.000
2:2:9	1.000	2.000	1.000	2.000
2:2:10	1.00	30.00	1.00	30.00
2:3:1	1.0000	2.0000	1.0000	2.0000
2:3:2	2.0000	2.0000	2.0000	2.0000
2:3:3	15.000	18.000	15.000	18.000
2:3:4	7.000	16.000	8.000	11.000
2:3:5	1.00	91.00	1.00	75.75
2:3:6	1.0000	1.0000	1.0000	1.0000
2:3:7	3.0000	3.0000	3.0000	3.0000
2:3:8	7.0000	7.0000	7.0000	7.0000
2:3:9	3.0000	3.0000	3.0000	3.0000
2:3:10	1.00	30.00	1.00	7.00
2:4:1	1.0000	2.0000	1.0000	2.0000
2:4:2	1.000	3.000	1.000	3.000
2:4:3	12.000	24.000	15.000	18.000
2:4:4	4.000	8.000	4.000	4.000
2:4:5	7.0	183.0	61.0	183.0
2:4:6	1.0000	1.0000	1.0000	1.0000
2:4:7	1.000	5.000	4.000	5.000
2:4:8	4.0000	4.0000	4.0000	4.0000
2:4:9	4.0000	4.0000	4.0000	4.0000
2:4:10	7.0	183.0	12.8	144.7

	N	N*	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
3:1:1	54	0	1.6852	2.0000	1.6458	0.6680	0.0909
3:1:2	54	0	1.7778	2.0000	1.7500	0.6344	0.0863
3:1:3	54	0	2.8704	3.0000	2.8542	0.6157	0.0838
3:1:4	54	0	1.833	1.000	1.688	1.299	0.177
3:1:5	54	0	1.6111	2.0000	1.5417	0.6845	0.0931
3:1:6	54	0	1.5741	1.5000	1.5000	0.6896	0.0938
3:1:7	44	10	1.636	2.000	1.550	0.718	0.108
3:1:8	54	0	1.4815	1.0000	1.4375	0.5743	0.0782
3:1:9	54	0	2.3704	2.0000	2.4167	0.6233	0.0848
3:1:10	54	0	1.3148	1.0000	1.2500	0.5434	0.0739
3:1:11	54	0	1.963	2.000	1.917	0.889	0.121
3:1:12	54	0	3.241	3.000	3.208	0.970	0.132
3:1:13	54	0	3.778	4.000	3.750	0.744	0.101
3:1:14	54	0	3.556	4.000	3.563	0.769	0.105
3:1:15	51	3	2.784	3.000	2.822	0.945	0.132
3:1:16	54	0	4.241	4.000	4.271	0.799	0.109
3:1:17	54	0	4.3148	4.0000	4.3542	0.7223	0.0983
3:1:18	54	0	4.389	5.000	4.438	0.738	0.100
3:1:19	44	10	3.5455	3.5000	3.5000	0.5888	0.0888
3:1:20	54	0	2.685	2.000	2.646	1.025	0.139
3:1:21	51	3	4.7059	5.0000	4.7333	0.4602	0.0644
3:1:22	54	0	4.6111	5.0000	4.6875	0.5961	0.0811
3:1:23	54	0	3.667	3.000	3.625	0.869	0.118
3:1:24	54	0	4.222	4.000	4.250	0.839	0.114
3:1:25	54	0	4.148	4.000	4.167	0.899	0.122
3:1:26	52	2	4.5192	5.0000	4.5870	0.6101	0.0846
3:2:1	54	0	7.09	3.50	6.48	8.25	1.12
3:2:2	54	0	12.30	11.00	12.33	7.43	1.01
3:2:3	50	4	13.660	13.000	13.795	6.580	0.930

	MIN	MAX	Q1	Q3
3:1:1	1.0000	3.0000	1.0000	2.0000
3:1:2	1.0000	3.0000	1.0000	2.0000
3:1:3	2.0000	4.0000	2.0000	3.0000
3:1:4	1.000	5.000	1.000	2.000
3:1:5	1.0000	4.0000	1.0000	2.0000
3:1:6	1.0000	4.0000	1.0000	2.0000
3:1:7	1.000	4.000	1.000	2.000
3:1:8	1.0000	3.0000	1.0000	2.0000
3:1:9	1.0000	3.0000	2.0000	3.0000
3:1:10	1.0000	3.0000	1.0000	2.0000
3:1:11	1.000	4.000	1.000	3.000
3:1:12	2.000	5.000	2.750	4.000
3:1:13	3.000	5.000	3.000	4.000
3:1:14	2.000	5.000	3.000	4.000
3:1:15	1.000	4.000	2.000	3.000
3:1:16	3.000	5.000	4.000	5.000
3:1:17	3.0000	5.0000	4.0000	5.0000
3:1:18	3.000	5.000	4.000	5.000
3:1:19	3.0000	5.0000	3.0000	4.0000
3:1:20	1.000	5.000	2.000	3.250
3:1:21	4.0000	5.0000	4.0000	5.0000
3:1:22	3.0000	5.0000	4.0000	5.0000
3:1:23	3.000	5.000	3.000	5.000
3:1:24	3.000	5.000	3.000	5.000
3:1:25	3.000	5.000	3.000	5.000
3:1:26	3.0000	5.0000	4.0000	5.0000
3:2:1	1.00	23.00	2.00	10.00
3:2:2	1.00	23.00	5.00	17.00
3:2:3	2.000	23.000	10.000	18.500

	N	N*	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
4:1:1	45	9	104.7	52.0	71.0	178.4	26.6
4:1:2	38	16	1.4474	1.0000	1.4412	0.5039	0.0817
41:3:1	36	18	17.000	17.000	17.562	4.554	0.759
41:3:2	22	32	17.136	17.000	17.000	1.424	0.304
41:3:3	11	43	18.818	18.000	18.667	1.401	0.423
4:1:4	23	31	73.7	60.0	67.8	61.1	12.7
4:1:5	44	10	263.0	183.0	251.3	137.3	20.7
4:2:1	54	0	8.93	1.00	1.92	34.70	4.72
4:2:2	52	2	1.2885	1.0000	1.2609	0.4575	0.0634
4:2:3:1	54	0	7.130	5.000	7.021	5.825	0.793
4:2:3:2	22	32	9.18	11.00	9.30	6.37	1.36
4:2:3:3	10	42	6.60	5.00	6.50	3.86	1.22
4:2:4	52	2	3.77	1.00	1.39	11.67	1.62
4:2:5	54	0	28.0	1.0	8.7	96.2	13.1
4:2:6	54	0	1.759	2.000	1.625	0.970	0.132
4:2:7	54	0	1.3704	1.0000	1.3542	0.4874	0.0663
4:3:1	26	28	222.5	183.0	224.5	124.8	24.5
4:3:2	26	28	2.000	2.000	1.958	0.938	0.184
4:3:3:1	17	37	14.00	16.00	14.73	4.94	1.20
4:3:3:2	8	46	13.25	17.00	13.25	6.94	2.45
4:3:3:3	2	36	3.0000	3.0000	3.0000	0.0000	0.0000
4:3:4	21	33	565.0	365.0	537.9	437.8	95.5
4:3:5	26	28	52.7	22.0	46.9	77.4	15.2
4:3:6	13	41	4.538	5.000	4.545	0.519	0.144
4:3:7	26	28	2.385	3.000	2.417	0.941	0.185
4:4:1	29	24	442.7	365.0	431.6	253.0	47.0
4:4:2	29	24	2.552	2.000	2.519	1.723	0.320
4:4:3:1	20	33	13.850	16.000	13.944	2.720	0.608
4:4:3:2	14	39	14.21	17.00	14.75	5.01	1.34
C30	0	0	*	*	*	*	*
4:4:4	20	30	529.3	365.0	527.2	186.3	41.7
4:4:5	27	26	531	183	428	1006	194
4:4:6	13	41	4.0000	4.0000	4.0000	0.0000	0.0000
4:5:1	45	9	35.4	5.0	29.9	69.5	10.4
4:5:2	45	9	1.2444	1.0000	1.2195	0.4346	0.0648
4:5:3:1	45	9	4.267	4.000	3.902	4.125	0.615
4:5:3:2	8	44	9.25	11.00	9.25	7.59	2.68
4:5:3:3	5	47	4.800	4.000	4.800	1.095	0.490
4:5:4	49	5	40.5	7.0	27.8	89.9	12.8
4:5:5	49	5	1.735	1.000	1.533	1.987	0.284
4:5:6	49	5	2.122	2.000	2.089	1.130	0.161
4:5:7	47	7	76.28	75.00	76.40	16.30	2.38
4:5:8	45	9	175.8	183.0	139.2	222.9	33.2
4:5:9	39	15	48.59	50.00	49.00	19.87	3.18
4:5:10	39	15	91.54	100.00	92.86	12.78	2.05
4:5:11	49	5	1.4082	1.0000	1.4000	0.4966	0.0709
4:6:1	10	44	519	395	454	503	159
4:6:2	10	44	3.200	3.000	3.125	0.422	0.133
4:6:3:1	2	25	12.000	12.000	12.000	0.000	0.000
4:6:3:2	2	25	2.0000	2.0000	2.0000	0.0000	0.0000
4:6:3:3	2	25	3.0000	3.0000	3.0000	0.0000	0.0000
C52	0	0	*	*	*	*	*
4:6:5	6	24	134.0	30.0	134.0	179.2	73.2
4:6:6	4	50	4.0000	4.0000	4.0000	0.0000	0.0000
4:7:1	54	0	31.13	4.00	23.52	60.57	8.24
4:7:2	54	0	1.2593	1.0000	1.2292	0.4423	0.0602
4:7:3:1	37	17	6.11	4.00	5.76	6.13	1.01
4:7:3:2	19	35	5.63	4.00	5.29	4.88	1.12
4:7:3:3	2	25	3.0000	3.0000	3.0000	0.0000	0.0000
4:7:4	52	2	33.69	7.00	26.09	61.05	8.47
4:7:5	54	0	6.54	7.00	5.42	7.60	1.03
4:7:6	49	5	14.37	12.00	13.84	8.08	1.15
4:7:7	33	21	156.5	30.0	127.6	229.6	40.0
4:7:8	31	23	7.581	6.000	7.185	3.009	0.540
4:7:9	33	21	17.85	12.00	16.86	11.09	1.93
4:7:10	41	13	2.561	2.000	2.514	0.896	0.140

	N	N*	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
5:1:1	48	6	1.3958	1.0000	1.3864	0.4942	0.0713
5:1:2	19	35	127.5	7.0	117.4	180.8	41.5
5:1:3	19	35	15.00	7.00	13.12	19.75	4.53
5:1:4	19	35	3.526	4.000	3.647	1.124	0.258
5:1:5	23	31	1.0000	1.0000	1.0000	0.0000	0.0000
5:2:1	35	18	1.4286	1.0000	1.4194	0.5021	0.0849
5:2:2	12	40	62.7	1.0	38.6	141.2	40.8
5:2:3	12	40	2.000	1.000	1.600	2.335	0.674
5:2:4	48	6	2.604	3.000	2.614	1.047	0.151
5:2:5	42	12	1.0476	1.0000	1.0000	0.3086	0.0476
6	54	0	1.4444	1.0000	1.4375	0.5016	0.0683

	MIN	MAX	Q1	Q3
4:1:1	18.0	960.0	42.0	60.0
4:1:2	1.0000	2.0000	1.0000	2.0000
41:3:1	1.000	24.000	16.000	18.000
41:3:2	16.000	21.000	16.000	17.250
41:3:3	18.000	21.000	18.000	21.000
4:1:4	20.0	252.0	42.0	60.0
4:1:5	30.0	730.0	183.0	365.0
4:2:1	1.00	183.00	1.00	1.00
4:2:2	1.0000	2.0000	1.0000	2.0000
4:2:3:1	1.000	15.000	2.000	15.000
4:2:3:2	1.00	15.00	1.00	15.00
4:2:3:3	3.00	11.00	3.00	11.00
4:2:4	1.00	61.00	1.00	1.00
4:2:5	1.0	365.0	1.0	1.0
4:2:6	1.000	5.000	1.000	2.000
4:2:7	1.0000	2.0000	1.0000	2.0000
4:3:1	30.0	365.0	122.0	365.0
4:3:2	1.000	4.000	1.000	2.000
4:3:3:1	1.00	16.00	15.00	16.00
4:3:3:2	2.00	17.00	5.75	17.00
4:3:3:3	3.0000	3.0000	*	*
4:3:4	183.0	1460.0	304.0	1095.0
4:3:5	1.0	243.0	1.0	53.0
4:3:6	4.000	5.000	4.000	5.000
4:3:7	1.000	3.000	1.000	3.000
4:4:1	91.0	1095.0	183.0	608.0
4:4:2	1.000	5.000	1.000	5.000
4:4:3:1	10.000	16.000	11.000	16.000
4:4:3:2	5.00	17.00	13.25	17.00
C30	*	*	*	*
4:4:4	365.0	730.0	365.0	730.0
4:4:5	1	3650	183	183
4:4:6	4.0000	4.0000	4.0000	4.0000
4:5:1	1.0	183.0	1.0	7.0
4:5:2	1.0000	2.0000	1.0000	1.5000
4:5:3:1	1.000	15.000	1.000	5.000
4:5:3:2	1.00	19.00	1.00	17.00
4:5:3:3	4.000	6.000	4.000	6.000
4:5:4	1.0	365.0	1.0	7.0
4:5:5	1.000	7.000	1.000	1.000
4:5:6	1.000	4.000	1.000	3.000
4:5:7	50.00	100.00	60.00	90.00
4:5:8	7.0	1095.0	61.0	183.0
4:5:9	10.00	80.00	40.00	60.00
4:5:10	60.00	100.00	90.00	100.00
4:5:11	1.0000	2.0000	1.0000	2.0000
4:6:1	122	1440	168	702
4:6:2	3.000	4.000	3.000	3.250
4:6:3:1	12.000	12.000	*	*
4:6:3:2	2.0000	2.0000	*	*
4:6:3:3	3.0000	3.0000	*	*

	MIN	MAX	Q1	Q3
4:6:5	7.0	365.0	7.0	365.0
4:6:6	4.0000	4.0000	4.0000	4.0000
4:7:1	1.00	183.00	1.00	18.00
4:7:2	1.0000	2.0000	1.0000	2.0000
4:7:3:1	1.00	17.00	1.00	10.00
4:7:3:2	1.00	16.00	1.00	10.00
4:7:3:3	3.0000	3.0000	*	*
4:7:4	1.00	183.00	1.00	30.00
4:7:5	1.00	30.00	1.00	7.00
4:7:6	5.00	35.00	9.50	15.00
4:7:7	1.0	730.0	1.5	183.0
4:7:8	5.000	16.000	6.000	9.000
4:7:9	8.00	42.00	8.50	29.00
4:7:10	2.000	4.000	2.000	4.000
5:1:1	1.0000	2.0000	1.0000	2.0000
5:1:2	1.0	425.0	1.0	365.0
5:1:3	1.00	61.00	1.00	30.00
5:1:4	1.000	4.000	4.000	4.000
5:1:5	1.0000	1.0000	1.0000	1.0000
5:2:1	1.0000	2.0000	1.0000	2.0000
5:2:2	1.0	365.0	1.0	7.0
5:2:3	1.000	7.000	1.000	1.000
5:2:4	1.000	4.000	2.000	3.000
5:2:5	1.0000	3.0000	1.0000	1.0000
6	1.0000	2.0000	1.0000	2.0000

COLUMN	NAME	COUNT	MISSING
C1	1:5	54	
C2	1:6	54	
C3	1:7	54	
C4	1:8	54	
C5	2:1:1	54	8
C6	2:1:2	54	8
C7	2:1:3	54	17
C8	2:1:4	54	8
C9	2:1:5	54	8
C10	2:1:6	54	8
C11	2:1:7	54	8
C12	2:1:8	51	37
C13	2:1:9	51	45
C14	2:1:10	54	8
C15	2:2:1	54	7
C16	2:2:2	54	7
C17	2:2:3	54	15
C18	2:2:4	54	7
C19	2:2:5	54	9
C20	2:2:6	54	7
C21	2:2:7	54	9
C22	2:2:8	52	32
C23	2:2:9	52	38
C24	2:2:10	54	9
C25	2:3:1	54	7
C26	2:3:2	51	35
C27	2:3:3	51	35
C28	2:3:4	51	35
C29	2:3:5	51	35
C30	2:3:6	51	35
C31	2:3:7	51	35
C32	2:3:8	51	42
C33	2:3:9	51	47
C34	2:3:10	51	35
C35	2:4:1	54	19
C36	2:4:2	53	32
C37	2:4:3	53	32
C38	2:4:4	49	34
C39	2:4:5	49	34
C40	2:4:6	49	34
C41	2:4:7	49	34
C42	2:4:8	53	47
C43	2:4:9	46	40
C44	2:4:10	49	41

COLUMN	NAME	COUNT	MISSING
C1	3:1:1	54	
C2	3:1:2	54	
C3	3:1:3	54	
C4	3:1:4	54	
C5	3:1:5	54	
C6	3:1:6	54	
C7	3:1:7	54	10
C8	3:1:8	54	
C9	3:1:9	54	
C10	3:1:10	54	
C11	3:1:11	54	
C12	3:1:12	54	
C13	3:1:13	54	
C14	3:1:14	54	
C15	3:1:15	54	3
C16	3:1:16	54	
C17	3:1:17	54	
C18	3:1:18	54	
C19	3:1:19	54	10
C20	3:1:20	54	
C21	3:1:21	54	3
C22	3:1:22	54	
C23	3:1:23	54	
C24	3:1:24	54	
C25	3:1:25	54	
C26	3:1:26	54	2
C27	3:2:1	54	
C28	3:2:2	54	
C29	3:2:3	54	4

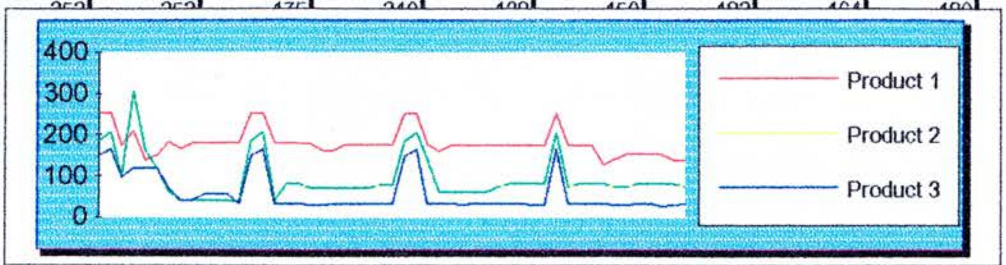
COLUMN	NAME	COUNT	MISSING
C1	4:1:1	54	9
C2	4:1:2	54	16
C3	41:3:1	54	18
C4	41:3:2	54	32
C5	41:3:3	54	43
C6	4:1:4	54	31
C7	4:1:5	54	10
C8	4:2:1	54	
C9	4:2:2	54	2
C10	4:2:3:1	54	
C11	4:2:3:2	54	32
C12	4:2:3:3	52	42
C13	4:2:4	54	2
C14	4:2:5	54	
C15	4:2:6	54	
C16	4:2:7	54	
C17	4:3:1	54	28
C18	4:3:2	54	28
C19	4:3:3:1	54	37
C20	4:3:3:2	54	46
C21	4:3:3:3	38	36
C22	4:3:4	54	33
C23	4:3:5	54	28
C24	4:3:6	54	41
C25	4:3:7	54	28
C26	4:4:1	53	24
C27	4:4:2	53	24
C28	4:4:3:1	53	33
C29	4:4:3:2	53	39
C31	4:4:4	50	30
C32	4:4:5	53	26
C33	4:4:6	54	41
C34	4:5:1	54	9
C35	4:5:2	54	9
C36	4:5:3:1	54	9
C37	4:5:3:2	52	44
C38	4:5:3:3	52	47
C39	4:5:4	54	5
C40	4:5:5	54	5
C41	4:5:6	54	5
C42	4:5:7	54	7
C43	4:5:8	54	9
C44	4:5:9	54	15
C45	4:5:10	54	15
C46	4:5:11	54	5
C47	4:6:1	54	44
C48	4:6:2	54	44
C49	4:6:3:1	27	25
C50	4:6:3:2	27	25
C51	4:6:3:3	27	25
C53	4:6:5	30	24
C54	4:6:6	54	50
C55	4:7:1	54	
C56	4:7:2	54	
C57	4:7:3:1	54	17
C58	4:7:3:2	54	35
C59	4:7:3:3	27	25
C60	4:7:4	54	2
C61	4:7:5	54	

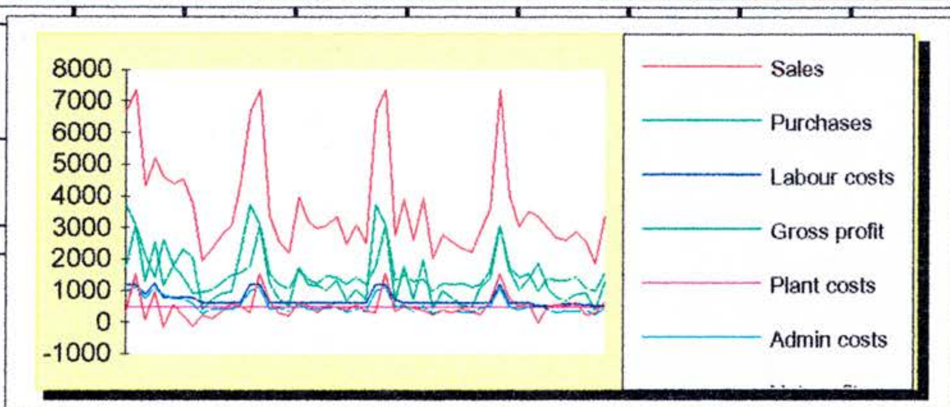
COLUMN	NAME	COUNT	MISSING
C62	4:7:6	54	5
C63	4:7:7	54	21
C64	4:7:8	54	23
C65	4:7:9	54	21
C66	4:7:10	54	13
C67	5:1:1	54	6
C68	5:1:2	54	35
C69	5:1:3	54	35
C70	5:1:4	54	35
C71	5:1:5	54	31
C72	5:2:1	53	18
C73	5:2:2	52	40
C74	5:2:3	52	40
C75	5:2:4	54	6
C76	5:2:5	54	12
C77	6	54	

Appendix 4 Spreadsheet Listings

Note to appendix 4:

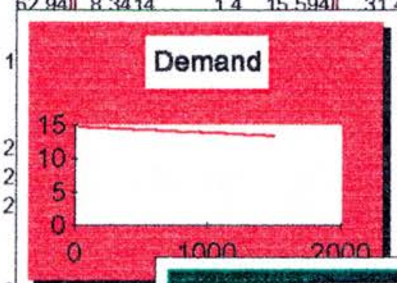
Sections from the first two models developed for the research are reproduced here. The pages are reproductions of the spreadsheet screens with formulae shown where appropriate. Extracts from the significant elements are shown, rather than the entire set of source code. They are meant to be indicative of the approach rather than a full definition.

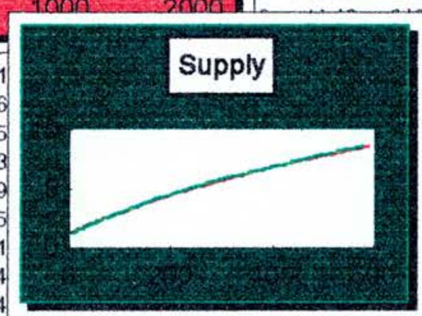




icy	28/9/96	23/11/91	2/5/92	9/5/92	16/5/92	23/5/92	30/5/92	6/6/92	13/6/92	20/6/92
duct 1	252	252	175	210	138	150	182	164	180	180
Purchas										180
duct 2										41
Purchas										41
duct 3										55
Purchas										55
nge staff										0
nge plant										0
nge admin limit										
nge capital										
mal										
s										2346
chases										724
our costs										606
ss profit										1016
t costs										472
in costs										430
profit										114
iber of staff										6
f surplus cap.										0
shortage										1
t output level										7
t output										638
t over capacity										3
t under capacity	0	0	0	0	0	0	0	0	0	0
luct 1										
e	14.50	15.95	14.66	6.58	14.85	15.03	18.27	18.31	6.84	8.22
ced quantity	252	252	175	210	138	150	182	164	180	180
ced value	3654	4019	2566	1382	2049	2255	3325	3003	1231	1480
material price	7	5	7	2	6	5	9	10	2	3
rial costs	1817	1373	1225	441	850	765	1631	1653	346	569
k balance	0	0	0	0	0	0	0	0	0	0
rial shortage	0	0	0	0	0	0	0	0	0	0
ur cost	662	633	531	578	359	403	550	610	467	451
inal cost down	12.04	8.60	12.04	5.16	12.04	10.32	13.76	15.48	5.16	6.88
inal cost up - sl	8.28	6.60	8.49	2.86	7.75	6.50	10.61	11.91	2.70	4.22
inal cost - medi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
inal cost - long	9.71	7.95	9.50	4.60	8.66	7.60	11.46	12.58	4.42	5.66
inal Revenue	14.50	15.95	14.66	6.58	14.85	15.03	18.27	18.31	6.84	8.22
s profit	1175	2013	810	363	840	1086	1144	740	419	460
uct 2										
	9.03	9.03	9.04	9.02	9.03	9.04	9.04	9.05	9.05	9.05
ced quantity	186	205	98	304	162	118	62	41	41	41
ced value	1680	1851	886	2742	1463	1067	560	371	371	371
material price	6	5	5	3	7	4	5	4	1	1
rial costs	1107	994	460	803	1100	517	303	181	38	61
: balance	0	0	0	0	0	0	0	0	0	0
rial shortage	0	0	0	0	0	0	0	0	0	0
ır cost	244	258	149	418	211	159	94	76	53	51
inal cost down	8.89	8.60	8.89	5.16	8.89	8.88	8.96	9.00	5.16	6.88
inal cost up - sl	7.08	6.07	6.22	3.36	8.33	5.82	6.98	6.61	1.66	2.70
inal cost - medi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
inal cost - long	7.20	6.10	5.94	3.89	8.04	5.63	6.13	5.66	2.18	2.73
inal Revenue	9.03	9.03	9.04	9.02	9.03	9.04	9.04	9.05	9.05	9.05
s profit	329	599	278	1521	152	391	164	114	280	259
uct 3										
uct 3 Price	9	9	9	9	9	9	9	9	9	9
ced quantity	149	164	97	118	118	118	69	41	41	55
ced value	1341	1476	873	1062	1062	1062	621	369	369	495

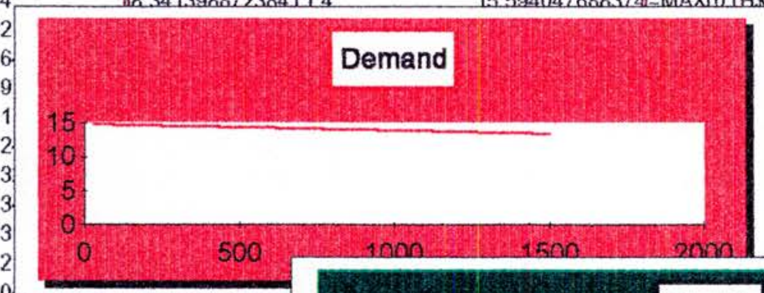
	Current period	Product 1					Next period					
	Finished good demand			Factor Supply			Finished good demand			Factor Supply		
Base	30	14		10	5		30	14		10	5	
Spread	10%	10%		100%	150%		10%	10%		100%	150%	
Stochasti	0%		Cumul	20%		Cumul.	0%		Cumul	20%		Cumul.
Order	Quantity	Price	Demand	Quantity	Price	Supply	Quantity	Price	Demand	Quantity	Price	Supply
0	31.5	14.7	31.5	7.2526	1.25	7.2526	31.5	14.7	31.5	5.4152	1.25	5.4152
1	31.44	14.672	62.94	8.3414	1.4	15.594	31.44	14.672	62.94	7.864	1.4	13.279
2	31.38	14.644	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.644	94.32	7.0863	1.55	20.365
3	31.32	14.616	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.616	125.64	8.8252	1.7	29.191
4	31.26	14.588	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	156.9	6.6546	1.85	35.845
5	31.2	14.56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.4954	2	44.341
6	31.14	14.532	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.1173	2.15	53.458
7	31.08	14.504	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.504	250.32	6.9072	2.3	60.365
8	31.02	14.476	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.476	281.34	8.986	2.45	69.351
9	30.96	14.448	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.448	312.3	9.2486	2.6	78.6
10	30.9	14.42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.8313	2.75	88.431
11	30.84	14.392	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.033	2.9	98.464
12	30.78	14.364	404.82	9.881	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.9834	3.05	108.45
13	30.72	14.336	435.54	7.6576	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5996	3.2	117.05
14	30.66	14.308	466.2	8.9315	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.0757	3.35	126.12
15	30.6	14.28	496.8	8.8963	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.0711	3.5	134.19
16	30.54	14.252	527.34	9.6019	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.4376	3.65	143.63
17	30.48	14.224	557.82	8.7285	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.0198	3.8	152.65
18	30.42	14.196	588.24	8.691	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.1655	3.95	161.82
19	30.36	14.168	618.6	9.8484	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.7755	4.1	171.59
20	30.3	14.14	648.9	10.34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.505	4.25	184.1
21	30.24	14.112	679.14	12.415	4.4	191.73	30.24	14.112	679.14	9.7678	4.4	193.87
22	30.18	14.084	709.32	9.4849	4.55	201.22	30.18	14.084	709.32	10.471	4.55	204.34
23	30.12	14.056	739.44	13.087	4.7	214.3	30.12	14.056	739.44	11.7	4.7	216.04
24	30.06	14.028	769.5	10.085	4.85	224.39	30.06	14.028	769.5	12.342	4.85	228.38
25	30	14	799.5	12.14	5	236.53	30	14	799.5	11.813	5	240.19
26	29.94	13.972	829.44	11.329	5.15	247.86	29.94	13.972	829.44	11.085	5.15	251.28
27	29.88	13.944	859.32	10.543	5.3	258.4	29.88	13.944	859.32	13.383	5.3	264.66
28	29.82	13.916	889.14	10.487	5.45	268.89	29.82	13.916	889.14	13.818	5.45	278.48
29	29.76	13.888	918.9	12.337	5.6	281.22	29.76	13.888	918.9	12.844	5.6	291.32
40	29.1	13.58	1242.3	12.904	7.25	436.37	29.1	13.58	1242.3	16.154	7.25	439.45
41	29.04	13.552	1271.3	13.859	7.4	450.23	29.04	13.552	1271.3	16.344	7.4	455.79
42	28.98	13.524	1300.3	14.167	7.55	464.39	28.98	13.524	1300.3	16.03	7.55	471.82
43	28.92	13.496	1329.2	17.324	7.7	481.72	28.92	13.496	1329.2	15.601	7.7	487.43
44	28.86	13.468	1358.1	14.269	7.85	495.98	28.86	13.468	1358.1	16.889	7.85	504.31
45	28.8	13.44	1386.9	13.863	8	509.85	28.8	13.44	1386.9	17.236	8	521.55
46	28.74	13.412	1415.6	14.888	8.15	524.74	28.74	13.412	1415.6	14.978	8.15	536.53
47	28.68	13.384	1444.3	17.535	8.3	542.27	28.68	13.384	1444.3	15.647	8.3	552.18
48	28.62	13.356	1472.9	18.164	8.45	560.43	28.62	13.356	1472.9	18.205	8.45	570.38
49	28.56	13.328	1501.5	16.193	8.6	576.63	28.56	13.328	1501.5	17.424	8.6	587.81
Adjusted												
Base	31.5	14.7		5	1.25		31.5	14.7		5	1.25	
Spread	-0.06	0.028		0.2	0.15		-0.06	0.028		0.2	0.15	
Stochasti	0			4			0			4		
Max	31.5	14.7		18.164	8.6		31.5	14.7		18.205	8.6	
Min	28.56	13.328		7.0852	1.25		28.56	13.328		5.4152	1.25	
Increment Cost			10			10			10			10
Administration cost			10			10			10			10
Long Term												
Asset value			0			0			0			0



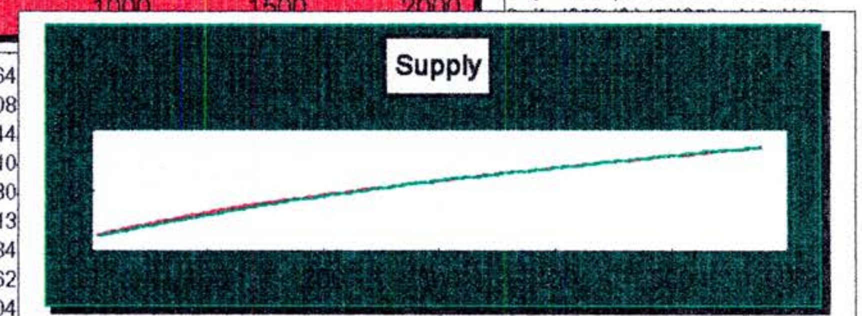


Update

	Current period		**Product 1**				**Next period**		
	Finished good d			**Factor Supply**			**Finished good d**		
Base	30	14		10	5		30	14	
Spread	0.1	0.1		1	1.5		0.1	0.1	
Stochasti	0		Cumul	0.2		Cumul.	0		Cumul
Order	Quantity	Price	Demand	Quantity	Price	Supply	Quantity	Price	Demand
0	31.5	14.7	31.5	7.25264881598	1.25	7.25264881598	=MAX(0,(H$58+(	=I$58-($A7*I$59)	=H7
1	31.44	14.672	62.94	8.3413988723841	1.4	15.594047688374	=MAX(0,(H$58+(	=I$58-($A8*I$59)	=J7+H8
2	31.38	14.644	94.32				8+(	=I$58-($A9*I$59)	=J8+H9
3	31.32	14.616	125.6				8+(	=I$58-($A10*I$59	=J9+H10
4	31.26	14.588	156.9				8+(	=I$58	H11
5	31.2	14.56	188.1				8+(	=I$58	12
6	31.14	14.532	219.2				8+(	=I$58	13
7	31.08	14.504	250.3				8+(	=I$58-($A14*I$59	=J13+H14
8	31.02	14.476	281.3				8+(	=I$58-($A15*I$59	=J14+H15
9	30.96	14.448	312.3				8+(	=I$58-($A16*I$59	=J15+H16
10	30.9	14.42	343.2						
11	30.84	14.392	374.0						
12	30.78	14.364	404.82	9.881028598264					
13	30.72	14.336	435.54	7.657589688808					
14	30.66	14.308	466.2	8.931529053044					
15	30.6	14.28	496.8	8.896258802510					
16	30.54	14.252	527.34	9.601892439830					
17	30.48	14.224	557.82	8.728533803913					
18	30.42	14.196	588.24	8.691035172784					
19	30.36	14.168	618.6	9.848359208962					
20	30.3	14.14	648.9	10.33979194704					
21	30.24	14.112	679.14	12.41495811718	4.4	191.73124518577	=MAX(0,(H$58+(	=I$58-($A28*I$59	=J27+H28
22	30.18	14.084	709.32	9.48492786106	4.55	201.21617304683	=MAX(0,(H$58+(	=I$58-($A29*I$59	=J28+H29
23	30.12	14.056	739.44	13.08745993261	4.7	214.30363297944	=MAX(0,(H$58+(	=I$58-($A30*I$59	=J29+H30
24	30.06	14.028	769.5	10.08534967480	4.85	224.38898265425	=MAX(0,(H$58+(	=I$58-($A31*I$59	=J30+H31
25	30	14	799.5	12.13983712407	5	236.52881977832	=MAX(0,(H$58+(	=I$58-($A32*I$59	=J31+H32
26	29.94	13.972	829.44	11.32882666479	5.15	247.8576464431	=MAX(0,(H$58+(	=I$58-($A33*I$59	=J32+H33
27	29.88	13.944	859.32	10.54271684698	5.3	258.40036329010	=MAX(0,(H$58+(	=I$58-($A34*I$59	=J33+H34
28	29.82	13.916	889.14	10.48708055500	5.45	268.8874438451	=MAX(0,(H$58+(	=I$58-($A35*I$59	=J34+H35
29	29.76	13.888	918.9	12.33720200133	5.6	281.22464584645	=MAX(0,(H$58+(	=I$58-($A36*I$59	=J35+H36
40	29.1	13.58	1242.3	12.90429540653	7.25	436.36673293346	=MAX(0,(H$58+(	=I$58-($A47*I$59	=J46+H47
41	29.04	13.552	1271.34	13.85902018439	7.4	450.22575311786	=MAX(0,(H$58+(	=I$58-($A48*I$59	=J47+H48
42	28.98	13.524	1300.32	14.16654919834	7.55	464.3923023162	=MAX(0,(H$58+(	=I$58-($A49*I$59	=J48+H49
43	28.92	13.496	1329.24	17.32374633634	7.7	481.7160486525	[illegible]	[illegible]	[illegible]



Update



	A	B	C	D	E	F	G
1	Product	1	Product	2	Product	3	
2	Orders	=MATCH(A4,A$5:A$5		=MATCH(C4,C5:C55)-		=MATCH(E4,E5:E55)-	
3	Quantity req	P. Price	Quantity req	P. Price	Quantity req	P. Price	
4	='C:\RODSDATA\MODEL	=VLOOKUP(A4,A$5:B	='C:\RODSDATA\MODEL	=VLOOKUP(C4,C5:D5	='C:\RODSDATA\MODEL	=VLOOKUP(E4,E5:F5	
5	0	0	0	0	0	0	
6	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	
51	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	
52	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	
53	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	
54	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	
55	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	='C:\RODSDATA\MODEL	='C:\RODSDATA\MOD	
56							
57							
58	Marginal						
59	Revenue	='C:\RODSDATA\MOD		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
60	Admin limit	0.05		0.05		0.05	
61	Plant limit	='C:\RODSDATA\MOD		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
62	Labour rate	='C:\RODSDATA\MOD		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
63	Plant rate	='C:\RODSDATA\MOD		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
64	Increment rate	='C:\RODSDATA\MOD		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
65	Admin rate	=B64*B2/A4		=D64*D2/C4		=F64*F2/E4	
66	Max cost sd	=B59		=D59		=F59	
67	Max cost su	=B59-B65		=D59-D65		=F59-F65	
68	Max cost m	=B59-B62		=D59-D62		=F59-F62	
69	Max cost l	=B59-B62-B63		=D59-D62-D63		=F59-F62-F63	
70	Orders sd	=MATCH(B66,B$5:B$		=MATCH(D66,D$5:D$		=MATCH(F66,F$5:F$5	
71	Orders su	=MATCH(B67,B$5:B$		=MATCH(D67,D$5:D$		=MATCH(F67,F$5:F$5	
72	Orders m	=MATCH(B68,B$5:B$		=MATCH(D68,D$5:D$		=MATCH(F68,F$5:F$5	
73	Orders l	=MATCH(B69,B$5:B$	Cost	=MATCH(D69,D$5:D$	Cost	=MATCH(F69,F$5:F$5	Cost
74	Quant sd	=INDEX(A$5:A$55,B7	=VLOOKUP(B74,A$5:B$	=INDEX(C$5:C$55,D7	=VLOOKUP(D74,C$5:D$	=INDEX(E$5:E$55,F7	=VLOOKUP(F74,E$5:
75	Quant su	=MIN(INDEX(A$5:A$5	=VLOOKUP(B75,A$5:B$	=MIN(INDEX(C$5:C$5	=VLOOKUP(D75,C$5:D$	=MIN(INDEX(E$5:E$5	=VLOOKUP(F75,E$5:
76	Quant s	=IF(C74>B59,B74,IF(		=IF(E74>D59,D74,IF(		=IF(G74>F59,F74,IF(	
77	Quant m	=MIN(INDEX(A$5:A$5	=VLOOKUP(B77,A$5:B$	=MIN(INDEX(C$5:C$5	=VLOOKUP(D77,C$5:D$	=MIN(INDEX(E$5:E$5	=VLOOKUP(F77,E$5:
78	Quant l	=INDEX(A$5:A$55,B7	=VLOOKUP(B78,A$5:B$	=INDEX(C$5:C$55,D7	=VLOOKUP(D78,C$5:D$	=INDEX(E$5:E$55,F7	=VLOOKUP(F78,E$5:

	A	B	C	D	E	F	G
1	**Production**	Product 1	Rates	Product 2		Product 3	
2	Output required	='C:\RODSDATA\M(		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
3	Material required	=B2*B22		=D2*D22		=F2*F22	
4	Labour	=B2*B23		=D2*D23		=F2*F23	
5	Plant	=B2*B24		=D2*D24		=F2*F24	
6	Material Purchased	='C:\RODSDATA\M(	='C:\RODSDATA\MOD	='C:\RODSDATA\MOD	='C:\RODSDATA\MOD	='C:\RODSDATA\MOD	='C:\RODSDATA\MOD
7	Stock bf	0	1.74	0	1.29	0	0.93
8	Stock issue	=MAX(MIN(B3-B6,B		=MAX(MIN(D3-D6,D7)		=MAX(MIN(F3-F6,F7),	
9	Stock receipt	=MAX(B6-B3,0)		=MAX(D6-D3,0)		=MAX(F6-F3,0)	
10	Stock balance cf	=B7-B8+B9	=C6	=D7-D8+D9	=E6	=F7-F8+F9	=G6
11	Material runout	=MAX(B3-B6-B8,0)		=MAX(D3-D6-D8,0)		=MAX(F3-F6-F8,0)	
12	Purchase cost	=B6*C6		=D6*E6		=F6*G6	
13	Stock issue cost	=B8*(C7+C13)	='C:\RODSDATA\MOD	=D8*(E7+E13)	='C:\RODSDATA\MOD	=F8*(G7+G13)	='C:\RODSDATA\MOD
14	Stock receipt cost	=B9*(C14-C6)	='C:\RODSDATA\MOD	=D9*(E14-E6)	='C:\RODSDATA\MOD	=F9*(G14-G6)	='C:\RODSDATA\MOD
15	Stockholding cost	=B10*C15	='C:\RODSDATA\MOD	=D10*E15	='C:\RODSDATA\MOD	=F10*G15	='C:\RODSDATA\MOD
16	Runout costs	=B11*C16	='C:\RODSDATA\MOD	=D11*E16	='C:\RODSDATA\MOD	=F11*G16	='C:\RODSDATA\MOD
17	Total product material cost	=SUM(B12:B16)		=SUM(D12:D16)		=SUM(F12:F16)	
18	Total product labour cost	=B4*C18	='C:\RODSDATA\MOD	=D4*E18	='C:\RODSDATA\MOD	=F4*G18	='C:\RODSDATA\MOD
19	Labour	=$B37*$B23		=$B37*$D23		=$B37*$F23	
20	Plant	=$B42*$B24		=$B42*$D24		=$B42*$F24	
21	**Factor inputs per output unit**						
22	Material	='C:\RODSDATA\M(		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
23	Labour	='C:\RODSDATA\M(		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
24	Plant	='C:\RODSDATA\M(		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
25	**Planned outputs**						**Total**
26	Short term down	='C:\RODSDATA\M(		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
27	Medium term	='C:\RODSDATA\M(		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
28	Long term	='C:\RODSDATA\M(		='C:\RODSDATA\MOD		='C:\RODSDATA\MOD	
29	Labour req s	=B26*B$23		=D26*D$23		=F26*F$23	=F29+D29+B29
30	Labour req m	=B27*B$23		=D27*D$23		=F27*F$23	=F30+D30+B30
31	Labour req l	=B28*B$23		=D28*D$23		=F28*F$23	=F31+D31+B31
32	Plant req s	=B26*B$24		=D26*D$24		=F26*F$24	=F32+D32+B32
33	Plant req m	=B27*B$24		=D27*D$24		=F27*F$24	=F33+D33+B33
34	Plant req l	=B28*B$24		=D28*D$24		=F28*F$24	=F34+D34+B34
35	Total labour units req	=B4+D4+F4					
36	Marginal staff cost - short	='C:\RODSDATA\M(					
37	Marginal staff cost - medium	='C:\RODSDATA\M(					
38	Marginal staff cost - long	='C:\RODSDATA\M(					
39	Total plant units req	=B5+D5+F5					
40	Marginal plant costs - short term	=IF(B50>0,C50,0)					
41	Marginal plant costs - medium term	=B40					
42	Marginal plant costs - long term	=(INDEX(A53:A103,					

	A	B	C	D	E	F	G
43	Output level bf	3					
44	Output level change	='C:\RODSDATA\M(					
45	Plant output level	=MAX(0,B43+B44)					
46	Output	=INT(INDEX(B53:B1					
47	Plant surplus	=MAX(B45-MATCH(					
48	Plant shortage	=MAX(MATCH(B39,					
49	Plant cost	=INDEX(A53:A103,E					
50	Excess use cost	=B48*C50	='C:\RODSDATA\MOD				
51	Total plant cost	=B50+B49					
52	Rate	Output					
53	0	0					
54	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
55	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
56	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
57	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
58	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
59	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
60	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
61	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
62	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
63	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
64	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
65	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
66	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
67	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
68	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
69	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
70	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
71	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
72	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
73	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
74	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
75	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
76	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
77	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
78	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
79	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
80	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
81	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
82	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
83	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
84	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					

	A	B	C	D	E	F	G
43	Output level bf	3					
44	Output level change	='C:\RODSDATA\M(					
45	Plant output level	=MAX(0,B43+B44)					
46	Output	=INT(INDEX(B53:B1					
47	Plant surplus	=MAX(B45-MATCH(					
48	Plant shortage	=MAX(MATCH(B39,					
49	Plant cost	=INDEX(A53:A103,E					
50	Excess use cost	=B48*C50	='C:\RODSDATA\MOD				
51	Total plant cost	=B50+B49					
52	Rate	Output					
53	0	0					
54	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
55	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
56	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
57	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
58	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
59	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
60	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
61	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
62	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
63	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
64	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
65	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
66	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
67	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
68	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
69	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
70	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
71	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
72	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
73	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
74	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
75	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
76	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
77	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
78	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
79	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
80	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
81	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
82	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
83	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					
84	='C:\RODSDATA\MODELS\EXTERNAL.XL	='C:\RODSDATA\M(					

	A	B	C	D	E	F	G	H	I
1	Product	1			2			3	
2	Price	6.98			9.04			9	
3	Orders obtained	5			4			3	
4	Quantity	140			83			33	
5	Price	Aggregate	Marginal	Price	Aggregate	Marginal	Price	Aggregate	Marginal
6	0	31.5	0	0	21	0	0	12	0
7	7.02	31.5	7.019435	9.05	21	9.045	9.00	12	9
8	7.01	62.94	7.006064	9.04	41.96	9.0432	9.00	24	9
9	6.99	94.32	6.992694	9.04	62.88	9.0414	9.00	36	9
10	6.98	125.64	6.979324	9.04	83.76	9.0396	9.00	48	9
17	6.89	343.2	6.885731	9.03	228.8	9.027	9.00	132	9
18	6.87	374.04	6.872361	9.03	249.36	9.0252	9.00	144	9
19	6.86	404.82	6.858991	9.02	269.88	9.0234	9.00	156	9
20	6.85	435.54	6.84562	9.02	290.36	9.0216	9.00	168	9
21	6.83	466.2	6.83225	9.02	310.8	9.0198	9.00	180	9
22	6.82	496.8	6.818879	9.02	331.2	9.018	9.00	192	9
23	6.81	527.34	6.805509	9.02	351.56	9.0162	9.00	204	9
24	6.79	557.82	6.792139	9.01	371.88	9.0144	9.00	216	9
25	6.78	588.24	6.778768	9.01	392.16	9.0126	9.00	228	9
26	6.77	618.6	6.765398	9.01	412.4	9.0108	9.00	240	9
27	6.75	648.9	6.752028	9.01	432.6	9.009	9.00	252	9
28	6.74	679.14	6.738657	9.01	452.76	9.0072	9.00	264	9
29	6.73	709.32	6.725287	9.01	472.88	9.0054	9.00	276	9
30	6.71	739.44	6.711917	9.00	492.96	9.0036	9.00	288	9
31	6.70	769.5	6.698546	9.00	513	9.0018	9.00	300	9
32	6.69	799.5	6.685176	9.00	533	9	9.00	312	9
33	6.67	829.44	6.671806	9.00	552.96	8.9982	9.00	324	9
34	6.66	859.32	6.658435	9.00	572.88	8.9964	9.00	336	9
35	6.65	889.14	6.645065	8.99	592.76	8.9946	9.00	348	9
36	6.63	918.9	6.631695	8.99	612.6	8.9928	9.00	360	9
37	6.62	948.6	6.618324	8.99	632.4	8.991	9.00	372	9
38	6.60	978.24	6.604954	8.99	652.16	8.9892	9.00	384	9
39	6.59	1007.82	6.591583	8.99	671.88	8.9874	9.00	396	9
40	6.58	1037.34	6.578213	8.99	691.56	8.9856	9.00	408	9
41	6.56	1066.8	6.564843	8.98	711.2	8.9838	9.00	420	9
42	6.55	1096.2	6.551472	8.98	730.8	8.982	9.00	432	9
43	6.54	1125.54	6.538102	8.98	750.36	8.9802	9.00	444	9
44	6.52	1154.82	6.524732	8.98	769.88	8.9784	9.00	456	9
45	6.51	1184.04	6.511361	8.98	789.36	8.9766	9.00	468	9
46	6.50	1213.2	6.497991	8.97	808.8	8.9748	9.00	480	9
47	6.48	1242.3	6.484621	8.97	828.2	8.973	9.00	492	9
48	6.47	1271.34	6.47125	8.97	847.56	8.9712	9.00	504	9
49	6.46	1300.32	6.45788	8.97	866.88	8.9694	9.00	516	9
50	6.44	1329.24	6.44451	8.97	886.16	8.9676	9.00	528	9
51	6.43	1358.1	6.431139	8.97	905.4	8.9658	9.00	540	9
52	6.42	1386.9	6.417769	8.96	924.6	8.964	9.00	552	9
53	6.40	1415.64	6.404399	8.96	943.76	8.9622	9.00	564	9
54	6.39	1444.32	6.391028	8.96	962.88	8.9604	9.00	576	9
55	6.38	1472.94	6.377658	8.96	981.96	8.9586	9.00	588	9
56	6.36	1501.5	6.364288	8.96	1001	8.9568	9.00	600	9
57	6.364287507		6.364288	8.9568	0	8.9568	9		9
58									
59	Marginal revenue	6.979324			9.0414			9	

	A	B	C	D	E	F	G
1	Product	1			2		
2	Price	=ROUND(INDEX(A6:A			=ROUND(INDEX(D6:D		
3	Orders obtained	=MATCH(B4,B6:B56)			=MATCH(E4,E6:E56)		
4	Quantity	='C:\RODSDATA\MOD			='C:\RODSDATA\MOD		
5	Price	Aggregate	Marginal	Price	Aggregate	Marginal	Price
6	0	=B7	0	0	=E7	0	0
7	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=A7	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=D7	='C:\RODSDATA\MO
8	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A8*B8-A8*B7)/(B8-E	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D8*E8-D8*E7)/(E8-E	='C:\RODSDATA\MO
9	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A9*B9-A9*B8)/(B9-E	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D9*E9-D9*E8)/(E9-E	='C:\RODSDATA\MO
10	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A10*B10-A10*B9)/(E	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D10*E10-D10*E9)/(	='C:\RODSDATA\MO
11	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A11*B11-A11*B10)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D11*E11-D11*E10)/	='C:\RODSDATA\MO
12	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A12*B12-A12*B11)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D12*E12-D12*E11)/	='C:\RODSDATA\MO
13	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A13*B13-A13*B12)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D13*E13-D13*E12)/	='C:\RODSDATA\MO
14	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A14*B14-A14*B13)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D14*E14-D14*E13)/	='C:\RODSDATA\MO
15	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A15*B15-A15*B14)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D15*E15-D15*E14)/	='C:\RODSDATA\MO
16	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A16*B16-A16*B15)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D16*E16-D16*E15)/	='C:\RODSDATA\MO
17	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A17*B17-A17*B16)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D17*E17-D17*E16)/	='C:\RODSDATA\MO
41	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A41*B41-A41*B40)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D41*E41-D41*E40)/	='C:\RODSDATA\MO
42	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A42*B42-A42*B41)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D42*E42-D42*E41)/	='C:\RODSDATA\MO
43	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A43*B43-A43*B42)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D43*E43-D43*E42)/	='C:\RODSDATA\MO
44	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A44*B44-A44*B43)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D44*E44-D44*E43)/	='C:\RODSDATA\MO
45	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A45*B45-A45*B44)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D45*E45-D45*E44)/	='C:\RODSDATA\MO
46	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A46*B46-A46*B45)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D46*E46-D46*E45)/	='C:\RODSDATA\MO
47	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A47*B47-A47*B46)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D47*E47-D47*E46)/	='C:\RODSDATA\MO
48	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A48*B48-A48*B47)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D48*E48-D48*E47)/	='C:\RODSDATA\MO
49	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A49*B49-A49*B48)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D49*E49-D49*E48)/	='C:\RODSDATA\MO
50	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A50*B50-A50*B49)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D50*E50-D50*E49)/	='C:\RODSDATA\MO
51	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A51*B51-A51*B50)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D51*E51-D51*E50)/	='C:\RODSDATA\MO
52	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A52*B52-A52*B51)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D52*E52-D52*E51)/	='C:\RODSDATA\MO
53	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A53*B53-A53*B52)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D53*E53-D53*E52)/	='C:\RODSDATA\MO
54	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A54*B54-A54*B53)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D54*E54-D54*E53)/	='C:\RODSDATA\MO
55	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A55*B55-A55*B54)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D55*E55-D55*E54)/	='C:\RODSDATA\MO
56	='C:\RODSDATA\MODELS\EXTERNAL.	='C:\RODSDATA\MOD	=(A56*B56-A56*B55)/(	='C:\RODSDATA\MO	='C:\RODSDATA\MOD	=(D56*E56-D56*E55)/	='C:\RODSDATA\MO
57	=A56		=(A57*B57-A57*B56)/(	=D56	0	=(D57*E57-D57*E56)/	=G56
58							
59	Marginal revenue	=INDEX(C6:C56,B3)			=INDEX(F6:F56,E3)		

	A	B	C	D	E	F	G
1	**Production**	Product 1	Rates	Product 2		Product 3	
2	Output required	140		83		33	
3	Material required	140		83		33	
4	Labour	140		41.5		24.75	
5	Plant	140		83		33	
6	Material Purchased	140	1.74	83	1.29	33	0.93
7	Stock bf	0	1.74	0	1.29	0	0.93
8	Stock issue	0		0		0	
9	Stock receipt	0		0		0	
10	Stock balance cf	0	1.74	0	1.29	0	0.93
11	Material runout	0		0		0	
12	Purchase cost	243.6		107.07		30.69	
13	Stock issue cost	0	-1	0	-1	0	-1
14	Stock receipt cost	0	2	0	2	0	2
15	Stockholding cost	0	1	0	1	0	1
16	Runout costs	0	20	0	20	0	20
17	Total product material cost	243.6		107.07		30.69	
18	Total product labour cost	355	2.54	105	2.54	63	2.54
19	Labour	2.50		1.25		1.88	
20	Plant	0.02		0.02		0.02	
21	**Factor inputs per output unit**						
22	Material	1.00		1.00		1.00	
23	Labour	1.00		0.50		0.75	
24	Plant	1.00		1.00		1.00	
25	**Planned outputs**						**Total**
26	Short term down	140.00		83.00		33.00	
27	Medium term	140.00		83.00		33.00	
28	Long term	613.83		785.07		785.07	
29	Labour req s	140.00		41.50		24.75	206l
30	Labour req m	140.00		41.50		24.75	206l
31	Labour req l	613.83		392.53		588.80	1595l
32	Plant req s	140.00		83.00		33.00	256l
33	Plant req m	140.00		83.00		33.00	256l
34	Plant req l	613.83		785.07		785.07	2184l
35	Total labour units req	206.25					
36	Marginal staff cost - short	3.75					
37	Marginal staff cost - mediu	2.50					
38	Marginal staff cost - long	2.50					
39	Total plant units req	256					
40	Marginal plant costs - shor	0					
41	Marginal plant costs - med	0					
42	Marginal plant costs - long	0.01652					
43	Output level bf	3					
44	Output level change	0					
45	Plant output level	3					
46	Output	271					
47	Plant surplus	0					
48	Plant shortage	0					
49	Plant cost	465.5					
50	Excess use cost	0	20				
51	Total plant cost	465.5					
52	Rate	Output					
53	0	0					
54	462.5	90					
55	464	180.4					
56	465.5	271.2					
57	467	362.4					
58	468.5	454					
59	470	546					
60	471.5	638.4					
61	473	731.2					
62	474.5	824.4					
63	476	918					

		Current	-0.1	Medium	Long	
Policy		34048	=(INT(B2/7)+1)*7	=INT(DATE(YEAR($B	=INT(DATE(YEAR($B	
Product 1	Production quantity	=B4	=ROUND(B3*(1+C$1)	=D4	=E4	
	Purchase quantity	140	=ROUND(B4*(1+C$1)	='C:\RODSDATA\MOI	='C:\RODSDATA\MOI	140
Product 2	Production quantity	=B6	=ROUND(B5*(1+C$1)	=D6	=E6	
	Purchase quantity	83	=ROUND(B6*(1+C$1)	='C:\RODSDATA\MOI	='C:\RODSDATA\MOI	83
Product 3	Production quantity	=B8	=ROUND(B7*(1+C$1)	=D8	=E8	
	Purchase quantity	33	=ROUND(B8*(1+C$1)	='C:\RODSDATA\MOI	='C:\RODSDATA\MOI	33
Change staff		0	=IF(B24>0,B24,IF(B23	='C:\RODSDATA\MOI	='C:\RODSDATA\MOI	0
Change plant		0	=IF(B27>0,-B27,IF(B2			0
Change admin limit			=ROUND(B11*(1+C$1			
Change capital			=ROUND(B12*(1+C$1			
Internal						
Sales		=B32+B47+B62				
Purchases & stocks		=B34+B49+B64				
Labour costs		='C:\RODSDATA\MOI				
Gross profit		=B15-B16-B17				
Plant costs		='C:\RODSDATA\MOI				
Admin costs		='C:\RODSDATA\MOI				
Net profit		=B18-B19-B20				
Number of staff		='C:\RODSDATA\MOI				
Staff surplus cap.		='C:\RODSDATA\MOI				
Staff shortage		='C:\RODSDATA\MOI				
Plant output level		='C:\RODSDATA\MOI				
Plant output		='C:\RODSDATA\MOI				
Plant over capacity		='C:\RODSDATA\MOI				
Plant under capacity		='C:\RODSDATA\MOI				
Product 1						
Price		='C:\RODSDATA\MOI				
Invoiced quantity		='C:\RODSDATA\MOI				
Invoiced value		=B31*B30				
Raw material price		='C:\RODSDATA\MOI				
Material costs		='C:\RODSDATA\MOI				
Stock balance		='C:\RODSDATA\MOI				
Material shortage		='C:\RODSDATA\MOI				
Labour cost		='C:\RODSDATA\MOI				
Marginal cost down - short term		='C:\RODSDATA\MOI				
Marginal cost up - short term		='C:\RODSDATA\MOI				
Marginal cost - medium term		='C:\RODSDATA\MOI				
Marginal cost - long term		='C:\RODSDATA\MOI				
Marginal Revenue		='C:\RODSDATA\MOI				

	A	B	C	D	E
1	New externals		New actuals		Close files
2	=OPEN("EXTERNAL.XLS")		=CALCULATION(3,FALSE,100,0.001,T		=ACTIVATE("STAFF.XLS")
3	=ECHO(FALSE)		=ACTIVATE("CONTROL.XLS:1")		=FILE.CLOSE()
4	=CALCULATION(3,FALSE,100,0.001,TRUE		=SELECT("R2C2:R73C2")		=ACTIVATE("SALES.XLS")
5	=ACTIVATE("external.xls")		=COPY()		=FILE.CLOSE()
6	=SELECT("R2C8:R56C13")		=ACTIVATE("ACTUALS.XLS")		=ACTIVATE("PRODUCT.XLS
7	=COPY()		=SELECT("R2C1")		=FILE.CLOSE()
8	=SELECT("R2C2")		=SELECT.END(2)		=ACTIVATE("CONTROL.XLS
9	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=SELECT("R[-1]C[1]")		=FILE.CLOSE()
10	=SELECT("R2C20:R56C25")		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=ACTIVATE("BUYING.XLS")
11	=COPY()		=PASTE.SPECIAL(4,1,FALSE,FALSE)		=FILE.CLOSE()
12	=SELECT("R2C14")		=SELECT("R1C2")		=ACTIVATE("ADMIN.XLS")
13	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=ACTIVATE("CONTROL.XLS:1")		=FILE.CLOSE()
14	=SELECT("R2C32:R56C37")		=CANCEL.COPY()		=ACTIVATE("ACTUALS.XLS"
15	=COPY()		=SELECT("R1C2")		=FILE.CLOSE()
16	=SELECT("R2C26")		=CALCULATION(1,FALSE,100,0.001,T		=RETURN()
17	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=RETURN()		
18	=SELECT("R2C42:R56C44")				Open Model
19	=COPY()		Clear quarter		=OPEN("MODEL.XLW",1)
20	=SELECT("R2C39")		=ECHO(FALSE)		=RETURN()
21	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=CALCULATION(3,FALSE,100,0.001,T		
22	=SELECT("R2C49:R56C51")		=ACTIVATE("ACTUALS.XLS")		
23	=COPY()		=SELECT("R1C15:R72C27")		Auto_open
24	=SELECT("R2C46")		=COPY()		=DIRECTORY("e:\RODSDAT
25	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=SELECT("R1C2")		=RETURN()
26	=SELECT("R64C8:R67C13")		=PASTE.SPECIAL(3,1,FALSE,FALSE)		
27	=COPY()		=CANCEL.COPY()		Open externals
28	=SELECT("R64C2")		=SELECT("R1C28:R72C40")		=OPEN("EXTERNAL.XLS")
29	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=COPY()		=RETURN()
30	=SELECT("R64C20:R67C25")		=SELECT("R1C15")		
31	=COPY()		=PASTE.SPECIAL(3,1,FALSE,FALSE)		Advance quarter
32	=SELECT("R64C14")		=CANCEL.COPY()		=Clear_quarter()
33	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=SELECT("R1C41:R72C52")		=FOR("i",1,3,1)
34	=SELECT("R64C32:R67C37")		=COPY()		=Iterate()
35	=COPY()		=SELECT("R1C29")		=NEXT()
36	=SELECT("R64C26")		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=Iterate_m()
37	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=CANCEL.COPY()		=FOR("i",1,3,1)
38	=SELECT("R64C42:R67C44")		=SELECT("R1C42:R72C54")		=Iterate()
39	=COPY()		=CLEAR(1)		=NEXT()
40	=SELECT("R64C39")		=SELECT("R1C1")		=Iterate_l()
41	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=CALCULATION(1,FALSE,100,0.001,T		=FOR("i",1,3,1)
42	=SELECT("R64C49:R67C51")		=ECHO(TRUE)		=Iterate()
43	=COPY()		=RETURN()		=NEXT()
44	=SELECT("R64C46")				=Iterate_m()
45	=PASTE.SPECIAL(3,1,FALSE,FALSE)				=Iterate()
46	=CANCEL.COPY()				=RETURN()
47	=SELECT("R1C10")				
48	=CALCULATION(1,FALSE,100,0.001,TRUE				Restore files
49	=SAVE()				=OPEN("sales.XLS")
50	=FILE.CLOSE()				=OPEN("staff.XLS")
51	=ECHO(TRUE)				=OPEN("product.XLS")
52	=RETURN()				=OPEN("control.XLS")
53					=OPEN("buying.XLS")
54					=OPEN("admin.XLS")
55	New admin and product				=OPEN("actuals.XLS")
56	=ACTIVATE("ADMIN.XLS")				=ACTIVATE("params.XLS")
57	=SELECT("R2C4:R28C4")				=RETURN()
58	=COPY()				

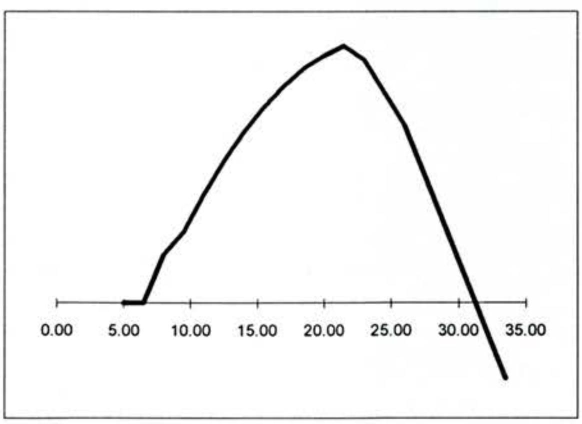
	A	B	C	D	E
59	=SELECT("R2C5")				
60	=PASTE.SPECIAL(3,1,FALSE,FALSE)				
61	=ACTIVATE("PRODUCT.XLS")				
62	=SELECT("R10C2:R10C7")				
63	=COPY()				
64	=SELECT("R7C2")				
65	=PASTE.SPECIAL(3,1,FALSE,FALSE)				
66	=SELECT("R45C2")				
67	=COPY()				
68	=SELECT("R43C2")				
69	=PASTE.SPECIAL(3,1,FALSE,FALSE)				
70	=ACTIVATE("CONTROL.XLS")				
71	=SELECT("R9C2")				
72	=FORMULA("0")				
73	=SELECT("R10C2")				
74	=FORMULA("0")				
75	=SELECT("R2C3")				
76	=COPY()				
77	=SELECT("R2C2")				
78	=PASTE.SPECIAL(3,1,FALSE,FALSE)				
79	=RETURN()				
80					
81	**Iterate**		**Iterate_m**		**Iterate_l**
82	=OPEN("EXTERNAL.XLS")		=OPEN("EXTERNAL.XLS")		=OPEN("EXTERNAL.XLS")
83	=ACTIVATE("external.XLS:1")		=ACTIVATE("external.XLS:1")		=ACTIVATE("external.XLS:1"
84	=SAVE()		=SAVE()		=SAVE()
85	=FILE.CLOSE()		=FILE.CLOSE()		=FILE.CLOSE()
86	=New_admin_and_product()		=New_admin_and_product()		=New_admin_and_product()
87	=ACTIVATE("CONTROL.XLS:1")		=ACTIVATE("CONTROL.XLS:1")		=ACTIVATE("CONTROL.XLS
88	=SELECT("R1C3")		=SELECT("R1C3")		=SELECT("R1C3")
89	=FORMULA("0.1")		=FORMULA("0.1")		=FORMULA("0.1")
90	=Cycle1()		=Cycle1_m()		=Cycle1_l()
91	=SELECT("R1C3")		=SELECT("R1C3")		=SELECT("R1C3")
92	=FORMULA("-0.1")		=FORMULA("-0.1")		=FORMULA("-0.1")
93	=Cycle1()		=Cycle1_m()		=Cycle1_l()
94	=SELECT("R1C3")		=SELECT("R1C3")		=SELECT("R1C3")
95	=FORMULA("0.1")		=FORMULA("0.1")		=FORMULA("0.1")
96	=Cycle2()		=Cycle2_m()		=Cycle2_l()
97	=SELECT("R1C3")		=SELECT("R1C3")		=SELECT("R1C3")
98	=FORMULA("-0.1")		=FORMULA("-0.1")		=FORMULA("-0.1")
99	=Cycle2()		=Cycle2_m()		=Cycle2_l()
100	=SELECT("R1C3")		=SELECT("R1C3")		=SELECT("R1C3")
101	=FORMULA("0.1")		=FORMULA("0.1")		=FORMULA("0.1")
102	=Cycle3()		=Cycle3_m()		=Cycle3_l()
103	=SELECT("R1C3")		=SELECT("R1C3")		=SELECT("R1C3")
104	=FORMULA("-0.1")		=FORMULA("-0.1")		=FORMULA("-0.1")
105	=Cycle3()		=Cycle3_m()		=Cycle3_l()
106	=New_actuals()		=New_actuals()		=New_actuals()
107	=RETURN()		=RETURN()		=RETURN()
108					
109	**Cycle1**		**Cycle1_m**		**Cycle1_l**
110	='C:\RODSDATA\MODELS\CONTROL.XLS		='C:\RODSDATA\MODELS\CONTROL		='C:\RODSDATA\MODELS\C
111	=SELECT("R4C2")		=SELECT("R4C2")		=SELECT("R4C2")
112	=COPY()		=COPY()		=COPY()
113	=SELECT("R4C6")		=SELECT("R4C6")		=SELECT("R4C6")
114	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE,FALSE		=PASTE.SPECIAL(3,1,FALSE
115	=CANCEL.COPY()		=SELECT("R4C3")		=SELECT("R4C3")
116	=SELECT("R4C3")		=COPY()		=COPY()

	A	B	C	D	E
117	=COPY()		=SELECT("R4C2")		=SELECT("R4C2")
118	=SELECT("R4C2")		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE
119	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=SELECT("R9C2")		=SELECT("R10C2")
120	=CANCEL.COPY()		=COPY()		=COPY()
121	='C:\RODSDATA\MODELS\CONTROL.XLS		=SELECT("R9C6")		=SELECT("R10C6")
122	=IF(A121>A110,GOTO(Cycle1))		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE
123	=SELECT("R4C6")		=SELECT("R9C3")		=SELECT("R10C3")
124	=COPY()		=COPY()		=COPY()
125	=SELECT("R4C2")		=SELECT("R9C2")		=SELECT("R10C2")
126	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE
127	=RETURN()		='C:\RODSDATA\MODELS\CONTROL		=SELECT("R9C2")
128			=IF(C127>C110,GOTO(C109))		=COPY()
129	**Cycle2**		=SELECT("R4C6")		=SELECT("R9C6")
130	='C:\RODSDATA\MODELS\CONTROL.XLS		=COPY()		=PASTE.SPECIAL(3,1,FALSE
131	=SELECT("R6C2")		=SELECT("R4C2")		=SELECT("R9C3")
132	=COPY()		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=COPY()
133	=SELECT("R6C6")		=SELECT("R9C6")		=SELECT("R9C2")
134	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=COPY()		=PASTE.SPECIAL(3,1,FALSE
135	=CANCEL.COPY()		=SELECT("R9C2")		='C:\RODSDATA\MODELS\C
136	=SELECT("R6C3")		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=IF(E135>E110,GOTO(E109)
137	=COPY()		=RETURN()		=SELECT("R4C6")
138	=SELECT("R6C2")				=COPY()
139	=PASTE.SPECIAL(3,1,FALSE,FALSE)		**Cycle2_m**		=SELECT("R4C2")
140	=CANCEL.COPY()		='C:\RODSDATA\MODELS\CONTROL		=PASTE.SPECIAL(3,1,FALSE
141	='C:\RODSDATA\MODELS\CONTROL.XLS		=SELECT("R6C2")		=SELECT("R10C6")
142	=IF(A141>A130,GOTO(Cycle2))		=COPY()		=COPY()
143	=SELECT("R6C6")		=SELECT("R6C6")		=SELECT("R10C2")
144	=COPY()		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE
145	=SELECT("R6C2")		=SELECT("R6C3")		=SELECT("R9C6")
146	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=COPY()		=COPY()
147	=RETURN()		=SELECT("R6C2")		=SELECT("R9C2")
148			=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE
149	**Cycle3**		=SELECT("R9C2")		=RETURN()
150	='C:\RODSDATA\MODELS\CONTROL.XLS		=COPY()		
151	=SELECT("R8C2")		=SELECT("R9C6")		**Cycle2_l**
152	=COPY()		=PASTE.SPECIAL(3,1,FALSE,FALSE)		='C:\RODSDATA\MODELS\C
153	=SELECT("R8C6")		=SELECT("R9C3")		=SELECT("R6C2")
154	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=COPY()		=COPY()
155	=CANCEL.COPY()		=SELECT("R9C2")		=SELECT("R6C6")
156	=SELECT("R8C3")		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE
157	=COPY()		='C:\RODSDATA\MODELS\CONTROL		=SELECT("R6C3")
158	=SELECT("R8C2")		=IF(C157>C140,GOTO(C139))		=COPY()
159	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=SELECT("R6C6")		=SELECT("R6C2")
160	=CANCEL.COPY()		=COPY()		=PASTE.SPECIAL(3,1,FALSE
161	='C:\RODSDATA\MODELS\CONTROL.XLS		=SELECT("R6C2")		=SELECT("R10C2")
162	=IF(A161>A150,GOTO(Cycle3))		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=COPY()
163	=SELECT("R8C6")		=SELECT("R9C6")		=SELECT("R10C6")
164	=COPY()		=COPY()		=PASTE.SPECIAL(3,1,FALSE
165	=SELECT("R8C2")		=SELECT("R9C2")		=SELECT("R10C3")
166	=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE,FALSE)		=COPY()
167	=RETURN()		=RETURN()		=SELECT("R10C2")
168					=PASTE.SPECIAL(3,1,FALSE
169			**Cycle3_m**		=SELECT("R9C2")
170			='C:\RODSDATA\MODELS\CONTROL		=COPY()
171			=SELECT("R8C2")		=SELECT("R9C6")
172			=COPY()		=PASTE.SPECIAL(3,1,FALSE
173			=SELECT("R8C6")		=SELECT("R9C3")
174			=PASTE.SPECIAL(3,1,FALSE,FALSE)		=COPY()

	A	B	C	D	E
175			=SELECT("R8C3")		=SELECT("R9C2")
176			=COPY()		=PASTE.SPECIAL(3,1,FALSE
177			=SELECT("R8C2")		='C:\RODSDATA\MODELS\C
178			=PASTE.SPECIAL(3,1,FALSE,FALSE)		=IF(E177>E152,GOTO(E151))
179			=SELECT("R9C2")		=SELECT("R6C6")
180			=COPY()		=COPY()
181			=SELECT("R9C6")		=SELECT("R6C2")
182			=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE
183			=SELECT("R9C3")		=SELECT("R10C6")
184			=COPY()		=COPY()
185			=SELECT("R9C2")		=SELECT("R10C2")
186			=PASTE.SPECIAL(3,1,FALSE,FALSE)		=PASTE.SPECIAL(3,1,FALSE
187			='C:\RODSDATA\MODELS\CONTROL		=SELECT("R9C6")
188			=IF(C187>C170,GOTO(C169))		=COPY()
189			=SELECT("R8C6")		=SELECT("R9C2")
190			=COPY()		=PASTE.SPECIAL(3,1,FALSE
191			=SELECT("R8C2")		=RETURN()
192			=PASTE.SPECIAL(3,1,FALSE,FALSE)		
193			=SELECT("R9C6")		**Cycle3_I**
194			=COPY()		='C:\RODSDATA\MODELS\C
195			=SELECT("R9C2")		=SELECT("R8C2")
196			=PASTE.SPECIAL(3,1,FALSE,FALSE)		=COPY()
197			=RETURN()		=SELECT("R8C6")
198					=PASTE.SPECIAL(3,1,FALSE
199					=SELECT("R8C3")
200					=COPY()
201					=SELECT("R8C2")
202					=PASTE.SPECIAL(3,1,FALSE
203					=SELECT("R10C2")
204					=COPY()
205					=SELECT("R10C6")
206					=PASTE.SPECIAL(3,1,FALSE
207					=SELECT("R10C3")
208					=COPY()
209					=SELECT("R10C2")
210					=PASTE.SPECIAL(3,1,FALSE
211					=SELECT("R9C2")
212					=COPY()
213					=SELECT("R9C6")
214					=PASTE.SPECIAL(3,1,FALSE
215					=SELECT("R9C3")
216					=COPY()
217					=SELECT("R9C2")
218					=PASTE.SPECIAL(3,1,FALSE
219					='C:\RODSDATA\MODELS\C
220					=IF(E219>E194,GOTO(E193))
221					=SELECT("R8C6")
222					=COPY()
223					=SELECT("R8C2")
224					=PASTE.SPECIAL(3,1,FALSE
225					=SELECT("R10C6")
226					=COPY()
227					=SELECT("R10C2")
228					=PASTE.SPECIAL(3,1,FALSE
229					=SELECT("R9C6")
230					=COPY()
231					=SELECT("R9C2")
232					=PASTE.SPECIAL(3,1,FALSE

Short term trading options

		Production	Costs	Income	Profit
		5.00	144.06	No sales	Not trading
Production function	1	6.50	165.48	No sales	Not trading
1 2 3 4 5		8.00	187.90	210.00	22.10
		9.50	211.34	243.68	32.34
Output market	2	11.00	226.34	275.55	49.21
1 2 3 4 5		12.50	241.34	305.63	64.29
		14.00	256.34	333.90	77.56
Factor market	1	15.50	271.34	360.38	89.04
		17.00	286.34	385.05	98.71
1 2 3 4 5		18.50	301.34	407.93	106.59
		20.00	316.34	429.00	112.66
Maximum Profit	117	21.50	331.34	448.28	116.94
	26%	23.00	346.34	457.24	110.90
Production level	22	24.50	361.34	457.24	95.90
		26.00	376.34	457.24	80.90
		27.50	399.34	457.24	57.90
		29.00	422.34	457.24	34.90
		30.50	445.34	457.24	11.90
		32.00	468.34	457.24	-11.10
		33.50	491.34	457.24	-34.10



Output Demand

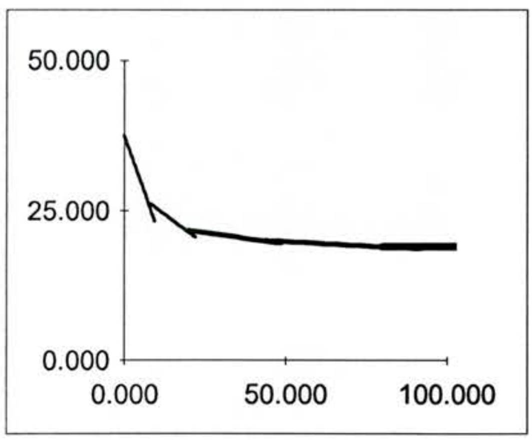
local

range

Dvn.Fall

DF1		DF2		DF3		DF4		DF5	
Quantity	0.000	Quantity	8.000	Quantity	20.000	Quantity	44.000	Quantity	80.000
Range	10.000	Range	15.000	Range	30.000	Range	50.000	Range	400.000
Price	37.500	Price	26.250	Price	21.750	Price	20.063	Price	19.013
Range	15.000	Range	6.000	Range	2.250	Range	1.500	Range	0.150
0.000	37.500	8.000	26.250	20.000	21.750	44.000	20.063	80.000	19.013
0.500	36.750	8.750	25.950	21.500	21.638	46.500	19.988	100.000	19.005
1.000	36.000	9.500	25.650	23.000	21.525	49.000	19.913	120.000	18.998
1.500	35.250	10.250	25.350	24.500	21.413	51.500	19.838	140.000	18.990
2.000	34.500	11.000	25.050	26.000	21.300	54.000	19.763	160.000	18.983
2.500	33.750	11.750	24.750	27.500	21.188	56.500	19.688	180.000	18.975
3.000	33.000	12.500	24.450	29.000	21.075	59.000	19.613	200.000	18.968
3.500	32.250	13.250	24.150	30.500	20.963	61.500	19.538	220.000	18.960
4.000	31.500	14.000	23.850	32.000	20.850	64.000	19.463	240.000	18.953
4.500	30.750	14.750	23.550	33.500	20.738	66.500	19.388	260.000	18.945
5.000	30.000	15.500	23.250	35.000	20.625	69.000	19.313	280.000	18.938
5.500	29.250	16.250	22.950	36.500	20.513	71.500	19.238	300.000	18.930
6.000	28.500	17.000	22.650	38.000	20.400	74.000	19.163	320.000	18.923
6.500	27.750	17.750	22.350	39.500	20.288	76.500	19.088	340.000	18.915
7.000	27.000	18.500	22.050	41.000	20.175	79.000	19.013	360.000	18.908
7.500	26.250	19.250	21.750	42.500	20.063	81.500	18.938	380.000	18.900
8.000	25.500	20.000	21.450	44.000	19.950	84.000	18.863	400.000	18.893
8.500	24.750	20.750	21.150	45.500	19.838	86.500	18.788	420.000	18.885
9.000	24.000	21.500	20.850	47.000	19.725	89.000	18.713	440.000	18.878
9.500	23.250	22.250	20.550	48.500	19.613	91.500	18.638	460.000	18.870

Scale	0.000	8.000	20.000	44.000	80.000
	10.000	15.000	30.000	50.000	400.000
	37.500	26.250	21.750	20.063	19.013
	15.000	6.000	2.250	1.500	0.150
Local	0.000	0.000	0.000	0.000	0.000
	10.000	10.000	10.000	10.000	10.000
	37.500	37.500	37.500	37.500	37.500
	15.000	15.000	15.000	15.000	15.000
Shift down	40.000	40.000	40.000	40.000	40.000
	40.000	40.000	40.000	40.000	40.000
	13.500	12.500	11.500	10.750	10.000
	1.500	1.500	1.500	1.500	1.500



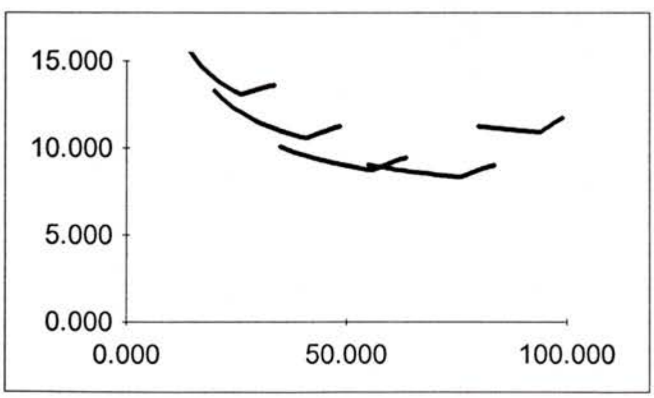
	PF 1	PF2	PF3	PF4	PF5	
	20.000	35.000	50.000	70.000	90.000	Scale
	10.000	8.000	6.500	6.500	9.000	Variable cost

Minimum cost	
Q	AC
26.000	13.077
41.000	10.561
56.000	8.732
76.000	8.342
94.000	10.915

Scale

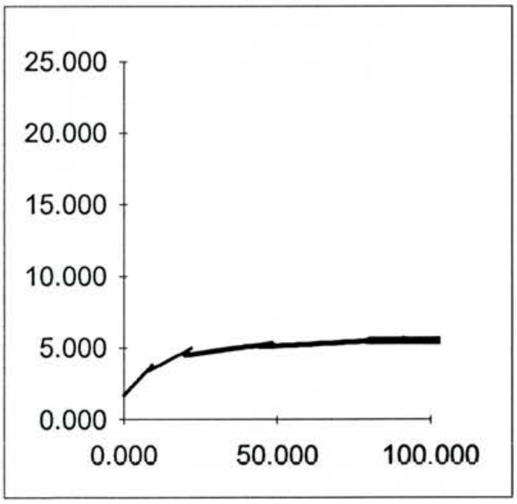
1 2

Output	Average	Output	Average	Output	Average	Output	Average	Output	Average
5.000	26.000	20.000	13.250	35.000	10.071	55.000	9.045	80.000	11.250
6.500	22.308	21.500	12.884	36.500	9.925	56.500	8.978	81.000	11.222
8.000	20.000	23.000	12.565	38.000	9.789	58.000	8.914	82.000	11.195
9.500	18.421	24.500	12.286	39.500	9.665	59.500	8.853	83.000	11.169
11.000	17.273	26.000	12.038	41.000	9.549	61.000	8.795	84.000	11.143
12.500	16.400	27.500	11.818	42.500	9.441	62.500	8.740	85.000	11.118
14.000	15.714	29.000	11.621	44.000	9.341	64.000	8.688	86.000	11.093
15.500	15.161	30.500	11.443	45.500	9.247	65.500	8.637	87.000	11.069
17.000	14.706	32.000	11.281	47.000	9.160	67.000	8.590	88.000	11.045
18.500	14.324	33.500	11.134	48.500	9.077	68.500	8.544	89.000	11.022
20.000	14.000	35.000	11.000	50.000	9.000	70.000	8.500	90.000	11.000
21.500	13.721	36.500	10.877	51.500	8.927	71.500	8.458	91.000	10.978
23.000	13.478	38.000	10.763	53.000	8.858	73.000	8.418	92.000	10.957
24.500	13.265	39.500	10.658	54.500	8.794	74.500	8.379	93.000	10.935
26.000	13.077	41.000	10.561	56.000	8.732	76.000	8.342	94.000	10.915
27.500	13.200	42.500	10.718	57.500	8.891	77.500	8.487	95.000	11.084
29.000	13.310	44.000	10.864	59.000	9.042	79.000	8.627	96.000	11.250
30.500	13.410	45.500	11.000	60.500	9.186	80.500	8.761	97.000	11.412
32.000	13.500	47.000	11.128	62.000	9.323	82.000	8.890	98.000	11.571
33.500	13.582	48.500	11.247	63.500	9.453	83.500	9.015	99.000	11.727



·actor ·upply	DF1		DF2		DF3		DF4		DF5	
	Quantity	0.000	Quantity	8.000	Quantity	20.000	Quantity	44.000	Quantity	80.000
	Range	10.000	Range	15.000	Range	30.000	Range	50.000	Range	400.000
local	Price	1.688	Price	3.375	Price	4.500	Price	5.063	Price	5.456
	Range	2.250	Range	1.688	Range	0.844	Range	0.563	Range	0.000
range	0.000	1.688	8.000	3.375	20.000	4.500	44.000	5.063	80.000	5.456
Dvn.Fall	0.500	1.800	8.750	3.459	21.500	4.542	46.500	5.091	100.000	5.456
	1.000	1.913	9.500	3.544	23.000	4.584	49.000	5.119	120.000	5.456
	1.500	2.025	10.250	3.628	24.500	4.627	51.500	5.147	140.000	5.456
	2.000	2.138	11.000	3.713	26.000	4.669	54.000	5.175	160.000	5.456
	2.500	2.250	11.750	3.797	27.500	4.711	56.500	5.203	180.000	5.456
	3.000	2.363	12.500	3.881	29.000	4.753	59.000	5.231	200.000	5.456
	3.500	2.475	13.250	3.966	30.500	4.795	61.500	5.259	220.000	5.456
	4.000	2.588	14.000	4.050	32.000	4.838	64.000	5.288	240.000	5.456
	4.500	2.700	14.750	4.134	33.500	4.880	66.500	5.316	260.000	5.456
	5.000	2.813	15.500	4.219	35.000	4.922	69.000	5.344	280.000	5.456
	5.500	2.925	16.250	4.303	36.500	4.964	71.500	5.372	300.000	5.456
	6.000	3.038	17.000	4.388	38.000	5.006	74.000	5.400	320.000	5.456
	6.500	3.150	17.750	4.472	39.500	5.048	76.500	5.428	340.000	5.456
	7.000	3.263	18.500	4.556	41.000	5.091	79.000	5.456	360.000	5.456
	7.500	3.375	19.250	4.641	42.500	5.133	81.500	5.484	380.000	5.456
	8.000	3.488	20.000	4.725	44.000	5.175	84.000	5.513	400.000	5.456
	8.500	3.600	20.750	4.809	45.500	5.217	86.500	5.541	420.000	5.456
	9.000	3.713	21.500	4.894	47.000	5.259	89.000	5.569	440.000	5.456
	9.500	3.825	22.250	4.978	48.500	5.302	91.500	5.597	460.000	5.456

·ale	0.000	8.000	20.000	44.000	80.000
	10.000	15.000	30.000	50.000	400.000
	1.688	3.375	4.500	5.063	5.456
	2.250	1.688	0.844	0.563	0.000
·cal	0.000	0.000	0.000	0.000	0.000
	10.000	10.000	10.000	10.000	10.000
	3.000	3.000	3.000	3.000	3.000
	4.000	4.000	4.000	4.000	4.000
·ift dowr	40.000	40.000	40.000	40.000	40.000
	40.000	40.000	40.000	40.000	40.000
	8.000	7.000	6.000	5.000	4.000
	1.500	1.500	1.500	1.500	1.500



Scale	Single	Low cost/inflexible
=ECHO(FALSE)	=ECHO(FALSE)	=CALCULATION(3,FALSE,100,0.001,TRUE,FALSE,FALSE
=PROTECT.DOCUMENT(FALSE,FALSE,,FALSE)	=PROTECT.DOCUMENT(FALSE,FALSE,,FALSE)	=SELECT("R25C2:R26C2")
=SHOW.LEVELS(0,1)	=SHOW.LEVELS(0,1)	=COPY()
=PROTECT.DOCUMENT(TRUE,TRUE,,TRUE)	=PROTECT.DOCUMENT(TRUE,TRUE,,TRUE)	=SELECT("R9C2")
=CALCULATION(3,FALSE,100,0.001,TRUE,FALSE,FALSE,TRUE,TRUE	=CALCULATION(3,FALSE,100,0.001,TRUE,FALSE,FALSE,TRUE,TRUE	=PASTE.SPECIAL(2,1,FALSE,FALSE)
=SELECT("R2C9")	=SELECT("R2C9")	=SELECT("R1C13")
=FORMULA("20")	=FORMULA("35")	=CANCEL.COPY()
=SELECT("R3C9")	=SELECT("R3C9")	=CALCULATION(1,FALSE,100,0.001,TRUE,FALSE,FALSE
=FORMULA("10")	=FORMULA("8")	=RETURN()
=CALCULATION(1,FALSE,100,0.001,TRUE,FALSE,FALSE,TRUE,TRUE	=SELECT("R2C21")	
=CALCULATION(3,FALSE,100,0.001,TRUE,FALSE,FALSE,TRUE,TRUE	=FORMULA("35")	**Nextflex**
=SELECT("R2C21")	=SELECT("R3C21")	=UNHIDE("FLEXPROD.XLS")
=FORMULA("50")	=FORMULA("8")	=ACTIVATE("FLEXPROD.XLS")
=SELECT("R3C21")	=SELECT("R2C27")	=SELECT("R1C2")
=FORMULA("6.5")	=FORMULA("35")	=RETURN()
=CALCULATION(1,FALSE,100,0.001,TRUE,FALSE,FALSE,TRUE,TRUE	=SELECT("R3C27")	
=CALCULATION(3,FALSE,100,0.001,TRUE,FALSE,FALSE,TRUE,TRUE	=FORMULA("8")	
=ECHO(FALSE)	=SELECT("R2C33")	
=SELECT("R2C27")	=FORMULA("35")	
=FORMULA("70")	=SELECT("R3C33")	
=SELECT("R3C27")	=FORMULA("8")	
=FORMULA("6.5")	=CALCULATION(1,FALSE,100,0.001,TRUE,FALSE,FALSE,TRUE,TRUE	
=CALCULATION(1,FALSE,100,0.001,TRUE,FALSE,FALSE,TRUE,TRUE	=SELECT("R1C1")	
=CALCULATION(3,FALSE,100,0.001,TRUE,FALSE,FALSE,TRUE,TRUE	=PROTECT.DOCUMENT(FALSE,FALSE,,FALSE)	
=SELECT("R2C33")	=SHOW.LEVELS(0,2)	
=FORMULA("90")	=PROTECT.DOCUMENT(TRUE,TRUE,,TRUE)	
=SELECT("R3C33")	=ECHO(TRUE)	
=FORMULA("9")	=RETURN()	
=CALCULATION(1,FALSE,100,0.001,TRUE,FALSE,FALSE,TRUE,TRUE		
=SELECT("R1C1")		
=RETURN()		

FLEXPROD.XLM

Appendix 5 Software acknowledgements

Both the research itself, and the thesis preparation made extensive use of proprietary software, as follows.

Excel, licenced by Microsoft Corporation was used throughout for the spreadsheets, although some of the techniques were earlier developed on fish processing applications using Lotus 123, licenced by Lotus Development Corporation

Paradox database software from Borland Software, and Minitab statistics package from Minitab Inc. were used to process the survey responses

Wordperfect was used for the thesis production with additional material generated using Corel Draw from Corel Systems Corporation and Autocad from Autodesk Inc.