

A MODEL OF THE UK ECONOMY

AN AID TO UNDERSTANDING ECONOMIC BEHAVIOUR

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Summary

Throughout the 1970's Corporate Managers, among others, have had a need to understand better the economic environment in which they operate. It is a need that was not so apparent in the two previous decades when the world economy was evolving along a relatively stable path. Since then we have entered a period of instability and uncertainty which has made the running of a company increasingly difficult. In this uncertain environment Corporate Managers have found that they can no longer rely, in the way that they used to, on the professional economic forecast. They have an increasing need to understand the assumptions on which it is based, their relative importance, the way different parts of the economy interact and to monitor for themselves the extent to which these assumptions remain valid as time progresses. In the UK there is always a dialogue in progress between industry and Government although it fluctuates in intensity over time. The pursuit of that dialogue in the present climate is often hampered by the lack of a shared framework of understanding - a framework through which disagreements about principles, causes, effects, etc. can be explored.

In short - there is a need for a model. There are, of course, already many economic models in existence, but the need here is for a model which promotes understanding and aids communication; not a model for

economists - but for the well informed layman. Conventional large econometric models, because of their technical opacity, have little to offer to the solution of this problem. The System Dynamics approach, or something conceptually related to it, seems to hold out more promise.

The paper describes a model of the UK economy which is being developed to try to meet these needs. It is not intended as a forecasting tool, although, hopefully, better forecasting might result from its use. The prime objective is the promotion of understanding and the improvement of communication. Within this prime objective the development of the model has been constrained by a number of guidelines:

- (i) It must be a model of the economy, not of the National Accounts. There is more to economic life than is measured and reported by the Government's statistical service. A set of National Accounts (albeit simplified) should be just one of the output documents from such a model.
- (ii) It must differentiate as clearly as possible between the physical entity that is the economy and the human behaviour processes which determine the way it operates. It is the author's belief that the description of the physical structure is the most easily achieved phase of the modelling and that it then provides a firm foundation upon which to build the much more contentious representation of the human behaviour processes. This differentiation is, therefore, aimed at focusing attention and argument on those aspects of economic life which are most open to question.
- (iii) It must represent decision making processes explicitly, modelling

them in terms that are recognisable to the decision makers themselves. It must permit each identifiable group of decision makers (a decision centre) to have its own objectives. These objectives need not, indeed often will not, be compatible one with another. Each decision centre will base its actions on different flows of information. It will never be possible to model the full complexity of a decision centre's behaviour. There may be circumstances in which greater learning can be achieved by not even trying, and by substituting one or more real persons for programmed algorithms and operating the model in an interactive simulation or game playing mode. To this end attempts are being made to improve the man-model interface by exploiting high quality colour graphics.

(iv) It must strike a balance between excessive complexity and oversimplification. Large, complex models are not good aids to understanding and communication - although greater complexity can probably be tolerated where it is expressed in every-day terms. There are complementary dangers, however, in oversimplification. The world is complex and there will be occasions when that complexity will lead to unexpected behaviour. The aim must be to reduce the number of those occasions to a minimum without defeating the prime objective.

(v) It must allow for inevitability. Some factors that are likely to influence economic activity, e.g. demographic ones, are already almost fully determined for some years ahead. Similarly, decisions are heavily constrained and it may only be possible to bring about significant change over a period of years.

The model is directed towards an understanding of the mechanisms at work during the business cycle of between four and five years duration. Its time horizon is therefore no greater than ten years, with the main emphasis on the next five. It is frequently argued that cycles of longer period than the business cycle exist, e.g. the 50 year long wave. It is not intended that this model should capture in detail the mechanisms producing them. However, their role in determining the underlying trend must be recognised, and their effects incorporated exogenously, perhaps by reference "offline" to other models designed to look at these more distant horizons.

In the first instance the number of decision centres has been limited to six: Households (in aggregate), Trading Companies (with no distinction between public and private ownership), Government (as administrator and supplier of public services), Financial Managers (who invest the financial surpluses of Households), Banks (as creators of credit) and Overseas.

Each of these decision centres attempts to manage a set of resource networks. The systems currently represented are the stock and flow networks for Money (readily realisable purchasing power), Financial Assets (long term lending), Goods and Services (distinguishing between perishables and durables), Fixed Assets (plant, machinery, building, etc.) and People. The term "manage" is defined to include the formulation of objectives (e.g. the Government's desired inflation rate), the collection of relevant information (e.g. Companies' profit and loss accounts), the making of decisions and the taking of action (e.g. Households' ordering of goods).

The whole system can usefully be thought of as a set of planes stacked vertically one above the other. The topmost planes define the decision centres and their objectives. Each of the lower planes contains a representation of the stock and flow network of one resource, the stocks being identified by ownership between the decision centres. Resources do not flow between planes; each plane represents a conservative (where appropriate) sub-system. Information flows upwards to the decision centres so that the state of the relevant parts of the economy can be monitored and compared with the objectives. Action then flows vertically downwards.

The full paper concentrates on the conceptual framework for the model rather than the results. It describes in more detail the overall structure, and the way in which the physical description of the economy and the decision making processes governing its behaviour have been modelled.

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1. INTRODUCTION

Throughout the 1970's Corporate Managers, among others, have had a need to understand better the economic environment in which they operate. It is a need that was not so apparent in the two previous decades when the world economy was evolving along a relatively stable path. Since then we have entered a period of instability and uncertainty which has made the running of a company increasingly difficult. In this uncertain environment Managers have found that they can no longer rely, in the way that they used to, on the professional economic forecast. They have an increasing need to understand the assumptions on which it is based, their relative importance, the way different parts of the economy interact and to monitor for themselves the extent to which these assumptions remain valid as time progresses. In the UK there is always a dialogue in progress between industry and Government, although it fluctuates in intensity over time. The pursuit of that dialogue in the present climate is often hampered by the lack of a shared framework of understanding - a framework through which disagreements about principles, causes, effects, etc. can be explored.

In short - there is a need for a model. There are, of course, already many economic models in existence, but the need here is for a model which promotes understanding and aids communication; not a model for

economists - but for the well informed layman. Conventional large econometric models, because of their technical opacity, have little to offer to the solution of this problem. The System Dynamics approach, or something conceptually related to it, seems to hold out more promise.

Corporate management is concerned with monitoring the state of its business on a monthly or quarterly basis, with assessing financial performance and profit prospects one to two years ahead and with the timing of new capacity in relation to market growth expectations anything up to ten years ahead. Questions that are frequently asked are: where are we in the business cycle?; have we reached the bottom (or top)?; how is current Government policy affecting the course of the cycle/depth of the recession/strength of the boom?; what has happened to the trend?

The model described in this paper is, therefore, directed towards an understanding of the mechanisms at work during the UK business cycle. Its time horizon is no greater than ten years, with the main emphasis on the next five. It is frequently argued that cycles of longer period than the business cycle exist, e.g. the 50 year long wave. It is not intended that this model should try to capture in detail the mechanisms believed to produce them. However, their role in determining the underlying trend must be recognised, and their effects incorporated exogenously, perhaps by reference "off-line" to other models designed to look at these more distant horizons.

The paper concentrates on the conceptual framework for the model. Section 2 sets out the objectives and guidelines and indicates briefly the relationship of the work to two other System Dynamics economic models. The

overall structure of the model is described in Section 3. Sections 4 and 5 discuss in more detail the physical description of the economy and the decision making processes governing its behaviour.

The model exists in programmed form but is not complete. Most of the ideas described in the following paragraphs have been incorporated, at least in a simple form, but several still await attention. The paper should, therefore, be regarded more as a progress report and as a stimulant to discussion rather than as a report on a finished product.

2. OBJECTIVES AND MODELLING GUIDELINES

The prime objective is the promotion of understanding and the improvement of communication. Within this prime objective the development of the model has been constrained by a number of guidelines:

(i) It must be a model of the economy, not of the National Accounts.

There is more to economic life than is measured and reported by the Government's statistical service. A set of National Accounts (albeit simplified) should be just one of the output documents from such a model.

(ii) It must differentiate as clearly as possible between the physical entity that is the economy and the human behaviour processes which determine the way it operates. In this respect it might be thought analogous to a piece of electronic equipment in which the physical description of the economy is represented by the circuit boards and the decision making processes are encoded on micro-processors plugged into them. It is the

author's belief that the description of the physical structure is the most easily achieved phase of the modelling, that differences of opinion on the adequacy of that description can be speedily resolved and that it provides a firm foundation upon which to build the much more contentious representation of the human behaviour processes. This differentiation is, therefore, aimed at focusing attention and argument on those aspects of economic life which are most open to question.

(iii) It must represent decision making processes explicitly, modelling them in terms that are recognisable to the decision makers themselves. It must permit each identifiable group of decision makers (a decision centre) to have its own objectives. These objectives need not, indeed often will not, be compatible one with another. Each decision centre will base its actions on different flows of information. It will never be possible to model the full complexity of a decision centre's behaviour. There may be circumstances in which greater learning can be achieved by not even trying, and by substituting one or more real persons for the inadequate microprocessors and operating the model in an interactive simulation or game playing mode. To this end attempts are being made to improve the man-model interface by exploiting high quality colour graphics.

(iv) It must strike a balance between excessive complexity and oversimplification. Large, complex models are not good aids to understanding and communication. There are complementary dangers, however, in oversimplification. The world is complex and there will be occasions when that complexity will lead to unexpected behaviour. The aim must be to reduce the number of those occasions to a minimum without defeating the prime

objective.

(v) It must allow for inevitability. Some factors, that are likely to influence economic activity e.g. demographic ones, are already almost fully determined for some years ahead. Similarly, decisions are heavily constrained and it may only be possible to bring about significant change over a period of years.

The guidelines outlined above lead naturally to a modelling approach based on System Dynamics concepts and it is, therefore, similar to that used at MIT (Ref. 1). However, it differs in two important respects. Firstly, the model is at least an order of magnitude simpler in terms of the amount of detail it represents and in terms of the number of equations it contains. This is intentional for the reasons already outlined; the associated risks have been accepted. Secondly, the model is being constructed from the outset as a total system even if, initially, oversimplified descriptions of the decision making processes have to be tolerated. Although individual sectors are researched 'off-line' they are incorporated into the overall framework at the earliest possible stage. Thus approximately equal emphasis has been placed on the interconnections between the sectors and the behaviour of the sectors themselves. The availability of the network diagrams, particularly that for the money flows, has contributed significantly to our own understanding of the way influences propagate within the economy. It is regrettable that such diagrams are so hard to find in economics text books.

There are also similarities with the work of Tomkins (Ref. 2, 3). In Tomkins' model the physical description of the economy plays a very secondary

role, at least at the explicit level, and the model is formulated in terms of a small number of subsystems, each representing a key decision making process. It is the feedback loops associated with these processes that dictate the model structure. Since these are a mixture of the physical and behavioural dimensions, Tomkins' formulation cuts diagonally across our own.

3. MODEL STRUCTURE

The model is structured in terms of a number of decision centres who seek to manage a set of resource networks. The term "manage" is defined to include the formulation of objectives, the collection of relevant information, the making of decisions and the taking of action. The definition of the decision centres and the resources are outlined in the following paragraphs.

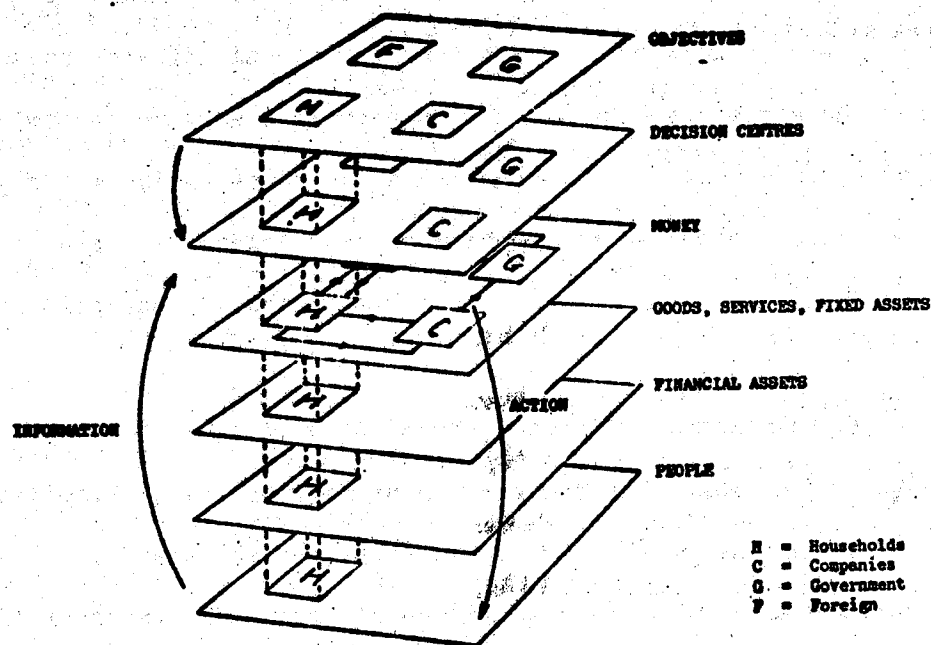


Figure 1 The Multi-Layer Structure

Building further on the analogy introduced earlier, the whole system can usefully be thought of as a set of circuit boards stacked vertically one above the other (Figure 1). The topmost boards define the decision centres and their objectives. Each of the lower boards contains a representation of the stock and flow network of one resource. Each board represents either a conservative sub-system or one with identifiable sources and sinks. Information flows upwards to the decision centres so that the state of the relevant parts of the economy can be monitored and compared with the objectives. Action then flows vertically downwards.

The Decision Centres

In the first instance the number of decision centres has been limited to six: Households, Companies, Government, Financial Managers, Banks and Overseas.

(1) Households:

The model is formulated in terms of a single aggregate household sector - the ensemble of all households. It is assumed that an average behaviour can be attributed to the ensemble, even though there are considerable variations in individual behaviour. No attempt has yet been made to divide households into high and low income groups or into professional and non-professional. Although it is recognised that purchasing power and spending patterns vary throughout the life of a household, no attempt has been made to represent the household age distribution. This could be a serious omission for the UK in the 1980s.

(ii) Companies:

This sector includes all trading organisations which sell goods and services in return for payment, whether private or State owned. It is assumed that, at least to a first approximation, the behaviour of the ensemble of all companies can be represented by a single "typical" company pursuing a set of average objectives. The validity of such an approximation can be challenged on many grounds. In a mixed economy such as the UK it is well known that the State owned corporations pursue different aims to the private sector. Similarly, there will be differences of emphasis in the behaviour of manufacturing and service companies. Nevertheless, there is sufficient commonality of purpose and behaviour to make the assumption a good starting point.

(iii) Government:

Since all State owned trading activities have been absorbed into the Company sector, the decision making role of the Government is limited in the model to macro-economic management and the free provision of public services.

(iv) Financial Managers:

The Financial Managers include the pension funds, life assurance companies and other financial institutions who manage the financial surpluses of Households. They are deemed not to hold stocks of assets on their own behalf and operate essentially as a switching mechanism, directing Households' funds into different types of assets.

(v) Banks:

A limited number of financial institutions have the power to create

money. In the accepted sense of the word a bank has three roles: as a profit-making trading organisation; as a safekeeper of money stocks owned by others; and as a creator of credit. It is only the last function that is included under "Banks". Decisions concerning normal commercial operations fall under the Companies heading. Those who possess money stocks perceive them as their own, even if they are on deposit with a bank. In the diagrammatic representations of the model all money stocks are therefore identified with their owners rather than with the Banks.

(vi) Overseas:

This encompasses all those outside the UK who can take decisions which can influence the operation of the UK economy.

The Resources

Five resources are currently included in the model: People, Goods and Services, Fixed Assets, Financial Assets and Money.

(i) People:

People form Households, are employed by Government and Companies in the production of goods and services, can be unemployed, purchase and consume goods and services, and manage a portfolio of assets which include their stocks of goods, financial assets and money.

(ii) Goods and Services:

There is a need to differentiate between goods on the one hand and services on the other, and between different types of goods. Goods and

service form a continuum with a spectrum of lives ranging from zero (a service) to more than 100 years (a dwelling). It is a useful simplification to divide this continuum into three parts: services, perishable goods and durable goods.

Services are intangible and cannot (by and large) be stocked by either producer or consumer. They are consumed immediately they are produced. Goods are tangible but are, nevertheless, valued more for the service they provide than intrinsically for themselves. Perishable goods provide a flow of service which is related to their rate of consumption, i.e. they are valued as a flow. Perishables have a (near) zero life, are not stocked in any significant quantity by consumers, but may be stocked by producers. Durable goods provide a flow of service which is related to the quantity owned and in beneficial operation, i.e. they are valued as a stock. Durables have a wide spectrum of lives and are stocked by both consumers and producers. They include dwellings, cars, clothing, white goods, etc.

These distinctions are important for two reasons. Firstly: if the flow of perishables ceases so also does the flow of service derived from it and dissatisfaction will grow rapidly. In contrast, if the flow of new durables is interrupted, the flow of service, and hence satisfaction, continues. It may decline as the durable stock is reduced by scrappage, but even then lives can be extended and the level of service maintained. Secondly: the UK economy is shifting steadily from manufacturing towards services. If the business cycle has its origins in the mechanisms of inventory control then its characteristics will change as the stock holding parts of the economy become of less importance.

(iii) Fixed Assets:

Fixed assets are the means of increasing the power of human labour in the provision of goods and services. There are only two stocks in the model: one owned by Companies (plant and machinery, buildings and works and vehicles), one owned by Government (schools, hospitals, roads, etc.). By definition Households do not own fixed assets; dwellings are categorised as durables.

(iv) Financial Assets:

Financial Assets are pieces of paper (bonds, etc.) which, although they represent purchasing power, are not normally used for transactions involving goods and services. They are receipts acknowledging the lending of the purchasing power temporarily to others. They have a spectrum of lives which range from infinity down to a few months. Assets at the 'short' end are sometimes used for transaction purposes and there is, therefore, a difficult grey area between Financial Assets and Money - which is in itself only a very short dated financial asset. For the purpose of this model Financial Assets are defined to include lives down to about a year. Any asset with a shorter life is classified as Money. A distinction is drawn between Government issued bonds and Company issued equity. Stocks of Financial Assets are owned by all the decision centres.

(v) Money:

Money is defined as "instantly realisable purchasing power". Thus it includes notes and coins, current account deposits, other short term bank deposits and financial assets having a life of less than one year. All decision centres own money stocks (their liquidity) although that maintained

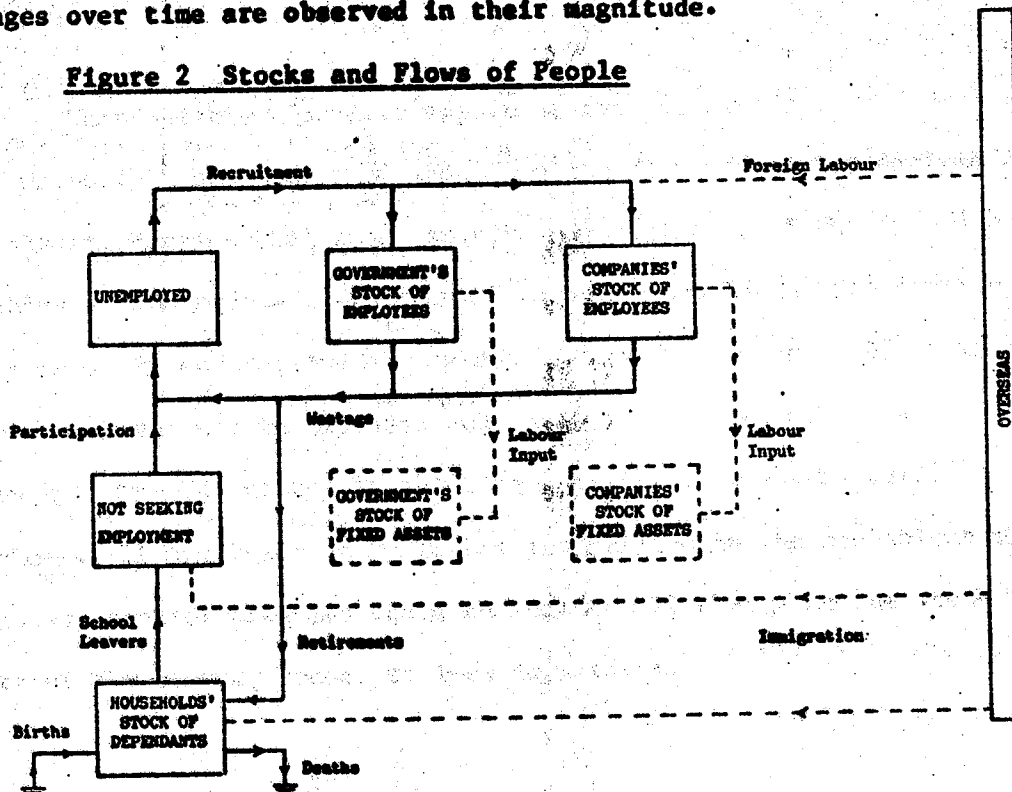
by Government is small. The "money supply" is made up of the four stocks of sterling owned by Households, Government, Companies and Foreigners. In addition, there are two stocks of foreign currency: the official reserves, owned by the Government and managed by the Bank of England, and a non-governmental stock owned predominantly by Companies.

4. THE RESOURCE SYSTEMS

People:

The stocks and flows of people are shown in Figure 2. Most people enter the system as young dependants. On leaving school they enter the stock of potential employees. Not every potential employee seeks paid employment. Most men do, but many women do not. The fraction of an age group who do seek paid employment is quantified in terms of "activity rates". Significant changes over time are observed in their magnitude.

Figure 2 Stocks and Flows of People



These changes are complex and can only really be described adequately by a full demographic model representing the detailed age distribution of the population. For simplicity the broad changes in the future stocks and flows are computed "off-line" and incorporated exogenously. Some allowance is made within the model, however, for feedback from the level of unemployment to overall activity rates.

When seeking paid employment it is assumed that everyone enters or re-enters the stock of unemployed, if only instantaneously. From there they are recruited into either Government or Corporate employment. There is a considerable turnover associated with these two labour forces. While in employment people receive a remuneration and in return provide a flow of labour, measured in person - hours per year. This, in combination with the fixed assets currently in operation, provides the output of goods and services being demanded by the economy.

Ultimately people retire from employment and re-enter the household stock of dependants. Death in employment does, of course, occur but is negligible in relation to other flows. For the UK, net immigration and foreign labour flows are small and have, therefore, been omitted.

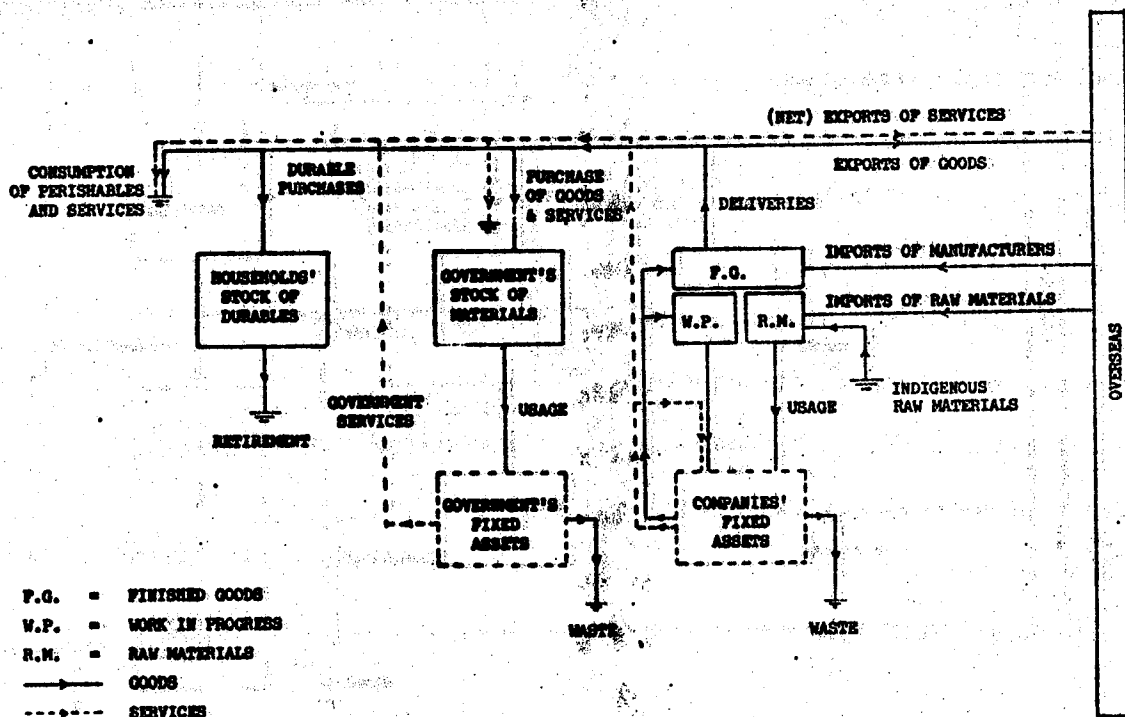
Each of the groups of people shown in Figure 2 places demands on the economy, resulting predominantly in flows of goods and services and/or money. The magnitudes of these flows are often directly proportional to the numerical size of the group and once the per capita demand or payment is specified these flows represent some of the inevitabilities, at least in the short term, faced by those managing the economy.

Goods and Services:

The stock and flow system for goods and services is shown in Figure 3. Raw materials are mined or imported and enter the corporate sector's Raw Material stock. From there they are drawn into the production process, being cycled through the companies' fixed assets, part going to waste, the remainder flowing into the stock of work-in-progress. These intermediate goods are further processed, drawing in additional raw materials, until they emerge finally into the stock of finished goods. Services are also produced by the corporate sector, and may require the usage of raw materials. They are delivered directly to the consumer. The stock of finished goods, largely in the hands of the wholesale and retail trades will be supplemented directly by imported manufactures.

Goods are delivered from stock to Households, Government and Overseas. For simplicity, no distinction is made at the production stage between

Figure 3 Stocks and Flows of Goods and Services

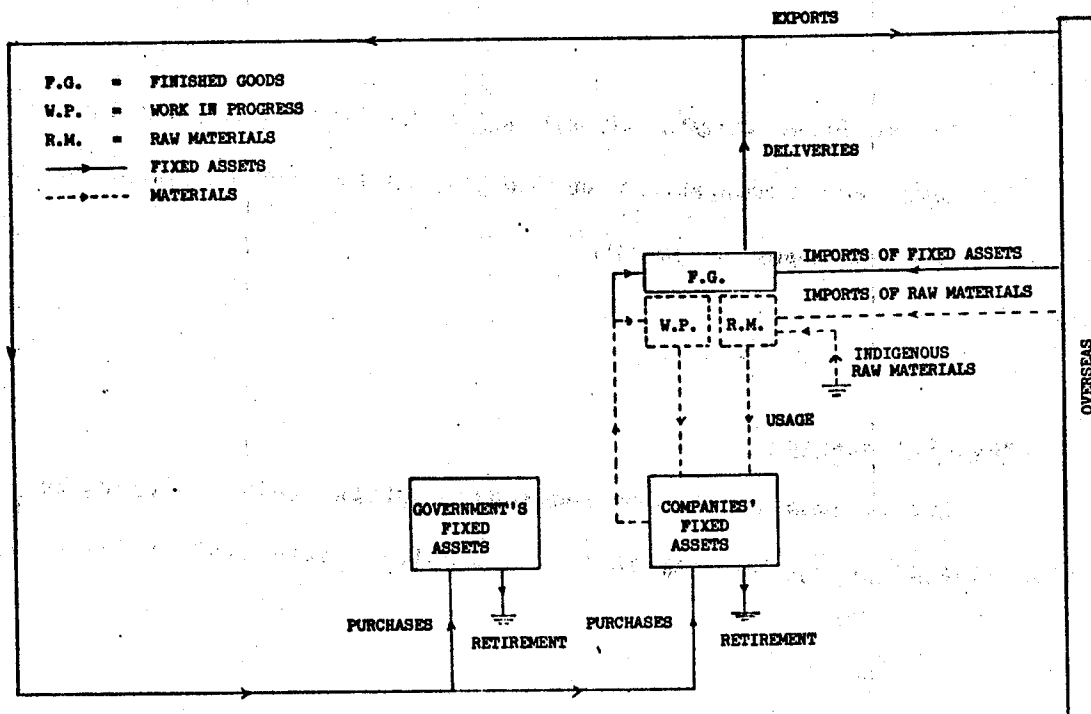


perishable and durable goods. It is assumed that industry has perfect flexibility in responding to any shift in the balance of demand between the two. As outlined above, services and perishables are consumed instantaneously by households while durables enter a stock from which they are scrapped (retired) with an average life T_{LD} , (i.e. a fraction $1/T_{LD}$ of the stock is retired each year). Government is also assumed to consume services and perishables instantly. Its durable purchases are recategorized as investment in fixed assets. For simplicity, and because State owned manufacturers are defined to be part of the Company sector, Government is assumed to supply only services.

Fixed Assets:

The flows of materials and capital goods which are accumulated into stocks of fixed assets are shown in Figure 4.

Figure 4 Stocks and Flows of Fixed Assets



The mechanics of producing capital goods is essentially the same as that for producing consumer goods described in the previous section.

Fixed assets have a spectrum of lives ranging from a year or two to decades. Two representations of the way the capital stock is accumulated have been explored. The first assumes capital goods to be perfectly homogeneous with a single average life T_{LK} . Once an investment is made it loses its identity within the stock (stirred tank approximation) and a fraction $1/T_{LK}$ of the stock is retired each year. All assets have the same capital productivity (output/plant-hour). The second, allows for several different lives and permits investment to retain its identity as it ages by accumulating it in a pipeline, the length of which is related to the asset lifetime. Investment in different years can have, and retain, different capital productivities. The former model is simple, undemanding in terms of data, but a poor representation of the dynamics of capital accumulation. The latter is a better representation but carries a heavy penalty in the need to know the investment history for a time T_{LK} prior to $t = 0$.

In the first version of the model the fixed asset and consumer goods systems have been combined and no distinction is made at the production stage between the two types of output.

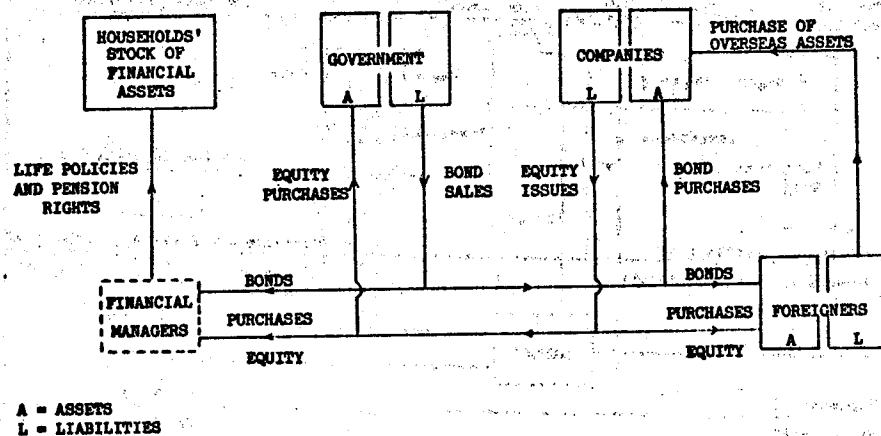
Financial Assets:

The current version of the model contains only a very rudimentary financial asset system (Figure 5). Companies create liabilities by issuing

new share capital; similarly Government, by providing a flow of new bonds. Only net flows are taken into account.

Newly issued equity and bonds are purchased by Financial Managers, who then re-issue them in the form of life policies, pension rights, etc. to Households, by Government, by Companies and Overseas. Stocks of Financial Assets are measured in volume terms and continuously revalued at current prices.

Figure 5 Stocks and Flows of Financial Assets



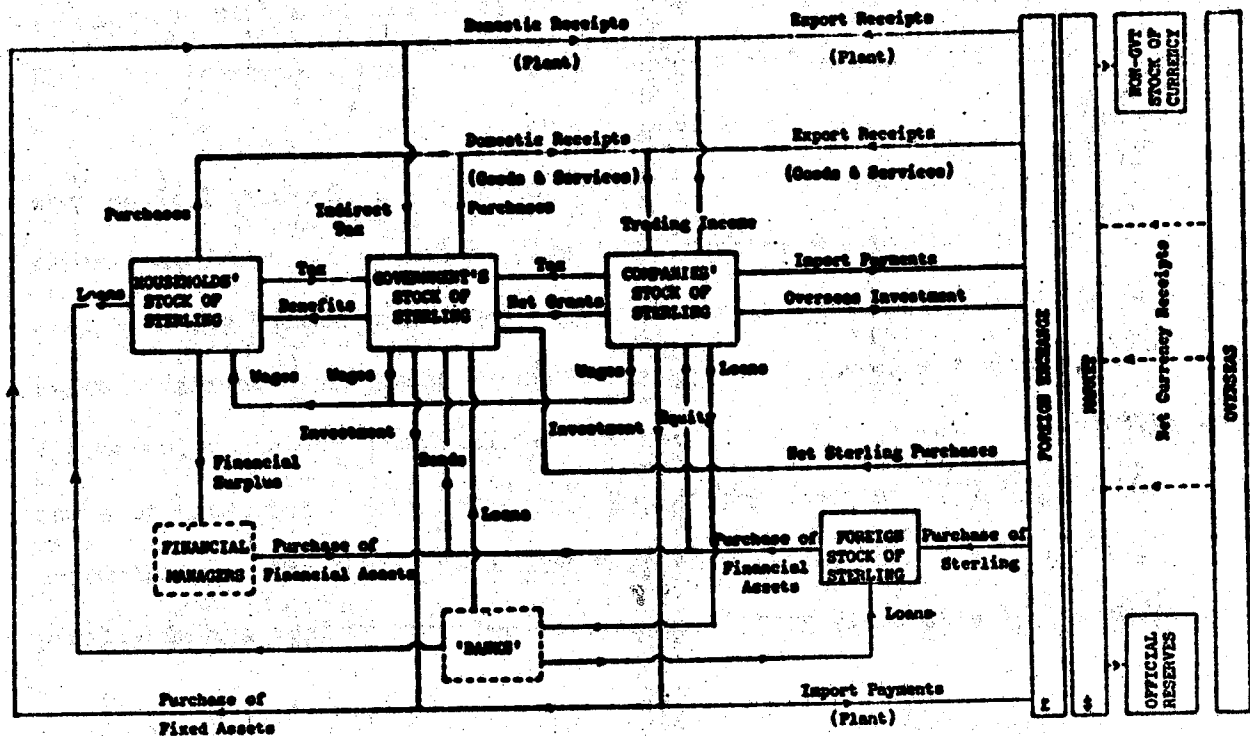
Money:

The stock and flow network for money, the most complex of all the networks is shown in Figure 6. There is a flow in this system mirroring each of the flows in the other diagrams. Corresponding pairs of flows are closely related (e.g. through price). There are, in addition, purely monetary flows having no counterpart elsewhere.

All stocks and flows to the left of the foreign exchange market in

Figure 6 refer to £ sterling. Everything to the right is in other currencies. Within the sterling system money is conserved except for the one source (or sink) represented by the "Banks". As explained in a previous section "Banks" are deemed not to own stocks of money in their own right.

Figure 6 Stocks and Flows of Money



These are owned by the other decision centres although part, indeed the bulk, of the money stock will be held in safekeeping for them by the Banks and will influence the extent to which the Bank can create additional credit by making loans. The stock of sterling represented by the Foreign exchange market is very small indeed. Thus, to a first approximation, the flows of sterling into and out of the foreign exchange market must at all times balance.

The network of money flows is best summarised by considering the income and expenditure of each decision centre in turn.

Households receive wages from Government and Companies and a range of benefits from Government. They also receive private pensions and other forms of investment incomes; for simplicity these are aggregated with wages. Households pay income tax and national insurance contributions. They pay for goods and services received, financed in part by loans raised from Banks. Their savings flow to the Financial Managers who use them to purchase a portfolio of financial assets.

Government income comes in the form of direct taxes on Households and Companies and also indirectly from taxes on expenditure. Payments are made for goods and services, wages are paid to employees and investment is undertaken in fixed assets. Benefits are disbursed to Households and grants and loans, net of subsidies, are made to Companies. Interest payments on outstanding Government debt are subsumed into wages. Since Government carries only a very small money stock, expenditure not financed out of tax revenues must be financed by borrowing. This is accomplished by selling bonds and, in the last resort, by raising short term loans from the Banks. Any direct intervention in the foreign exchange market also creates an income or expenditure attributable to Government.

Companies receive income from trading in consumer goods, capital goods and services, both at home and overseas. This is supplemented by net grants from Government, by the issue of new share capital and by the raising of loans from the Banks. They pay wages to their employees, interest and

dividends on their liabilities (included in wages) and taxes and national insurance contributions to Government. Payments are made for goods and services, purchased predominantly as intermediates from other UK companies, but also imported from abroad. The intermediate transactions lie wholly within the Company sector and have been omitted from Figure 6 in the interests of clarity. Payments are made for the purchase of fixed assets (investment), some supplied from the UK, others imported. Funds also flow abroad to finance investment overseas.

The description of foreign involvement in the domestic money supply has been pared to the very minimum. Foreigners transfer money into the country by purchasing sterling on the foreign exchanges. They also raise sterling loans from the Banks. They are assumed either to hold their funds in liquid form or to use them to purchase equity and bonds.

'Banks' in their defined role of credit creators provide a (net) flow of sterling loans to Households, Government, Companies and Foreigners.

Sterling flows into the foreign exchange market when currency has to be bought to pay for imported goods and services or finance overseas investment. It flows from the market into the economy when there are capital inflows or payments being received for exports in currencies which are then converted into sterling. Finally, if there is an imbalance between these flows and the Government wishes to defend the existing exchange rate then it can buy and sell sterling using the official reserves as its source (or sink) of currency.

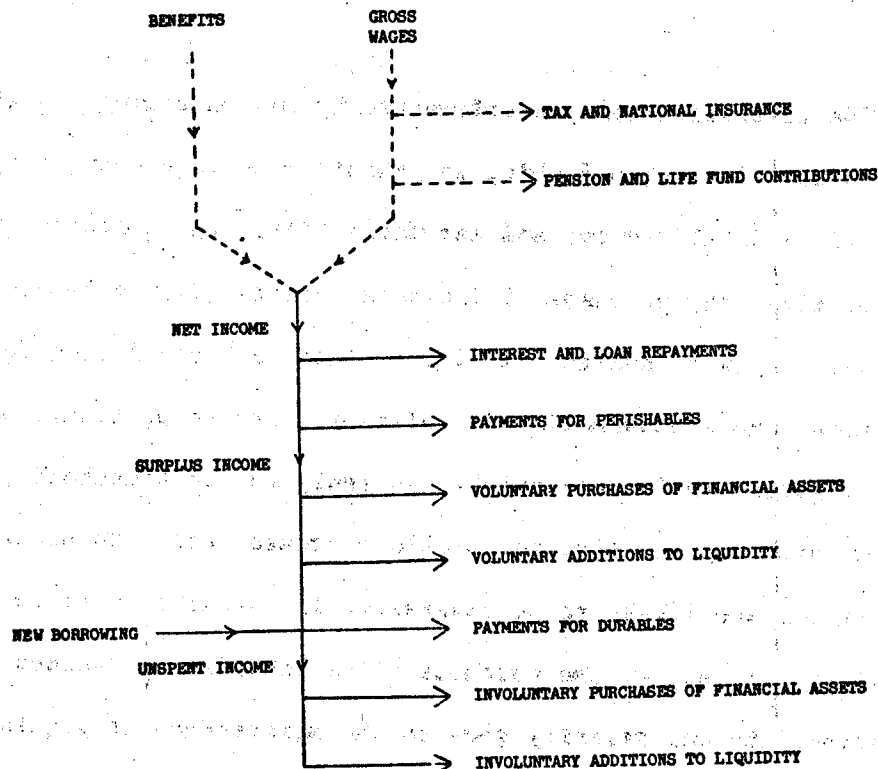
5. THE DECISION MAKING PROCESSES

The modelling of the decision processes for Households, Companies and Government are discussed in the following paragraphs. Since the decisions of Financial Managers, Banks and Overseas are currently modelled only in terms of simple allocation rules they are not described in detail.

Households:

Household decisions are primarily concerned with the management of income in relation to perceived material needs.

Figure 7 Households' Cash Flow



Households are assumed to have two sources of income: gross wages and benefits (including investment income) received from Government, private pension and life assurance funds.

Two charges take a pre-emptive strike at this gross income: Tax plus National Insurance, and contributions to private pension and life assurance funds. The residual income will be referred to as Households' net income (Figure 7). It is what is seen on the salary slip or in the wage packet. Payments to pension and life assurance funds are assumed to be a straight percentage of gross wages.

A third deduction is also treated as pre-emptive: repayment (including interest) of outstanding loans. It is assumed that loans have an average life of T_L years and that a fraction $1/T_L$ of the outstanding loans is repaid each year.

The residual income, supplemented by new borrowing, is then used for four purposes: (i) establishing and maintaining liquidity, (ii) the purchase of perishable goods and services, (iii) the purchase of durable goods, and (iv) the purchase of financial assets (discretionary saving). The problem now is to assign priorities to these expenditures for households in aggregate. Most households will give priority to perishables; these might be regarded as "necessities". In newly formed households, saving will have a low priority relative to durable purchase, while in older households the priorities are likely to be reversed. In the version of the model described in this paper, the purchase of perishables is assumed to be have top priority. Second priority goes to the maintenance of liquidity. Third

priority is a minimum level of discretionary saving, leaving expenditure on durables, financed in part by new borrowing, as the lowest priority. Any income remaining unspent is regarded as involuntary saving and allocated between liquidity and financial assets.

Expenditure on perishables is assumed to be "volume and flow" driven, e.g. households need so many kilograms of food per day. In contrast, expenditure on durables is "value and stock" driven; households having available a sum of money with which to establish and maintain their stock of durable goods.

The rate, measured in volume terms, at which perishable goods are ordered will be determined predominantly by the rate of ordering at previous times. However, if households perceive that they have become more affluent, the amount desired might be expected to increase. Households will feel more affluent if their surplus income increases relative to their net income, or if they have excessive bank balances. Actual expenditure will depend on price (a corporate decision) and the level of indirect Taxation (a Government decision).

The allocation of income to the maintenance of liquidity is assumed to be determined by the stock of money desired, the discrepancy between the actual and desired stock and the urgency with which the discrepancy is to be eliminated (measured in terms of the household liquidity reaction time). The desired stock of money is assumed to be directly proportional to net income.

Discretionary saving is assumed to be proportional to surplus income.

For simplicity discretionary and involuntary savings are aggregated with non-discretionary saving and channelled to the Financial Managers for investment in a portfolio of Financial Assets.

Durable goods are valued by households for the flow of services they provide, a flow which is broadly proportional to the stock owned. Decisions on durable purchase will be governed by the desired magnitude of this stock. It is assumed that the desired stock will increase with the level of affluence and will decline only under exceptionally adverse conditions. The planned rate of acquiring durables will depend on the rate at which existing durables are being retired and therefore need replacing, the discrepancy between the actual and desired stocks, and the urgency with which the shortfall is to be eliminated. If the available funds are insufficient, purchases will be limited to what can be afforded. In extremis this expenditure may be insufficient even to replace the planned retirements. If it is assumed that households will never give up the services to which they have been accustomed, then they will resist any fall in the durable stock by deferring retirement and extending the life of the assets. If funds once more become available, an early priority will be the acceleration of scrappage and the replacement of these veteran durables.

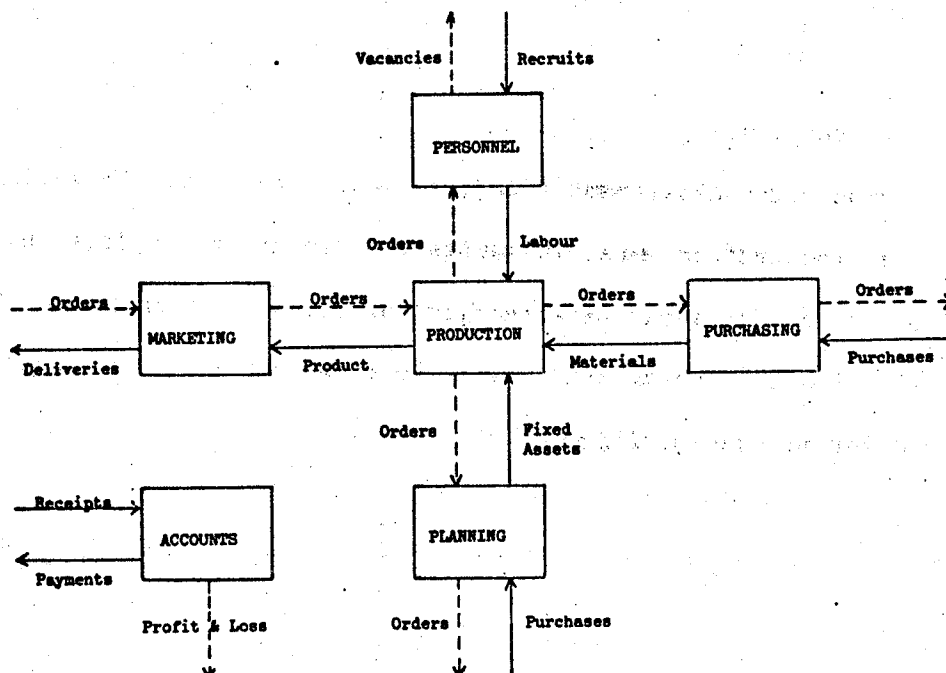
It is assumed that all expenditure on durables will be financed in part by new borrowing (the amount being determined by a "down-payment ratio"). Constraints may be imposed on new borrowing by the Government. No provision has yet been made for the running down of financial assets in order to generate funds for durable purchase or for the effects of inflationary expectations on the desired composition of the households asset portfolio.

However, the basic information is generated and readily available for such an extension.

Companies:

In the majority of companies, decision making is not centralized but is delegated to individuals and functional departments. It is therefore convenient to model the aggregate corporate sector by breaking it down into a small set of functions: marketing, production, purchasing, personnel, planning and accounting (Figure 8). It is assumed that the ensemble of each type of department can be represented by the behaviour of a single entity in which the spectrum of different responses appearing at different times can be represented by an average response spread over a limited time interval.

Figure 8 Corporate Functions



(i) Marketing:

The typical marketing department is concerned with the flow of orders from, and deliveries to, customers, the management of the orderbook and the level of finished goods stock, the setting of prices, the communication of current demands to the Production function and of forecast future demands to Planning.

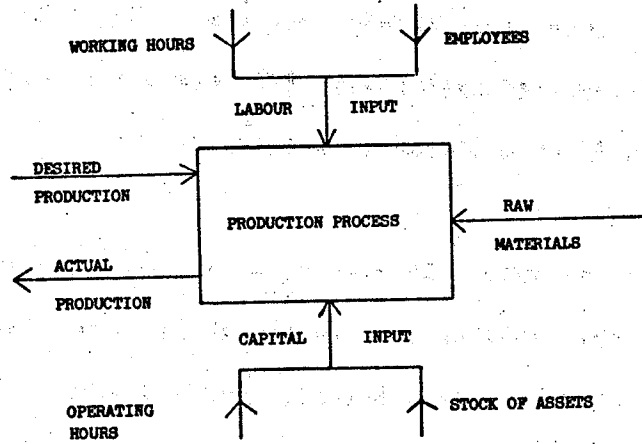
The desired production rate is determined by a classical industrial-dynamic algorithm (Ref. 4). The rate desired is that which will simultaneously satisfy incoming orders, eliminate the gaps between actual and desired stock levels, and actual and desired orderbook lengths with an urgency determined by the respective adjustment times.

The actual price level achieved is determined by the desired price level modified by a measure of demand pressure. The desired level is based on a combination of profit margin and return on capital targets. Demand pressure is linked to orderbook lengths, stock levels and current plant occupancy.

(ii) Production:

Production department's objectives are to supply Marketing with product at the desired rate, to manage the labour and capital resource available to it, to anticipate changes for both, to communicate those needs to Personnel and Planning and finally to draw from stock the raw materials required for production (Figure 9).

Figure 9 The Production Process



The production management require three inputs: labour, measured in terms of the number of employees (N) and the number of man-hours worked per man per year (T_N); capital measured in terms of the number of "plants" (K) and the number of plant-hours worked per plant per year (T_K); and raw materials. No distinction is currently made between energy and other raw material inputs.

Under normal operating conditions the capital stock operates for a normal annual number of hours T_{K0} , at a normal productivity P_{K0} (output/plant-hr), workers are employed for normal hours T_{N0} , yielding a normal output Q_0 where

$$Q_0 = P_{K0} \cdot T_{K0} \cdot K.$$

There will be a normal manning ratio M_0 (man-hours/plant-hour) given by

$$M_0 = \frac{N}{K} \frac{T_{N0}}{T_{K0}}.$$

M_0 is the normal number of workers required to be present when a unit of plant is in operation. It is assumed to be technologically determined and to change only slowly over time. The total number of workers required on the payroll of each plant (N/K men/plant) will exceed M_0 if $T_{K0} > T_{No}$, i.e. there is multi-shift working.

If the desired output is more or less than Q_0 , management has a number of actions available to it. In the short term it can increase or decrease P_K by running the plant harder or more slowly. There will be upper and lower limits beyond which such flexibility will be exhausted. When those limits are reached, it can increase or decrease T_K . Since it will still have the same labour force, this will imply an increase or decrease in T_N , i.e. overtime or short time working for employees.

There will be workers' resistance to both excessive overtime and excessive short time working. Unit costs will also rise. There will come a point where to reduce unit costs, and restore profitability, management will be forced either to shed labour or initiate the recruitment of workers. In the latter case, it is being assumed that additional output can be extracted from the capital stock by increasing the manning level. Once again there will be an upper limit and, if demand is any higher, the corporate sector will have been forced to its ultimate short term supply limit. The focus of attention then falls on the Planning function to invest in additional capacity or, in adverse conditions, to reduce capacity by closing plant down.

(iii) Purchasing:

As Production draws down the stocks of raw materials it is the role of Purchasing to restore them to the desired level with an urgency measured in terms of a raw material purchasing reaction time.

(iv) Personnel:

Personnel department responds to the labour needs of Production by recruiting new employees and managing wastage (natural or redundancy). It is also responsible for responding to the wage demands arising from Households. If, for any significant length of time, Production is forced to work its labour force for more or less than T_{No} , it will incur unit labour costs in excess of those in normal operation. The target labour force (N_d) it communicates to Personnel is that which provides just the required labour input while working normal hours T_{No} . Thus

$$N_d = M_o K \left(\frac{T_K}{T_{No}} \right).$$

If $N > N_d$, Personnel attempt to achieve a wastage rate which will eliminate the difference in a time T_w . In practice there will be upper and lower limits to this rate. The lower limit will be set by the rate of "natural" wastage, itself a function of the current unemployment level. The upper limit will be determined by concepts such as social responsibility.

If $N < N_d$, Personnel have a recruitment task. The desired recruitment rate is set equal to the current wastage rate plus the additional recruitment necessary to eliminate the difference between N and N_d in a time T_R . This rate is subject to an upper limit which is dependant on the

level of unemployment. If unemployment is high, recruitment will be "easy" and vice versa. Since natural wastage always occurs the recruitment and wastage activities will be going on in parallel.

(v) **Accounts:**

The Accountancy function receives the corporate income, makes payments, raises finance (new borrowing), manages liquidity and credit, draws up profit and loss accounts and balance sheets and forecasts future profit and cash flow.

(vi) **Planning:**

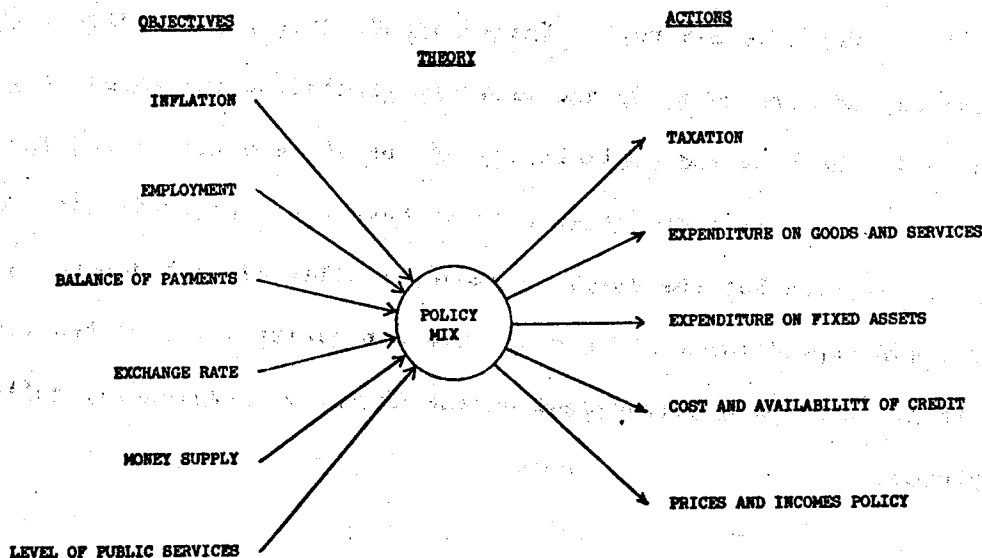
The Planning function anticipates, on the basis of market forecasts and the pressure of demand on existing assets, the capital stock requirements of the future. It will seek to place orders for new capital which will be sufficient both to replace expected retirements and expand the capital stock to its desired level within the planning horizon. If the funds available for investment, including new borrowing, are inadequate then actual expenditure will be limited to what can be afforded. The level of new borrowing and its disposition between equity and loans will depend on corporate profitability, the state of the equity market and corporate capital and interest gearing levels in relation to current targets.

Government:

In modelling the Government's decision making processes three essential elements must be taken into account: its objectives, the actions

that are available to it and its beliefs concerning the relationships between the two (Figure 10).

Figure 10 The Government's Decision Making Process



Government has a number of economic policy objectives which are probably subservient to its prime objective of re-election. Its objectives frequently appear incompatible and it therefore has to set priorities. The order of priority depends on the 'colour' of the Government, the economic theories currently in vogue, the particular policy which is most astray and the proximity of the next election. There appear to be three overriding objectives: the rate of inflation, the level of unemployment and the balance of payments. Subsidiary objectives are related to the growth of the money supply, the level of public services and the exchange rate.

In theory, it is possible to formulate an overall objective function which is a weighted average of the percentage deviations of these variables

from their desired values. The weights, and the desired levels themselves, will be functions of political philosophy and current circumstances. The practice is by no means easy!

The Government, in the pursuit of its objectives, has a number of economic "levers" it can pull. These include direct and indirect taxation, its own expenditure on goods and services (including the wages of its employees), the cost and availability of credit, and prices and incomes policies. In none of these areas does it have total control. It can set the rates of taxation but the absolute amounts collected will depend on incomes, profits and expenditure. It can set the per capita value of benefits but the amounts actually paid will depend on the number of pensioners, children and unemployed.

The extent to which Government pulls any particular combination of levers depends on the theory currently influencing its thinking. The outcome may not always be what is expected but this will not necessarily cause a change of policy. Trying harder is the most likely initial response. When policy changes do occur they are likely to be discontinuous, perhaps in association with a change of Government.

The formulation and programming of an algorithm which can represent this multi-input, multi-output decision making process is difficult. The algorithm currently included in the model is simplistic and inadequate. Improvement is undoubtedly possible but it may be more valuable, in view of the understanding and communication objectives of the work, to model only the "inevitableities" and to replace the algorithm with a person operating the

model in an interactive mode, i.e. acting the role of Chancellor of the Exchequer. It is in this direction that future developments are planned.

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